

## **An Integrated Agency–Resource Dependence View of the Influence of Directors’ Human and Relational Capital on Firms’ R&D Spending**

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**ABSTRACT** In this paper, we contribute to the agency and corporate entrepreneurship literatures by focusing on board antecedents of research and development (R&D). Some researchers in this stream find outside directors negatively influence R&D spending, yet popular opinion suggests boards should be composed of outsiders, and at the same time, firms should be innovative and entrepreneurial. We begin to address this conflict by extending agency theory and incorporating resource dependence views in order to explore the influence of a wider range of director characteristics on R&D spending, a precursor of innovation and entrepreneurial activity. Our empirical results demonstrate that aspects of directors’ human and relational capital (e.g. education, entrepreneurial finance experience, technical experience, and interlocks) significantly influence R&D spending. Our findings illustrate that boards can be configured to improve efficiencies, thereby reducing R&D spending, and/or to augment R&D spending. They reveal the merits of considering inside and outside directors separately and show how the independence (i.e. inside/outside status) of directors shapes the effect of their human and relational capital on R&D spending.

### **INTRODUCTION**

Established corporations contribute significantly to the innovation and entrepreneurship that fuel the US economy (Zahra, 1996). Research and development by IBM into voice dialogues between humans and computers (VoiceXML), proactive forays by Apple and Gateway into consumer electronics, and numerous drugs developed by established biotech and pharmaceutical companies illustrate significant innovations by public corporations (Gassmann et al., 2004).

Owing to the importance of such innovations and their centrality to entrepreneurial growth, practitioners and scholars share an interest in what drives innovation by established firms. One important predictor is research and development (R&D) expenses. Researchers find that committing resources to R&D enables firms to create R&D

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capabilities, which are known to influence innovation (Helfat, 1997). Innovation is central to entrepreneurial action and, as such, it can enhance the performance of many corporations (Zahra and Covin, 1995). Control, empowerment, and numerous other factors enhance the potential for R&D investments to produce innovation and related entrepreneurial outcomes (Nobel and Birkinshaw, 1998; Zahra, 1996). While the relationship between firms' R&D expenses and innovation is far from simple (Rothaermel and Hess, 2007), it is difficult for firms to develop effective R&D capabilities without effective guidance and sufficient funds. Accordingly, directors may need to act as guardians of R&D (Kor, 2006), particularly when other functions vie for resources. In addition to helping to ensure that managers do not under-invest in R&D, directors can also help limit unnecessary R&D expenses through monitoring.

In fact, corporate governance reforms (e.g. US Sarbanes–Oxley, UK Combined Code) have underscored the value of independent boards that control agent behaviour and protect shareholders from excessive expenses, a focus indicative of agency theory (Jensen and Meckling, 1976). Similarly, the few studies that examine the influence of boards on R&D often employ agency perspectives (e.g. Deutsch, 2005; Zahra, 1996). In a recent theoretical study, however, Hillman and Dalziel (2003) draw attention to the limitations of agency theory. They suggest that agency perspectives be enhanced by integrating them with resource dependence (RD) theory (Pfeffer and Salancik, 1978). They predict that board human and relational capital ('board capital') may be the primary antecedent of board function fulfilment.

In this study, we refine their work by examining numerous specific human and relational capital variables and their influence on R&D spending. We also extend the thinking of Hillman and Dalziel (2003) that the influence of board capital on board functioning may be moderated by board independence (i.e. a board-level emphasis). We advocate the view that each director's independence (i.e. inside vs. outside status) should be evaluated in combination with his/her own (human and relational) capital (i.e. an individual-level emphasis). In contrast to a board level interaction approach, which implies that the *overall* independence of the board influences how the board as a whole uses its *collective* resources, our approach emphasizes the independence and resources of individual directors before aggregating them to the group level and predicting their influence.

This theoretical distinction shapes our hypotheses, approach to measurement, and tests. We develop hypotheses contrasting the influence of inside and outside directors' human and relational capital on R&D spending, measure the capital of insiders and outsiders separately, and run separate models testing the influence of inside and outside directors. We conduct this study using a sample of 221 established biotechnology and pharmaceutical firms; and find that the influence of the human and relational capital of outsiders on R&D spending often differs from that of insiders. Our models support the view that much can be learned by evaluating the (human and relational) capital of insiders and outsiders separately. These models identify several aspects of directors' human and relational capital that are significant predictors of R&D spending, a precursor to innovation and corporate entrepreneurship (Zahra, 1996). As such, our work provides insights into how boards can be staffed and utilized to increase and/or reduce R&D spending, thereby improving firms' capacities to balance efficiency and exploration.

We begin with a review of relevant literature, followed by theory linking aspects of inside and outside directors' human and relational capital to R&D expenses. We introduce our sample, report findings of our statistical analysis, discuss relevance, acknowledge limitations, and provide implications for practitioners; including specific levers for augmenting and reducing R&D in established corporations. We conclude by suggesting future avenues of inquiry.

## **EXTENDING RESEARCH ON THE CORPORATE GOVERNANCE ANTECEDENTS OF R&D SPENDING**

### **The Benefits and Limitations of R&D Spending**

Because the potential for innovation to enhance firm performance is extolled by practitioners and supported by academics (e.g. Roberts, 1999) under the right conditions (e.g. Zahra and Covin, 1995), it can be easy to assume that simply spending money on R&D improves performance. Such a conclusion is problematic. R&D spending is inherently risky (Baird and Thomas, 1985); and can dampen short-run performance. In addition, when R&D spending is not bolstered by control, communication, and inter-functional cooperation, firms are less able to develop innovative capabilities (Nobel and Birkinshaw, 1998), which are needed to produce innovations (Helfat, 1997). Researchers also find that performance enhancements from R&D spending can erode quickly (Rothaermel and Hess, 2007), and simply 'throwing' money at R&D is unlikely to produce efficient results.

Though research demonstrates that R&D spending does not guarantee innovation, organizational acceptance, commercialization, or better performance (De Clercq et al., 2011), R&D spending is necessary for corporations that pursue innovation (Thornhill, 2006) and entrepreneurial exploration (Zahra, 1996). In fact, organizational ambidexterity or juggling exploration and exploitation is a key to long term success (Andriopoulos and Lewis, 2009). This is especially true in R&D intensive industries – like biotech and pharmaceuticals – where influencing R&D allocations, managing expenses, and improving R&D efficiency are keys to success. Accordingly, we focus on understanding the antecedents of the level of R&D spending by corporations in these industries.

### **The Corporate Board Antecedents of R&D**

Researchers studying the predictors of R&D spending are examining the influence of corporate governance antecedents like ownership (e.g. Hoskisson et al., 2002), compensation (e.g. Makri et al., 2006), the market for corporate control (e.g. Hitt et al., 1996), and boards (e.g. Kor, 2006) on R&D spending, capabilities, and innovation. The link between boards and R&D spending may be particularly promising since boards are known to exert influence over numerous areas of corporate governance. For example, boards influence governance by owning stakes, shaping strategies including entrepreneurship, adjusting compensation, implementing anti-takeover provisions, and selecting the CEO, among others (Westphal and Zajac, 1995; Zahra et al., 2000). Given the influence of boards on this array of governance matters, their influence on key budgets (e.g. R&D spending) warrants attention.

