BOARD OF DIRECTORS' HUMAN CAPITAL: EFFECT ON INNOVATION IN LARGE FIRMS

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This study investigates the relationship between a board of directors' human capital and innovation outcomes. Building upon previous work, we conceptualize the human capital of the board of directors' depth, breadth, and ambidexterity. We test our model using random sample data from S&P 500 companies. The results show that the capital depth of a board leads to more industry-specific innovation while a board's breadth will enable a more diversified innovation portfolio. Further, board ambidexterity is associated with increased patents. Theoretical and practical contributions are discussed.

INTRODUCTION

Innovation has proven itself as the new business religion and the main driver of competitiveness in the business landscape (Skroupa, 2017). Organizations are showing a great emphasis on innovation as a driver of sustainable competitive advantage (Chatzoglou & Chatzoudes, 2018). The topic of innovation outcomes is capturing the attention of both practitioners and academics attention. Innovation mechanisms and the resources needed to ensure success are among the questions that need further research in business disciplines such as management, marketing, operations, and supply chain management. Previous research on innovation has investigated the process of innovation and its content. The process includes the generation, development, and implementation of innovation (Argyres & Silverman, 2004). The content perspective reflects the type (product, process, and organizational) and its nature (radical, incremental, modular, and architectural) (Henderson & Clark, 1990). Chang and Hughes (2012) were among the pioneering work to distinguish between exploitative and explorative innovation. The current study will expand on this research area by looking at innovation depth and breadth.

Top management commitment to the innovation path is important to the success of any innovation initiative (Guo et al., 2017). In large companies, top management will follow board member instructions and directives influencing the firm's results. While numerous studies have demonstrated the role of the human capital of the board of directors in influencing firm performance (e.g., Hermelin & Weisbach, 1991; Hillman & Dalziel, 2003), there is little research
on how the individual characteristics of board members or the composition of the team impact firms innovation outcomes. More precisely, the relationship between the board of directors' characteristics and innovation performance provides an opportunity for further investigation (Srinivasan et al., 2018). Some studies addressed the impact of top management characteristics on innovation outputs. For example, Li et al. (2013) investigated the relationship between the CEO selection process and the intensity of innovation outputs. The role of the board of directors' composition and how it impacts innovation results is gaining more interest (Srinivasan et al., 2018).

The board of directors represents a firm's resource composed of both human and structural elements leading to the generation of board depth and board breadth (Haynes & Hillman, 2010). The board of directors provides strategic orientation, contributes to positive outcomes, and creates the capability to innovate. Miles et al. (1978) addressed the issue of strategic business orientation. Strategic orientation will influence the firm's results. This paper draws on March's (1991) work to conceptualize exploitative and explorative strategic orientation. March's taxonomy becomes embedded within academic thinking for topics related to innovation, organizational learning, and competitive advantage (Wilden et al., 2018). The framework explains that organizations can learn either from their existing members and past knowledge (exploitation) or through innovation and opening to external resources (exploration). Organizations should seek to balance both activities and achieve ambidexterity capability (Gupta et al., 2006). The purpose of the current study is to investigate the impact of the board of directors' capital (depth, breadth, and ambidexterity) on innovation outputs.

To investigate our research model, we collected data from 186 firms listed in the S&P 500. We collected data relative to their board of directors' characteristics from the Bloomberg website, and we measured the board depth, breadth, and ambidexterity. We also gathered data related to the firms' innovation outcomes to measure the depth and breadth of the innovation. The results show that board depth leads to more industry-specific innovation (depth) while board breadth generates more innovation breadth. Our results also showed that ambidextrous boards are associated with more innovation outreach.

**LITERATURE REVIEW**

Our study relates to mainly two streams of literature: board capital and innovation. We first present a summary of the board literature that mainly relates to our study. We then link the board capital to firm performance and emphasize innovation as the main outcome.

