Attributes and Structure of an Effective Board of Directors: A Theoretical Investigation

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March 2015

We would like to thank Mike Ettredge, Theresa Libby, Ted Mock, John Roberts, workshop participants the Deakin University, University of Queensland, University of Sydney, attendees of the 2013 American Accounting Association Strategic and Emerging Technologies Section meeting, 2013 – International Conference on Corporate Governance – co-sponsored by the University of Essex and Sri Venkateswara University and the 2014 – EY Center for Auditing Research and Technology Research Conference for their helpful comments on a previous version of the paper. Professors Srivastava and Masli acknowledge research support from the EY CARAT at The University of Kansas.

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ABSTRACT

The boards of directors represents the interests of shareholders and shoulder the task of monitoring managements' actions, protecting shareholder interests, and overseeing the activities of the company. Despite the large stream of academic research on board efficacy there exists a lack of well-developed theory about the interrelationship of attributes that lead to an effective board of directors (Larcker et al. 2007; Brown et al. 2011; Roberts 2012). We argue that for a board to be effective, directors must possess, to some degree, the following four attributes: 1) be independent of management, 2) be able to carry out their duties in a competent manner, 3) be active or diligent in fulfilling their board responsibilities, and 4) possess appropriate behavioral attributes. We define an "And" relationship between board effectiveness and the four attributes and argue that a board of directors is effective *if and only if* each of the characteristics are present. We also introduce the concept of "safeguards" – i.e., the level of attentiveness by the board and its members to safeguard against unbecoming conduct, and analytically demonstrate its influence on the effectiveness of the board. We first develop a theoretical framework comprised of four core board constructs plus safeguards. We next employ Bayesian Logic to model the effectiveness of the board in four unique scenarios in order to examine the influence of the "And" relationship on the assessment of board effectiveness. Finally, through the use of inferential statistics we demonstrate the importance of our theoretical "And" relationship and the importance of "safeguard" when examining the board of directors.

Keywords: Board of Directors, Corporate Governance, Attributes of Board of Directors, Bayesian model

1. Introduction

On July 8, 2002 the Permanent Subcommittee on Investigations issued a report entitled 'The Role of the Board of Directors in Enron's Collapse'. The report highlights a number of significant fiduciary failures by Enron's board, including a lack of independence between board members and management, inactivity in the performance of key fiduciary duties and a lack of strong intra-board behaviors, such as questioning one another, and providing constructive criticism of suggestions made by fellow board members.[1] The report identifies over a dozen red flags which should have caused Enron's board to ask hard questions, examine policies, and consider changing course. However, the board simply ignored the red flags. We quote from the report's conclusion "In too many instances, by going along with questionable practices and relying on management and auditor representations, the Enron Board failed to provide the prudent oversight and checks and balances that its fiduciary obligations required and a company like Enron needed. By failing to provide sufficient oversight and restraint to stop management excess, the Enron Board contributed to the company's collapse and bears a share of the responsibility for it."

Less than a year later WorldCom Inc., which like Enron went bankrupt following a significant financial statement fraud, issued a report regarding its board of directors (WorldCom, Incorporated, 2003). The report identifies numerous characteristic similarities between the WorldCom and Enron boards. While ultimately concluding the board was unaware of the fraud, the report notes significant deficiencies in its role of direction and cultural supervision of the company. The reports conclude that while appearing to satisfy the checklist mentality, the board

[1] In this case, inactivity does not relate to the number of meetings per-se, rather it implies an unwillingness to take proactive action on behalf of the stakeholders. In effect the board members were willing to turn a blind eye to the firm's true state of affairs.

failed to "exhibit the energy, judgment leadership or courage that WorldCom needed".

These board failures either contributed to (i.e. Enron's board) or failed to impede (WorldCom's board) two of the largest frauds and subsequent bankruptcies in the history of American industry and played a prominent role in the passage of the Sarbanes-Oxley Act. While the above discussion only presents two examples of the potential severe consequences of poor board behavior there are numerous others.[2] It is clear a connection exists between the characteristics of the board of directors and the potential for extremely negative outcomes.

In this study we develop and test through Bayesian Logic, a theoretical framework of key board attributes, to assess a board of directors' efficacy. Our framework investigates the relationship between the board's effectiveness and the four elements critical to a board's effectiveness: independence from top management, competency in performing board duties, activeness /diligence in performing duties, and having the appropriate behavioral disposition as directors. Within our framework, we also take into account the effect of public and private safeguards in place to limit conduct that violates the board's fiduciary duties. While the constructs in our framework are not new, this is the first study, to our knowledge, to utilize applied decision making and inferential statistics to examine and define the relationship among them. We further examine, how the constructs interconnection affects the overall effectiveness of the board, and how external observers can utilize these inferences when assessing the strength of a board.

There is prevalent recognition that corporate governance arrangements, of which the

[2] Other financial frauds include, but are not limited to Olympus, Parmalat, Satyam, and Madoff, which have resulted in hundreds of billions of dollars in losses to the global economy (Brickey 2003; Anand 2009). In addition, we have recently witnessed a global financial crisis, which resulted in trillions of dollars in losses to society and threatened the very existence of the financial markets, financial institutions and in some instances, national governments (Claessens et al. 2010; Helleiner 2011).

board of directors plays a primary role, substantially influence corporate decisions and shareholder wealth (e.g., Core et al. 1999; Klein 2002; Larcker et al. 2007; Bebchuk et al. 2009).[3] Prior research indicates that when properly designed and implemented, by an effective board of directors, corporate governance can be an assurance mechanism that restores stakeholders' trust in corporations (Hilb 2012). However, prior recent literature also calls into question the degree to which academic scholars are developing and testing theory regarding the role of corporate governance and the board or directors. In particular, Brown et al. (2011) voice this concern in their review of corporate governance indices, such as the board of directors. A similar sentiment is expressed by Larcker et al. (2007), who also raise concerns regarding the lack of well-developed theory surrounding the complex and multi-dimensional nature of various aspects of corporate governance.

While prior literature lacks theory on the collective intra-workings of the board of directors, it does provide insight into the constructs which influence board performance. These constructs include; independence from management, possessing the competency to perform key board duties, and maintaining an appropriate level of activity (or diligence) in carrying out its duties (e.g., NACD 1996; Carcello et al. 2002, Cicero et al. 2010). Academics (e.g., Finkelstein and Mooney 2003; Huse 2005; Roberts et al. 2005) additionally suggest that characteristics pertaining to the inner-workings of the board, as well as, directors' behavioral disposition and professional relationships with each other influence board effectiveness.[4]

Following prior studies (e.g., Stewart and Kinney 2013; Srivastava et al. 2012), we use Bayesian Logic to assess our theoretical model of board effectiveness. The theoretical

[3] Corporate governance involves a set of relationships between a company's management, its board, its shareholders and other stakeholders (OECD, Principles of Corporate Governance, revised May 2004).
[4] Roberts et al. (2005) observe that research on corporate governance and board of directors lacks understanding of the behavioral processes within boards of directors and have not fully considered such factors in evaluating board effectiveness.

framework is comprised of the four primary constructs noted in the preceding paragraph. Prior research examines these board attributes primarily from an ex-post point of view (e.g. Cicero et al. 2010; Boone et al. 2011; Knyazeva et al. 2013). Moreover, the effects of these constructs on corporate performance have been empirically investigated only by considering one or two constructs at a time and thus it is difficult to draw conclusions about whether presence or absence of the other constructs at the same time strengthens or weakens the effectiveness of the BOD. In addition, prior research lacks an ex-ante theoretical discussion regarding how the interrelationships among these constructs influence each other and the overall effectiveness of the board. In our analytical model, we argue for a logical "And" relationship among these four attributes. Through the use of our Bayesian model we demonstrate that the board is most effective if and only if the directors are independent, competent, active, and display appropriate behavioral attributes. While this result is far from surprising, we also extend the use of inferential statistics to identify the probable impact to board effectiveness when any combination of these attributes is diminished or absent from the board. Thus making this the first paper, to our knowledge, which provides evidence on the implied inferential influence of the presence or absence of the four BOD attributes on its effectiveness.

In addition to the four primary board constructs, we also introduce into our framework the concept of safeguards (controls) within the board, as an important component to the board's effectiveness. These safeguards are represented by mechanisms (both internal and external to the firm) that may regulate or influence a board members actions. These include a directors' level of attentiveness to how the board's actions may threaten her reputation, heighten her potential of litigation, or subject her to regulatory enforcement. The effectiveness of safeguards varies between boards, as not all board members view potential risks in a similar manner. Additionally

the weight each board member puts on the safeguards is likely to vary among the four constructs. To address these concerns in our framework, safeguards function as a direct control to board effectiveness, and not as an individual board attribute. Ultimately, boards are most effective when a high level of safeguards accompany a strong presence of board independence, competence, activity, and appropriate behavioral attributes. It is important to note that the current literature identifies safeguard, i.e., control mechanism, for controlling the BOD effectiveness as "accountability" and considers this to be an attributes of the BOD members. We argue that safeguard is not an attribute of BOD members rather it is a control mechanism (safeguard) that impacts all the constructs (attributes). Although it is an empirical question, one can argue that if the BOD members are held accountable, they will make sure that they possess all the four attributes before they accept to be a member of the BOD.

This paper contributes to the extant literature on the attributes which comprise an effective board of directors. First, using prior literature we develop a theoretical framework of core constructs a board of directors requires to be effective. We then apply inferential statistics, through a Bayesian methodology, to examine how the presence or absence of these constructs (with varying level of certainty) influence board effectiveness. Thus answering the calls for research to advance formal theoretical work on corporate governance and the board of directors (Larcker et al. 2007; Brown et al. 2011). At the same time, the use of applied logic allows us to take an ex-ante point of view in answering questions that prior studies fail to address. These questions include, 'How does the presence or absence of a core construct, with certainty, influence board effectiveness?'; 'Can perceived strength in one attribute compensate for perceived weakness in another?'; 'To what degree would enforcing boards to absolute adherence of these constructs provide additional benefit to the outside stakeholders the board represents?';

and ‘To what degree do external safeguards influence the collective board’s actions, when properly implemented?’. We present these questions not as formal research questions, but as examples of the type of questions one might consider addressing via Bayesian logic, and address them via multiple case scenarios below. Further this is the first paper, to our knowledge, which provides theoretical support to the notion that it is essential for researchers, when assessing the effectiveness of the board’s function to implement the “And” relationship, not the “Or” relationship among the board constructs of interest.

While the primary support for our choice of constructs comes from the finance and accounting literature, due to the diverse nature of the subject, we intentionally exclude any discipline-specific focus from the paper. The mathematical methods we employ and the conclusions we draw are equally applicable to all fields of study. Further given the influence of board effectiveness on corporate outcomes is of importance to all stakeholders, our study should be relevant beyond the academic realm. Regulators, auditors, executives, investors, and even current board members should benefit from both the framework we present and the conclusions from our Bayesian analysis. Using the interrelationships of four core attributes, we provide a unique manner in which all stakeholders can evaluate potential board effectiveness.

The remainder of the study is as follows. The next section provides background and support regarding the primary constructs of an effective board of directors. Section three outlines the Bayesian Model for assessing board effectiveness. Section four presents four cases in which we apply the Bayesian Model, highlighting potential outcomes of varying level of the constructs. Section five provides a summary of the paper and discusses potential areas for future research. Finally, Appendix A derives the Bayesian model of the effectiveness of the board of directors in terms of posterior probability having obtained the evidence pertaining to the various

attributes.