Thus far, the influence of boards on R&D and related outcomes has primarily been explored through an agency lens, which focuses on the control role of boards (Jensen and Meckling, 1976). While it may be the dominant theoretical approach in the field, agency theory predictions are not always consistent and findings are mixed. For example, agency logic can be used to suggest that outside directors positively influence R&D (Kor, 2006); insofar as outside directors are more inclined to exert a controlling influence on inherently risk-averse managers (Jensen and Meckling, 1976), who might otherwise avoid risky R&D spending (Wiseman and Gomez-Mejia, 1998).

In contrast, agency logic is also used to argue that outside directors deter R&D spending. For example, Baysinger and Hoskisson (1990) argue that outside directors prefer financial controls and this preference results in a focus on efficiency and lower R&D spending by the firm. In empirical studies, scholars find evidence that outside directors are negatively (Deutsch, 2005) and non-significantly (Kor, 2006) associated with R&D spending. Given these contradictory uses of agency logic and mixed findings, this area warrants clarification.

One explanation for these mixed results relates to the equivocal assumption that outside directors are more apt to control agents than insiders. Some have argued that outsiders can easily become beholden to the CEO, reducing their likelihood of monitoring (e.g. Westphal, 1999). Others find that insiders – seeking to avoid the appearance of self-interest – are not always averse to monitoring (e.g. Boyd, 1994). An additional explanation is that considering the inside/outside status of directors (e.g. their motivation to monitor) without considering their expertise and other resources (e.g. their ability to monitor) provides a muddled picture of director influence. We advocate a more robust treatment of inside and outside directors.

In keeping with research (e.g. Hillman and Dalziel, 2003), we suggest that considering directors' *human capital* (expertise, experience, knowledge, and skills; Becker, 1964) and *relational capital* (potential resources embedded within and available through personal network ties with constituents in the environment; Jacobs, 1965) can also help to predict the influence of the board. By evaluating directors' human and relational capital in conjunction with their status as insiders/outside, we expect to capture a more complete view of their abilities, resources, and likelihood of exerting control on or supporting R&D spending. In view of this focus, we advocate complementing agency theory with RD perspectives (Pfeffer and Salancik, 1978) to investigate board influence on R&D.

### **An Integrated Agency–Resource Dependence View of Directors**

RD theory emphasizes the merits of board (human and relational) capital, which enables the board to perform the provision of resources function. In support of this position, numerous studies find that board capital predicts who is invited to join the board (e.g. Hillman et al., 2000; Westphal and Zajac, 1995) and the types of strategies, structures, and policies the board recommends and supports (e.g. Westphal et al., 2001).

While the empirical evidence for RD logic is compelling, studying the influence of board capital, without considering how motivated a board is in providing resources to

the organization, is a limitation. We therefore build upon the work of Hillman and Dalziel (2003). Their theoretical contributions predict that board capital influences board functioning and this relationship may be moderated by board independence. Parts of their propositions have begun to be tested in empirical studies, which collectively show that board capital significantly predicts board provision of advice, service, and involvement in strategy. Yet, much of this work (e.g. Pugliese and Wenstøp, 2007) has been conducted in small, family, and private firms, where boards have different functions than in public firms; and the proposed interaction between independence and capital merits attention (Walters et al., 2008).

Responding to this need, we integrate RD and agency logic into our model of director influence on R&D spending in a sample of established corporations. We argue that directors' independence and (human and relational) capital indicate their interests and resources and can be used to predict their influence on R&D spending. We provide the following illustration to clarify our position.

Let us consider an *inside* director 'Y' faced with a choice for or against expenditures in support of activity 'Z'. Let us assume that the efficiency of 'Z' is in decline. (This assumption is relevant to our research on R&D spending, since R&D efficiency was in decline in the biotech and pharmaceutical industries at the time of this study. In fact, several experts (e.g. Kenneth Kaitin of the Tufts Center for the Study of Drug Development) were calling for cost-efficient R&D and innovation (Malek and Kager, 2003) and recommending ways to improve the efficiency of R&D, including the use of emerging technologies and early withdrawal from unpromising R&D programmes (Adams, 2002).) In the context of declining efficiency in 'Z', agency theory calls for increases in monitoring of costs to ensure that money spent in pursuit of 'Z' is used efficiently. It also suggests that an outside director, because of his/her independence, will be more helpful than our inside director 'Y', because, as an insider, 'Y' is assumed to be more susceptible to CEO influence and less likely to monitor expenditures.

Unfortunately, these assumptions may be limiting our understanding of why an outside director would be more motivated *and* capable of exerting control than our inside director 'Y'. This logic may also be problematic since empirical findings do not always support the view that outsiders exert more effective control than insiders (e.g. Boyd, 1994). We suggest that integrating RD perspectives with agency theory will allow us to learn more about each director's background and relationships (in addition to his/her inside/outside status) and may improve our ability to predict his/her likelihood of controlling or supporting R&D expenses.

For example, let us assume that our inside director 'Y' has a functional background in finance. From an RD perspective, a background in finance endows director 'Y' with knowledge of financial controls and their ability to improve efficiency. By integrating this thinking with the agency views reviewed above, we suggest that, despite his lack of independence, inside director 'Y' seems *less* likely to give wholehearted support to unchecked spending on 'Z', owing to his/her background.

In so far as we suggest that independence (i.e. inside/outside status) should be evaluated together with the (human and relational) capital of each individual director, our approach complements the approach advocated by Hillman and Dalziel (2003,

p. 391). They predicted a board-level interaction between board independence and board capital in predicting board influence. Our approach is different because it considers the experiences and interests of each individual director before aggregating directors together. We suggest that a more accurate view of director influence may be gleaned from this approach. Accordingly, we measure each director's independence and (human and relational) capital before aggregating directors together or predicting their influence.

Returning to our illustration, let us assume that inside director 'Y' is serving on a board with a large number of outsiders, who, according to agency theory, are likely to control expenses. Let us assume that this same board has a number of directors with backgrounds in finance, so this board is also (collectively) capable of exerting control on expenses. At the board-level, we might predict that the finance experience of this board will be negatively associated with expenses and that this negative relationship will be moderated (strengthened) by the board's independence. However, there are times when this board-level logic might not be accurate.

Suppose that most of the finance experience of this board actually comes from inside directors, like director 'Y', rather than from the outsiders. In such a case the outsiders may be less capable of exerting financial control over R&D spending, and the insiders, though capable, may be less enthusiastic about rigorously scrutinizing budgets supported by the CEO. For these reasons, we may find less support for any proposed board-level effects. By evaluating a director's individual human and relational capital at the same time as we consider whether he/she is an insider or outsider, we are able to build separate models for inside and outside directors' capital and compare their influence on R&D spending. Thus, we extend Hillman and Dalziel's (2003) integration of agency and RD theories and attempt to more accurately predict the combined effect of director capital and director independence on R&D spending.

In the following sections, we illustrate how our integrated agency–RD logic extends to both inside and outside directors, and various elements of directors' human and relational capital. We provide examples of directors' career, functional, and educational backgrounds, and their interlock ties. We seek to demonstrate that the proclivity of an inside/outside director to exert control depends not only upon his/her independence, but also upon his/her human and relational capital; and thus, outside directors do not uniformly reduce R&D expenses, just as insiders do not unequivocally endorse them. In pursuit of these contributions, it is worth noting some other characteristics and structures, which are inherently board level constructs (e.g. an independent board leadership structure in which the CEO and Chair roles are separate), may still be best considered at the board level.