**Board Capital**

The board of directors has mainly two functions. First, it monitors the work of the managers to preserve the stockholders' investment (Dalton et al., 2003). Second, the board of directors represents a valuable resource for the firm's management team providing strategic and technical advice (Dalton et al., 1999). Research on board of directors and their impact on firms' performance was a subject of an extensive number of studies for decades. The first wave of studies looked at
the basic board composition, such as size and composition and how it relates to firms' performance (e.g., Boyd, 1990; Dalton et al., 1999; Pfeffer, 1972). The content slightly shifted to discuss the change in the board of directors' composition and dynamics and its influence on organizations' outcomes (Baysinger & Butler, 1985) and to achieve and sustain competitive advantage. Board capital diversity in terms of gender, ethnicity, and nationality improves stakeholder management. This relationship is moderated by the board's previous collaboration (Fernandez & Thams, 2019). Along this line, the board of director's capital is conceptualized as the combination of the human and social capital of the board of directors, which is reflected by the board's ability to provide resources to the firm (Hillman & Dalziel, 2003). More recent studies have built on the previous research to conceptualize the board capital as the breadth and the depth of the director's human and social capital (Haynes & Hillman, 2010). The current study will draw on Haynes and Hillman's (2010) work and elaborate on the concepts of board capital breadth and board capital depth.

Board capital depth reflects the board member's embeddedness in the firm's principal industry. The board member embeddedness can be reflected through the "industry interlocking directorates" (Haynes & Hillman, 2010). Interlocking directories happens when members of a firm board of directors serve in multiple corporations (Scott, 1997). Interlocking is possible via three main ways: (a) horizontal—among competing organizations; (b) vertical—among organizations located in adjacent stages of production; and (b) symbiotic—among complementary organizations (Pennings, 1980). In this paper, board capital depth is defined as the embeddedness of directors in the firm's primary industry through interlocking directorships, managerial positions, or occupational experience in the primary industry of the firm. It is also measured by the sum of the directors' intra-industry human and social capital (Haynes & Hillman, 2010).

On the other hand, board capital breadth reflects the board member demographics and expertise heterogeneity which can be drawn from previous research of management team heterogeneity (Pegels et al., 2000). The management team's diversity is reflected by educational and functional diversity (Pegels et al., 2000). Haynes and Hillman (2010) extrapolated the concept of heterogeneity to the board member, created, and validated a new construct, board capital breadth. In this study, board capital breadth is defined as the level of board heterogeneity as measured by functional occupancy and professional experience and is reflected through the portfolio of directors' functional occupational, social, professional experiences, and extra-industry ties. This construct will capture the diversity of the directors' human and social capital (Haynes & Hillman, 2010).

Board of Directors and Firm Performance

Scholars have extensively examined the role of the board of directors in predicting a firm's performance (Drees & Heugens, 2013). The work of the board capital depth and breadth provided researchers with an agenda for further investigation of the board of directors' dynamics and their impact on organizations' performance. Board capital diversity represents an important component of its depth and breadth and is posited to contribute to the firm's strategic knowledge and therefore influence its performance (Westphal, 1999). The board of directors' outside reach via an affiliation with financial institutions is positively associated with sales growth (Peng, 2004). De Villiers et al. (2011) discussed the role of the board of directors' extra-industry ties, which is a reflection of capital depth and breadth, during the management of environmental crisis and the improvement of
sustainability performance. The board of directors' political ties provide firms with more financing options and therefore impact its financial health (Bona-Sánchez et al., 2014). The board of director knowledge capital through years of educations enhances firms' return on equity and assets (Khanna et al., 2014).

In recent years, scholars showed more interest in investigating the role of directors in enhancing innovation capabilities. Chen (2014) looked at the education's capital impact on research and development investments and found that a higher level of educational background helps firms engage in more R&D activities. Using a network perspective, Srinivasan et al. (2018) showed that the board of directors interlock with the firm's industry impacts new product development. Despite the large number of studies that looked at the impact of the board of directors on firm performance (Fernandez et al., 2019), small attention was given to its role in enabling innovation outcomes. Innovation represents a major capability that organizations are striving to gain and sustain a competitive advantage. For almost 100 years, scholars investigated innovation and defined it in multiple ways emphasizing different features (e.g., Galunic & Eisenhardt, 2001; Knight, 1967; Schumpeter, 1934). For example, innovation has been defined based on the outcomes (Tushman & Nadler, 1986). Moreover, innovation was identified as the process of transforming ideas into new outcomes (Baregheh et al., 2009). Scholars have used patents related measures to assess innovation performance (Trajtenberg et al., 1997). Innovation originality, generalization, and patent counts are widely used measures to compare innovation performance. The current study aims at adding the extant literature by addressing some of the research gaps and expand on Srinivasan et al. (2018) work by investigating the role of board capital's characteristics (i.e., depth, breadth, and ambidexterity) in innovations outcomes. We provide a summary of our research constructs’ definition in Table 1.