2. Attributes of an Effective Board of Directors

The principles of agency theory imply that agents (i.e., management) may be reluctant to impose strict and binding mechanisms of corporate governance that may limit the agents' ability to act in their own best interest (Ross 1973; Eisenhardt 1989). As a result, there arises a need for stakeholders to have an entity on the inside to play a role in governing and monitoring the firm's actions on the stakeholder's behalf – i.e., the board of directors (Baysinger and Butler 1985; Hillman and Dalziel 2003; Xie et al. 2003). Prior research establishes that boards face a dual set of responsibilities which can, and do, compete with one another to serve as the board's primary area of focus. In particular, companies elect a board in order to provide operating guidance to the firm's management team and/or serve as a monitoring mechanism over firm management (e.g., Boone et al. 2007; Baldenius et al. 2014; Kim et al. 2014).

The board of director constructs we describe, and employ throughout this paper are relevant to boards focusing on either monitoring management or providing guidance to management. Boards do not treat these two objectives as being mutually exclusive (Kim et al. 2014), nor is there a "one-size fits all" model applicable to all boards (Coles et al. 2008; Wintoki 2007). As a result, there is clearly overlap in the characteristics of importance to both the monitoring and the guidance functions. Thus, the same basic characteristics are of significant importance regardless of the board's primary focus (Coles et al. 2008; Cicero et al. 2013; Kim et al. 2014).

Prior research (e.g., Gompers et al. 2003; Deutsch 2005; Brown et al. 2011; Roberts 2012) suggests that efficacy of the board of directors can be influenced by certain characteristics, including independence (I) of the board members from management, competence (C) or

expertise of the board members (e.g., knowledge about business processes within the firm, particular fields (accounting, law, etc.), industry expertise, etc.), active (A) board members (i.e., the members meet frequently with the CEO and CFO to monitor their activities and advise, members diligent in attending board meetings and being active in those meetings), and appropriate behavioral attributes (B) by directors to act cohesively and constructively. We discuss each of these four attributes in turn.

Independence of Board Members

Prior studies suggest that more independent boards act in the best interest of shareholders and have stronger incentives to prevent and detect opportunistic behavior by management (Fama and Jensen 1983; Beasley 1996; Cotter et al. 1997). Between 1950 and 2005, Gordon (2007) reports that the composition of large public company boards has shifted from approximately 20% to 75% independent. He suggests that such dramatic increase is due to the increasing importance of shareholder value as the primary corporate objective and the greater informativeness of stock prices. He further notes that when the company commits to a shareholder maximizing strategy, independent directors are more valuable than insiders.

To enhance the corporate governance of publicly traded companies, the Sarbanes-Oxley Act of 2002 and major U.S. stock exchanges have promoted and imposed requirements for board independence (Public Law 107-204; Chhaochharia and Grinstein 2007). For example, section 301 of SOX requires that each member of the audit committee be independent. The rule changes adopted by the NYSE and NASDAQ require firms to have a majority of independent board members and entirely independent compensation and nominating/governance committees (Engel et al. 2005; Linck et al. 2008). In a recent study, Linck et al. (2008) find that board of directors during the post-SOX period are more independent and more likely to separate the two posts of

CEO and chairman of the board.

Boone et al. (2007) examine changes in board structure as a firm ages from IPO to 10 years of age. They find that as a firm ages and grows in size; the board takes on more of a monitoring role as evidenced by firms adding independent board members, as well as firms increasing board size. However, they also find that boards of growing firms add independent board members in order to tap into outside expertise as the firm moves into new regions or diversified service offerings.

A number of other studies document the value of having independent directors. For example, Beasley (1996) finds that the inclusion of larger proportions of outside members on the board of directors reduces the likelihood of financial statement fraud.[5] Klein (2002) shows a negative relation between board independence and abnormal accruals. Further, she finds significant increases in abnormal accruals accompany reductions in board or audit committee independence. Using a sample of firms in the United Kingdom, Peasnell et al. (2005) find the likelihood of managers making income-increasing abnormal accruals, to avoid reporting losses and earnings reductions, is negatively related to the proportion of outsiders on the board. Anderson et al. (2004) find that board and audit committee independence are associated with lower cost of debt financing, indicating that creditors place importance on director independence in monitoring financial accounting reports.

More recently, Knyazeva et al. (2013) show that proximity to larger pools of local director talent leads to more independent boards. Using the local pool of potential directors as an instrument for determining board independence, they find that board independence has a positive effect on firm value, operating performance, fraction of CEO incentive-based pay, and CEO

[5] Examining a sample of U.S. firms from 1978 to 2001, Uzun et al. (2004) find that firms with more independent boards, and board sub-committees are associated with lower levels of corporate fraud.

turnover. In sum, prior work largely supports the notion that independence is an element that constitutes an effective board.

Activity of Board Members

The second construct that we examine is the activity level of the board of directors. As noted by Carcello et al. (2002, p. 371), the activity or diligence of the board consists of "factors such as the number of board meetings and the behavior of individual board members surrounding such meetings (e.g., preparation before meetings, attentiveness and participation during meetings, and post-meeting follow-up)." Regulators and academics largely support the proposition that high activity level and diligence in completing board duties increase board effectiveness (Lipton and Lorsch 1992; Vafeas 1999; Carcello et al. 2002). The Blue Ribbon Committee, for example, advocates that the audit committee of the board can provide better assurance over the quality of the financial statements by having at least 4 meetings a year (Anderson et al. 2004).

The vast majority of academic empirical work measure board activity and diligence by the number of board meetings, finding associations between such measure and economic outcomes. For example, Vafeas (1999) finds that share price declines are followed by higher meeting frequencies and years with an abnormally high meeting frequency are followed by improvements in operating performance. MacAvoy and Millstein (1999) find boards that meet frequently help companies produce higher rates of return for their shareholders, as measured by earnings in excess of cost of capital and net of the industry average. Furthermore, Anderson et al. (2004) find evidence suggesting that audit committee activity is quite important to creditors. Specifically, their findings reveal that firms with more audit committee meetings are associated with a significantly lower cost of debt financing.

A stream of research also associates board meeting frequency with better monitoring effectiveness. For example, Carcello et al. (2002) find that diligent boards promote shareholder interests by purchasing differentially higher-quality audit services. In addition, Xie et al. (2003) document that board and audit committee meeting frequencies are associated with reduced levels of earnings management.

Competence of Board Members

The third board effectiveness construct is competence or ability of the board. Even if the mix of independent-to-non independent board members is ideal and these board members are actively engaged in performing their duties, if the board does not contain individuals properly qualified to provide guidance and monitoring to management, the board will ultimately be ineffective.

Some have argued that directors who hold multiple directorships have made a significant investment in developing their reputation capital as competent directors (e.g., Fama and Jensen 1983; Carcello et al. 2002; Abbott et al. 2003). Ferris et al. (2003) note that firm performance, during a director's tenure, has a positive effect on the number of board seats a director subsequently obtains, thus suggesting that reputation matters in the market for directors. In addition, some studies document benefits to multiple directorships. For example, Cotter et al. (1997) document that boards having directors holding multiple directorships are able to obtain larger premiums in tender offers for their shareholders. Carcello et al. (2002) find that boards where multiple directorships are common are more likely to protect shareholder interests and purchase differentially higher-quality audit services.[6]

[6] Ferris et al. (2003) test the hypothesis that directors who serve on multiple boards become so busy that they cannot monitor management adequately (i.e., the busyness hypothesis). Their results suggest that market participants do not view the appointment of a multiple director as a negative event for the firm;

Regulatory provisions and prior academic work also associate competence with expertise or knowledge held by directors. For example, the SEC acknowledges the importance of financial expertise on the audit committee and requires companies to disclose whether it has at least one "audit committee financial expert" serving on its audit committee. In this case, such an expert has characteristics that are particularly relevant to the functions of the audit committee, such as: a thorough understanding of the audit committee's oversight role, expertise in accounting matters as well as understanding of financial statements, and the ability to ask the right questions to determine whether the company's financial statements are complete and accurate (SEC 2003).[7]

Studies have documented value from having directors with specific expertise. Kroll et al. (2008) document that boards comprising of directors that are vigilant as well as having appropriate knowledge gained through experience are better monitors and more useful advisors to top managers. DeFond et al. (2005) find a positive market reaction to the appointment of accounting financial experts assigned to audit committees, suggesting that the market deems accounting-based financial skills to improve the audit committee's ability to ensure high-quality financial reporting. Other works also document the positive effects of having financial and legal experts on the audit committee on internal controls and financial reporting quality (e.g., Carcello et al. 2002; Krishnan 2005; Krishnan and Visvanathan 2008; Krishnan et al. 2011).

More recently, Kim et al. (2014) suggest that a director's tenure with the firm is positively associated with the director's competency to advise and monitor firm performance. More specifically, they contend that "longer director tenures reflect more board and committee

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multiple directors actually sit on more committees and attend more meetings; no statistically significant evidence that firms with multiple directors are more vulnerable to securities fraud litigation. They conclude that the evidence does not support the proposition that multiple board memberships harm firm value.

[7] Linck et al. (2008) find that, in the post-SOX period, board members are more likely to be lawyers, consultants, financial experts or retired executives.

meetings attended, likely increased committee assignments, greater experience with the firm's strategies and policies, and greater within-firm deal-level experience (Kim et al. 2004, p. 111)." Consistent with their hypotheses, they find outside director tenure to be associated with better firm acquisition/investment policy advising performance, lower CEO rent extraction, and higher operating performance measures.

Behavioral Attributes of Board Members

The final construct necessary for board effectiveness is the behavioral attributes and relationships among directors. The board's behavioral attributes can be broadly defined as the ability of the board to act as a cohesive unit, allow for constructive suggestions among its members, work well together as a team, and foster a positive intra-working relationship among team members (Forbes and Milliken 1999; Finkelstein and Mooney 2003; Roberts 2012). Using in-depth interviews with company directors, Roberts et al. (2005) examine the behaviors and relationships of non-executive directors to evaluate board effectiveness. The authors suggest that while board structure, composition, and independence each play an important role, it is ultimately the actions and conduct by individual board members that determine board effectiveness. Specifically, they suggest that a variety of behaviors – challenging, questioning, probing, discussing, testing, informing, debating, exploring, encouraging – are crucial for directors to be effective.

Forbes and Milliken (1999) integrate research on workgroup effectiveness with research on the board of directors. They identify group cohesiveness (agreement on the common goals of the board) along with the degree to which task-oriented disagreement (constructive criticism of another's idea) is permissible among board members, as necessary elements in assessing board effectiveness. Furthermore, Finkelstein and Mooney (2003) identify five interrelated board

behavioral processes that can make boards more effective – engage in constructive conflict, avoid destructive conflict, work together as a team, know the appropriate level of strategic involvement, and address decisions comprehensively.[8] Finally, Roberts et al. (2005) advance three linked sets of behaviors that suggest directors should be 'engaged but non-executive', 'challenging but supportive' and 'independent but involved.'

Safeguards within the Board of Directors

Directors are attentive to protecting their reputational capital (Fama and Jensen 1983; Gilson 1990). Indeed, prior academic work informs that directors who are associated with corporate catastrophes and fail to exercise reasonable care in fulfilling their responsibilities are often subject to labor market penalties (Fama 1980; Gilson 1990; Carcello et al. 2002). Srinivasan (2005), for example, finds that director (especially audit committee) turnover is higher for firms that restate their earnings (i.e., overstated their earnings) compared to non-restating firms.[9] Fich and Shivdasani (2007) investigate the reputational impact of financial fraud for outside directors, finding that directors of sued fraud-committing firms experience a significant decline in board seats held at other companies.