Before developing our hypotheses, it may also be important to highlight that we do not argue boards play the role of innovators or entrepreneurs in corporations (though inside directors with senior positions in the firm's R&D function or others may, at times, facilitate these roles). Instead, we contend that boards use their human and relational capital to provide and allocate resources that can limit or enhance the firm's R&D spending. The knowledge, experience, and connections of directors shape how they govern, and the ideas and resources they provide.

## DIRECTORS' HUMAN AND RELATIONAL CAPITAL–R&D EXPENSE RELATIONSHIP

### Entrepreneurial Finance Experience

From extant research, we learn that directors with career experience in entrepreneurial finance (i.e. venture capitalists, investment bankers) are heavily involved in supplying capital, monitoring financial performance (Dalziel et al., 2011), and influencing the strategies and entrepreneurial actions of the corporations they direct (Fried et al., 1998). Thus, examining a possible link between directors' career experience in entrepreneurial finance and corporate investments in R&D seems promising. In the following paragraphs, we contend that inside directors with career experience in entrepreneurial finance tend to support R&D spending owing to their inside affiliations, and this effect is weakened by their career experience; whereas outsiders with similar backgrounds are capable and motivated to improve cost efficiencies, thereby reducing R&D spending.

We first consider inside directors. Because they are often senior managers of the firm, agency theory suggests that they are less willing to monitor other managers (Fama and Jensen, 1983). Owing to their expertise in finance, inside directors with backgrounds in entrepreneurial finance are likely to share responsibility with other top managers for creating budgets and forecasting income and expenses. Given their familiarity with the firm's financials and their skills in entrepreneurial finance, these insiders are well suited to understand the need for investments in R&D and the time horizons involved in recouping R&D investments. Owing to their experience, they may also provide useful advice on the timing of stock repurchases, aimed at reassuring investors of the value of the firm's R&D activities. In sum, inside directors with backgrounds in venture capital and/or investment banking are well positioned to make forward-looking valuations of the benefits of the firm's R&D investments, and to shore up shareholder confidence. For these reasons, we anticipate that they may be supportive of R&D spending by firms, particularly in R&D intensive industries that use innovation to create value for shareholders.

However, it is also important to acknowledge that insiders with entrepreneurial finance experience are also often skilled in the use of financial controls, which are known to reduce expenses and risk-taking (Baysinger and Hoskisson, 1990). Accordingly, we do not anticipate inside directors with entrepreneurial finance experience to wholeheartedly support unchecked R&D spending, but overall, we anticipate them to be positively associated with R&D spending. Formally stated, we hypothesize:

*Hypothesis 1a:* The entrepreneurial finance experience of inside directors will be positively related to the firm's R&D expenses.

We now turn to outside directors with entrepreneurial finance experience, many of whom work for investment banks and venture capital firms. When venture capitalists make investments, they consider time horizons for harvesting returns and often serve as outside directors on these firms (Fried et al., 1998). Many venture capitalists have significant investment horizons in mind (around 5 or more years), yet in the years after a firm goes public, they are often interested in exiting their investment in the hope of

generating returns for investors in their venture capital funds (Brennan and Franks, 1997). Given the pressure to satisfy their investors with high returns, outside venture capitalists serving on the boards of post-initial public offering (IPO) corporations often seek to increase the liquidity of the firm's equity. One way of doing this is to endorse decisions that boost performance, in view of making the firm's equity more attractive, thereby facilitating a timely and profitable exit.

Similarly, outside directors with investment bank experience often represent the interests of their employer, an underwriter. While underwriters maintain a stake in the firm after the IPO, their primary goals are to ensure the liquidity of the new stock and to create a market in the new stock (see Ellis et al., 1999, for a review of this process). Once these objectives have been reached, however, they often reduce their interest in the public firm to free up capital for use in other underwriting transactions. Thus, we anticipate that both outside investment banker and venture capitalist directors will be less likely to support expenses that negatively impact short-term performance because they are likely to impede the stock liquidity of post-IPO firms.

Accordingly, outside entrepreneurial financiers (both venture capitalists and investment bankers) are likely to value cost efficiency, insofar as it can improve firm performance, increase the liquidity of their investment in the firm, and allow them to generate favourable returns for their own investors. Accordingly, in R&D intensive firms, they may take an active voice in supervising R&D budget allocations and expenditures. They seem likely to exert control aimed at minimizing waste and promoting cost-effective R&D practices. In select cases, they may even discourage ambitious long-term investments by the firm (Jenkinson and Ljungqvist, 2002), including those in R&D. To the extent that firms depend upon the experience of these directors (and the investment firms they represent) for financial counsel and budgetary control, it seems likely that they will make fewer investments in R&D. Accordingly, we hypothesize:

*Hypothesis 1b:* The entrepreneurial finance experience of outside directors will be negatively related to the firm's R&D expenses.

## Technical Experience

In keeping with the logic of numerous board researchers (e.g. Pfeffer and Salancik, 1978), we suggest that functional experience shapes directors' contributions to the firm and may therefore influence firm R&D spending. For example, functional experience in R&D areas (e.g. science and engineering), also known as 'technical experience' (Tyler and Steensma, 1998), seems likely to influence the level of R&D spending by the firm. We anticipate this influence to be different for inside and outside directors.

Because many inside directors also serve on the top management team (TMT), insights from the TMT literature may be useful in predicting the influence of insiders with technical experience on R&D expenses. Findings from this literature consistently support the view that technical experience is positively associated with R&D spending (e.g. Barker and Mueller, 2002; Schoenecker et al., 1995). Such findings are consistent with logic from RD theory (Hillman et al., 2000), which suggests that board members rely upon knowledge and expertise derived from their functional experience. Thus, the



technical experience of inside directors seems likely to provide them with knowledge, which allows them to provide advice and counsel on R&D projects. Integrating this RD logic with agency thinking, we further contend that insiders with R&D experience are motivated to allocate funds to the R&D function, because many of them serve within it. Accordingly, funding devoted to R&D can benefit their own area of the firm and self-interests because it can be used to support compensation, equipment, and research facilities, among others. Collectively, these arguments suggest that inside directors with technical experience are both prepared by their human capital and motivated by their insider status to support R&D spending. Thus, we formally hypothesize:

*Hypothesis 2a:* The technical experience of inside directors will be positively related to the firm's R&D expenses.

Outside directors with technical experience, on the other hand, have very different interests. Their independence from the firm means that they do not stand to benefit personally from the funds which are allocated to the firm's R&D. Compounding this issue, they are responsible for fulfilling their fiduciary duty to shareholders by monitoring and controlling the corporation's expenses. A director with technical experience is particularly capable of monitoring expenses because relevant functional experience augments his/her understanding of research, its stage of development, and its ultimate viability. Accordingly, an outside director with technical experience is not only motivated to monitor spending, but he/she is also likely to be well prepared to scrutinize R&D spending (e.g. by identifying cases of premature or excessive spending, among others). In addition, such a director may possess knowledge that permits him/her to recommend cost-cutting measures without sacrificing the innovativeness of the firm (e.g. more efficient R&D practices or technologies). Accordingly, outside directors with technical skills and experience are both prepared by their human capital and motivated by their independent status to reduce unnecessary R&D spending and improve the efficiency of R&D processes. They also seem more likely to recommend the timely discontinuation of unfruitful R&D projects, owing to their experience and independence. Thus, we expect:

*Hypothesis 2b:* The technical experience of outside directors will be negatively related to the firm's R&D expenses.