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Definition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board Capital</td>
<td>The embeddedness of directors in the firm's primary industry through</td>
<td>(Haynes &amp; Hillman, 2010)</td>
</tr>
<tr>
<td>Depth</td>
<td>managerial positions in the firm's primary industry.</td>
<td></td>
</tr>
<tr>
<td>Board Capital</td>
<td>The level of board heterogeneity as measured by functional occupancy and</td>
<td>(Haynes &amp; Hillman, 2010)</td>
</tr>
<tr>
<td>Breadth</td>
<td>professional experience.</td>
<td></td>
</tr>
<tr>
<td>Board Capital</td>
<td>The extent to which a board of directors has a high level of Depth and</td>
<td>Construct</td>
</tr>
<tr>
<td>Ambidexterity</td>
<td>Breadth.</td>
<td>conceptualized</td>
</tr>
<tr>
<td>Innovation Depth</td>
<td>The Extent to which a firm's patent portfolio is related to the firm's</td>
<td>Construct</td>
</tr>
<tr>
<td></td>
<td>main industry.</td>
<td>conceptualized</td>
</tr>
<tr>
<td>Innovation</td>
<td>The firm's patent portfolio diversity.</td>
<td>Construct</td>
</tr>
<tr>
<td>Breadth</td>
<td></td>
<td>conceptualized</td>
</tr>
</tbody>
</table>
HYPOTHESES DEVELOPMENT

The board of directors’ capital (depth, breadth, and ambidexterity) is expected to influence the firm’s performance, more precisely, innovation outcome. In this section, we present the hypotheses and the research model in Figure 1.

Board Capital and Innovation Performance

Board members positioning within their focal industry provides an opportunity to access more specific information (Oehmichen et al., 2017). Board capital depth implies a greater understanding of the firm's industry. The board member will show high knowledge of the industry practices. Board capital depth will lead to less strategic change and more focus on incremental improvement (Haynes & Hillman, 2010). The board depth will favor more incremental changes and will make the firm a strategic position more as a defender. Drawing on Miles et al. (1978) typology, we can argue that the board depth is a tightly related defender's strategy. In fact, a more "deep" board will promote activity aiming to improve the firm's efficiency by focusing mainly on the practices available in the firm's acting industry. Therefore, we expect that firms with high capital depth will lead to more innovation related to the firm's primary industry. Additionally, Srinivasan et al. (2018) argued that board capital interlock centrality, which represents the level to which the board members are anchored to the main industry, leads to incremental innovation.

Hypothesis 1: Board of Director Depth will be positively associated with deep patents portfolio.

In contrast, the board's breadth will lead to more strategic change, such as expanding into new markets or diversifying the available product and services offered (Haynes & Hillman, 2010). The diverse background and expertise as shown by the board members will provide firms with different perspectives as targeting different markets. The board breadth will favor broader and unique changes and make the firm's strategic position more like that of a prospector. Drawing on Miles et al. (1978) typology, we can argue that the board depth is a tightly related prospector strategy. Moreover, drawing on the strength of weak ties perspectives (Granovetter, 1973), board breadth will reflect the diversity of resources such as different industry backgrounds or diversified expertise. In fact, the strength of weak ties states that a relationship made up of two or more entities that are different will represents a source of extra knowledge and will make the relationship more beneficial. The same logic can be applied to the board member made of people with different backgrounds and expertise. The board will be expected to generate more diversity will help the company explore more opportunities. Previous studies associated with the relationship between explorative depth will impact exploration potential, which will lead to more diverse innovation (Phelps, 2010). The board functional background heterogeneity is expected to increase the firm's explorative strategic orientation (Heyden et al., 2015), which provides firms with more opportunities to expand their innovation activities outside of their main industry. Therefore, we expect that board capital breadth will create more broad innovation outcomes. In light of the previous paragraphs, we formulate the following hypothesis:
Hypothesis 2: Board of Director Breadth will be positively associated with broad patents portfolio.

