1. Introduction

Business R&D – the innovative efforts funded and organised on a systematic basis by firms – is a key ingredient for sustainable growth. Empirical investigations into the drivers of these activities have intensified over the past 30 years and have evolved to become a distinct area of research. On the aggregate level, scholars have analysed the cyclicality of business R&D (Barlevy, 2007), its response to cost reductions caused by subsidies and tax credits (Guellec and van Pottelsberghe, 2003; David *et al*, 2000), its reactivity to credit constraints (Aghion *et al*, 2005), and the industrial structures of countries (Mathieu and van Pottelsberghe, 2008). These factors have also been addressed on the microeconomic level in order to test the Schumpeterian hypothesis that large firms and firms with monopolistic power devote more resources to R&D (e.g., Cohen *et al*, 1987; Levin and Reiss, 1984).

One recent stream of research has assessed the effect of corporate governance practices on the R&D orientation of firms (Lee and O'Neil, 2003; Munari *et al*, 2010; Aghion *et al*, 2009). However, few dimensions of corporate governance have actually been addressed, with the exception of ownership characteristics (see Table 1 for a review of recent literature on corporate governance arrangements and innovation). Recent contributions have analyzed the impacts of the degree of ownership concentration (Lee and O'Neil, 2003; Tribo *et al*, 2007), owner identity (Hoskisson *et al*, 2002; Kim *et al*, 2008; Munari *et al*, 2010), the role and composition of the board of directors (Kor, 2006), and compensation schemes for CEOs, managers and directors (Barker and Mueller, 2002; Coles *et al*, 2006; Hoskisson *et al*, 2002).

Overall, the empirical evidence varies, and several critical issues have yet to be investigated. First, existing studies have largely analyzed the effects of a single dimension of corporate governance on R&D and innovation. Second, these studies tend to measure structural characteristics of governance

practices (such as the share of external directors in the board), but they do not investigate the actual implementation or outcomes of such practices in detail. Finally, the empirical evidence is often limited to single countries (predominantly the United States), while multi-country studies are nearly non-existent. This is a significant limitation given the heterogeneity of corporate governance systems around the world (Lee and O'Neil, 2003; Munari *et al*, 2010). Addressing these issues is important, as recent empirical evidence indicates that measures designed to improve shareholders' protection might have a negative impact on flexibility and risk-taking, as evidenced by the case of the Sarbanes-Oxley Act in the United States (Bargeron *et al*, 2009; Cohen *et al*, 2009).

The objective of this paper is to contribute to this growing field by providing new, quantitative insight into the relationships among several dimensions of the corporate governance of firms and their efforts in R&D. We test the relationship between multiple corporate governance practices and R&D investments using a sample of 279 publicly listed western European companies involved in research activities. Our reliance on a multi-faceted corporate governance index allows us to consider the simultaneous impact on R&D intensity of four major characteristics of corporate governance provisions designed to improve transparency and accountability: the role and composition of the board of directors, the characteristics of the audit committee and internal control system, shareholders' rights, and the executive remuneration system. As major investments must generally be validated by the board, we propose that governance dimensions might affect the management of R&D and the propensity to invest in such intangible activities. Furthermore, the strategic orientation of top executives may influence R&D investments depending on their freedom to operate, their mode of remuneration and the firm's decision process. As these executives are expected to maximise shareholder wealth, they are controlled by the board and the shareholders.

The paper is divided into five sections. Section 2 summarises the existing literature on the effect of corporate governance practices on firm performance and R&D investments, and presents the

hypotheses. Section 3 describes the sample used for the econometric analysis as well as the two main databases utilised in this study. Section 4 presents and interprets the econometric results. Section 5 provides a discussion of our conclusions and identifies areas for further research.

1. Literature review and hypotheses

1.1. Corporate governance and R&D: theoretical roots and recent advancements

"Corporate governance" refers to the set of internal and external control mechanisms that reduce the conflicts of interest between managers and shareholders arising from the separation of ownership (by shareholders) and control (by managers) (Berle and Means, 1968; Baysinger and Hoskisson, 1990; Shleifer and Vishny, 1997).[1] The different dimensions of corporate governance structures and instruments create a set of conditions that can profoundly affect the nature and direction of innovation activities. Economic approaches rooted in transaction cost theory and agency theory focus on the high level of uncertainty that characterises innovation activities, the presence of asymmetric information between the researchers and the decision makers, and the high level of asset specificity generated by dedicated R&D investments, as the factors linking governance structures and innovation (Munari and Sobrero, 2003). According to agency theory, shareholders might benefit from the high risk/high return strategies associated with R&D investments because of their ability to distribute investment variance throughout their portfolios. In contrast, managerial risk is inherently firm specific and cannot be diversified. Managers are, therefore, naturally modelled as risk averse and assumed to prefer short-term gains derived from efficiency-seeking strategies, which might dampen long-term returns.

1 A comprehensive definition of corporate governance is provided by the OECD (2004): "Corporate governance involves a set of relationships between a company's management, its board, its shareholders and other stakeholders. Corporate governance also provides the structure through which the objectives of the company are set, and the means of attaining those objectives and monitoring performance are determined. Good corporate governance should provide proper incentives for the board and management to pursue objectives that are in the interests of the company and its shareholders and should facilitate effective monitoring" (OECD 2004, p. 11). One possible approach to the corporate governance problem emphasises the roles of external institutions and laws in alleviating the agency costs arising from the specialisation of management and finance, as in the case of legal protection given to investors from the risk of expropriation by managers (Shleifer and Vishiny, 1997; La Porta, 1998). However, in this paper, we explicitly focus on the internal characteristics of a company's governance system, such as the board of directors, the audit committee and internal controls, the shareholders' role, and the monitoring and remuneration systems.

In order to provide a more rigorous and complete assessment of the effectiveness of corporate governance arrangements, recent studies have examined the relationships between a large set of corporate governance provisions and firm performance (Bebchuck *et al*, 2009; Gompers *et al*, 2003; Klapper and Love, 2004). These studies are based on the calculation of "corporate governance indexes", which take an entire set of provisions aimed at enhancing shareholders' rights into account.

The interest of a similar approach stems from two intertwined trends that have been evident over the past two decades. First, in several countries, corporate governance codes have been introduced that encompass a set of principles and best practices expected to enhance shareholders' rights. These codes were motivated by a desire for more transparency and accountability, and by a desire to increase investor confidence in the stock market. They are often introduced in response to financial scandals or corporate collapses.[2] Although compliance with such codes is generally voluntary, some governments have implemented legislative reforms calling for stricter regulation of the governance of firms, as was the case with the 2002 Sarbanes-Oxley Act in the United States. Second, interest in the topic of corporate governance has surged among governments, investment banks, rating agencies and other specialised financial institutions, which has led a number of private firms to collect firm-level data on differences in corporate governance across firms in different countries. The resulting availability of detailed and longitudinal data facilitates empirical academic research in this field (Bebchuck and Weisbach, 2009).