### **Advanced Education**

Other forms of board human capital are also likely to be associated with R&D expenses. For example, advanced education (e.g. a doctoral-level degree in business, engineering, science, and other fields) is likely to equip directors with skills in research that facilitate assessment of research projects in the focal firm. It may provide them with knowledge related to innovation management (Collins et al., 1991) or even familiarity with specific research related to the R&D pursuits of the focal firm. Such a view is supported by the logic of numerous board researchers (e.g. Carpenter and Westphal, 2001) who argue that the educational backgrounds of directors create important differences in their abilities to contribute to strategic decision-making. Extending this logic, we hypothesize that the

advanced education of insiders will be positively associated, whereas the advanced education of outsiders will be negatively associated with R&D expenses.

We begin by developing logic related to the influence of inside directors. Because inside directors often serve simultaneously on the TMT, and TMT researchers study the influence of education level on R&D spending and innovation-related outcomes, their research may lend valuable insights here. Interestingly, some TMT scholars find evidence that college degrees do not predict R&D (Barker and Mueller, 2002), whereas others find that executives with higher levels of education promote more innovation in the firms they run (Bantel and Jackson, 1989) and allocate more money to R&D (Schoenecker et al., 1995).

While this research collectively lends some support to a possible (positive) link between the advanced education of inside directors and R&D in firms, this relationship is, as yet, understudied. Applying the thinking of Carpenter and Westphal (2001) and other board researchers cited above, we contend that inside directors with advanced education will be more likely to have the cognitive capacity to advise successfully on matters related to the R&D efforts of the focal corporation. Since well-educated insiders also possess knowledge of the inner workings of the firm and ties to inside constituents, their insider status may motivate them to influence R&D and related innovation efforts and make them more prone to supporting R&D spending proposals. Accordingly, we expect that their familiarity with research and the firm prepares well-educated insiders to allocate monies to R&D in the firms they direct. Formally stated:

*Hypothesis 3a:* The advanced education of inside directors will be positively related to the firm's R&D expenses.

We anticipate just the opposite for the advanced education of outside directors. While the advanced education of outside directors provides them with knowledge of research, their independent status is likely to shape their use of this knowledge. Specifically, we contend that outside directors with advanced education are motivated by their independent status to fulfil their 'duty of care' and to scrutinize and monitor spending (Jensen and Meckling, 1976). Because their independence is coupled with their knowledge of research, we expect these directors to be particularly effective monitors of R&D spending, capable of guiding the firm to make better use of R&D funds. They are likely to possess better abilities to assess the appropriateness of planned R&D budget allocations, forecast the value of R&D projects, and identify the misuse of R&D funds. For these reasons, we expect that well-educated outside directors will exert a negative influence on R&D spending. Formally stated:

*Hypothesis 3b:* The advanced education of outside directors will be negatively related to the firm's R&D expenses.

## **Ivy League Education**

In addition to education level, we expect educational quality to influence the firm's R&D spending. To begin addressing this, we direct our attention to the case of an Ivy League

education. Ivy League schools are renowned for hiring top-notch researchers, providing large research endowments, and for success in cutting edge research and innovation (Bianco and Rupani, 2007). To the extent that researchers at Ivy League schools share information pertaining to or involving their students in their research, Ivy alumni are more likely to be aware of the benefits of research. Knowledge and experience of this kind is likely to provide both inside and outside directors with a higher comfort level and willingness to spend money on R&D. Insiders, having been exposed to successful research during their educations at Ivy League schools, may take more optimistic views of the potential for R&D to create value for themselves and the firm and outsiders may also be more likely to encourage managers to invest in R&D.

The self-confidence and ability of Ivy alumni may also augment their penchant for R&D spending. A variety of factors (e.g. the success of their parents (Dick and Bronson, 2005) and their own achievements in rigorous educational training (Rosenberg and Kaplan, 1982, p. 443; Weidman et al., 1972)), augment the self-esteem of Ivy graduates and instil confidence in their ability to succeed in the endeavours they pursue. This is important to us because researchers find that high self-esteem predicts risk taking (McElroy et al., 2007). Thus, we anticipate that (inside and outside) directors who are Ivy alumni will be more willing to invest in R&D despite the inherent risks.

The legitimizing effect of directors' Ivy League credentials may also facilitate R&D spending. To illustrate, Ivy League schools are known for matriculating and graduating the best and the brightest, and all directors are responsible for sharing some of their knowledge of the firm with external parties (e.g. shareholders, analysts, and others). Together these observations suggest that the prestige of their Ivy League credentials is likely to add credibility to the communications of directors as they represent the firm to external parties, increasing the legitimacy of risky R&D projects and making it easier to gain support for R&D spending. This logic applies to inside directors, who provide first-hand knowledge of the firm, and to outside directors who contribute objectivity in their external communications. Accordingly, we expect this aspect of human capital to overshadow the differences in motivation indicated by inside/outside status. In consequence of all of these arguments, we hypothesize:

*Hypothesis 4:* The Ivy League educational experience of inside and outside directors will be positively related to the firm's R&D expenses.

### **High-Tech Interlocks Compared with Low-Tech Interlocks**

The relational capital of directors (e.g. board interlocks) is also relevant to our work. Board interlocks are formed when directors of the focal firm serve on the boards of outside firms. From an RD perspective, these interlocks act as conduits for conveying resources. Pfeffer and Salancik (1978) suggest that interlocks provide channels for exchanging strategic knowledge 'which may impinge on or affect the focal organization' (p. 145). Interlocks and other relational ties facilitate the transfer of knowledge pertaining to accountability systems, decision-making processes, and organizational structures, among others (Palmer et al., 1993). Accordingly, we suggest that interlocks act as conduits for knowledge, which enables directors to influence R&D (e.g.

information about the viability and potential of alternative research trajectories, knowledge of effective R&D executive compensation, insights about R&D performance metrics, and organizational structures and systems that ease the development of R&D capabilities).

Knowledge related to R&D seems likely to come from firms actively engaged in R&D. Thus, we expect interlocks to high-technology firms, which are by definition more R&D intensive, to influence R&D spending differently than interlocks to other firms. In addition to predicting different effects for high- vs. low-tech interlocks, we also anticipate directors' use of their resources (e.g. interlocks) to vary with their independence or their propensity to exert control (Gulati and Westphal, 1999). We therefore consider the high- vs. low-tech interlocks of insiders and outsiders in two separate hypotheses.

We begin by predicting the comparative influence of insiders' high- vs. low-tech interlocks. We anticipate inside directors' interlocks to *high-tech* firms to be richer sources of R&D-related knowledge, than inside directors' interlocks to *low-tech* firms. As inside directors gain knowledge of R&D through their high-tech interlocks, we anticipate that they will use this knowledge to support R&D spending by the focal firm. We do not anticipate this relationship to be unequivocal, however. For example, owing to the tendency for cooperation between inside directors and other top managers, research suggests that insiders may be more likely to utilize their high-tech interlocks to facilitate R&D alliances (Gulati and Westphal, 1999), which could reduce the need for internal R&D spending (Ernst et al., 2011; Grimpe and Kaiser, 2010). This suggests that insiders' high-tech interlocks are capable of exerting some downward influence on R&D spending.