Board Capital Ambidexterity and Innovation Outcomes

The seminal work by March (1991) on exploration and exploitation inspired numerous studies to investigate the organization's ambidexterity within the innovation context (He & Wong, 2004). They argue that the need for both explorative and exploitative technological innovation activities will lead to higher sales growth. When the human capital of the board of directors provides both deep and broad knowledge related to the organization industry, it will provide more opportunities for innovation outcomes (He & Wong). Thus, we define board capital ambidexterity as both the depth (The embeddedness of directors in the firm's primary industry through managerial positions in the firm's primary industry) and breadth (The level of board heterogeneity as measured by functional occupancy and professional experience). The ambidexterity concept, as discussed by Gupta et al. (2006), suggests that the organization will manage and excel in both directions. In the context of the board of directors, an ambidextrous board enables the organization to have a strategy based on leveraging existing knowledge and generate value as well as exploring external sources. The organization's opportunity to engage in exploitative research and development activities will enable them to generate innovation within its main core competencies. We expect that "deep board," as discussed in Hypothesis 1, will provide an opportunity for an organization to have a focused innovation output leading to industry-specific patents. Additionally, a broader board of directors will enable the firm to participate in innovation activities that are not necessary within its industry. This is expected to provide organizations with more freedom to explore the potential of innovation outcomes that are not necessary linked to its core competency. As such, we can expect that an "ambidextrous board" represents an opportunity for a larger volume of innovation outcomes. Additionally, board ambidexterity provides firms with leadership adaptability within return would lead to exploitative and explorative innovation (Chang & Hughes, 2012). This, in turn, will lead to a larger level of innovation output. Based on the previous discussion, we propose the following hypothesis:

Hypothesis 3: Board Capital Ambidexterity is positively associated with the number of patents.
Figure 1. Conceptual Model

METHODOLOGY

Data Collection

The study uses a random sample from S&P 500 firms. A total of 186 firms were selected, allowing for a possible missed observation. We used three data sources. First, the board of director's information is obtained from the Bloomberg database. For each observation in our sample, an exhaustive list of board members was determined. Information related to their expertise, functional backgrounds, ties to the focal company and its industries, age, and years of tenure was compiled. Second, the innovation data is obtained from the Derwent Innovation Index database. The database provides information about patents and classifies them into different categories, also known as "Derwent Classes." For each company, we collected the list of patents for the past ten years. Since we are using data that relates to current board members, we judged it prudent to use an innovation outcome that is consistent with the board of director formation. Additionally, given that the average tenure of the S&P 500 board of director tenure is more than eight years, we want to have a large window allowing us to see a possible impact of the board on innovation. Finally, we used the Compustat Database to acquire firm and industry-specific data for control variables.

Variable Operationalization

Dependent variables. The current study uses three dependent variables: Innovation Depth, Innovation Breadth, and Innovation Reach. Previous studies provided methods to measure exploitative innovation using survey items (e.g., Chang & Hughes, 2012). We expand that conceptualization to measure innovation depth. When filing for patents, the firm will provide a list of related specifications. Innovation depth is determined by the percentage of patents that belong to the firm's primary area of expertise. This conceptualization is similar for each firm and was used...
to assess its patents' portfolio. Patents are classified according to areas such as Engineering, Computer Science, Medicine, Chemistry, and Transportation and can be classified under more than one. For each firm's we have identified the ratio of the number of classifications of the firm's primary focus to the total number of patents. A deep innovation will be characterized by high focused innovation within the firm's core industry. As such, innovation depth is measured as the ratio of patents filed within the firm's industry. Innovation breadth reflects the firm's diverse patent portfolio. We have computed The Herfindahl-Hirschman (HH) diversity index for the firm's innovation portfolio. The HH index represents a widely used measure to assess the diversity of a group. In our case, we are using it to assess the breadth of a patents' portfolio. A list of classification frequencies is determined for each firm to compute the HH index. Finally, as discussed in the hypothesis section, innovation reach reflects the firm's ability to provide a deep and broad innovation which we measure as the total number of patents.