As a result of these trends, a large number of studies link specific characteristics of corporate governance systems to R&D efforts or innovative output on the company level (see Table 1). However, this research has provided mixed or controversial evidence (Munari *et al*, 2010). One possible reason for the lack of consensus may be a failure to consider the effect of complementarities within the

2 Examples of such codes and guidelines include the Cadbury Report (1992) and the Combined Code (2003) in the United Kingdom, the OECD Principles of Corporate Governance (1999), and the Winter Report by the EU High Level Group of Company Law Experts (2001). A complete list of corporate governance codes introduced worldwide can be found on the website of the European Corporate Governance Institute: http://www.ecgi.org/codes/all_codes.php.

governance practices on innovation development. Recently, several scholars have stressed the importance of considering corporate governance as a system of interdependent elements. They have explored how multiple practices interact and jointly influence firm performance (Aguilera *et al*, 2008; Tosi, 2008). With few exceptions (i.e., Lhuillery, 2009), the literature to date has only focused on a few facets of corporate governance in terms of its influence on R&D and innovation. Moreover, previous studies have mainly focused on the US context, so that limited evidence is available on other countries.

2.2 Multiple corporate governance practices and R&D investments

Some studies have found that corporate governance provisions designed to strengthen shareholder rights may lead to positive economic results on the company level, perhaps in the form of improved operating performance or higher market valuation (Gompers *et al*, 2003; Klapper and Love, 2004). However, recent work has also emphasised that some of these provisions are likely to discourage risk taking by public companies, thereby leading to a reduction in R&D and capital expenditures (Bargeron *et al*, 2009; Cohen *et al*, 2009). For instance, Shadab (2008) argues that by increasing outside monitoring and emphasising financial control, the Sarbanes-Oxley Act (SOX) might have had a detrimental effect on innovation-related activities. Empirical support for this claim is provided by two recent empirical studies (Bargeron *et al*, 2009 and Cohen *et al*, 2007) that demonstrate that US companies significantly reduced their investments in R&D after the SOX was implemented.

These results suggest that, in the long run, the adoption of corporate governance provisions aimed at strengthening shareholders' rights might have some unintended consequences in the form of a reduction of investments in R&D and innovation. However, existing empirical evidence is limited, especially for countries other than the United States.[3] For that reason, this paper tests the relationship between multiple corporate governance practices and R&D investments for a sample of western

3 An exception is suggested by Lhuillery (2009) based on a sample of 110 large, publicly listed French business groups. Lhuillery finds that most shareholder-oriented practices have a positive impact on R&D investments. However, Lhuillery also finds two exceptions for practices that are key in the shareholders' model – compensation schemes and voting rules – and the author finds no support for the hypothesis of complementarity between practices.

European companies. The construction of a unique corporate governance index allows us to consider the simultaneous impact of four major characteristics of corporate governance provisions:

1. The role and composition of the board of directors (BD);
2. The characteristics of the audit committee and internal control system (AC);
3. Shareholders' rights (SR); and
4. The executive remuneration system (ER).

This paper, therefore, considers the influence that practices aimed at protecting shareholders' rights have on R&D investments. The following sections briefly summarise the findings of existing literature on the influence of each governance dimension on R&D investments. The review suggests that the benefits of improving legal protection for shareholders through governance provisions may be partially offset by hidden costs related to the reduction of flexibility and risk taking. These changes may ultimately lead to lower levels of R&D investments.

2.2.1 The role and composition of the board of directors (BD)

One of the most important internal corporate governance mechanisms used to reduce the agency problem between managers and shareholders is the board of directors.[4] Organisational control theory (Eisenhardt, 1985) implies that because directors are responsible for controlling, evaluating and rewarding management performance, their characteristics and behaviour may consistently affect managers' strategic decision-making processes and, hence, firm performance.

Some studies have highlighted the potential impact of the board's characteristics on a firm's propensity to engage in R&D activities, to promote corporate entrepreneurship, and to undertake strategic change

4 As the legal representatives of corporate stockholders, directors have the formal authority to ratify managers' decisions, to monitor executive behaviour and performance, and to evaluate and reward managers. The board of directors generally nominates additional organs, such as remuneration, audit and nomination committees, which are generally allowed to make decisions with greater independence.

or renewal (Hill and Snell, 1988; Baysinger and Hoskisson, 1990; Zahra, 1996). In particular, the composition of the board of directors – in terms of the presence of external directors and the proportion of external directors to internal directors – has been often identified as an important element in efforts to align shareholders' and managers' interests to temperate the agency problem.[5] External directors may lack the necessary specific knowledge and experience with the firm's capabilities and processes, and they may have insufficient knowledge of the environment in which the firm competes. In contrast, internal directors actively participate in the operations of the company, have a superior amount of information with higher quality, and, consequently, should be more competent in assessing the strategic desirability of decisions and their potential consequences in the short or long run (Baysinger and Hoskisson, 1990; Baysinger *et al*, 1991; Hill and Snell, 1988; Zhara, 1996).

From these considerations, it follows that the balance between internal and external directors within the board is particularly important for firms facing high levels of uncertainty and dynamism, such as R&D-intensive firms. Similarly, the control of the agenda by a chairman who is not the CEO will not benefit companies active in uncertain and dynamic environments because decisions need to be made quickly in such situations (Eisenhardt, 1989). Following this line of reasoning, corporate governance practices increasing the degree of board independence, such as those suggested by the OECD code of practices or favoured by the SOX Act, might have unintended negative consequences in terms of corporate risk-taking and innovation.

Hypothesis 1: *A transparent policy for board member designation (including the chairman) and a high ratio of independent directors will negatively affect R&D intensity*.

5 Other studies focus on the demographic characteristics of the directors. For instance, Lacetera (2000) has studied specific attributes of board members, such as their scientific background, that might affect R&D intensity.

2.2.2 The role of internal controls and audit committees (AC)

Several corporate governance codes promoted in the recent past emphasise the importance of companies' internal control mechanisms for the prevention and monitoring of the risk of error or fraud by corporate managers (Mallin, 2003). Internal control systems aim to provide reasonable assurance that: a) financial information is reliable; b) legal regulations, and internal rules and procedures are respected; and c) the company's main processes operate efficiently. In this respect, one of the most controversial aspects of SOX is Section 404, which urges companies to evaluate and disclose the accuracy of their internal financial controls in annual reports (Bargeron *et al*, 2009).[6]

Two criticisms of the introduction of internal control systems have been put forth. First, internal control mechanisms are costly to implement, especially for companies that have specialised knowledge, intangible resources, decentralised organisational structures or complex transactions. Bargeron *et al* (2009) argue that the costs associated with Section 404 of SOX are higher for innovative companies and that they may lead to reduced investments in projects characterised by a high degree of uncertainty. Second, some corporate governance codes and legislation (eg Section 301 of SOX) explicitly require the increasing independence of the audit committee from management and the involvement of financial experts. Such requirements strengthen the emphasis on financial control systems and may reduce the propensity to invest in R&D projects (Shadab, 2008). Klein's study (2002) of a sample of companies listed on the S&P 500 finds that the level of audit committee independence decreases among companies with high-growth opportunities because of the complexities and uncertainties associated with operating in such an environment.

6 In 2003, the SEC implemented this requirement, which requires companies with a given market capitalisation to disclose the following information about internal controls in annual reports: "[…] (a) a statement of management's responsibility for establishing and maintaining adequate internal controls; (b) identification of the framework used by management to evaluate the adequacy of the internal controls; (c) a statement as to whether or not the system of internal controls as of year-end is effective; (d) disclosure of any "material weaknesses" in the system of internal controls; and (e) a report by the company's external auditor attesting to management's assessment of the firm's internal controls" (Bargeron *et al*, 2009).

To the best of our knowledge, few studies examine the effects of the adoption of internal control systems or the composition of audit committee on R&D investments. The audit committee does not seem to have a significant influence on strategic decisions, such as investments in R&D or in risky projects. Therefore, a direct impact cannot be assumed.