Directors are also attentive to avoiding or minimizing legal liability (Gilson 1990; Kesner and Johnson 1990; Carcello et al. 2002). Recent lawsuits against directors of companies such as Target, Groupon, and News Corp. highlight examples of current cases where directors are targets of shareholder lawsuits. As suggested by Brochet and Srinivasan (2013), directors named as defendants in securities lawsuits face the possibility of financial and reputational harm, lost time and emotional distress. Brochet and Srinivasan (2013) also show that directors named in lawsuits

[8] Please see Appendix B for more information about Finkelstein and Mooney (2003) five board behavioral processes.

[9] Srinivasan (2005) also documents that directors of firms with overstated earnings are no longer present in 25% of their positions on other boards.

receive more negative recommendations from the proxy advisory firm and attain significantly more negative shareholder votes than directors in a benchmark sample. Furthermore, directors are often wary of conducting improprieties that may cause predicaments with regulatory authorities (i.e., SEC, IRS, etc.). Section 305 of the Sarbanes-Oxley Act, for example, states that the SEC may issue an order to prohibit any person from acting as a director of an issuer if the SEC has found that such person's conduct "demonstrates unfitness" to serve as a director of any such issuer (Marden and Edwards 2005).

We contend that safeguards greatly influence board effectiveness. Our concept of safeguards pertains to the strength of mechanisms that regulate and oversee the board's conduct. The mechanisms include numerous factors, such as the company's own disciplining procedures for board misconduct; extensiveness of corporate bylaws and code of ethics; monitoring over the board by shareholders, institutional investors, and analysts; penalties in the labor market for directors; professionalism guidelines, board evaluations; as well as industry-specific and/or market-wide regulations. Safeguards can also reflect individual director's (and the overall board's) proclivity to guard against actions and decisions that can jeopardize reputational capital, heighten litigation risk, and violate regulatory provisions or rules of conduct. We treat this construct of safeguards as a direct control to board effectiveness, because the level of safeguards has a direct impact on each of the other four constructs (i.e., independence, competence, activity, and behavior attributes).

We maintain that the level of safeguards can vary from one board (or individual director) to another. While all directors should ideally be concerned about their reputation capital, litigation risk, and compliance with regulatory provisions, it is likely some directors are less alarmed by such issues than others. Based on a sample of securities class-action lawsuits from 1996 to 2010,

Brochet and Srinivasan (2013) show that only a minority of independent directors have actually been named as defendants. Black et al. (2006) argue that litigation risk for directors may be exaggerated and report that outside directors of U.S. public companies who fail to meet their fiduciary duties almost never face personal liability losses because of such factors as directors and officers (D&O) liability insurance.

In the following sections, we present both a structure and a set of basic attributes that define effective board of directors. The basic attributes have been obtained from the research domains mentioned above. We provide a logical argument based on Bayesian reasoning to relate these attributes to the overall effectiveness of the board.

3. Bayesian Model for the Effectiveness of Board of Directors

In this section we develop a theoretical model for the effectiveness of board of directors (BOD) under the Bayesian framework in terms of the basic attributes of board effectiveness. We use the Mautz and Sharaf (1961) philosophical approach to determine the basic attributes of BOD and their relationship to BOD effectiveness. As established by several researchers (e.g., Brown et al. 2011; Gompers et al. 2003; and Roberts 2012) and as discussed in the previous sections, the board of directors effectiveness is determined, basically, by several characteristics (attributes) such as Independence (I) of the board members from the management, Competence (C) of the board members in firm-specific knowledge, particular fields of expertise (e.g., accounting, finance, law, etc.), and the specific industry in which the firm operates, Active (A) board members (i.e., the members meet frequently with the CEO and CFO to monitor their activities and advise, members are diligent in attending board meetings and being active in those meetings), and the board members possess appropriate behavioral attributes (B) to act cohesively

and constructively as a team player.[10] As discussed in Section 2, we consider an additional construct "safeguards" for the effectiveness of BOD. We argue that the construct "safeguards" is not a basic attribute of the BOD members to make it effective rather it is a control mechanism to governing the basic attributes of the BOD members. Some examples of "safeguards" such as legal liability against BOD members and reputation loss of BOD members of companies that are involved in fraudulent behavior are discussed in Section 2.

The current literature on the characteristics of an effective BOD simply identifies the above attributes (Independence, I; Competence, C; Active members, A; and Behavioral attributes, B) without providing any insights into their interrelationships. In addition, as mentioned earlier, the significance of these attributes for BOD effectiveness has been established through empirical research by considering one or two attributes at a time and thus it is difficult to draw conclusions about whether presence or absence of the other attributes at the same time would strengthen or weaken the BOD effectiveness. The question is how should these factors be related to the BOD effectiveness?

It seems, some rating agencies such as Corporate Library (see Van den Berghe and Levrau 2004 for details) use a linear scale to combine individual scores in each area (multiple factors are considered in each area or attribute, i.e., construct, which are individually rated for their presence) to determine an overall Board Effectiveness Rating without any theoretical consideration. A linear relationship implies that one can substitute one attribute for another. However, when one tries to interpret the linear relationship logically it may not make sense. For example, consider the following situation where all the BOD members were independent, regularly met with the CEO and CFO to discuss the company's strategies, plans and activities,

[10] See Table 1 for examples of characteristics that constitute each of the four board effectiveness attributes.

and had the appropriate behavioral characteristics, but were incompetent. Would this be an effective board? No, not at all! In fact, the BOD will not be effective if any one, any two, any three, or all the four of the attributes are absent. Thus, we argue for an "And" relationship among these attributes with the effectiveness of BOD. In other words, the BOD will be most effective only when all four attributes, I, C, A, and B, are present. That is, the BOD is most effective *if and only if* the BOD members are independent (I), competent (C), active (A), and the members possess appropriate behavioral characteristics (B). We analyze various scenarios in this section after developing the probabilistic model. It is important to point out that we employ a probability model because of the uncertainties involved in assessing whether certain attributes are present or absent.

The "And" relationship can be expressed in terms of the following set notations:

$$eb = i \cap c \cap a \cap b,$$

where 'eb' represents the state that the BOD is effective, 'i' represents the state that BOD members are independent, 'c' represents the state that BOD members are competent, 'a' represents the state that BOD members are active, and 'b' represents the state that BOD members possess appropriate behavioral characteristics. In terms of the negations of the above states, one can write the above relationship as an "Or" relationship:

$$\begin{aligned}\sim eb = {} & (\sim i \cap c \cap a \cap b) \cup (i \cap \sim c \cap a \cap b) \cup (i \cap c \cap \sim a \cap b) \cup (i \cap c \cap a \cap \sim b) \cup (\sim i \cap \sim c \cap a \cap b) \\ & \cup (\sim i \cap c \cap \sim a \cap b) \cup (\sim i \cap c \cap a \cap \sim b) \cup (i \cap \sim c \cap \sim a \cap b) \cup (i \cap \sim c \cap a \cap \sim b) \cup (i \cap c \cap \sim a \cap \sim b) \\ & \cup (\sim i \cap \sim c \cap \sim a \cap b) \cup (\sim i \cap \sim c \cap a \cap \sim b) \cup (\sim i \cap c \cap \sim a \cap \sim b) \cup (i \cap \sim c \cap \sim a \cap \sim b) \cup (\sim i \cap \sim c \cap \sim a \cap \sim b).\end{aligned}$$

The above equation implies that the BOD will be ineffective (~eb) if any one, any two, any three, or all the four of the attributes are absent. In the present discussion, we have assumed all the attributes to be binary variables. Thus, we want to develop a formula for the posterior probability that BOD is effective given that we have information about the four attributes, I, C, A, and B, whether they are present or absent.

Similar arguments are common in audit and information systems literature. For example, the audit literature argues that an account is fairly stated *if and only if* all its management assertions such as Existence, Completeness, Valuation, Rights and Obligation, etc. are true (see AICPA's SAS 106, 2006). In developing a fraud risk assessment formula, Srivastava et al. (2007) have used the "And" relationship among the fraud triangle factors, Incentives to benefit from fraud, Attitude to commit fraud, and Opportunity to commit fraud, with the commitment of fraud by management. All the three fraud factors have to be present for management to commit fraud. Desai et al. (2010) have used similar arguments in determining the strength of the internal audit function. They argue that the internal audit function will be strong *if and only if* the internal auditors are competent, they are objective, and their work is of high quality.

----- Figure 1 about here -----

Figure 1 depicts an evidential diagram (Srivastava 2011) for the problem at hand. The main assertion that BOD is effective is related to four attributes (i.e., constructs) through the "And" relationship. In general, they are known as variables. These variables are assumed to be binary and are represented by rounded boxes. The rectangular boxes in Figure 1 represent items of evidence pertaining to the variables they are connected to. We have derived a general formula, Equation (A9), in Appendix A, for the posterior probability of the main variable being true as a function of the strength of evidence pertaining to the main assertion and each sub-assertion expressed in terms of the likelihood ratio, λ, and the corresponding prior odds, O. In the case of BOD, we have five variables, the main assertion, EB, representing the effectiveness of BOD with two values {eb, ~eb}; 'eb' representing "effective BOD" and '~eb' representing "ineffective BOD", and four sub-assertions with two values, representing the presence and absence of the corresponding variable, Independence (I), Competence (C), Active (A), and Appropriate

Behavior (B). The corresponding items of evidence are represented by $E1_{EB}$, $E2_{EB}$, E_I, E_C, E_A, and E_B, and the related likelihood ratios, representing the strength of evidence, are given by λ_{1EB}= $P(E1_{EB}|eb)/P(E1_{EB}|\sim eb)$, λ_{2EB}= $P(E2_{EB}|eb)/P(E2_{EB}|\sim eb)$, λ_I= $P(E_I|i)/P(E_I|\sim i)$, λ_C= $P(E_C|c)/P(E_C|\sim c)$, λ_A= $P(E_A|a)/P(E_A|\sim a)$, and λ_B= $P(E_B|b)/P(E_B|\sim b)$. The corresponding prior odds and the related β's are given by: O_{EB}= $P(eb)/P(\sim eb)$, O_I= $P(i)/P(\sim i)$, O_C= $P(c)/P(\sim c)$, O_A= $P(a)/P(\sim a)$, and O_B= $P(b)/P(\sim b)$, and β_{EB}= $\lambda_{1EB}\lambda_{2EB}O_{EB}$, β_I= $\lambda_I O_I$, β_C= $\lambda_C O_C$, β_A= $\lambda_A O_A$, and β_B= $\lambda_B O_B$. Substituting these values in Equation (A9) with n = 4, we obtain the following expression for the posterior probability that BOD is effective given all the information about all the variables:

$$P(eb|E_I E_C E_A E_B E1_{EB} E2_{EB}) = \frac{\beta_I\beta_C\beta_A\beta_B\beta_{EB}}{1 + \sum_i \beta_i + \sum_{i,j,i\neq j} \beta_i\beta_j + \sum_{i,j,k,i\neq j\neq k} \beta_i\beta_j\beta_k + \beta_I\beta_C\beta_A\beta_B\beta_{EB}} \qquad (1)$$

where i, j, k ∈{I, C, A, B}.

Equation (1) is a general expression for the posterior probability for the strength of BOD being effective given that we have evidence related to all the variables (attributes) and the two items of evidence, $E1_{EB}$ and $E2_{EB}$ at the main assertion level. In our model, we consider the evidence $E1_{EB}$ to represent the presence or absence of the factor "safeguards," which serves as a control and the evidence $E2_{EB}$ represents the other potential evidence[11] that pertain to the overall BOD effectiveness but does not pertain to "safeguard". The presence or absence of safeguards impacts all the attributes. For example, if there is a strong legal liability punishable by jail terms for not serving the board effectively or being negligent, the members will not serve on the board

[11] This item of evidence is added to make the model more general. If such an item of evidence is not obtained or considered then one can just replace the corresponding likelihood ratio, λ_{2EB}, in Equation (1) by 1.0 (i.e., λ_{2EB}= 1).

if they think that either they lack the competence or cannot meet the challenges of the responsibilities for fear of being prosecuted for being negligent. Under such a situation, even if they decide to serve, they will make sure that they maintain independence, and acquire the required competence and possess other attributes to be effective.