**Independent variables.** Following Haynes and Hillman (2010) board capital depth reflects the firm's embeddedness within its industry. First, we calculated the ratio of members that belong to the same industry classification of the main form. This will measure the board members' industry interlock. Second, we computed the level of the board member interlock with the main firm. For each member, we determined whether he/she is primarily working for the firm. For example, Tim Cook, CEO of Apple, is also a board member. The board of directors breadth measure is computed using a diversity index measure. Each board member is identified by a variety of functional and occupational backgrounds. Following previous work, we use Blau's (1977) diversity index to determine the level of the board of directors' breadth. Finally, the board of director ambidexterity is computed using the combination of congruence and level of both boards of director breadth and depth (Fernhaber & Patel, 2012). Congruence reflects the absolute value of the difference between depth and breadth. The level is the average of the depth and breadth level. Similar to the conceptualization of exploitation and exploration, an ambidextrous board of directors has at the same time high congruence and level.

**Control variables.** A list of control variables is determined to provide a more in-depth analysis. Because of the focus on innovation outcomes, we use R&D intensity. Research and Development intensity reflects a firm's innovative capability and may have an impact on the firm's financial performance, especially in the pharmaceutical industry. It is expected that R&D intensity has a positive impact on financial performance. It is measured by a firm's R&D expenditure and normalized by sales. We also control for the board size and the firm's size as larger boards are expected to results in higher performance (Johnson et al., 2011). We use the natural logarithm of total assets as a proxy for firm size. We also account for the industry level by controlling for the firm's primary SIC code. Next, our sample from the S&P 500 did not contain all the firms in the industry. We use the inverse Mills ratio to account for any selection bias. The use of the Mills ratio will control for any selection bias that might occur when selecting only certain firms across the
S&P 500 firms list (Puhani, 2000). The Mills ratio is computed using the Probit models as suggested by the literature (Hamilton & Nickerson, 2003).

**Empirical Model**

To account for selection bias, we rely on Heckman's (1979) procedure to estimate the non-selection bias using all the firms from the S&P 500. Additionally, to account for any outliers' influence on the validity of the results, we rely on the ROBUSTREG procedure as it is often recommended because it inherently helps derive stable estimates (Leone et al., 2019). We apply robust regression to test Hypotheses 1 and 2. Hypothesis 3, on the other hand, includes patent count as the dependent variable, and it is tested using a negative binomial regression. The negative binomial distribution is appropriate when the dependent variable follows a Poisson distribution. The negative binomial model accounts for overdispersion and provides more appropriate estimates (Cameron & Trivedi, 1986).

**RESULTS AND ANALYSIS**

We analyze the results using SAS software. Table 2 provides summary statistics of the data by industry. We found that information and communication technology (ICT) sectors have a relatively high innovation depth while energy and utilities sectors have the highest innovation breadth. The ICT sector is also associated with a high level of board depth. The summary statistics from Table 2 did not reflect any notable difference in the board ambidexterity across the sectors. Table 3 shows the summary statistics for the entire sample along with the pairwise correlation of the model variables. It shows statistically significant correlation coefficients vary from 0.122 to 0.354. We additionally checked the variance inflation factor to eliminate any multicollinearity concerns. To test our model results, we first proceed with a cluster analysis, then we run a set of regression analyses.

**Cluster Analysis**

As part of our exploratory analysis, we develop a cluster analysis using the Aceclus procedure in SAS. The procedure will determine the canonical distance among the various cluster. Our finding showed that we have four clusters shown in Figure 2. The first cluster represents firms with relatively low depth and breadth. A second cluster represents the deep board and is characterized by high depth and low breath. A third cluster has a relatively high breadth and low depth that we label broad board. Finally, we identify the ambidextrous cluster represented by high depth and breadth. We further investigate the study outcomes by board classification. In Table 4, we provide total observations by the board as well as the average of the innovation depth, breadth, and the number of patents. The results suggest that deep boards have a relatively higher specific industry innovation while the average innovation breadth is higher for the broad board. The results relative to the board ambidexterity showed that ambidextrous boards enjoy a higher number of patents.
TABLE 2
Summary Statistics by Industries Defined at the Two-Digit Global Standard Classification Level