Hypothesis 2: *The creation of an independent audit committee will have no impact on R&D intensity.*

2.2.3. Shareholders' rights (SR)

Corporate governance provisions primarily aim to reduce the agency problems that arise from the separation of ownership and control. Corporate governance codes and rating systems generally focus on principles and mechanisms oriented towards reinforcing shareholders' rights. They aim to guarantee the equitable treatment of all shareholders and facilitate the effective exercise of voice through voting (OECD, 1999; Gompers *et al*, 2003).[7] Recent studies have shown that the adoption of a system of corporate governance provisions that enhances shareholders' rights is associated with a higher stock market valuation, as measured by Tobin's Q (Gompers *et al*, 2003; Klapper and Love, 2004). The long-term impact of such practices on innovation efforts, however, is not completely understood.

First, the presence and influence of large shareholders can contribute to the monitoring of managerial action and affect strategic decision making relative to investments in R&D activities. The rationale, rooted in agency theory, posits that the higher the stockholding concentration, the easier and less costly it should be for individual stockholders to coordinate the collection and diffusion of relevant information, or to signal a credible threat of retaliation to a reluctant management team. In other words, large shareholders have greater abilities and more incentives to monitor investment activity and

7 For instance, Gompers *et al* (2003) present numerous examples of restrictions (at least 24) that limit shareholders' rights and increase managerial power. They include the existence of anti-takeover devices, unequal voting rights (limiting the voting rights of some shareholders and expanding those of others), and special meeting requirements (increasing the level of shareholder support required to call a special meeting). In contrast, more "democratic" corporate governance schemes aim to eliminate or reduce such restrictions in order to strengthen shareholders' rights.

encourage those that are likely to generate innovation. A number of studies have addressed the influence of ownership concentration on R&D investments but the results have been mixed. Several studies find that stock concentration is positively related to R&D investments (Hansen and Hill, 1991; Hill *et al*, 1988; Hosono *et al*, 2004; Lee and O'Neil, 2003), while others find a negative (Yafeh and Yosha, 2003) or no significant relationship (Francis and Smith, 1995).[8]

Second, in terms of the market's role in corporate control, critics have argued that takeover pressures might force managers to reduce profitable long-term investments in favour of short-term investments offering immediate results (for contradictory results, see Stein, 1988, and Meulbroek *et al*, 1990). Therefore, some practices that enhance shareholders' rights might influence the R&D-orientation of firms. This seems logical in relation to the medium to long-term performance of firms, which must rely on R&D investments in order to stay competitive.

Hypothesis 3: *The egalitarian treatment of shareholders and the absence of anti-takeover devices will negatively affect a firm's propensity to invest in R&D.*

2.2.4 The executive remuneration system (ER)

Compensation schemes and remuneration plans are another critical area for shareholders in terms of steering management actions toward their objective of return maximisation. Research in internal control theory focuses on the type of information being collected and processed by corporate level managers and the board on the basis of the assumption that this information can help predict the firm's investment strategy and its propensity to innovate (Johnson *et al*, 1993; Hoskisson and Hitt, 1988; Baysinger and Hoskisson, 1989, 1990). According to Eishenardt (1985, p.137), control systems not only reward and measure behaviours – they also alter risk-sharing patterns.

8 A growing number of studies consider other factors that may moderate the relation between ownership structure and innovation, including differences in the characteristics of the owners (Berrone *et al*, 2007; David *et al*, 2001; Hoskisson *et al*, 2002; Whitley, 1999). Several studies evaluate the impact on R&D investment of shareholding by institutional investors (Aghion and Van Reenen, 2008; Bushee, 1998; David *et al*, 2001; Hoskisson *et al*, 2002; Kochhar and David, 1996); by families (Munari *et al*, 2010); by the state (Munari *et al*, 2003); and by banks and financial institutions (Tribo *et al*, 2007).

According to this literature, compensation schemes that are tightly linked to financial indicators of success may lead managers to focus on more predictable and easily measurable short-term activities, ultimately hampering the commitment to innovative projects (Hoskisson and Hitt, 1988; Hitt *et al*, 1996). Several studies have tried to assess the impact of compensation schemes (such as stock, stock options or bonuses) aimed at aligning directors' and managers' objectives with shareholders' views. However, the findings are inconclusive – some studies show a positive association between stock ownership and R&D spending (Barker and Mueller, 2002; Coles *et al*, 2006; Hoskisson *et al*, 2002), while others find indications of a negative relationship (Holthausen *et al*, 1995; Lacetera, 2001; Souder and Shaver, 2010).

It can be argued that compensation based on short-term financial performance is likely to negatively affect the R&D intensity of a firm. In addition, the use of stock options has a negative impact when a research project has a longer horizon than the option. Contrary to the popular view, severance pay could offset this short-term perspective by insuring the executive a high level of compensation if the risky project is not fruitful. In this case, one must differentiate between risk taking in R&D and purely financial risk taking.

Hypothesis 4: *A remuneration system for top executives based on financial performance will negatively affect a firm's propensity to invest in R&D, as well as the absence of severance pay*.

Table 1: Recent studies on governance and innovation

Authors	Year	Country	Dependent Var.	Explanatory factors
Aghion *et al*	2009	1,000 listed US firms	Patents (weighted by citations) and R&D experience	Proportion of stock held by institutional investors
Coles *et al*	2006	US	R&D/total assets	Executive compensation
David *et al*	2001	73 US firms	R&D/sales; number of new product announcements	Cumulative institutional activism; new institutional activism
Hosono *et al*	2004	Japan	R&D experience/ total assets	Ratio of large shareholders to total shareholders; leverage ratio; share of bank loans in total debt
				In 1989: keiretsu affiliation and cross-shareholdings
Hoskisson *et al*	2002	234 US firms	Internal/external innovation	Institutional ownership; internal directors
Kim *et al*	2008	253 Korean firms	R&D/sales	Family ownership; affiliated ownership; domestic institutional ownership; foreign ownership
Kor	2006	77 US firms	R&D/sales	Top management team composition; board composition (external/internal)
Lacetera	2000	US	R&D/sales	Insiders and scientists in boards
Lhuillery	2009	France SBF-120 Index	R&D/employee.	Governance index (non linear); foreign quotes
Lee and O'Neil	2003	US and Japan	R&D/sales	Ownership concentration
Munari *et al*	2010	France, Germany, Italy, Norway,	R&D/sales	Financial institution; family ownership; state ownership
		Sweden, UK		
Ortega-Argilés *et al*	2003	Spain	Dummy variable =1 with R&D experience	More than 50% of shares; separation of owner/manager; abroad; foreign and public
Smith *et al*	2003	Denmark	R&D probability	Number of blockholders; legal form and foreign market
Tribo *et al*	2007	3,638 Spanish firms	R&D/sales	Number of blockholders; bank ownership; corporate ownership; individual ownership

This table reports the studies published from 2000 to 2010 on the relationship between corporate governance and innovation. For a review of previous studies, see Munari and Sobrero (2003). Tylecote and Ramirez (2006) show that governance structure influences the specialisation of countries in specific industrial sectors. Should these sectors be R&D intensive, one would expect to find some relation to governance.