Next, we use Equation (1) to analyze the impact of various attributes being present or absent on the posterior probability of BOD effectiveness. Also, we use Equation (1) to analyze the impact of "safeguards" on BOD effectiveness. We want to emphasize here that the measure of presence or absence of attributes in our approach is modeled through the likelihood ratios. The likelihood ratio is a continuous variable and hence is a better measure of the presence or absence of an attribute than the measures, 1 or 0, used by the academic researchers.

Case 1: Impact of Presence or Absence of Attributes with Certainty on BOD Effectiveness

In this case we assume that we have information that I, C, A, and B are present with certainty, i.e., BOD members are independent, they are competent, they are active, and they possess right behavioral characteristics to be effective. This situation is the ideal situation and implies that $\lambda_I = \lambda_C = \lambda_A = \lambda_B \rightarrow \infty$. For this case, Equation (1) yields the posterior probability, $P(eb| E_I E_C E_A E_B E1_{EB} E2_{EB}) = 1$, irrespective of the value of λ_{1EB} (i.e., irrespective of the presence of "safeguards") and λ_{2EB}, and for any value of the prior odds for all the variables. This is a logical result. If we know for sure that BOD members are independent of the management, are competent, are active in overseeing the management, and possess appropriate behavioral characteristics then the BOD for sure will be effective. However, when any one, any two, any three, or all the four of the factors are absent the BOD will be ineffective. Equation (1) yields this result. The condition that any one factor is absent is obtained by setting the corresponding

likelihood ratio to zero. For example, if BOD members are not independent then $\lambda_I = 0$, i.e., $\beta_I = 0$. This condition yields $P(eb|E_IE_CE_AE_BE1_{EB}E2_{EB}) = 0$, and $P(\sim eb|\ E_IE_CE_AE_BE1_{EB}E2_{EB}) = 1$, irrespective of the prior odds and whether the other three factors are present or not present. Similarly, one can show that $P(eb|E_IE_CE_AE_BE1_{EB}E2_{EB}) = 0$, and $P(\sim eb|E_IE_CE_AE_BE1_{EB}E2_{EB}) = 1$, when any two, any three, or all the four factors are absent. The above results are again logical as one would expect under the "And" relationship. Next, we discuss situations where the items of evidence are uncertain about the presence or absence of the variables.

Case 2: Impact of Presence or Absence of Attributes with Uncertainties on BOD Effectiveness

In this section, we demonstrate the effect of the presence or absence of the attributes on BOD effectiveness, especially under the condition when we do not have full knowledge about their presence or absence, i.e., there is uncertainty about their presence or absence. Figure 2 is a graph of the posterior probability that BOD is effective as a function of the strength of evidence showing the presence or absence of various attributes. In this figure, we do not consider the presence or absence of Safeguards (i.e., we do not have any information whether Safeguards are present or not, thus, the corresponding likelihood ratios, $\lambda_{1EB} = 1$ and $\lambda_{2EB} = 1$). As we can see from the top solid line (Line 1) in Figure 2, the posterior probability of BOD being effective is the highest when all the four attributes are present, and increases as the strength of attributes increases (i.e., as the support for the presence of all the attributes increases). Since the strength of evidence is represented by the likelihood ratio, a value of $\lambda = 9$, means the corresponding attribute is present with probability 0.90 (Posterior Probability = $\lambda/(1+\lambda)$ with the prior odds = 1, i.e., with no prior knowledge of the presence or absence of the variable). The second line from the top (Line 2) in Figure 2 represents the posterior probability of BOD being effective in the presence of only three of the four attributes. This posterior probability is much smaller than the

posterior probability of BOD being effective when all four attributes were present. The posterior probability further decreases as additional attributes are eliminated from consideration as demonstrated from Line 3 and Line 4 in Figure 2. Thus, the BOD effectiveness is the highest when all the four attributes are present and increases further as the strength of these attributes increase.

----- Figure 2 about here -----

----- Figure 3 about here -----

Figure 3 compares the posterior probability of BOD being effective when all the four attributes are present with the posterior probability of BOD effectiveness when either some attributes are known to be absent or we have no knowledge about their presence. From Figure 3, we see that the posterior probability of BOD effectiveness increases, in general, as the likelihood of the presence of the attributes increases and it is the highest when all the four attributes are present (see Line 1 in Figure 3). In principle, the posterior probability of BOD effectiveness will approach unity when all the four attributes are present for sure (i.e., when the likelihood ratios, λs, for all the attributes approach infinity). Notice the significant decrease in the posterior probability when we have the knowledge that one of the attributes is not present (say with probability 0.66 in our case) compared to when we have no knowledge about the presence or absence of that attribute (compare Line 3 with Line 2 in Figure 3). In our case, this means that if we have, for example, the knowledge that BOD members are not independent or not competent, the posterior probability of BOD effectiveness is much smaller than when we have no knowledge that whether BOD members are independent or not independent or competent or not competent (the corresponding likelihood ratio = 1, no information). The posterior probability of BOD being effective further decreases when we have evidence in support of only two of the attributes and

the other two are either absent or we have no knowledge about their presence (Compare Line 4 with Line 5 in Figure 3). In our illustration, Line 5 represents the worst scenario case, where two of the factors are known to be absent with probability 0.66 (the corresponding likelihood ratio being 0.5). This is a logical result, when you know that two of the attributes are absent, the BOD effectiveness will be lower than for the situation where only one attribute is known to be absent, which will be lower than for the situation when all the attributes are present (compare Lines 1, 2, 3, 4, and 5 in Figure 3).

Case 3: Impacts of Safeguards on the BOD Effectiveness

Here we analyze the impact of safeguards on the posterior probability of BOD effectiveness. As discussed earlier, safeguard factors impact BOD effectiveness as a whole and their role is more like a control mechanism. Figure 4 illustrates the variation of the posterior probability of BOD effectiveness as a function of the strength of safeguards. As we see in Figure 4, in general, the posterior probability of BOD effectiveness increases as the strength of safeguards increases. This result makes logical sense; stronger the safeguards higher the BOD effectiveness.

----- Figure 4 about here -----

Next, we examine the impact of the presence or absence of the attributes on BOD effectiveness as a function of the strength of safeguards. From Figure 4, we observe that the posterior probability of BOD effectiveness is the highest (Line 1) when we have the knowledge that all the four attributes are present with certain probability (in Figure 4 it is 0.66 with the corresponding likelihood ratio equal to 2.0). The second line from the top (Line 2) represents the posterior probability of BOD effectiveness when only two of the four attributes are present with certain probability, 0.66 in our case, and for the other two there is no knowledge whether they

are present or not. Line 3 represents the posterior probability when we have no knowledge of the presence or absence of all the four attributes. Finally, Line 4 in Figure 4 represents the posterior probability of BOD effectiveness when we have knowledge with certain probability, 0.66 in our case, that two of the attributes are absent and for the other two we have no knowledge about their presence or absence. It is clear that as the strength of safeguards increases the posterior probability of BOD effectiveness increases and also it increases as the presence of more attributes become known (Line 1 is higher than Line 2, which is higher than Line 3, which is higher than Line 4). *These results suggest that BOD is most effective when all the attributes are present and BOD members are accountable through the safeguards for their acts*. Safeguards as a control mechanism can be introduced through some kind of regulations to make BOD members accountable for their acts. Stronger the safeguards and higher the probability of the presence of all the four attributes, higher the BOD effectiveness.

----- Figure 5 about here -----

Figures 5 and 6 further illustrate the impacts of safeguards on the effectiveness of BOD when three of the four attributes are present with increasing likelihoods and for the fourth one we either do not know whether it is present (Figure 5) or know that it is not present (Figure 6). It is clear that Lines 1 and 2 in Figure 5, which represent the effectiveness of BOD under strong "safeguards," are higher than Lines 3 and 4, which represent the effectiveness of BOD under no safeguards being considered. This finding has a strong practical implication. This suggests that with the same characteristics of BOD, the board will be more effective if there is a safeguard mechanism in place compared to a situation where there is no safeguard.

----- Figure 6 about here -----

Figure 6 is similar to Figure 5. The only difference is that in Figure 5 some attributes (one

for Lines 1 and 3, two for Lines 2 and 4) are not considered to be present or absent whereas in Figure 6 these attributes are known to be absent with probability 0.66. As one can see by comparing the lines in Figure 5 with the lines in Figure 6, for a given level of safeguards (strong presence and unknown presence), the effectiveness of BOD is much lower when the attribute(s) is (are) known to be absent compared to the case where we have no knowledge of its (their) presence.

Case 4: BOD Effectiveness – Additional Analysis

Figure 7 demonstrates the value of the presence of all four attributes along with the presence of safeguards. Line 1 and Line 3, respectively, represent the BOD effectiveness when all four attributes are present with moderately strong safeguards (the corresponding likelihood ratio $\lambda_{1EB} = 4$) and with no consideration of safeguards. While, Line 2 and Line 4, respectively, represent the BOD effectiveness when only three attributes are present and one attribute is absent with probability 0.66 with strong safeguards (the corresponding likelihood ratio $\lambda_{1EB} = 9$) and with no consideration of safeguards. In Figure 7 we see that Line 1 is higher than Line 2. This suggests that the BOD effectiveness is higher for the case where all the four attributes are present with *moderately strong* safeguards than for the case when only three attributes are present with one being absent with probability 0.66 but with *strong safeguards*.

----- Figure 7 about here -----

It is important to note that all four attributes must be present for a high level of BOD effectiveness (compare Lines 1 and 3 with lines 2 and 4). However, the BOD effectiveness would further increase if safeguards were present (Compare Lines 1 and 2 with Lines 3 and 4). The BOD effectiveness would not be as high even with strong safeguards if one or more attributes are absent. However, in the limit, if we consider *infinitely strong* safeguards then BOD

effectiveness for the case where one or more attributes are absent may be higher than BOD effectiveness where we have all the four attributes present but *moderately strong* safeguards. It is not easy to think of examples of infinitely strong safeguards in the real world. One could consider "execution" as being such a safeguard to control BOD members' behaviors. But this ideal situation will never be possible in reality.[12] Thus, for realistic situations with *moderately strong* safeguards the BOD effectiveness is higher for the case where all the four attributes are present than for the case where only three or fewer attributes are present and the others are either absent or not being considered even with *strong safeguards*. This shows the importance of all the four attributes and the safeguards.

4. Conclusion

Corporate governance provides the structure through which the objectives of the company are set, and the means of attaining those objectives and monitoring performance are determined (OECD 2004). An effective corporate governance framework necessitates strategic guidance of business activities and monitoring of management actions, among others. In which case, the BOD constitutes an essential component of the corporate governance system. The BOD is a trust engendering mechanism intended to ensure that managers are made accountable for their actions and that decisions are made to the benefit of shareholders' interests (Baysinger and Hoskisson 1990; Hilb 2012).

While a vast number of studies examine the association between characteristics of the BOD and corporate outcomes, there is scant formal theoretical work underlying the interrelationships between attributes of an effective board (Larcker et al. 2007; Brown et al.

[12] China executed its former top food-and-drug regulator, Zheng Xiaoyu, who was taking bribes from pharmaceutical companies (see http://www.denverpost.com/headlines/ci_6389912).