Conversely, owing to their insider status, inside directors lack independence and are often less able to exert control or reduce expenses (Fama and Jensen, 1983). While all directors share the duty of encouraging the firm to avoid excessive spending (e.g. by making appropriate investments in R&D), inside directors may be more reluctant to fulfil this duty as it could mean scrutinizing R&D budget proposals supported by the CEO and other executives. Even if insiders attempt to improve the efficiency of R&D, they are likely to be influenced by levels of R&D spending in the other firms they govern. Thus, interlocks to high-tech firms are likely to provide salient knowledge of higher levels of R&D spending than interlocks to low-tech firms. As this knowledge informs the judgment of insiders we anticipate that those with interlocks to high-tech firms will tend to support higher levels of R&D spending as compared to those with interlocks to low-tech firms. In view of this logic, we propose:

*Hypothesis 5a:* The interlock ties of inside directors to high-technology firms will be more positively associated with focal firm R&D spending than the interlock ties of inside directors to low-technology firms.

Having considered the influence of inside directors' interlocks, we now turn our attention to outside directors' interlocks. An outside director, with interlocks to high-technology firms, often has access to knowledge of R&D and, because of his/her independent status, seems more likely to focus on improving the efficiency of R&D (Baysinger and Hoskisson, 1990). Knowledge obtained via his/her interlock ties may

make a director more aware of technological developments (e.g. shifts in technology trends, emerging dominant platforms, or the market potential of different research trajectories). This knowledge is likely to enable him/her to guide managers to make the right choices between costly R&D projects or avoid projects that may not pay off given recent external developments (e.g. the emergence of new technologies). From an integrated agency–RD perspective, this well-informed director is also likely to be more motivated to question the appropriateness of unproductive R&D projects, owing to his/her independence from the firm. In sum, we anticipate that outside directors equipped with R&D knowledge conveyed via interlocks will be apt to improve the efficiency of R&D.

Other factors being equal, outside directors with interlocks to low-tech firms have less knowledge of R&D relative to their peers serving on the boards of high-tech firms. These outside directors may still be motivated by their independence to use financial controls and improve the cost-efficiency of R&D, but they are less likely to possess sufficient knowledge to identify effective ways to reduce R&D expenses without jeopardizing R&D productivity. In view of their comparatively limited knowledge, we anticipate that these outside directors will be less capable of exercising control over R&D spending. Formally stated, we propose:

*Hypothesis 5b:* The interlock ties of outside directors to high-technology firms will be more negatively associated with focal firm R&D spending than the interlock ties of outside directors to low-technology firms.

## METHODS

Because boards connect firms to their environment (Pfeffer and Salancik, 1978) and the nature of the environment varies by country and industry (e.g. government incentives vary across countries and often target research and technological development in specific industries), we used a sampling frame that allowed us to limit variance in our outcome variable caused by country and industry. We collected data in the US biotechnology and pharmaceuticals industries (i.e. publicly traded US firms from SIC codes 2833–2836, which are interdependent). Given that R&D investments occur over time and are often measured over multi-year periods (Zahra, 1996), our chosen population included firms in continual operation from 2001 to 2003.

Our sample consisted of all firms in our target population that were covered in ReCap, a well-respected database of biotechnology and pharmaceutical firms (Gulati and Higgins, 2003). Of the 332 firms available in ReCap, several cases were removed due to missing data, leaving 225 complete cases. We ran descriptive statistics and normality plots (e.g. qq and pp plots) in STATA and identified four outliers. We ran our models using both the full and final (outliers removed) samples and found very similar results. At the time of the study, the average firm in the sample was 17.02 years old ( $SD = 13.7$ ). It employed 1975 people ( $SD = 10,716$ ), had assets totalling \$509.2 million ( $SD = \$2218.8$ ), and *t*-tests comparing these variables revealed no significant differences between our sample and other firms in these industries.

## Measurement

Given that most R&D investments need to be sustained over multi-year periods (Helfat, 1997), we used Compustat data to measure average R&D expenses from 2001 to 2003. To ensure that our findings were not a function of our *ex ante* choice to measure our dependent variable over three years, we repeated our analysis using two and four year averages as well. These analyses produced findings very similar to our reported models. Consistent with related research (e.g. Rothaermel and Hess, 2007), we chose not to use a measure of R&D intensity because intensity measures lead to uncertainty as to whether the effects are due to the numerator (R&D expenses) or the denominator (a proxy of firm size like number of employees or revenues). Also, the firms we are reporting on are publicly traded biotech/pharmaceutical companies. These firms often go public in the first 4–5 years of their operations (Gulati and Higgins, 2003), yet it takes them about 10 years of R&D to introduce a new product to market (Burrill and Lee, 1993; Gassmann et al., 2004). Because of this long R&D cycle, many of the firms in our sample had yet to generate significant revenues at the time of the study and some of their most important assets were intangible. Accordingly, we needed to avoid using an R&D intensity measure like R&D/sales or R&D/assets. Instead, we used the average of R&D expenses and controlled for firm size. To validate this approach, we also ran our models using a sub-sample of firms averaging >\$10 million in revenues. These models substantiated most of our findings, with the notable exception that advanced education (<0.10) was no longer significant in Models 4 and 6.

Our independent variables captured elements of directors' human capital as well as their relational ties. We collected data from proxy statements in the SEC's EDGAR database and in the Dun and Bradstreet Reference Book of Corporate Managements for these measures. We measured our independent variables using 2001 data since we expected the board to have an immediate and lasting impact on R&D expenses over the 2001–03 period. We classified directors as insiders (e.g. employees of the firm), affiliates (e.g. those associated with the firm, including founders and other prior employees, current and former consultants (law professionals, patent experts, strategists, etc.), and family members), and outsiders (directors who are 'independent' from the firm – not insiders or affiliates). When a director, an outsider for example, had a certain type of human or relational capital, the score for that aspect of capital was tallied together with that of other outsiders. The same procedure was followed for insiders, to arrive at group-level scores for various aspects of insiders' and outsiders' capital.

For example, we used a binary measure of experience in entrepreneurial finance (e.g. venture capital, investment banking experience) to score each director (one if they had such experience and zero if they did not) and aggregated these individual-level scores through summation to the group level for inside and outside directors. To validate this approach we reran our models with separate predictors for venture capital and investment banking experience, respectively. As anticipated, all of the coefficients had the same sign (negative), but interestingly a Chow test revealed that outside directors' investment banking experience exerted a stronger negative influence on R&D spending than did outside directors' venture capital experience ( $p < 0.05$ ). We measured experience in science and engineering, also known as technical experience (Tyler and Steensma, 1998),

by scoring each director with primary functional experience in this area as one and others as zero. We then added these individual scores to create group-level human capital measures of technical experience for insiders and outsiders.

We followed this same procedure to calculate board Ivy League educational experience. In the case of advanced education, directors scored one if they had earned a doctoral-level degree (e.g. Doctor of Jurisprudence (JD), Doctor of Philosophy in any field (PhD), or a Medical Doctorate (MD)) and zero if they had not. As a robustness check, we reran our models counting only doctoral-level degrees in science and medicine (e.g. PhD, MD), as this kind of advanced education was likely to be particularly relevant to R&D in our sample. This check produced similar results in Models 2 and 4, with the notable difference that the advanced education coefficient in Model 4 was no longer significant. We infer that a wider treatment of advanced education generates more significant predictions of R&D spending.