3. Empirical investigation

To test if the main components of corporate governance affect firms' propensities to invest in R&D, two databases were merged. The first database (provided by Vigeo) relates to the measurement of corporate governance practices, while the second (from the European Commission) relates to R&D expenditures. Even if firms in a given country face similar governance rules, there is no guarantee of their effective enforcement (Khanna *et al*, 2006). Therefore, the implementation of such rules must be monitored by independent agencies (public or private). Vigeo is one such firm. It is an independent rating agency based in France that assesses the corporate governance setting of publicly listed companies on the basis of the four broad governance criteria discussed in the previous section:

- Board of Directors (BD)
- Audit and Internal Controls (AC)
- Shareholders' rights (SR)
- Executive remuneration (ER)

Each criterion is subdivided by Vigeo into three levels of commitment: liabilities (L), implementation (I) and results (R). Liabilities refer to the existence of the basic practices that would protect shareholders. Implementation reflects the operationalisation of these practices. Results encompass the shareholders' satisfaction (e.g., approval at general meetings) and the level of realisation (e.g., reliability of financial statements). Twelve scores are therefore available (see Table 2), each of which is computed as a weighted average of several topics. Because of confidentiality constraints, the actual weight of each question cannot be disclosed.[9]

9 Two examples of computation with hypothetical figures help to clarify the scoring method. 1) BD-L: 0.75*100 + 0.25*0 = 75. A score of 100 indicates that there is a nomination committee for the board of directors and no executive sits on this committee, while a score of 0 indicates that the CEO and the chairman of the board are the same person. 2) SR-L: 0.5*80+0.5*100 = 90. A score of 80 indicates that there are some safeguards (but not all) on the transactions executed by large shareholders, while a score of 100 indicates that all the shareholders can easily attend the annual general meeting (AGM) and add items to the agenda.

Scores for each topic are assigned so that the "better" or more transparent a governance practice is relative to the governance code, the higher the score. A global governance score (CG score) is also computed by Vigeo as a weighted average of the four sub-criteria scores (BD, AC, SR and ER).[10]

Table 2: Basic scores for corporate governance practices

Criteria	Levels of commitment	Score	Topics of questions (the more the conditions are met, the higher the score)
Board of Directors (BD)	Liabilities (L)	BD-L	- Existence and independence of nomination committee - Chairman of the board not the CEO
	Implementation (I)	BD-I	- Percentage of independent board members - Skills and background of non-executive members - Training provided for board members - Regular attendance at board meetings
	Results (R)	BD-R	- Regular election and evaluation of board members
Audit and Internal Controls (AC)	Liabilities (L)	AC-L	- Existence and independence of an audit committee - Skills and backgrounds of audit committee members - Scope of risks covered by internal control systems
	Implementation (I)	AC-I	- Role of the audit committee in relation to internal and external controls - Rotation of external auditors
	Results (R)	AC-R	- Independence of external auditors - Reliability of financial statements - CSR reporting
Shareholders' rights (SR)	Liabilities (L)	SR-L	- Limitation of voting rights restrictions (one share – one vote – one dividend policy) - Limitation of anti-takeover devices
	Implementation (I)	SR-I	- Safeguards relative to transactions with major shareholders - AGM: access and agenda modification possibility

10 One hypothetical example of the calculation of the global governance code could be: 0.2*100 + 0.3*70 + 0.2*80 + 0.3*100 = 87, where BD = 100; AC = 70; SR = 80 and ER = 100.

	Results (R)	SR-R	- Voting results (consensus among shareholders at AGM)
Executive Remuneration (ER)	Liabilities (L)	ER-L	- Existence and independence of remuneration committee - Disclosure of senior executives' remuneration
	Implementation (I)	ER-I	- Link between incentives and economic performance (financial ratio and stock options)
	Results (R)	ER-R	- Limitations of severance pay allowed for executives - Approval of executive remuneration by the annual general meeting

The Vigeo database covers several European countries and several manufacturing sectors, which provides a unique research perspective. The corporate governance of each company is assessed every 18 months. The database covers five years (2003 to 2007). However, the uneven distribution of the observations prevents the use of a balanced panel data analysis. The database focuses on the Dow Jones STOXX Europe 600 Index, and is composed of 1,315 observations on firms mostly originating from the United Kingdom, Ireland, Germany, France, Belgium and Luxembourg. Several industries are covered, although a larger share of firms are active in financial services, consumer services, industrial goods and services, and utilities-energy (Table 3).

Table 3: Distribution of observations by sector and region in each database (%)

	Frequency %		
Variables	**Corporate governance database (Vigeo)**	**R&D database (European Commission)**	**Final database**
Sectors			
Automobiles	2.6	4.6	6.8
Chemicals	4.1	5.8	8.5
Construction basic	8.6	5.6	6.8
Consumer services	21.2	4.9	7.3
Financials	20.5	3.2	4.6
Food and beverage	5.0	4.1	5.9
Health care	3.2	13.6	8.5
Industrial goods and services	12.7	26.6	15.1
Personal and household goods	3.3	5.6	3.7
Technology	7.5	17.4	14.4
Telecommunications	3.3	4.0	6.6
Utilities-energy	7.8	4.7	11.7
Countries			
France, Belgium and Luxembourg	20.8	15.7	24.4
Germany	8.3	17.8	13.7
Nordic countries	10.7	19.0	13.7
Southern countries	15.1	6.6	7.3
Switzerland and Austria	6.7	6.5	8.8
The Netherlands	5.3	4.5	4.9
The UK and Ireland	33.2	29.9	27.3
Years			
2003	3.0	15.9	13.7
2004	20.3	21.7	22.4
2005	28.5	31.1	27.3
2006	23.0	31.3	36.6
2007	25.2	0	0
# observations	1,315	3,163	409

Data on R&D expenditures is obtained from the scoreboards for the most R&D-intensive companies in the world, which are released each year by the European Commission. The scoreboards are constructed from audited annual reports of consolidated groups. The country in which the company is registered is used as its geographical origin (European Commission, 2007). The number of observations per scoreboard varies over time. For the purpose of the present study, data on the R&D to net sales ratio and the number of employees from 2003 (top 500) to 2006 (top 1,000) was used. The distribution among sectors and countries differs from the corporate governance database, as companies are more focused in industrial goods and services, health care and technology, and the share of companies in the Nordic countries is higher (Table 3).

Table4: Descriptive statistics for the main variables

	Database	Mean	Min.	Max.	Std. deviation	Obs.
CG score	Corp.gov.	46.8	3.00	91.0	16.9	1315
	Final	46.3	7.00	91.0	16.2	409
R&D/sales	R&D	12.2	0.01	532.0	34.7	3163
	Final	4.3	0.01	45.2	6.1	409
R&D/empl.	R&D	18.5	0.01	411.1	33.0	3163
	Final	11.5	0.04	101.6	17.6	409
Sales (EUR millions)	R&D	5475.6	5	260.0	16,007.6	3163
	Final	18358.4	129	260.3	31,952.9	409
Empl.	R&D	20483.91	17	507641	47735.52	3163
	Final	55877.60	290	507641	74040.68	409

The corporate governance and R&D databases were matched to create the final database used for the empirical analysis. As a result of the matching, the sample size decreased to 409 observations, which can be explained by the fact that the most capitalised companies are not particularly active in R&D, especially in the services industry. Firms' geographical locations were grouped into regional areas according to two main criteria: geographical proximity and the regional legal systems defined by La Porta (1998). The Nordic group includes Finland, Sweden, Norway and Denmark, and the southern group includes Spain, Italy, Portugal and Greece. Firms are therefore classified as originating in one of seven regions or countries, and they are classified by sector. The means of the variables in the "R&D database" and in the "final database" are different. When moving from the R&D database to the final database, R&D intensity decreases and becomes more centred: minima are higher and maxima are lower, which means that potential outliers have been suppressed.