<table>
<thead>
<tr>
<th>Sector</th>
<th># of Observations</th>
<th>Innovation Breadth</th>
<th>Innovation Depth</th>
<th># of Patents</th>
<th>BC Breadth</th>
<th>BC Depth</th>
<th>Board Ambidexterity</th>
<th>R&amp;D Intensity</th>
<th>Board Size</th>
<th>Total Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>16</td>
<td>0.839</td>
<td>0.958</td>
<td>501</td>
<td>31.933</td>
<td>2.818</td>
<td>0.567</td>
<td>0.479%</td>
<td>12.688</td>
<td>41,400</td>
</tr>
<tr>
<td>Material</td>
<td>13</td>
<td>0.852</td>
<td>0.852</td>
<td>693</td>
<td>27.007</td>
<td>2.840</td>
<td>0.563</td>
<td>1.895%</td>
<td>14.385</td>
<td>13,264</td>
</tr>
<tr>
<td>Industrial</td>
<td>37</td>
<td>0.796</td>
<td>0.898</td>
<td>1490</td>
<td>27.591</td>
<td>3.326</td>
<td>0.561</td>
<td>2.331%</td>
<td>11.784</td>
<td>17,000</td>
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<tr>
<td>Consumer Directory</td>
<td>23</td>
<td>0.808</td>
<td>0.902</td>
<td>456</td>
<td>28.530</td>
<td>3.297</td>
<td>0.557</td>
<td>2.261%</td>
<td>12.652</td>
<td>14,550</td>
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<tr>
<td>Consumer Staples</td>
<td>26</td>
<td>0.823</td>
<td>0.852</td>
<td>431</td>
<td>29.615</td>
<td>2.810</td>
<td>0.583</td>
<td>0.937%</td>
<td>13.846</td>
<td>17,125</td>
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<td>Health Care</td>
<td>30</td>
<td>0.827</td>
<td>0.928</td>
<td>357</td>
<td>26.093</td>
<td>3.382</td>
<td>0.585</td>
<td>12.019%</td>
<td>11.800</td>
<td>13,478</td>
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<tr>
<td>Financials</td>
<td>13</td>
<td>0.684</td>
<td>0.934</td>
<td>192</td>
<td>24.202</td>
<td>3.041</td>
<td>0.581</td>
<td>0.000%</td>
<td>13.923</td>
<td>187,178</td>
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<tr>
<td>Information Technology</td>
<td>24</td>
<td>0.769</td>
<td>0.955</td>
<td>2220</td>
<td>26.079</td>
<td>4.047</td>
<td>0.546</td>
<td>11.028%</td>
<td>11.458</td>
<td>12,728</td>
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<td>Telecommunication</td>
<td>2</td>
<td>0.731</td>
<td>0.988</td>
<td>183</td>
<td>32.281</td>
<td>6.079</td>
<td>0.571</td>
<td>0.000%</td>
<td>12.000</td>
<td>28,068</td>
</tr>
<tr>
<td>Utilities</td>
<td>2</td>
<td>0.819</td>
<td>0.863</td>
<td>120</td>
<td>14.637</td>
<td>2.545</td>
<td>0.518</td>
<td>0.000%</td>
<td>9.500</td>
<td>19,043</td>
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TABLE 3
Descriptive Statistics and Correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean</th>
<th>sd</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Innovation Depth</td>
<td>0.91</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Innovation Breadth</td>
<td>0.80</td>
<td>0.06</td>
<td>-0.34*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 # of Patents</td>
<td>865.23</td>
<td>1.91</td>
<td>0.00</td>
<td>0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 BC Breadth</td>
<td>27.56</td>
<td>13.41</td>
<td>0.13*</td>
<td>-0.11</td>
<td>0.31*</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5 BC Depth</td>
<td>3.28</td>
<td>1.64</td>
<td>-0.06</td>
<td>0.04</td>
<td>0.23*</td>
<td>0.35*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Board Ambidex</td>
<td>0.57</td>
<td>0.09</td>
<td>-0.04</td>
<td>0.04</td>
<td>0.16*</td>
<td>-0.11</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 R&amp;D Intensity</td>
<td>0.04</td>
<td>0.08</td>
<td>0.03</td>
<td>0.20*</td>
<td>0.07</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Board Size</td>
<td>12.53</td>
<td>4.16</td>
<td>-0.18*</td>
<td>0.06</td>
<td>0.14*</td>
<td>0.00</td>
<td>-0.15*</td>
<td>-0.12*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Total Assets</td>
<td>9.88</td>
<td>1.46</td>
<td>-0.16*</td>
<td>0.03</td>
<td>0.27*</td>
<td>0.35*</td>
<td>0.13*</td>
<td>-0.03</td>
<td>-0.21*</td>
<td>0.29*</td>
</tr>
</tbody>
</table>