2011). Given the impetus to develop a theoretical framework on board effectiveness, we present an analytical model demonstrating that for a board to be effective, the following four criteria must be met: (i) independence from management, (ii) competent in performing its functions and responsibilities, (iii) active in board duties, and (iv) have appropriate behavioral attributes.

We identify these four attributes from professional guidance and prior academic research that examine the efficacy of corporate boards. Our theoretical model defines an "And" relationship between a board being effective and the four attributes independence, competency, activity, and behavioral attributes. Because one cannot trade one attribute for the other, we conclude that a board of directors is most effective if and only if the board exhibit high levels of independence, competency, activity and behavioral traits. In addition, we demonstrate that even when all the four attributes are present the presence of "safeguards" further increases the effectiveness of the board. Thus, as an implication of this study, we propose that some short of "safeguard" mechanism should be in place to control the behavior of the board member to make the board more effective.

Of particular interest to regulators and other governance bodies, may be the identification of the importance of the "And" relationship in assessing Board effectiveness. Prior attempts to address Board effectiveness such as, the SEC's 2003 adoption of board compensation requirements as proposed by the NYSE and Nasdaq for listed firms, take an "Or" approach. Focusing on an individual construct (in this case board independence), while failing to address the interrelationship with other constructs.

The analytical model we present in this paper is a strong first step in understanding the core requirements necessary for a BOD to be effective; however, we recognize that it is only a beginning. As with any analytic model there are questions it can help inform answers to, but

cannot directly answer itself. In an effort to help address these shortcomings, we encourage researchers to take this framework and use it as a starting point for future research. In particular we encourage archival based researchers to develop and validate proxies for each of the models constructs, and to use those proxies further to explain the role the Board of Directors plays in firm guidance and governance. The attributes of board competency and the board's behavioral attributes are of particular interest as they have, to a certain extent, been ignored by prior archival research. Upon developing suitable proxies, researchers may consider examining changes to the role and structure of the board following an economic shock, such as the recent financial crisis, or changes to board culture following a negative accounting outcome, such as a restatement of financial reports. Additionally, there is significant room within the behavioral research space to develop and test research questions regarding the degree of confidence one needs when assessing the board's constructs. In particular, it would be very insightful to know if each construct is viewed to carry the same level of importance, and if not to identify the pecking order of importance among attributes. Finally, given the broad influence of the board of directors, we encourage our fellow scholars in disciplines such as management, finance, and psychology to consider our theoretical framework, and to apply its characteristics and constructs to situations from their field of study.

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APPENDIX A

Posterior Probability of Main Assertion Given the Knowledge about 'n' Sub-Assertions in an 'AND' Tree

We use the induction approach to develop the formula for posterior probability of the main assertion, M, which consists of n-sub-assertions, $A_1 \ldots A_n$, that are related to the main assertion through the "And" relationship, as depicted in Figure 1A. The rounded boxes represent variables (assertion and sub-assertions), and the rectangular boxes represent items of evidence pertaining to the variables to which they are connected. The "And" relationship implies that the main assertion is met, i.e., it is true *if and only* if all the sub-assertions are true. We assume these variables to be binary in nature. An upper case letter is used to represent the name of the variable, while the lower case letter is used for its values. For example, M represents the main assertion with 'm' representing the value that it is true, i.e., the assertion is met, and '~m' represent the negation of the variable M that it is not true. Figure 1A is a tree type evidential diagram, where each item of evidence pertains to only one variable. If an item of evidence pertains to more than one variable then the evidential diagram becomes a network. Deriving an analytical formula for a network evidential diagram becomes intractable.

We want to determine the posterior probability that the main assertion is true given that we have observed all the evidence related to all the variables: $E_M, E_1, \ldots E_n$ (See Figure 1A). In other words, we want to answer the question that what would be the likelihood that the main assertion is true given that we have collected and evaluated all the evidence related to all the variables as given in Figure 1A. We use Shenoy and Shafer (1990, see also Srivastava 2011) technique to derive the general formula. Srivastava et al. (2012) have used the Shenoy and Shafer approach to derive a general formula for the likelihood of a particular cause to be the reason for an effect under the situation where multiple causes are the reason for the effect. In

some sense, our problem is similar to theirs, except we want to determine the likelihood of the presence of the effect (the main assertion) based on the presence of all the causes (all the sub-assertions).

First, we develop the analytical formula for the posterior probability that the main assertion, M, is true for the simple case with two sub-assertions, A_1 and A_2, and then by induction we derive the formula for n sub-assertions. In general, we also assume that we have partial knowledge about the presence of the main assertion, M, through evidence E_M.

Two Sub-Assertions Case

Consider a situation where two sub-assertions, A_1 and A_2 are related to the main assertion M through an "And" relationship. This relationship implies that the main assertion M is true *if and only if* A_1 is true and A_2 is true. Under the set notations, one can write this relationship as: $m = a_1 \cap a_2$, where a_1 represents the state that sub-assertion A_1 is true, a_2 represents the state that sub-assertion A_2 is true, and m represents the state of the main assertion M that it is true. The "And" relationship between M, and A_1 and A_2, can be expressed in terms of "Or" relationship for the negation of the main assertion M as represented by the following equation in terms of set notations:

$$\sim m = (a_1 \cap \sim a_2) \cup (\sim a_1 \cap a_2) \cup (\sim a_1 \cap \sim a_2),$$

which means that the main assertion M is not true when any one of the sub-assertions is not true or when both of them are not true.

To derive the formula for the posterior probability that the main assertion is true given that we have observed and evaluated all the evidence, $P(m|E_M E_1 E_2)$, we use the Shenoy and Shafer (1990) approach of combining probability information. Under this approach we first

identify all the probability information relevant in the problem. Probability information on a variable (variables being M, A_1, and A_2) is expressed in terms of what Bayesian literature refers to as probability potentials (Shenoy and Shafer 1990). The probability potentials at a variable essentially are probabilities or conditional probabilities associated with the variable, but are not necessarily normalized, i.e., they do not necessarily add to one. For example, the conditional probabilities associated with variable M due to the evidence E_M could be expressed as potentials at M with two values, one for 'm' that it is present and the other for '~m' that it is not present, and are represented as $P(E_M|m)P(m)$ and $P(E_M|\sim m)P(\sim m)$. In general, we use the symbol $\phi(.)$ to express the potential for the argument given in the parenthesis. For example, the potentials on the state space {m, ~m} of the binary variable 'M' based on the conditional probabilities can be expressed as: $\phi(m) = P(E_M|m)P(m)$, and $\phi(\sim m) = P(E_M|\sim m)P(\sim m)$. Basically, under the Shenoy and Shafer (1990) approach, all the potentials are vacuously extended[13] to the joint space of all the variables, point-wise multiplied,[14] and then marginalized[15] to variables of interest to determine the posterior probability of that particular variable. The following discussion provides the details of combining all the potentials and finally determining the overall potentials at M, the variable of interest.

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[13] Vacuous extension can be easily explained in terms of an example. Suppose we have the following probability information about, say a binary variable X: P(x) and P(~x). We can vacuously extend the above probability information to the joint space {xy, x~y, ~xy, ~x~y} as follows: P({xy, x~y}) = P(x), and P({~xy, ~x~y}) = P(~x). There is no information about Y in the above probability information. That is the reason it is called vacuous extension.

[14] Point-wise multiplication means that one element of a potential is multiplied to the same element of another potential yielding the resultant potential.

[15] Marginalization is the opposite of vacuous extension. Suppose we want to marginalize the probability information, P({xy, x~y}), and P({~xy, ~x~y}) to variable X. This is achieved by summing the probability information over the variable Y that is not needed. Thus, we obtain the following: P({xy, x~y}) marginalized to X yields P(x), and P({~xy, ~x~y}) marginalized to X yields P(~x).

Step 1: Identify all the Probability Potentials for two sub-assertions case in Figure 1A

Probability Potentials at 'M 'due to Evidence E_M: $\begin{bmatrix} \phi(\mathrm{m}) \\ \phi(\sim \mathrm{m}) \end{bmatrix} = \begin{bmatrix} P(E_M \mid m)P(m) \\ P(E_M \mid \sim m)P(\sim m) \end{bmatrix}$

Probability Potentials at variable A_1 *due to Evidence* E_1: $\begin{bmatrix} \phi(\mathrm{a}_1) \\ \phi(\sim \mathrm{a}_1) \end{bmatrix} = \begin{bmatrix} P(E_1 \mid a_1)P(a_1) \\ P(E_1 \mid \sim a_1)P(\sim a_1) \end{bmatrix}$

Probability Potentials at Variable A_2 *due to evidence* E_2: $\begin{bmatrix} \phi(\mathrm{a}_2) \\ \phi(\sim \mathrm{a}_2) \end{bmatrix} = \begin{bmatrix} P(E_2 \mid a_2)P(a_2) \\ P(E_2 \mid \sim a_2)P(\sim a_2) \end{bmatrix}$

Probability Potentials related to "And" relationship:

$$\begin{bmatrix} \phi(\mathrm{a}_1\mathrm{a}_2 m) \\ \phi(\mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \\ \phi(\sim \mathrm{a}_1\mathrm{a}_2 \sim m) \\ \phi(\sim \mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \end{bmatrix} = \begin{bmatrix} P(\mathrm{a}_1\mathrm{a}_2 m) \\ P(\mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \\ P(\sim \mathrm{a}_1\mathrm{a}_2 \sim m) \\ P(\sim \mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \end{bmatrix} = \begin{bmatrix} 1.0 \\ 1.0 \\ 1.0 \\ 1.0 \end{bmatrix}$$

Step 2: Combination of Potentials

We combine the potentials using the Shenoy and Shafer (1990) approach. Under their approach one needs to perform point-wise multiplication of all the potentials by first vacuously extending the potentials at M, A_1 and A_2 to the joint space {a_1a_1m, a_1~a_2~m, ~a_1a_1~m, ~a_1~a_1~m}, which happens to be the state space of the "And" relationship. As mentioned earlier, under point-wise multiplication, each element of a potential is multiplied with the same element of another potential. Given below is an example of the vacuous extension of the potential at M.

$$\begin{bmatrix} \phi(\mathrm{a}_1\mathrm{a}_2 m) \\ \phi(\mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \\ \phi(\sim \mathrm{a}_1\mathrm{a}_2 \sim m) \\ \phi(\sim \mathrm{a}_1 \sim \mathrm{a}_2 \sim m) \end{bmatrix} = \begin{bmatrix} P(E_M \mid m)P(m) \\ P(E_M \mid \sim m)P(\sim m) \\ P(E_M \mid \sim m)P(\sim m) \\ P(E_M \mid \sim m)P(\sim m) \end{bmatrix} \qquad \text{(A1)}$$

Next, we point-wise multiply the four sets of potentials (three sets from the three variables A_1, A_2, and M, and one set from the "And" relationship). In other words, we point-wise multiply the potentials defined earlier at M, A_1, A_2, and the potential for the "And" relationship after vacuously extending the potentials onto the joint space of the three variables. This multiplication yields the following potentials:

$$\begin{bmatrix} \Phi(a_1 a_2 m) \\ \Phi(a_1 \sim a_2 \sim m) \\ \Phi(\sim a_1 a_2 \sim m) \\ \Phi(\sim a_1 \sim a_2 \sim m) \end{bmatrix} = \begin{bmatrix} P(E_1 \mid a_1)P(a_1)P(E_2 \mid a_2)P(a_2)P(E_M \mid m)P(m) \\ P(E_1 \mid a_1)P(a_1)P(E_2 \mid \sim a_2)P(\sim a_2)P(E_M \mid \sim m)P(\sim m) \\ P(E_1 \mid \sim a_1)P(\sim a_1)P(E_2 \mid a_2)P(a_2)P(E_M \mid \sim m)P(\sim m) \\ P(E_1 \mid \sim a_1)P(\sim a_1)P(E_2 \mid \sim a_2)P(\sim a_2)P(E_M \mid \sim m)P(\sim m) \end{bmatrix}. \quad \text{(A2)}$$