4. Empirical results

Before examining the relationship between corporate governance and R&D, four regressions were performed to check the robustness of the results across the two databases and their congruence with past studies.[11]

$$CG_{it} = c + \phi_{country} + \chi_{sector} + \psi_{t} + \mu_{it}, \text{ and} \quad (1)$$

$$IRD_{it} = c + \phi_{country} + \chi_{sector} + \psi_{t} + \mu_{it}. \quad (2)$$

The corporate governance score is essentially explained by the geographical origin of firms (country dummies explain nearly half the variance: 48.7%). The countries that are significant for the corporate governance data remain significant in the final sample, which attests to the role of regional business cultures and legislation in the adoption of governance mechanisms. In short, origination from the Netherlands, the UK and Ireland has a positive impact on the corporate governance score, while origination from the southern region has a negative impact. This result confirms the differences in corporate governance and shareholder treatment found by La Porta *et al* (1998). The sector effects show less significance in the final sample.

Table 5: Results of regressions of CG score and R&D intensity (RDI)

Dependent variables	**CG score**		**RDI**	
	Corp	**Final**	**R&D**	**Final**
The Netherlands	11.185***	5.394*	-1.031	0.444
Switzerland and Austria	1.462	1.638	-1.636	1.008
Southern countries	-6.453***	-5.757**	-4.811*	0.380
Nordic countries	1.103	0.869	3.122*	-0.556
France, Belgium and Luxembourg	-1.739	-1.916	-2.410	0.032
The UK and Ireland	22.868***	24.700***	2.792	0.687

11 The companies are indexed by i (i=1…279) and the years are indexed by t (t=1...4). $\phi_{country}$, χ_{sector} and ψ_{t} are country, sector and time dummies, respectively. An intercept (c) is included with the three sets of dummies. One country dummy (Germany as reference country), one sector (consumer services) and one year (2003) are suppressed in the control variables, as they are the closest to the median value.

Automobiles	-2.971	-4.565	3.325	3.032*
Personal and household goods	-4.658**	-7.814**	1.272	0.852
Financials	3.155***	-1.525	-0.165	-0.099
Telecommunications	1.920	2.356	6.468*	-0.098
Health care	-1.420	-5.331*	42.789***	12.538***
Food and beverage	-3.837**	-1.997	-1.330	-0.311
Chemicals	1.963	-0.948	1.142	2.207**
Technology	1.063	1.054	16.020***	9.515***
Utilities-energy	3.205**	2.265	-0.674	-0.923
Industrial goods and services	-1.931	-2.304	2.384	2.610***
Construction basic	-1.096	0.149	-1.768	-0.776
2004	5.271**	8.455**		
2005	4.380**	5.053	-3.141*	-0.360
2006	4.394**	6.924**	-1.702	-0.974
2007	4.703**		-2.014	-1.003
Intercept	34.91	34.60	3.85	1.80
Adj. R^2	**0.486**	**0.498**	**0.174**	**0.499**
Obs.	**1,315**	**409**	**3,163**	**409**

Significance: * at 10%, ** at 5 % and *** at 1%. The "final" database corresponds to the merger of the two databases (CG and RDI).
Sources: CG database, EC's R&D scoreboard.

R&D intensity is mostly explained by the firm's sector and much less by the firm's geographical origin. Of the sectors, health care and technology have a particularly strong effect, while the industrial sectors alone explain 50.1% of the variance. Companies originating from southern countries have significantly less R&D intensity, while companies originating from the Nordic countries show significantly more R&D intensity. In the final sample, the industry dummies are generally more significant. The observed variance in R&D intensity confirms the results of Mathieu and van Pottelsberghe (2010), who found much greater variance in R&D intensity across industries than across countries. Given the structural differences between the major explanatory variables of corporate governance (more geographically related) and R&D intensity (more related to the industrial sector), the governance factor is expected to play a relatively limited role in the R&D intensity model.

A GLM model is used to test the impact of a firm's corporate governance structure on its R&D intensity (see equation (3)). This model takes the heteroscedasticity of the error term into account. The model explains firm-level R&D intensity (IRD_{it}) in terms of various corporate governance scores (CG_{it}), firm size and several control variables. The companies are indexed by *i* (*i*=1 …279) and years are indexed by *t* (*t*= 1...4). $\phi_{country}$ χ_{sector} and ψ_{t} are the country, sector and time-specific vectors of dummies. L_{it} is the number of employees and controls for the size effect. As in the previous regressions, an intercept is included. One country dummy (Germany), one sector dummy (consumer services) and one year dummy (2003) serve as the benchmarks.

$$IRD_{it} = c + \alpha CG_{it} + \beta L_{it} + \phi_{country} + \chi_{sector} + \psi_{year} + \mu_{it}. \quad (3)$$

Column (1) of Table 6 shows the results for firm size, geographical dummies and year effects. The number of employees has a clear negative and significant impact on R&D intensity. Contrary to the Schumpeterian hypothesis, the results suggest that large firms are less R&D intensive. In terms of country groupings, southern countries, Nordic countries, the UK and Ireland all have a significant negative impact, which means that firms from these countries invest relatively less in R&D than firms in Austria, Switzerland, Germany, Belgium, the Netherlands, Luxembourg and France. The unexpected negative impact of Nordic origination can be explained by the fact that some information was lost by merging Sweden and Finland with less R&D-intensive countries like Denmark and Norway.

The sector dummies are added in column (2), five of which have a highly significant and positive impact: chemicals, industrial goods and services, automobiles, technology, and health care. As in Table 5, the geographical dummies lose their significance, which suggests that once the industrial structure is taken into account, country differences in R&D intensity vanish. In column (3), the corporate governance (CG) score is included but it does not seem to add any additional information, as the AIC (Akaike Information Criterion: the

goodness of fit of the model) criterion does not decrease. The parameter associated with corporate governance is not significantly different from zero.

Table 6: Impact of corporate governance practices (CG score) on R&D intensity

	(1)		(2)		(3)		(4)		(5)	
CG score					-0.01		-0.01			
St. error					*0.02*		*0.02*			
CG score (PCA)									-0.02	**
St. error									*0.01*	
Log Empl	-1.40	***	-0.49	***	-0.47	**	-7.67	***	-7.60	***
St. error	*0.23*		*0.18*		*0.19*		*1.89*		*1.89*	
Log Empl squared							0.36	***	0.36	***
St. error							*0.09*		*0.09*	
The Netherlands	-0.04		0.26		0.34		0.63		0.98	
Switzerland and Austria	-0.13		0.55		0.59		0.78		0.95	
Southern countries	-3.14	**	0.08		0.01		0.52		0.54	
Nordic countries	-2.65	**	-1.06		-1.03		-0.25		0.05	
France, Belgium and Luxembourg	-0.89		-0.23		-0.25		-0.14		-0.09	
UK Ireland	-1.69	*	0.26		0.60		0.89		1.93	**
Automobiles			3.69	***	3.60	***	3.34	***	3.01	**
Personal and household Goods			1.06		0.95		1.41		1.12	
Financials			0.07		0.04		0.03		0.17	
Telecommunications			0.35		0.36		0.25		0.37	
Health care			12.53	***	12.46	***	12.53	***	12.31	***
Food and beverage			0.06		0.02		-0.04		-0.30	
Chemicals			2.32	**	2.30	**	2.75	**	2.74	**
Technology			9.12	***	9.15	***	8.78	***	8.77	***
Utilities-energy			-0.66		-0.64		-0.62		-0.62	
Industrial goods & services			2.94	***	2.89	***	2.88	***	2.69	***
Construction basic			-0.42		-0.43		-0.38		-0.45	
2004	-1.33		-0.44		-0.33		-0.46		-0.04	
2005	-2.66	*	-1.06		-0.99		-1.10		-0.68	
2006	-1.82		-1.14		-1.04		-1.31		-0.83	
Intercept	21.79	***	7.04	***	7.29	***	42.11	***	42.19	***
# obs.	409		409		409		409		409	
AIC	6.39		5.81		5.81		5.78		5.77	
BIC	11125		4837		4834		4579		4503	

Significance: * at 10%; ** at 5 % and *** at 1% probability thresholds.
"CG score" is the weighted average of the four main components (BD, AC, SR and ER), while "CG score (PCA)" reflects the coordinates of the firms on the first factorial axis of a principal component analysis of the same four components (see Table 2). The principal component analysis is presented in the Appendix, Table A.5.