Finally, we measured interlocks, formed when directors of the focal firm also served as directors of outside organizations, as a proxy of relational capital. We counted interlocks to for-profit organizations only, because they are consistently reported on proxy statements due to US regulations. We began by coding the directors' interlocks (1645 total interlocks, averaging about one per director). We then used data from EDGAR, Melissa DATA, and company websites to determine the industry (SIC code) of each interlock firm. To differentiate between interlocks to high- and low-technology firms, we obtained Compustat data and calculated the average R&D/sales figures for all of the industries of the interlocked firms. We compared these industry figures with the average of all industries in the Compustat North America universe of firms. Those that had R&D/sales values greater than the mean of the entire population were considered R&D intensive or high-tech and were coded one, whereas all others were coded zero. We then tallied the high- and low-tech interlocks at the director and group levels. In addition to relying upon Compustat data to code interlocks as high-tech vs. low-tech, we also performed a robustness check by compiling a list of industries described as high-tech by authors in articles published over the past three years in five journals (i.e. *Academy of Management Journal*, *Administrative Science Quarterly*, *Journal of Management Studies*, *Organization Science*, and *Strategic Management Journal*). The resulting list included industries such as biotechnology and pharmaceuticals, computers, electronics, and semiconductors. Interlocks to firms in high-tech industries were coded one; others were coded zero, and group-level tallies for insiders and outsiders were made. This approach produced virtually identical findings as our reported models.

Because we were interested in specific aspects of board influence on R&D expenses, we paid close attention to potentially confounding industry, firm, and board characteristics. Data for our control variables were obtained from Compustat and annual proxy statements found in the SEC's EDGAR data files. We controlled for industry through a series of dummy variables with SIC 2836 as the base industry in our models. We controlled for firm age, calculated from the year each firm was founded. We controlled for firm size using the natural log of the number of employees because, in samples such as ours, sales are not preferred owing to the low and varying revenue streams of some firms (Sorensen and Stuart, 2000). Because prior firm performance may influence the funds available for R&D, we controlled for return on assets (ROA) calculated as net

earnings/total assets for the three-year period preceding measurement of our dependent measure. We controlled for slack resources and leverage using the current ratio (current assets/current liabilities) and the debt to assets ratio (total debt/total assets). In keeping with Hoskisson et al. (1993), we also controlled for diversification using total diversification (the sum of the related and unrelated components of diversification), calculated using the entropy measure (Davis and Duhaime, 1989).

In addition to these industry and firm level controls, we also controlled for several board variables. We controlled for average director age and tenure because researchers have found that the average age of directors predicts the board's ability to influence the firms' strategy (Golden and Zajac, 2001), and the average tenure of directors is significantly associated with R&D expenses (Kor, 2006). We also controlled for board size, using the total number of directors; and for duality, using a binary variable, with one indicating that the same individual is both CEO and Chair. We controlled for affiliate directors in all models (Jones et al., 2008). When predicting the effects of inside directors (Models 1–2) and all directors (Models 5–6), we controlled for a count of outside directors; and, likewise, we controlled for inside directors when predicting the effects of outside directors (Models 3–4).

## RESULTS

We used hierarchical ordinary least squares (OLS) regression to test our predictions. Table I contains the descriptive statistics and the bivariate correlation matrix for our variables. Table II presents our findings. Models 1, 3, and 5 are control models, while Models 2, 4, and 6 contain hypotheses and associated tests. All models have unstandardized betas and all variance inflation factors (VIFs) are below the recommended cut-off (10), suggesting that multicollinearity is not a problem.

The results in Model 2 pertain to Hypotheses 1a, 2a, 3a, 4, and 5a, which predict relationships between the human and relational capital of *inside* directors and corporate R&D spending. Hypotheses regarding the entrepreneurial finance experience, technical experience, and advanced education of inside directors (Hypotheses 1a, 2a, and 3a) were not supported. We did, however, receive support ( $p < 0.05$ ) for Hypothesis 4, revealing a positive relationship between the Ivy League experience of inside directors and R&D spending. Conversely, a Chow test revealed no significant difference ( $p = 0.33$ ) between the effects of insiders' interlocks to high- and low-tech interlocks and R&D spending.

In Model 3 we report the findings of predictions of the influence of *outside* directors' human and relational capital on R&D spending (Hypotheses 1b, 2b, 3b, 4, and 5b). We find significant relationships between most of these outside director variables and R&D spending. We find support for our predictions (Hypotheses 1b and 3b) that outsiders' entrepreneurial finance experience ( $p < 0.05$ ) and advanced education ( $p < 0.10$ ) are negatively related to R&D spending. We also find support for a positive relationship (Hypothesis 4) between the Ivy League education of outside directors and R&D spending ( $p < 0.05$ ). Contrary to Hypothesis 2b, the technical experience of outside directors is positively related to R&D spending ( $p < 0.10$ ). In keeping with Hypothesis 5b, a Chow test provided evidence ( $p = 0.01$ ) that the interlocks of outside directors to low- versus high-technology firms have significantly different effects on R&D spending. Yet, in





Table II. OLS regression on R&D spending

<i>Variables</i>	<i>Model 1 (control)</i>	<i>Model 2 (insiders)</i>	<i>Model 3 (control)</i>	<i>Model 4 (outsiders)</i>	<i>Model 5 (control)</i>	<i>Model 6 (all directors)</i>
Entrepreneurial finance experience		-35.08 (22.86)		-35.42* (14.88)		-35.18** (13.41)
Technical experience		0.68 (20.02)		38.66† (21.79)		8.67 (9.68)
Advanced education		-6.76 (18.53)		-28.96† (15.44)		-32.79† (18.79)
Ivy League education		77.49* (34.97)		21.78* (8.93)		24.35** (7.92)
High-tech interlocks		-6.58 (14.06)		0.92 (2.87)		0.32 (2.67)
Low-tech interlocks		116.33 (88.05)		31.38** (11.31)		33.90** (11.81)
Industry 2833	-133.13* (56.11)	-99.16* (47.39)	-133.13* (56.11)	-102.37 (65.24)	-133.13* (56.11)	-89.40 (64.09)
Industry 2834	3.26 (19.86)	6.92 (18.66)	3.26 (19.86)	24.43 (24.72)	3.26 (19.86)	26.86 (23.44)
Industry 2835	-33.62 (26.38)	-38.66 (29.83)	-33.62 (26.38)	-14.28 (25.03)	-33.62 (26.38)	-14.03 (24.70)
ROA	-13.74 (14.60)	-11.76 (19.39)	-13.74 (14.60)	-17.14 (12.22)	-13.74 (14.60)	-15.81 (12.28)
Ln (firm size)	82.35 (54.55)	60.42 (63.75)	82.35 (54.55)	57.99† (32.79)	82.35 (54.55)	45.37 (35.42)
Ln (firm age)	147.01† (86.82)	122.00† (62.58)	147.01† (86.82)	107.50† (60.06)	147.01† (86.82)	101.45† (53.08)
Current ratio	-1.20 (0.82)	-1.44† (0.82)	-1.12 (0.82)	-1.23† (0.67)	-1.20 (0.82)	-1.31* (0.61)
Debt to assets ratio	-24.44 (15.10)	-20.62 (15.89)	-24.44 (15.10)	-15.76 (11.56)	-24.44 (15.10)	-13.18 (11.41)
Diversification	-53.14 (74.23)	-9.21 (62.08)	-53.14 (74.23)	-5.92 (58.33)	-53.14 (74.23)	24.47 (52.53)
Average age of directors	-2.78 (2.77)	-2.95 (2.69)	-2.78 (2.77)	-4.88† (2.76)	-2.78 (2.77)	-4.75† (2.57)
Board size	13.40 (19.56)	-10.70 (21.28)	43.09* (16.98)	21.17* (10.64)	13.40 (19.56)	0.50 (17.02)
Board tenure	3.68 (5.78)	3.35 (5.06)	3.68 (5.78)	1.89 (4.84)	3.68 (5.78)	0.91 (4.49)
CEO is also chairman	30.18 (21.23)	22.85 (19.83)	30.18 (21.23)	21.59 (18.10)	30.18 (21.23)	24.09 (18.06)
Inside directors			-29.69† (17.71)	-12.72 (15.55)		
Outside directors	29.69† (17.71)	52.36* (25.21)			29.69† (17.71)	15.96 (14.50)
Affiliate directors	8.87 (21.98)	23.89 (26.08)	-20.81 (19.19)	-2.36 (18.89)	8.87 (21.98)	-1.01 (24.22)
Constant	-7,789.98 (11,740.78)	-7,041.75 (10,217.86)	-7,789.98 (11,740.78)	-3,916.93 (9,772.27)	-7,789.98 (11,740.78)	-1,948.39 (9,045.14)
F-statistic	6.75***	7.31***	6.75***	9.27***	6.75***	10.82***
R <sup>2</sup>	0.33	0.44	0.33	0.50	0.33	0.53
Improvement over control ( $\Delta R^2$ )		0.11*		0.16***		0.20***