To determine the combined potentials at variable M, we marginalize the above potential in (A2) onto the state space of M. The marginalization process yields the following potentials at M.

$$\begin{bmatrix} \Phi(m) \\ \Phi(\sim m) \end{bmatrix} = \begin{bmatrix} X_1 \\ X_2 + X_3 + X_4 \end{bmatrix}, \quad \text{(A3)}$$

where X_1, X_2, X_3, and X_4 are defined below:

$$X_1 = P(E_1|a_1)P(a_1)P(E_2|a_2)P(a_2)P(E_M|m)P(m),$$

$$X_2 = P(E_1|a_1)P(a_1)P(E_2|\sim a_2)P(\sim a_2)P(E_M|\sim m)P(\sim m),$$

$$X_3 = P(E_1|\sim a_1)P(\sim a_1)P(E_2|a_2)P(a_2)P(E_M|\sim m)P(\sim m),$$

$$X_4 = P(E_1|\sim a_1)P(\sim a_1)P(E_2|\sim a_2)P(\sim a_2)P(E_M|\sim m)P(\sim m). \quad \text{(A4)}$$

Equation (A3) provides the overall potentials at variable M after combining all the items of evidence including the priors. The potentials in (A3) when normalized yield the posterior probability that M is true given all the evidence about M, A_1, and A_2. To simplify the final result, we divide both the numerator and denominator of the normalized potentials by

$P(E_1|\sim a_1)P(\sim a_1)P(E_2|\sim a_2)P(\sim a_2)P(E_F|\sim m)P(\sim m)$ and define the following likelihood ratios, λ's, and prior odds, O's:

$$\lambda_1 = P(E_1|a_1)/P(E_1|\sim a_1);\ \lambda_2 = P(E_2|a_2)/P(E_2|\sim a_2);\ \lambda_M = P(E_M|m)/P(E_M|\sim m),$$

$$O_1 = P(a_1)/P(\sim a_1),\ O_2 = P(a_2)/P(\sim a_2),\ O_m = P(m)/P(\sim m), \qquad \text{(A5)}$$

We obtain the following posterior probability of m:

$$P(m|E_1E_2E_M) = \frac{\lambda_1 O_1 \lambda_2 O_2 \lambda_M O_M}{1 + \lambda_1 O_1 + \lambda_2 O_2 + \lambda_1 O_1 \lambda_2 O_2 \lambda_M O_M} \qquad \text{(A6)}$$

We can rewrite the above posterior probability by defining $\beta_i = \lambda_i O_i$ as the product of the likelihood ratio and the prior odds as:

$$P(m|E_1E_2E_M) = \frac{\beta_1 \beta_2 \beta_M}{1 + \beta_1 + \beta_2 + \beta_1 \beta_2 \beta_M}\ . \qquad \text{(A7)}$$

Equation (A7) represents the desired posterior probability that the main assertion is true for the two sub-asetions case in terms of the likelihood ratios, λ's, and prior odds O's, as given by β's, $\beta = \lambda O$, given that we have observed the following evidence: E_1, E_2, and E_M. Equation (A7) is a general expression. Next, we extend the above formula for the situation where there are 'n' sub-assertions.

Extension to 'n' Sub-Assertions

As we can see from (A7), the two-assertions case, there is a definite pattern in the formula. For example, the denominator consists of four terms, one plus three additional terms, two for the two individual sub-assertions and one joint term consisting of the product of the likelihood ratios and prior odds for all the three variables, A_1, A_2, and M. For a three sub-assertion system one would have the following expression for the posterior probability that the main assertion is true:

$$P(m|E_1E_2E_3E_M) = \frac{\beta_1\beta_2\beta_3\beta_M}{1 + \beta_1 + \beta_2 + \beta_3 + \beta_1\beta_2 + \beta_1\beta_3 + +\beta_2\beta_3 + \beta_1\beta_2\beta_3\beta_M} \quad \text{(A8)}$$

Thus, by induction we can generalize the above result for the case where we have n sub-assertions as follows:

$$P(m|E_1E_2\ldots E_nE_M) = \frac{\prod_{i=1}^{n}\beta_i\beta_M}{1+\sum_{i=1}^{n}\beta_i + \sum_{i,\,j,\,i\neq j}^{n}\beta_i\beta_j + \sum_{i,\,j,\,k,\,i\neq j\neq k}^{n}\beta_i\beta_j\beta_k + \ldots + \prod_{i=1}^{n}\beta_i\beta_M} \quad \text{(A9)}$$

where i, j, and k, vary from 1 to n. The symbol β is defined to be the product of the likelihood ratio, λ, and the corresponding prior odds, O, i.e., $\beta_i = \lambda_i O_i$.

In general, the likelihood ratio, $\lambda = P(E|a)/P(E|{\sim}a)$, represents the strength of evidence E pertaining to A, where 'a' represents the state that Assertion A is true, and ~a represents the state that A is not true. For a positive piece of evidence the likelihood ratio takes the following values: $\infty>\lambda>1$, for a neutral piece of evidence $\lambda = 1$, and for a negative piece of evidence the value of the likelihood ratio lies between 1 and zero, i.e., $1>\lambda>0$. The extreme values of the likelihood ratio represent certainties. For example, $\lambda\rightarrow\infty$ implies that the assertion is true for such a piece of evidence, i.e., P(a|E) = 1. Similarly, $\lambda = 0$ implies that the assertion is not rue with certainty, i.e., P(~a|E)=1.

Appendix B

Finkelstein and Mooney (2003) Five Goals for Board Effectiveness

1. Constructive Conflict

Directors hold and debate diverse views among themselves and the executives (or CEO). Directors engage in open and free dialogue. Directors are cognizant of management missteps and are able to act fast and aggressive in addressing those missteps. Directors are not merely "yes-men," but are able and willing to challenge dominant CEOs. They are inquisitive and not shy to challenge other directors or the CEO.

2. Avoid Destructive Conflict

Strong views are balanced with degree of tolerance and open-mindedness. Directors are able to avoid conflicts from being personal in nature. They have dialogue or debates to resolve problems and issues, and not attack personally.

3. Work Together as a Team

Directors work together and share resources, information, and decisions. The board avoids only having a few directors "dominate" the discussion and decisions. Directors respect and value the contribution of each other. In sum, there is good chemistry among directors.

4. Appropriate Level of Strategic Involvement

Directors go beyond the just monitoring role. They are also interested in the strategic direction of the company. However, directors are careful not to be overly involved in management's duties, i.e., micromanagement.

5. Comprehensive Decision Making

The board makes decision in a comprehensive manner. Directors as a team tackle problems in an in-depth manner, explore alternative decisions, actively seek help from experts, and engage in meaningful deliberations.

Table 1. Characteristics of Attributes for Board of Directors

BOD Attributes	No.	Characteristics
Independence	1	Percentage of independent outside directors
	2	Percentage of grey directors
	3	Complete independence within critical committees such as audit, compensation, and nominating committees
	4	Duality in CEO chairmanship
	5	Involvement of CEO in nominating/selecting board members
Competence	1	Board member's knowledge about company and business strategies
	2	Board member's knowledge about the industry and competitive landscape
	3	Financial expertise within audit committee
	4	Legal expertise within audit committee
	5	Board member's number of directorships held in other corporations
	6	Participation in ongoing education for board members on significant issues facing the organization, changing technology, and emerging risk areas.
	7	Education level of board members
Active	1	Preparation and planning for board meetings
	2	Number of held board meetings (regular and special meetings)
	3	Board member's attendance in board and committee meetings
	4	Influence of other held directorships or other outside job functions on a board member's activity/participation
Behavioral Attributes	1	Accept constructive suggestions from other directors
	2	Ability to work together as a team
	3	Foster positive working environment within the boardroom
	4	Able to work through disagreements in a productive manner
	5	Willingness to work toward a common goal that benefits the entire group

Figure 1: Evidential Diagram for Board of Directors Effectiveness with four attributes: Independence (I), Competence (C), Active (A), and Appropriate Behavioral Characteristics (B). The rectangular boxes with rounded corners represent the attributes (variables) and the rectangular boxes represent items of evidence pertaining to the variables they are connected to.