In column (4), the squared size variable (number of employees) is included in the model to test whether a non-linear relationship exists between firm size and R&D intensity. The negative impact of firm size and the positive impact of the squared variable suggest that a U-shape curve depicts the relationship between firm size and relative efforts in research activities – small firms and large firms undertake more research than medium-size firms. This quadratic model confirms the results presented by Grabowski and Vernon (1994), and Lacetera (2000) that the relationship between size and R&D efforts is U-shaped in high R&D-intensive industries.

The CG score variable is 'imposed' by Vigeo's chosen weighted average of sub-scores, which are, in turn, averages of several questions. Therefore, we conducted a principal component analysis of the four subcomponents of the corporate governance survey. The coordinates of the firms on the first factorial axis were then used as explanatory variables (see the principal component analysis presented in Appendix Table A5). The first factorial axis, which captures 58% of the variance, provides an alternative governance index to the weighted average provided by Vigeo. The results presented in column (5) suggest that the corporate governance index derived from the coordinates on the first factorial axis correlates negatively and significantly with firms' R&D intensity. This result reflects the combination of the four hypotheses, all of which predict that governance practices will have a negative or null effect on R&D intensity.

The negative impact means that the higher the score (i.e., the better the governance practices), the lower the R&D intensity. There are two ways to interpret this relationship. The first is that better governance should induce more efficient management (and, hence, more productive research activities). Therefore, the company should need fewer resources to generate profitable, innovative ideas. Indeed, some scholars have shown that better governance might lead to better performance (Gompers *et al*, 2001; Bhagat *et al*, 2008). The second interpretation is that the companies that promote better governance do so to the detriment of research activities, which are intrinsically risky and highly uncertain. A high score might indicate a willingness

to be more "attractive" for the equity market and, perhaps, an overly strong focus on short-term returns to the detriment of long-term strategies. Here, the "short-termism" of some governance practices would be an issue for R&D-intensive companies.

Table 7: Impact of corporate governance practices (sub-global scores) on R&D intensity

Variables	BD		AC		SR		ER	
BD (board of directors)	-0.02							
St. error	*0.01*							
AC (audit committee)			$-1\,10^{-3}$					
St. error			*0.02*					
SR (shareholders' rights)					-0.02	**		
St. error					*0.01*			
ER (executive remuneration)							-0.05	***
St. error							*0.01*	
Log Employment	-7.75	***	-7.71	***	-7.63	***	-7.70	***
St. error	*1.90*		*1.90*		*1.89*		*1.87*	
Log Employment squared	0.37	***	0.36	***	0.36	***	0.37	***
St. error	*0.10*		*0.10*		*0.09*		*0.09*	
Country	Yes		Yes		Yes		Yes	
Sector	Yes		Yes		Yes		Yes	
Year	Yes		Yes		Yes		Yes	
Constant term	42.15	***	41.51	***	42.39	***	42.00	***
Obs.	407		407		407		407	
AIC	5.78		5.79		5.78		5.76	
BIC	4575		4598		4524		4426	

Significance: * at 10%, ** at 5% and *** at 1% probability thresholds. BD stands for the average score related to the board of directors, AC is related to audit and control systems, SR is related to shareholders' rights, and ER is related to the executive remuneration schedule.

The negative relationship between a global governance score and R&D intensity might actually "hide" some strong links between R&D and only a few sub-components of the corporate governance score. This possibility is investigated in Table 7, which shows that the BD (board of directors) and AC (audit committee and control system) variables are not associated with a significant parameter. In other words, the degree of corporate skills and independence of the board have no influence or only a weak influence on a firm's propensity to invest in R&D. This result, therefore, does not validate hypothesis 1. The same is true for the audit process of the firm. Good control and transparency from the audit committee do not have an immediate impact on R&D intensity, which is in line with the second hypothesis. The design of audit control is too far removed from decisions to invest in R&D. The parameter associated with the SR variable is significant and negative, which

means that the higher a company scores in terms of its shareholders' rights policy, the less it tends to invest in R&D. The same observation applies to the ER variable. In fact, the remuneration dimension appears to be the most significant variable. One interpretation of its negative impact is that the more top management's remuneration is associated with firm performance, the lower the long-term commitment to risky projects is likely to be. This, in turn, indicates a lower R&D intensity.

At first glance, hypotheses 3 and 4 are confirmed, which suggests that shareholders' rights and executive remuneration systems affect the extent to which a firm invests in R&D. In order to obtain a more in-depth understanding of these relationships, the effect of each of their three sub-components (liability, implementation and results) is tested (Table 8). Negative and significant impacts on R&D intensity are associated with shareholders' rights liability and with the three dimensions of the executive remuneration system. The shareholders' rights liability (SR-L) indicator measures the voting right restrictions and the anti-takeover devices. More precisely, the value of this indicator is higher when the company respects the "one share – one vote – one dividend" principle (i.e., there are no voting rights restrictions) and when there is no reference to anti-takeover devices in the company's reporting. The executive remuneration system liability (ER-L) indicator takes stock of the creation and independence of the remuneration committee, and of the disclosure of senior executives' pay. The implementation (ER-I) indicator accounts for incentive plans, and the results (ER-R) indicator examines severance pay and remuneration votes at annual general assemblies.

In terms of the role of SR-L, a decrease of voting right restrictions, which should lead to the principle "one share – one vote – one dividend", tends to reduce R&D investments. This result might be interpreted in the light of literature suggesting that the presence of large, stable shareholders (such as strong blockholders with concentrated voting power) may favour long-term investment policies, including those focused on R&D and innovation activities (Hansen and Hill, 1991; Hill *et al*, 1988; Hosono *et al*, 2004; Lee and O'Neil, 2003). At the same time, this result indicates that the issuance of non-voting shares or the issuance of preferential shares

does not prevent R&D activity. However, if the company scores high and is therefore close to the "one share – one vote – one dividend" principle, it is likely to attract investors interested in fast returns and unprepared to agree to the long-term commitments typically needed for research projects.

In terms of anti-takeover rules, the weaker the presence of anti-takeover devices (the higher the score), the lower the R&D intensity. Companies need to have some assurance regarding their future and their independence to make long-term investments in research projects. This result is consistent with the literature, which suggests that the presence of anti-takeover provisions could protect managers from takeover pressures and lead to an increase in R&D expenditures (Stein, 1988). This may be logical but it is contrary to the view that takeovers act as a regulatory tool against poor performing companies (Becht, 2002).