Notes: † p < 0.1; \* p < 0.05; \*\* p < 0.01; \*\*\* p < 0.001. Unstandardized betas with robust standard errors in parentheses. All VIFs < 10.

contrast with Hypothesis 5b, outside directors' interlocks to low-technology firms were positively associated with R&D spending ( $p < 0.01$ ).

Consistent with our theory, these findings support the idea that specific aspects of directors' human and relational capital influence R&D spending. They also reveal differences between the effects of insider and outsider human and relational capital. Implicit in each of our hypotheses is the idea that considering each director's independence in conjunction with his/her (human and relational) capital before aggregating to the group level would extend our understanding of the board's influence. To more fully explore the value of this approach, and in response to the advice of helpful blind reviewers on this paper, we also included (board-level) post hoc analysis as a point of reference (i.e. Models 5–6). In these models, we aggregated the collective human and relational capital of *all* directors on the board together. Model 5 includes our controls and Model 6 includes tests of the effects of the human and relational capital of the entire board. *It is worth noting that outside directors are not significantly related to R&D spending in Model 6, yet the influence of outsider status is apparent in Model 4 when it is considered in conjunction with elements of directors' capital.* To explore this board-level approach thoroughly, we modelled the interaction of outside directors with our human and relational capital variables, but the results presented excessive multicollinearity even after centring the variables, and so they are not included. We also employed two alternative measures of board independence (i.e. percentage of outside directors and board leadership structure or duality), but the board-level interaction effects could still not be estimated effectively because of problematic multicollinearity ( $VIF > 20$ ).

Having presented these results, it is important to acknowledge that there is the potential for endogeneity in the selection of directors. For example, it might be the case that firms trying to discourage R&D appoint directors who will further discourage R&D spending. If this is the case, then modelling board composition as influencing R&D spending is flawed. To address this issue, we established a lag between the initial collection of the board composition information and the final R&D outcomes. We also paid attention to industry and selected a sample which is subject to similar environmental pressures. In addition, we attempted to statistically control for the possibility that the composition of the board is a reflection of, rather than a predictor of the firm's R&D spending, by using a Heckman procedure. Following Hamilton and Nickerson (2003) and Villalonga and Amit (2006), we used the variables from our control model (Model 1) in a probit procedure to predict whether boards with R&D insiders had appointed other inside directors with R&D backgrounds to the board. Our rationale was that the appointment of R&D insiders to the board would suggest that the firm intended to devote resources to R&D and thereby indicate that board capital was endogenous with R&D spending. To ensure the robustness of this approach, we ran other probit models as well. To illustrate, we ran a model which predicted whether boards with R&D directors had appointed any directors (insiders and/or outsiders) with similar (R&D) backgrounds. Though these approaches produced significant probit models, the inverse Mills ratios were non-significant in *all* of our models and so a statistical control for endogeneity was excluded to improve the parsimony of our models. In addition to our efforts to control for endogeneity, we employed numerous alternative treatments of our independent and dependent variables to confirm the robustness of our findings.

## DISCUSSION

Our theoretical arguments and empirical findings reveal: (1) the human and relational capital of directors does influence R&D spending; (2) the insider/outsider status of directors influences the way they use their capital; and (3) these effects can be easily observed by estimating the effect of the (human and relational) capital of inside and outside directors separately.

### Outsiders

Our empirical findings provided support for many of our predictions related to the capital of outside directors. These results are meaningful because they support an integrated agency–RD view of boards and extend studies which find a negative relationship between outsiders and R&D spending (e.g. Deutsch, 2005). Our work contributes to this literature by identifying specific aspects of human and relational capital of outside directors that influence R&D spending. For example, outsider entrepreneurial finance experience and advanced education were shown to be negatively related to R&D spending. While these findings support our integrated agency–RD perspective, some of these experienced and educated directors may also have been attracted to firms that make more efficient use of R&D funds.

Our findings further reveal that in addition to promoting efficiency and reducing R&D spending, outside directors are also positively associated with R&D spending. This finding lends support to the thinking of those who have postulated a positive link between outsiders and R&D (e.g. Kor, 2006), but were unable to validate this claim by examining the independence of directors without considering their (human and relational) capital. Thus, our work sheds light on how board composition can be configured to manage R&D spending levels and may be useful to R&D intensive firms responding to regulatory requirements for higher numbers of outsiders.

We found evidence that the Ivy League experience of all directors (both outsiders and insiders) was positively related to R&D spending. This finding is important because it has received limited attention in the governance literature, and it is easily observed. This relationship is also important because it suggests, in some instances, that the effects of the human capital of directors may supersede the influence of their inside/outside status. It is also worth noting that the significant effect of an Ivy League education on R&D spending is not necessarily limited to Ivy League schools and may extend to other prestigious research-oriented universities as well.

Our results suggest that technical experience only appears to affect R&D spending for outside directors. This finding counters our integrated agency–RD theory prediction. Instead, it is more consistent with RD and board decision making literatures, which suggest that the functional experience of directors predicts their contributions to the firm. This is particularly interesting when juxtaposed with the finding that outsiders' advanced education (which also gives them involvement in research) is negatively related to R&D spending. It seems to suggest that work experience may inspire more support for R&D than education.

The finding that outsiders' interlock ties to low-tech firms were more positively related to R&D spending than their interlock ties to high-tech firms was inconsistent with our

logic. While we (correctly) predicted a significant difference between the effects of outsiders' high- and low-tech interlocks, we had anticipated that their high-tech interlocks would have a more negative relationship with R&D spending. As they had a non-significant effect, countervailing influences may be at work. For example, consistent with behavioural agency theory (Wiseman and Gomez-Mejia, 1998), it may be that outsiders also have tendencies to promote risk-taking, and when these tendencies work together with knowledge of R&D obtained via high-tech interlocks, outsiders were inclined to promote and support additional R&D spending, despite any associated risks.