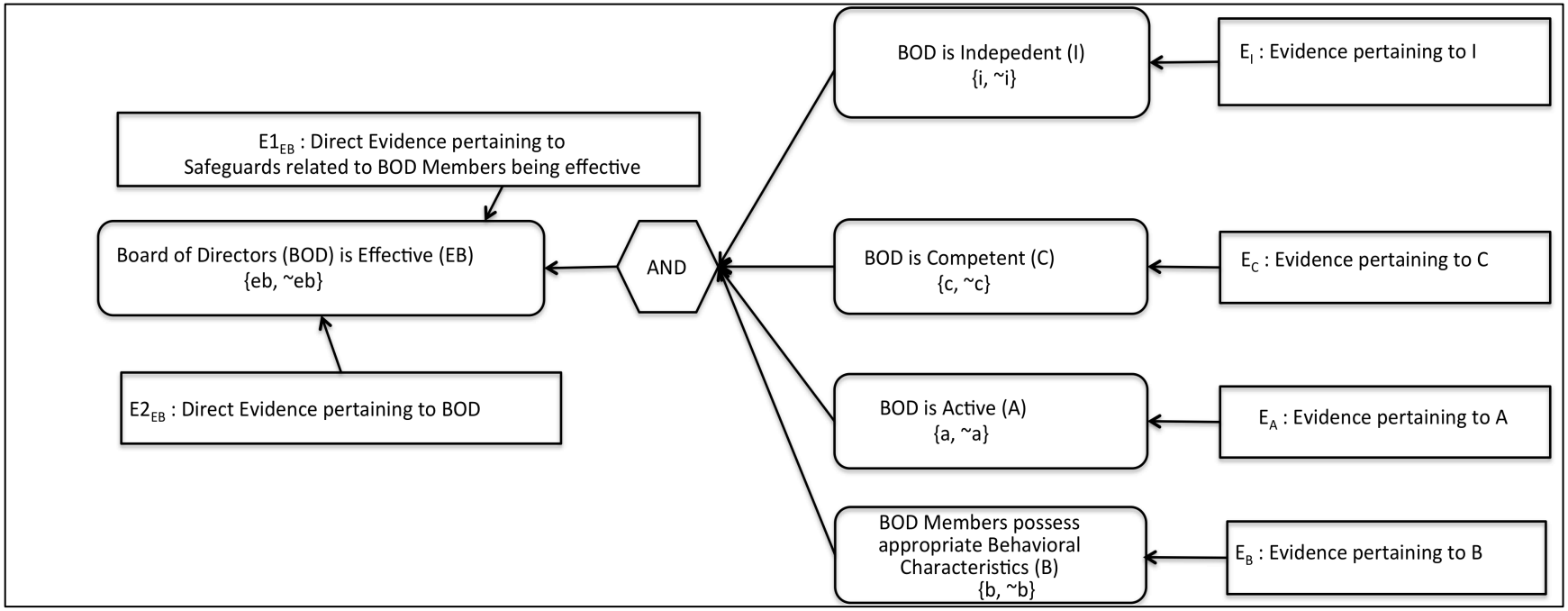
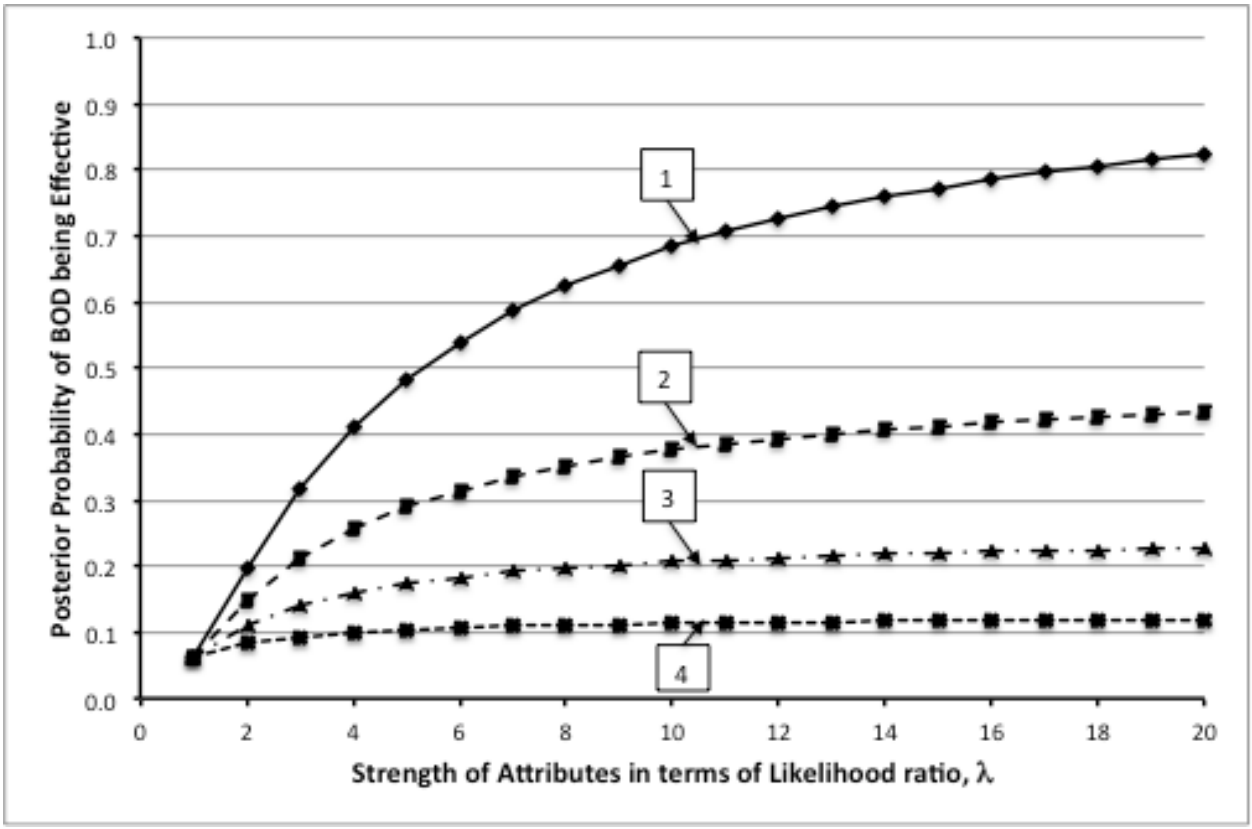
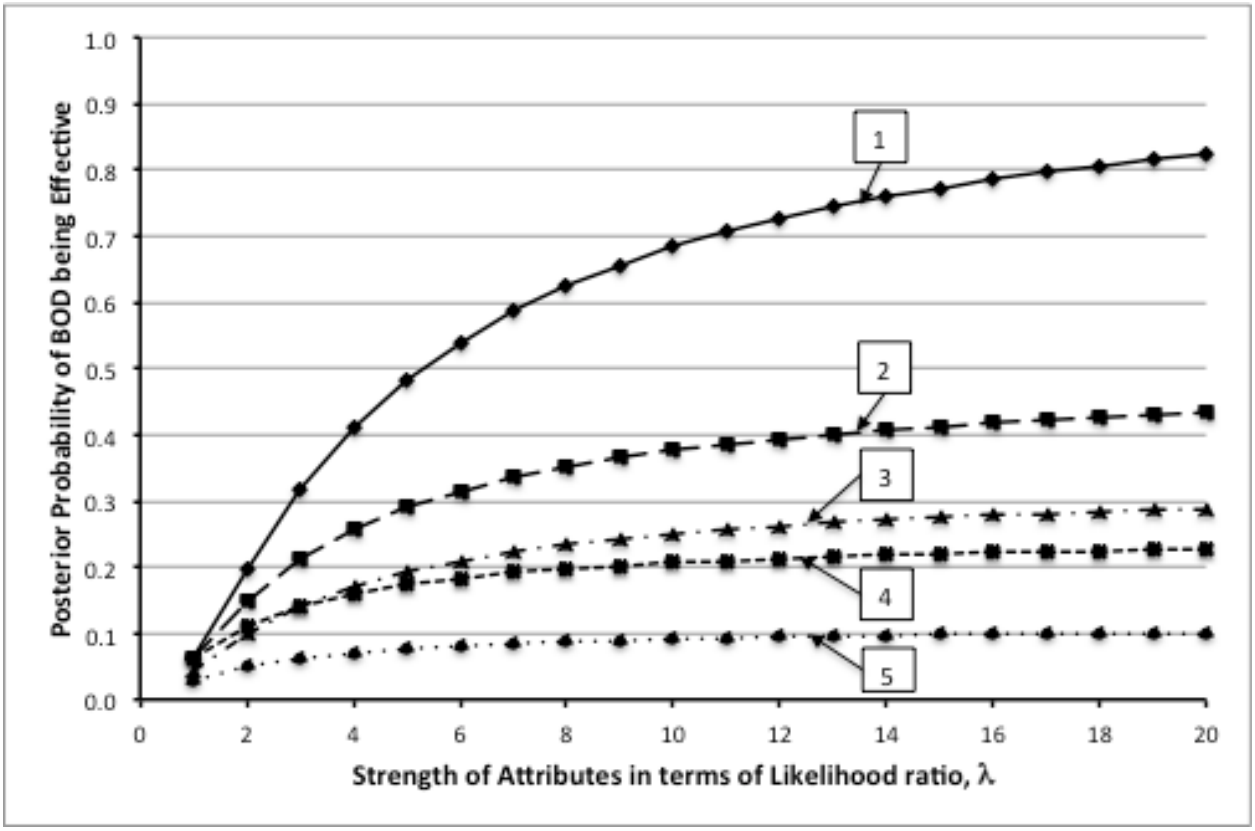


Figure 2: Effectiveness of BOD as a function of the strength of various Attributes of BOD with no consideration of Safeguards. The strength of an attribute is represented by the likelihood ratio, λ, correspoonding to the attribute where λ =1 means no knowledge of its presence and λ = 19 means 0.95 probability that the atribute is present (Probability of attribute being present based on the evidence = λ/(1+λ)).



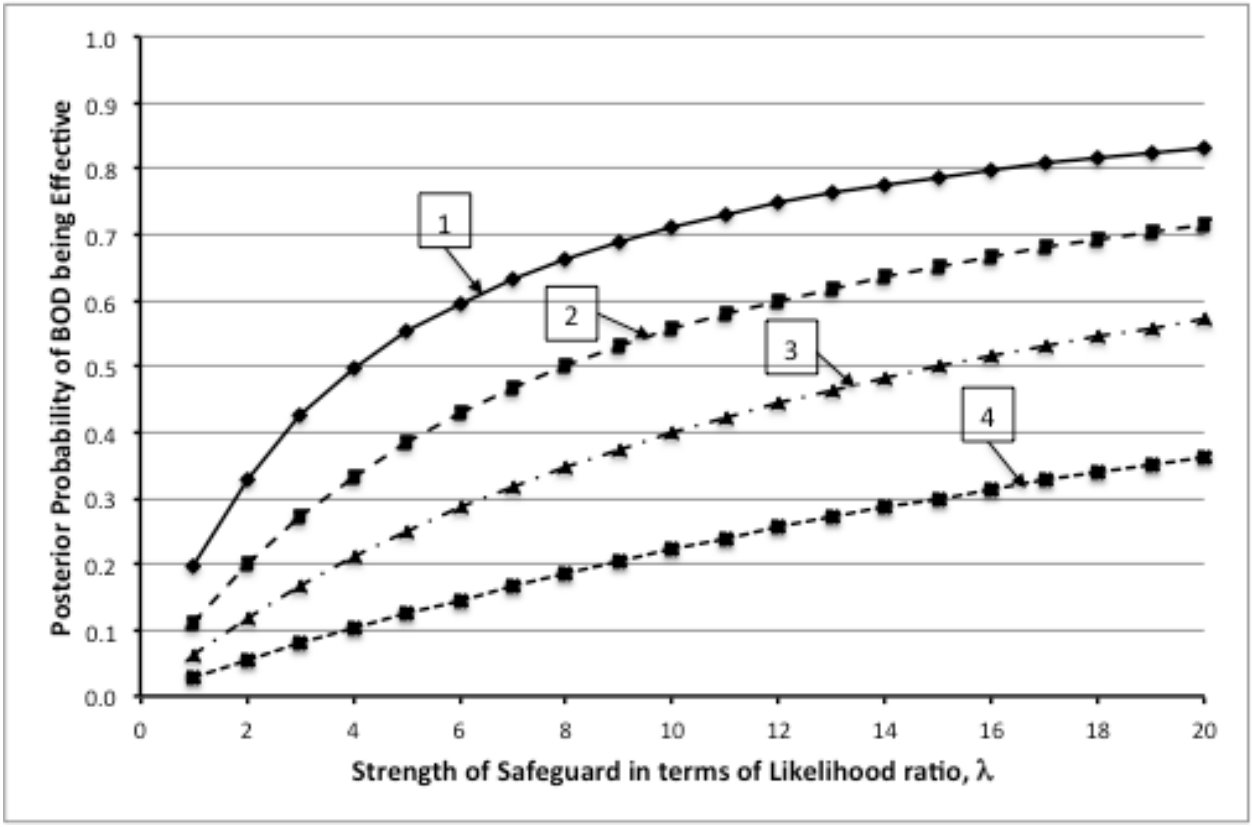
1. All the **four** attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are present.
2. Any **three** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are present.
3. Any t**wo** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are present.
4. Only **one** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD is present.

Figure 3: Comparison of Effectiveness of BOD as a function of the strength of various Attributes of BOD with no consideration of Safeguards. The strength of an attribute is represented by the likelihood ratio, λ, corresponding to the attribute where λ =1 means no knowledge of its presence, and λ = 19 means 0.95 probability that the atribute is present (Probability of attribute being present based on the evidence = λ/(1+λ)).