As for ER-L, one could speculate that the independence of the remuneration committee has a negative impact because independent directors can ignore the specificities of the R&D projects and fail to optimally evaluate the appropriate level of remuneration for managers who opt to pursue research-driven strategies. The second component of ER-L relates to the disclosure of the remuneration.

The adoption of performance-related executive remuneration (ER-I) also has a negative effect on R&D intensity. Existing studies fail to reach a consensus on this issue. For example, Holthausen (1995) finds a negative relation. One explanation is related to the design of the contract, which aims to decrease agency problems and does not specifically encourage R&D. Furthermore, companies' performance measures are mostly based on financial ratios, which offer objective metrics but suffer from short-termism and encourage low-risk strategies (Munari and Sobrero, 2003). If a company's performance assessment is based on a strategic control system rather than a financial control system, shareholders will tend to value R&D more highly (Hoskisson and Hitt, 1988).

ER-R encompasses two topics: severance pay (i.e., the monetary package employees receive when they are dismissed from a firm) and voting results (i.e., the extent to which shareholders approve resolutions on executive remuneration). The estimates suggest that the higher the severance pay (the smaller the index), the higher the R&D intensity. Indeed, managers with high severance pay might be more willing to undertake risky projects, especially projects that are R&D intensive. In terms of the voting results, the more shareholders approve of the executive remuneration, the less R&D is promoted. Firms with antagonistic shareholders tend to challenge themselves more and tend to be more innovative. We can therefore assume that firms with critical shareholders who challenge remuneration resolutions tend to be more innovative.

Table 8: Results with basic scores as explanatory variables

Variables	SR-L		SR-I		SR-R		ER-L		ER-I		ER-R	
SR-L	-0.01	*										
St. errors	*0.01*											
SR-I			-4.710^{-3}									
St. errors			*0.01*									
SR-R					-0.01							
St. errors					*0.01*							
ER-L							-0.02	*				
St. errors							*0.01*					
ER-I									-0.02	**		
St. errors									*0.01*			
ER-R											-0.02	**
St. errors											*0.01*	
Log Empl	-7.73	***	-7.72	***	-7.65	***	-8.06	***	-7.49	***	-7.48	***
St. errors	*1.89*		*1.90*		*1.89*		*1.90*		*1.89*		*1.89*	
Log Empl sq	0.36	***	0.36	***	0.36	***	0.38	***	0.36	***	0.35	***
St. errors	*0.09*		*0.10*		*0.10*		*0.10*		*0.09*		*0.09*	
Country	Yes		Yes		Yes		Yes		Yes		Yes	
Sector	Yes		Yes		Yes		Yes		Yes		Yes	
Year	Yes		Yes		Yes		Yes		Yes		Yes	
Constant term	42.83	***	41.55	***	41.43	***	43.29	***	41.05	***	40.40	***
Obs.	407		407		407		407		407		407	
AIC	5.78		5.79		5.78		5.78		5.77		5.77	
BIC	4539		4598		4555		4541		4514		4506	

Significance: * at 10%, ** at 5 % and *** at 1% probability thresholds.

In summary, all of the scores related to the executive remuneration system have a significant, negative impact on a firm's propensity to invest in R&D. As discussed in Munari and Sobrero (2003), the linking of executive remuneration to tight financial performance assessments may not be optimal. Furthermore, it

might encourage short-termism. The concentration of voting rights and the establishment of protection against external takeovers might favour the establishment of a permanent ownership base. This, in turn, could enhance blockholders' abilities and incentives to monitor risky investments, and encourage those that are likely to generate innovation.

5. Conclusion

The objective of this paper is to assess the extent to which the corporate governance profile of European firms may affect their investments in R&D and innovative activities. This paper presents one of the first microeconomic empirical analyses to cover several countries and to rely on a rich dataset characterising the entire governance structure. This investigation was motivated, in part, by two recent policy debates: the widespread discussions of executives' remuneration packages and Europe's failed Lisbon agenda. In terms of the first issue, criticisms have been voiced since the start of the 2008 crisis and remuneration packages remain a bone of contention. Regardless of whether the issue at hand is the golden parachutes of chief executive officers or the end-of-year bonuses of traders, the wage structure attracts attention. The latter issue relates to the relatively weak propensity in Europe to invest in R&D. The European R&D intensity has averaged less than 2% of GDP for more than 20 years, while it has averaged 3% or more in the US and Japan.

Based on such considerations, we empirically assessed the impact on R&D intensity of four broad dimensions of corporate governance - the board of directors (BD), the audit and control process (AC), shareholders' rights (SR) and the executive remuneration system (ER) – based on a new dataset of 279 Western European companies. The main results suggest that the global corporate governance score of a firm is negatively correlated with its R&D intensity. However, a more detailed investigation shows that the dimensions related to the characteristics of the "board of directors" and to the "audit and control" profiles do not affect a firm's propensity to invest in R&D. At the same time, the other components –in particular, shareholder-protection devices and executive remuneration systems – play a significant role in influencing the propensity to invest in long-term innovative projects.

These results confirm that the principal-agent tension (the relationship between shareholders and managers) indeed affects R&D orientation in R&D-intensive companies. They also illustrate two types of expectations:

the expectations of the shareholders regarding company performance and managers' attitudes, and the expectations of the managers regarding their own risks and remuneration.

It seems, therefore, that traditional governance tools might generate some unintended consequences, and that they have the potential to hamper ambitious strategies and innovative projects. It could be argued that a good governance mechanism should improve management efficiency and that, in turn, R&D expenses could be reduced without a loss of innovativeness. However, the evidence seems to favour an alternative explanation. Some governance trends might not fit the profile of highly R&D-intensive firms. Governance practices that are designed to respond to the short-term expectations of financial markets might prove to be detrimental to long-term R&D investments. Furthermore, governance provisions emphasising financial control and the contestability within the ownership base of firms could ultimately discourage innovation and risk-taking. In this respect, the results presented in this paper are in line with recent evidence from the United States suggesting that publicly-listed companies significantly reduced their R&D investments after the SOX reforms were introduced (Bargeron *et al*, 2009; Cohen *et al*, 2009).

One implication of these results is that a regulatory framework that imposes uniform corporate governance requirements on all type of firms could have negative consequences. In particular, firms operating in sectors with high growth opportunities and in those that require high levels of R&D expenditures might need different governance mechanisms than companies operating in more stable or predictable environments.

The empirical evidence presented in this paper is subject to some limitations and drawbacks, which create additional research opportunities. For instance, the dependent variable – R&D intensity – is an imperfect measure of a firm's propensity to innovate. In addition, the paper does not assess the impact of R&D investments on productivity. Further research could, therefore, adopt alternative measures based on output measures, such as citation-weighted patents (Lee, 2005), new product introductions (Kochhar and David,

1996) or corporate entrepreneurship (Zahra, 1996). In addition, the empirical exercise is limited to large, publicly listed companies and it might not be valid for other types of firms. An interesting extension of this work could be to analyze the influence of multiple corporate governance arrangements on the innovative behaviour and performance of young, technology-based companies. Finally, the external financial and institutional context may moderate the relationship between companies' corporate governance practices and R&D investments (Munari *et al*, 2010). Further work based on multi-country datasets may focus on more detailed variables that measure specific aspects of the institutional context that could influence the relationship.