This logic might also explain the significant positive association between outsiders' low-tech interlocks and R&D spending. Other factors being equal, outside directors with interlocks to low-tech firms have less knowledge of R&D relative to their peers serving on the boards of high-tech firms. These outside directors may still have been motivated by their independence to encourage executives to invest in risky R&D projects (Kor, 2006), but they seem less likely to have possessed sufficient knowledge of how to delay R&D investments as appropriate, or identify other effective ways to reduce R&D expenses. In view of their comparatively limited knowledge, these outside directors may have been less capable of exercising control and more likely to provide 'unqualified' support of R&D spending, as compared with outside directors who possess interlock ties to high-tech firms. In fact, the lack of (external) knowledge of R&D from the ties of these directors may have heightened the need for internal R&D spending.

## Insiders

We found that the entrepreneurial finance experience of insiders was non-significantly related to R&D spending. This finding is inconsistent with our prediction that it would be positively associated with R&D spending. It underscores the tension between the propensity of insiders to support R&D spending in R&D intensive firms and their focus on efficiency derived from their experience in entrepreneurial finance. It may be that this tension between independence and experience substantially weakened the effect of this variable. This interpretation reinforces the value of research that integrates the board and TMT literatures by considering the influence of insiders that serve on the board as well as those that do not (e.g. Kor, 2006; Walters et al., 2008).

It is interesting that we did not find support for a significant relationship between the advanced education and the technical experience of inside directors and R&D spending, particularly since power analysis revealed that the likelihood of Type II error was just 0.02. Because inside directors with advanced degrees (PhDs and MDs) and technical experience (work history in science and engineering) are often executives in the R&D function of the firm, known for exerting a positive influence on R&D spending (e.g. Barker and Mueller, 2002; Schoenecker et al., 1995), our results seem to suggest that once appointed to the board of their own company, these same insiders may no longer significantly influence their own budget (i.e. R&D spending). This surprising conclusion is consistent with compensation research, which finds that insiders actively avoid the appearance of self-interest and misconduct by exerting control (e.g. Boyd, 1994). It suggests that appointing them to the board may be an effective means of limiting their potential to engage in self-interested (R&D) spending.

Our results also suggest that insiders' interlocks have little effect on R&D spending. Our data reveal that this is due in part because insiders do not have many interlock ties. An additional explanation is that insiders have access to a considerable amount of internal data, and owing to bounded rationality are more likely to filter environmental data (Bettis and Prahalad, 1995), including knowledge obtained via interlocks, thereby lessening their effect on R&D spending.

### **Limitations**

By testing the influence of the human and relational capital of inside directors separately from outside directors, we were able to learn more about directors' influence on R&D spending and find some support for our integrated agency–RD view of boards. Our work, however, is not without limitations. It is cross-sectional, which allows us to document associations, but makes it difficult to impute causality. We include a small range of industries, which allows us to control for cross-industry sources of variance, but opens the door for tests of the generalizability of our findings. Our independent variables, which are operationalizations of aspects of human and relational capital, indicate the presence of resources, but we were not able to explicitly measure the transfer of resources (e.g. the transfer of knowledge via interlocks), as directors and executives from these firms were largely unresponsive to surveys. We did, however, examine several new variables (i.e. whose relationships with R&D spending have not been the subject of prior research) and we went beyond mere counts of interlocks by specifying the nature of the ties (i.e. high- vs. low-tech), an approach which we believe is more indicative of the types of resources that flow through interlock ties.

### **CONCLUSION AND FUTURE EXTENSIONS**

In conclusion, this paper is devoted to examining the link between corporate directors and R&D spending, which is known to be associated with entrepreneurial actions, including innovation (Zahra, 1996; Zahra and Covin, 1995). Most studies in this area of the strategic entrepreneurship literature have adopted agency perspectives and some have found that board composition (number or percentage of outside directors) can reduce R&D spending. We complemented this area of research by employing an integrated agency–RD perspective, which allowed us to examine several aspects of each director's human and relational capital in conjunction with his/her independence. This approach allowed us to differentiate between the inside and outside director influence, explore how independence and capital shape this influence, and identify limitations in board-level aggregation approaches.

Our findings yield insights into which directors both augment and reduce R&D spending by the firm. Our work suggests that director independence (i.e. outside vs. inside status) influences the degree to which directors use their human and relational capital and how they employ these resources to effect R&D, which leads to innovation and related entrepreneurial actions. Our results reveal that the effects of independence may best be observed by evaluating insiders and outsiders separately. Specifically, our work suggests that firms pursuing innovation may be able to increase R&D spending by

appointing directors with Ivy League educations, and outside directors with technical experience and interlocks to low-technology firms. Conversely, for firms wanting to improve the efficiency of R&D or limit their R&D spending (e.g. to focus on external innovation or reduce their burn rates to reassure shareholders), our work suggests that appointing outside directors with experience in entrepreneurial finance or those with advanced education may be viable approaches.

We note that director appointments should be made carefully as aspects of a given director's (human and relational) capital can exert competing influences on R&D spending. This suggests it is wise to evaluate each director's capital thoroughly. In addition, since the appointment of venture capitalists and investment bankers to the board often occurs at early stages of a firm's development, our work confirms theory suggesting that the appointment of directors in the entrepreneurial stage of a firm's development has lasting effects on the firm's strategic direction (Lynall et al., 2003). Another implication of our work is that conventional views on outside directors (manifest in Sarbanes–Oxley and similar regulations) may be too simplistic. By considering both the human and relational capital of directors in conjunction with their outsider status, a more fine-tuned approach to improving director composition might be achieved.

Our study also opens the door for additional research, which will enhance our understanding of the influence of boards on R&D and related entrepreneurial outcomes. For example, we focused on a tightly defined segment of the economy where R&D is critical. Future studies might compare these findings with samples in other industries.

In keeping with much of the board literature, we relied on data from the firm's proxy statements to measure human and relational capital. These statements provided a brief biography of each director, which enabled us to code whether or not a director had a certain type of human or relational capital. Future studies could examine other variables in these statements, such as legal or industry experience. Since our archival approach resulted in support for a relationship between several aspects of directors' capital and R&D spending, future studies might also rely upon survey methods to more specifically assess the various experiences of directors. Surveys might also be used to measure directors' reliance upon their human and relational capital in controlling and providing resources to influence R&D and innovation.

In this paper, we focused on boards of directors. While this allowed us to consider several board-related variables, researchers (e.g. Hoskisson et al., 2002) have also established relationships between other governance mechanisms (e.g. ownership and compensation) and the firm's R&D investments. Because governance mechanisms can exert complementary and substitutive effects, our work could be extended to consider how various owners, ownership structures, or compensation schemes interact with directors' human and relational capital to influence the firm's R&D spending. Because we find that aspects of the human and relational capital of directors can exert differing effects on R&D spending, future research might consider how individual directors resolve these competing influences. Other R&D inputs (e.g. R&D related alliances) and associated outcomes (e.g. new product introductions, strategic renewal, and venturing) might also be considered. Our work could also be extended by examining potential moderating effects of director capital and independence on the links between R&D spending, innovation, and performance. We look forward to examining such areas of inquiry.

## ACKNOWLEDGMENTS

We wish to express our sincerest thanks for the involvement of Robert E. Hoskisson, Special Issue Editor, and for the contributions of three anonymous reviewers whose constructive guidance were beyond the call of duty and helped us to improve the manuscript profoundly. We also wish to acknowledge the excellent support of Amy J. Hillman, Michael A. Hitt, and Albert A. Cannella Jr, who provided helpful feedback on prior versions of this research.

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