*p < .05
**Figure 2. Cluster Analysis**

**TABLE 4**
Average Outputs by Board Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Observations</th>
<th>Innovation Depth</th>
<th>Innovation Breath</th>
<th>Number of Patents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Performers</td>
<td>37</td>
<td>.875</td>
<td>.742</td>
<td>707</td>
</tr>
<tr>
<td>Deep Boards</td>
<td>49</td>
<td>.926</td>
<td>.805</td>
<td>422</td>
</tr>
<tr>
<td>Broad Board</td>
<td>45</td>
<td>.911</td>
<td>.832</td>
<td>1004</td>
</tr>
<tr>
<td>Ambidextrous Board</td>
<td>55</td>
<td>.915</td>
<td>.815</td>
<td>1253</td>
</tr>
</tbody>
</table>

**Hypotheses Testing Results**

We ran a robust regression to test the validity of our overall model, with reliance on the adjusted r-squared. The results from the regression analysis in Table 5 demonstrate that the full model for all three regression analyses is adding more explanatory information, as shown by a significant F value for the delta adjusted r-squared. The board of director depth is positively associated with innovation depth ($\beta = 0.006, p < 0.1$). This provides marginal support to Hypothesis 1. Additionally, we find support for Hypothesis 2. As the board of director breadth increases, the diversification of the innovation outcomes increases ($\beta = 0.001, p < 0.05$). Finally, the board ambidexterity level contributes to the organization's patents count. The results from the negative binomial regression show that as the ambidexterity level increases, companies will experience a higher number of patents ($\beta = 3.931, p < 0.001$). This provides support to Hypothesis 3.
TABLE 5
Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Innovation Depth</th>
<th>Innovation Breadth</th>
<th>Patents' Count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Model</td>
<td>Direct Effect Model</td>
<td>Control Model</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.014</td>
<td>-0.003</td>
<td>0.5432***</td>
</tr>
<tr>
<td>BC Depth</td>
<td>0.006†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC Breadth</td>
<td></td>
<td>0.001*</td>
<td></td>
</tr>
<tr>
<td>BC Ambidexterity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D Intensity</td>
<td>-0.004</td>
<td>-0.015</td>
<td>-0.044</td>
</tr>
<tr>
<td>Board Size</td>
<td>-0.0018*</td>
<td>-0.002*</td>
<td>0.0017*</td>
</tr>
<tr>
<td>Firm's Size</td>
<td>0.007*</td>
<td>0.007*</td>
<td>-0.0213***</td>
</tr>
<tr>
<td>Industry</td>
<td>0.001</td>
<td>0.001</td>
<td>-0.0021***</td>
</tr>
<tr>
<td>Mills Ratio</td>
<td>0.049***</td>
<td>0.042**</td>
<td>-0.0853***</td>
</tr>
<tr>
<td>Adj. R_Squared</td>
<td>4.02%</td>
<td>5.21%</td>
<td>14.12%</td>
</tr>
<tr>
<td>Δ Adj. R_Squared</td>
<td>1.19%</td>
<td></td>
<td>1.41%</td>
</tr>
<tr>
<td>Δ r F – statistics</td>
<td>2.335 †</td>
<td>3.105 *</td>
<td></td>
</tr>
</tbody>
</table>

N= 186, †p0.1, *p<0.05, ** p<0.01, *** p<0.001

DISCUSSION

This study provides an attempt to address the relationship between board capital characteristics and the firm's innovation outputs. We draw on March's (1991) exploration and exploitation parallelism to assess the relationship between the board of directors' depth and breadth and innovation outputs. This study demonstrates the importance of leadership commitment to include innovation in strategy and to make strategic and financial decisions to support innovation activities.