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Table A.1. Number of observations per country, sector and year in each database

	Corp. Gov.	Final	R&D
Supersector			
Automobiles	34	28	144
Basic resources	34	9	95
Chemicals	54	34	182
Construction and materials	83	19	83
Consumer services	279	30	154
Financials	269	19	101
Food and beverage	66	24	128
Health care	42	35	431
Industrial goods and services	167	62	842
Personal and household goods	43	15	176
Technology	98	59	551
Telecommunications	43	27	127
Utilities-energy	103	48	149
Country			
Austria	14	6	89
Belgium	33	13	111
Denmark	28	15	127
Finland	31	12	204
France	234	85	367
Germany	109	56	562
Greece	25		10
Ireland	32	3	32
Italy	73	15	130
Luxembourg	7	2	17
Norway	17	9	19
Portugal	15	1	4
Spain	85	14	65
Sweden	64	20	250
Switzerland	74	29	118
The Netherlands	70	20	143
United Kingdom	404	109	915
Year			
2003	39	16	503
2004	267	100	687
2005	375	144	983
2006	303	149	990
2007	331	0	0
# obs.	1,315	409	3,163

Table A.2. Descriptive statistics for all variables, final database

Vigeo variables	Mean	Min.	Max.	Std. Dev.	Obs.
Cg-score	46.279	7	91	16.216	409
Industry scoreboard data					
R&D investment (EUR millions)	477.039	3.56	5658	963.077	409
Change t & t-1 (%)	12.193	-73.35	699.73	58.351	395
CAGR 3 years (%)	4.359	-60.18	213.83	25.020	350
Net sales (EUR millions)	18358.390	129	260028	31952.920	409
Change t & t-1 (%)	9.506	-39.22	178.1	18.388	409
CAGR 3 years (%)	7.441	-38.37	118.77	15.841	391
Number of employees	55877.600	290	507641	74040.680	409
Change t & t-1 (%)	4.432	-44	792.7	42.176	407
CAGR 3 years (%)	2.920	-53.17	124.69	16.678	391
Rd/net sales t	4.330	0.01	45.18	6.124	409
Rd/net sales t-1	4.505	0	54.72	6.392	397
Operating profit t (% net sales)	12.046	-201.37	50.52	16.082	409
Operating profit t-1 (% net sales)	10.926	-139.39	51.47	14.919	393
Rd/employee t	11.511	0.04	101.59	17.562	409
Rd/employee t-1	11.596	0	104.19	18.173	396
Market cap. (Eur million)	21863	134	183476	31707	408
Change t & t-1 (%)	26.280	-88.02	1049.19	63.407	377

Table A.3. Correlation matrix: basic scores

	BD-L	BD-I	BD-R	AC-L	AC-I	AC-R	SR-L	SR-I	SR-R	ER-L	ER-I	ER-R
BD-L	1.000											
BD-I	0.476	1.000										
	0.000											
BD-R	0.213	0.355	1.000									
	0.000	0.000										
AC-L	0.504	0.612	0.289	1.000								
	0.000	0.000	0.000									
AC-I	0.251	0.380	0.176	0.491	1.000							
	0.000	0.000	0.000	0.000								
AC-R	-0.089	0.036	0.005	-0.029	0.070	1.000						
	0.072	0.465	0.915	0.562	0.162							
SR-L	0.125	0.161	0.122	0.108	0.123	-0.066	1.000					
	0.012	0.001	0.014	0.029	0.013	0.186						
SR-I	0.284	0.367	0.168	0.382	0.402	-0.080	0.235	1.000				
	0.000	0.000	0.001	0.000	0.000	0.108	0.000					
SR-R	0.053	0.065	-0.088	0.093	0.165	0.100	0.160	0.237	1.000			
	0.285	0.194	0.078	0.061	0.001	0.044	0.001	0.000				
ER-L	0.490	0.495	0.308	0.612	0.437	0.006	0.106	0.433	0.141	1.000		
	0.000	0.000	0.000	0.000	0.000	0.909	0.032	0.000	0.004			
ER-I	0.383	0.313	0.260	0.508	0.290	-0.121	0.089	0.430	0.193	0.459	1.000	
	0.000	0.000	0.000	0.000	0.000	0.015	0.073	0.000	0.000	0.000		
ER-R	0.381	0.382	0.287	0.486	0.279	0.007	0.154	0.451	0.337	0.541	0.488	1.000
	0.000	0.000	0.000	0.000	0.000	0.884	0.002	0.000	0.000	0.000	0.000	

Table A.4. Correlation matrix: sub global scores

	CGL	CGI	CGR	BD	AC	SR	ER
CGL	1.000						
CGI	0.739	1.000					
	0.000						
CGR	0.422	0.499	1.000				
	0.000	0.000					
BD	0.647	0.642	0.410	1.000			
	0.000	0.000	0.000				
AC	0.514	0.603	0.364	0.526	1.000		
	0.000	0.000	0.000	0.000			
SR	0.393	0.382	0.465	0.220	0.278	1.000	
	0.000	0.000	0.000	0.000	0.000		
ER	0.646	0.704	0.495	0.601	0.550	0.414	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	

Table A.5. Principal Component Analysis

1. Global score (coordinates on Comp1)

Summary statistics of the variables				
Variable	Mean	Std. Dev.	Min.	Max.
BD	51.292	19.870	0	98
AC	49.039	16.594	6	87
SR	50.479	22.621	0	100
ER	34.681	24.520	0	100
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.329	1.501	0.582	0.582
Comp2	0.828	0.343	0.207	0.789
Comp3	0.485	0.127	0.121	0.910
Comp4	0.358		0.090	1.000
Eigen vectors used to compute the coordinates				
Variable	Comp1			
BD	0.523			
AC	0.518			
SR	0.371			
ER	0.566			

Table A.6. Impact of corporate governance practices (CG score and PCA) on R&D intensity (GLM regressions)

	1		2		3		4	
CG score					-0.02			
					0.02			
Global score (PCA)							-0.03	***
							0.01	
Empl	0.00	***	0.00		0.00		0.00	
	0.00		0.00		0.00		0.00	
The Netherlands	0.21		0.35		0.47		0.87	
Switzerland and Austria	0.45		0.88		0.94		1.09	
Southern countries	-3.32	**	0.24		0.16		0.21	
Nordic countries	-2.38	**	-0.75		-0.70		-0.34	
France, Belgium and Luxembourg	-0.62		-0.07		-0.09		-0.02	
The UK and Ireland	-1.35		0.54		1.04		2.14	**
Automobiles			3.18	***	3.07	***	2.68	**
Personal and household goods			0.84		0.69		0.38	
Financials			-0.07		-0.10		0.05	
Telecommunications			0.00		0.03		0.14	
Health care			12.52	***	12.42	***	12.14	***
Food and beverage			-0.23		-0.28		-0.61	
Chemicals			2.18	*	2.16	*	2.15	*
Technology			9.47	***	9.50	***	9.37	***
Utilities-energy			-0.89		-0.85		-0.88	
Industrial goods and services			2.70	***	2.64	***	2.38	**
Construction basic			-0.72		-0.73		-0.82	
2004	-1.81		-0.37		-0.21		-0.23	
2005	-2.81	*	-0.99		-0.89		-0.65	
2006	-1.99		-1.01		-0.88		-0.58	
Constant term	8.30	***	2.02		2.64		3.76	***
# obs.	409		409		409		409	
AIC	6.46		5.83		5.83		5.82	
BIC	12054.55		4958.56		4946.22		4832.74	

For each score variable: coefficient and standard error
Significance: * at 10%, ** at 5 % and *** at 1%
Global score comes from a PCA of CG1, CG2, CG3 and CG4