First, we find that the level of innovation depth (the degree to which company innovation relates to its main focal industry) is influenced by the level of depth within the board of director's structure. This is very common in industries where the main focus is innovation related to the main industry, such as the pharmaceutical industry (Correa, 2011). We investigated, for example, the board of directors of Pfizer, and we found a relatively large number of members of people with ties to the healthcare industry. At an aggregate level, our results show that the healthcare industry has a large average of board depth compared to the average dataset.

Second, the findings show the innovation breadth (the degree to which a company's innovation does not relate to its main focal industry) is influenced by the level of breadth within the board of director's structure. Telecommunication and information technology industries provide a good example for a sector where diverse innovation is very important as technology represents an
innovation enabler (Dibrell et al., 2008). However, our granular analysis did not show that these industries have a larger average board of director diversity. Finally, the organization's ability to balance its exploitative and explorative strategic orientation by selecting an "ambidextrous" board of directors will provide larger innovation outputs.

The current study has both academic and practical contributions. This study demonstrates the need to widen the research on the relationships between organizational and individual impacts on innovation. It sheds light on the question of the impact of the board of director structure on firms' innovation outputs. Haynes and Hillman (2010) suggest investigating the role of the board of director capital on a firm's performance. Additionally, the study provides a different alternative to measure the main model constructs leveraging multiple data sources for secondary data. The study also conceptualizes a new construct, board capital ambidexterity, and tests for its impact on innovation outputs. While we know that individuals within the company can influence a company's innovation, most research focuses on individuals within research and development, such as technical leaders (e.g., engineers). This study illustrates the need to expand research on the types of individuals studied, as well as strategic influences on innovation.

From a practical perspective, the current work provides managers with directives when it comes to board member selection. Depending on the firm's strategic orientation, a company will decide about the qualifications and the dynamics among its board members. This paper provides practitioners with a series of detailed recommendations. Each aspect of human capital is significantly related to some aspect of innovation. Therefore, organizations need to form boards wisely to ensure they comprise, for example, the requisite diversity of knowledge, skills, abilities, experiences, and relationships. Specifically, the findings of this research suggest that firms need to select the board of directors with the appropriate background/specialization to achieve the firm innovation objectives (innovation depth/breadth or number of patents). In particular, the board director's background should align with the firm innovation goals. If people are chosen for a board seat who are already within the CEO's network, for example, the board is already limiting its breadth (Carcello et al., 2011). This study exemplifies the continued need to challenge the status quo of the CEO having a major influence on who sits on the board. While the current study is focusing mainly on tangible innovation, the human capital of boards is likely to impact companies in other sectors in much the same way.

Like other studies, the current research presents some limitations, which provide areas of improvement and future research directions. Given that this study was conducted with secondary data, it is not possible to make causal or temporal inferences. While we argue that the board influences the strategic orientation of the firm, given that we cannot conclude causation, there may be other plausible explanations. For example, industry-focused firms may intentionally choose more industry-focused directors. Additionally, there may be another outside factor impacting both boards as well as patents, such as industry isolation, as in pharmaceuticals. It would be interesting to use qualitative research methods to closely examine the attitudes, behaviors, interactions, and strategies of the board of directors' members. The data collected from S&P 500 firms are located only in the United States. Given the wide range of differences within business environments and cultures (e.g., regulations, competition, and risk-taking) around the world, this study does not address business nations where the business environment and culture may be very different. Thus, the information may not apply to different business cultures. Therefore, it would be good to engage
in comparative research to determine the impact of the business environment and culture on the board of directors' behavior and firm innovation output. Finally, a longitudinal analysis could assess how these relationships change over time and the impact of board member turnover.

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