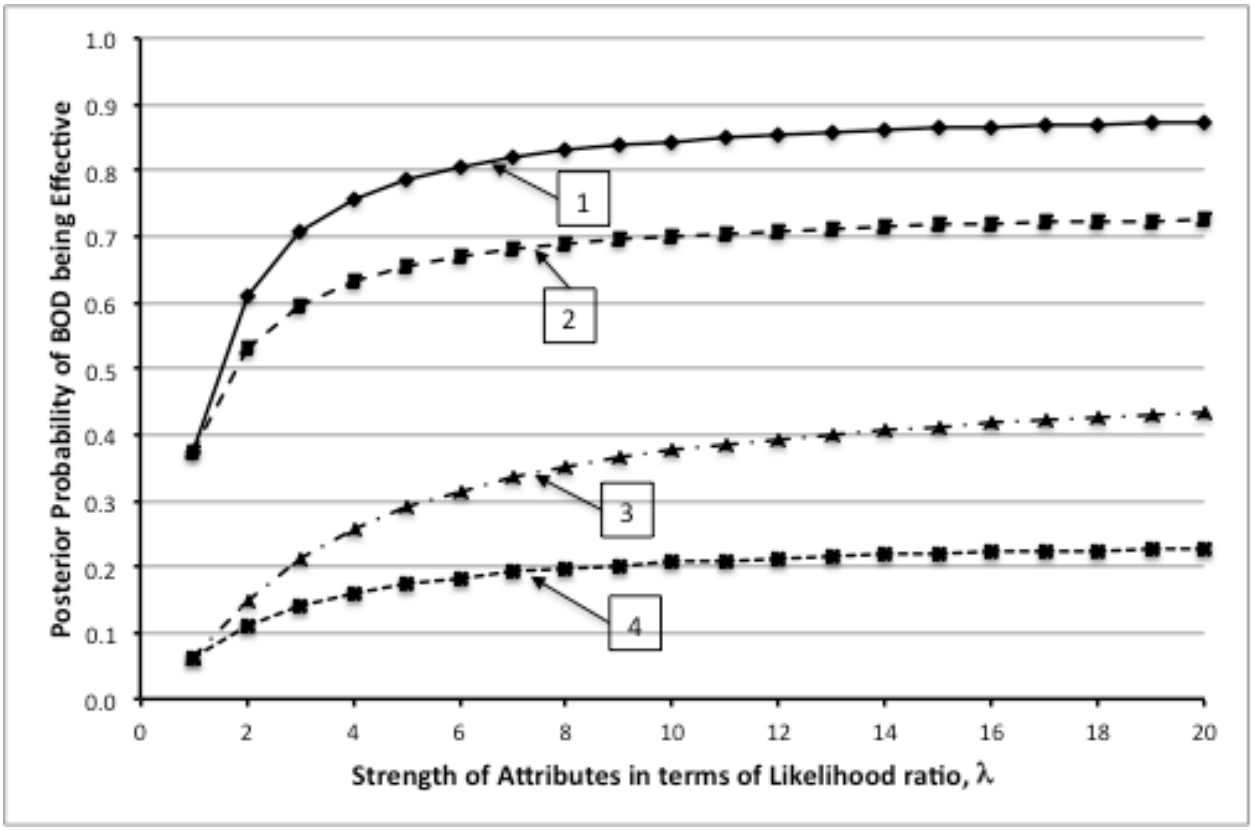
1. All the **four** attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are **present**.
2. Any **three** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are **present** with the fourth **one not considered** (unknown existence).
3. Any **three** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are **present** with the fourth **one not present** with probability 0.66.
4. Any **two** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are **present** with the other **two not considered** (unknown existence).
5. Any **two** of the four attributes (Independence, Competence, Active, and Behavioral characteristics) of BOD are present with the other **two not present** with probability 0.66.

Figure 4: Effectiveness of BOD as a function of the Strength of Safeguards with fixed (given) level of strength for various Attributes. The strength of Safeguards is represented by the likelihood ratio, λ, based on the evidence pertaining to the presence of Safeguards, where λ = 1 means no knowledge of its presence and λ = 19 means 0.95 probability that Safegaurds are present.



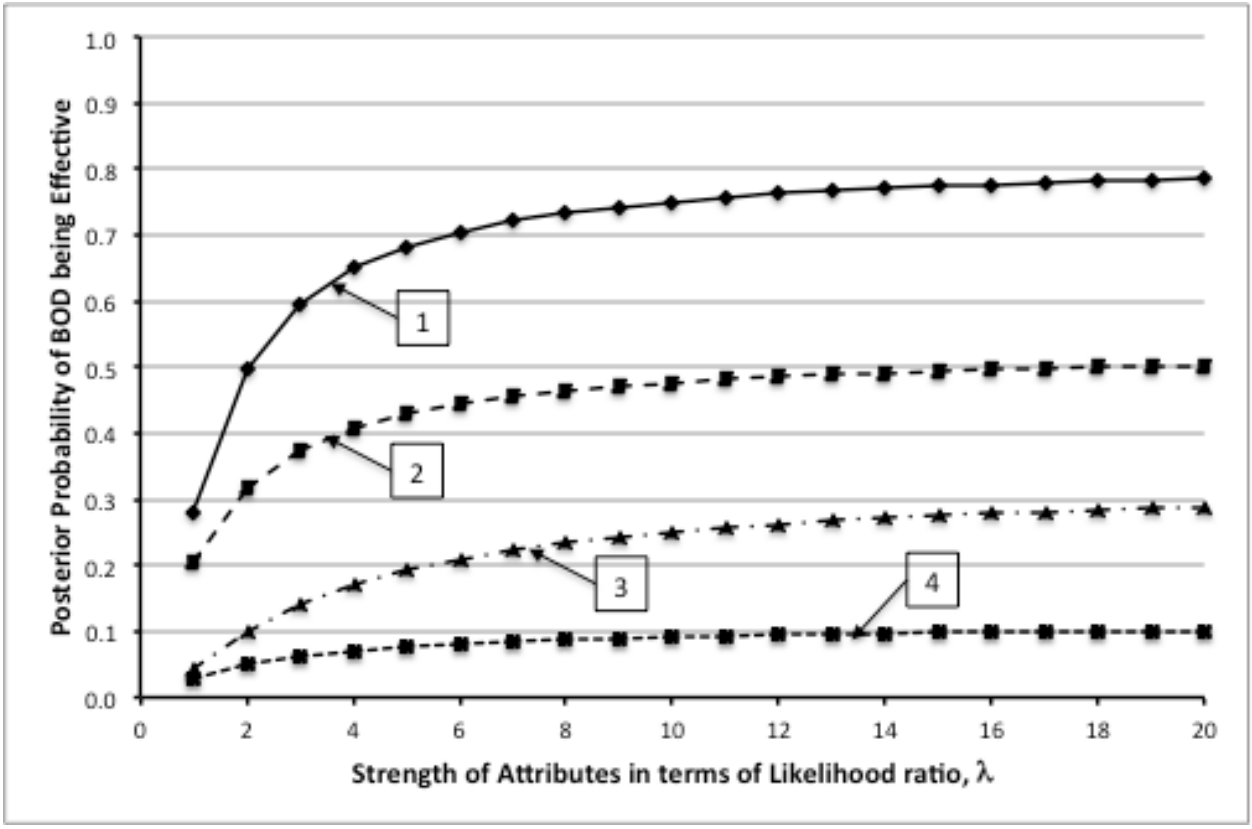
1. **All Four** attributes are **present** with probability 0.66 each.
2. **Two** attributes are **present** with probability 0.66 and **no knowledge** about the presence of the other **two attributes**.
3. **No knowledge** about the presence of all the **four attributes**.
4. **No knowledge** about the presence of **two attributes** and 0.66 probability that the other **two attributes are not present**.

Figure 5: Impact of Safeguards on Effectiveness of BOD – Effectiveness of BOD as a function of the strength of various Attributes with one or two being **unknown** to be present for different levels of the Strength of Safeguards.



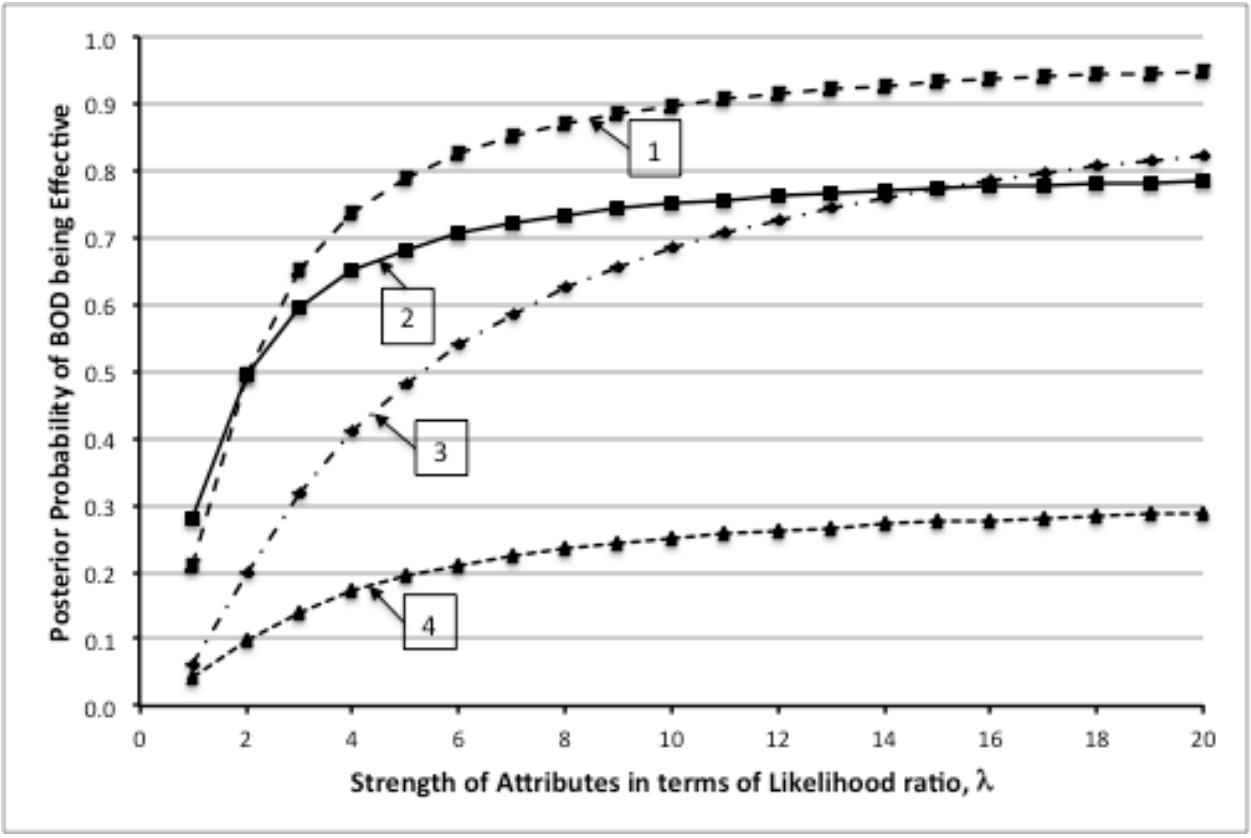
1. **Strong Safeguards** (λ_{1EB} = 9, Probability of its presence = 0.9) with **three** attributes being **present** with increasing likelihoods, and **one** attribute being **unknown** (its likelihood ratio, λ = 1, no evidence about its presence).
2. **Strong Safeguards** (λ_{1EB} = 9, Probability of its presence = 0.9) with **two** attributes being **present** with increasing likelihoods, and **two** attributes being **unknown** (their likelihood ratios, λs = 1, no evidence about their presence).
3. **No Safeguards** (λ_{1EB} = 1, Probability of its presence = 0.5) with **three** attributes being **present** with increasing likelihoods, and **one** attribute being **unknown** (its likelihood ratio, λ = 1, no evidence about its presence).
4. **No Safeguards** (λ_{1EB} = 1, Probability of its presence = 0.5) with **two** attributes being **present** with increasing likelihoods, and **two** attributes being **unknown** (their likelihood ratios, λs = 1, no evidence about their presence).

Figure 6: Impact of Safeguards on Effectiveness of BOD – Effectiveness of BOD as a function of the strength of Attributes with one or two attributes being **absent** for different levels of the Strength of Safeguards.



1. **Strong Safeguards** (λ_{1EB} = 9, Probability of its presence = 0.9) with **three** attributes being **present** with increasing likelihoods, and one attribute is **absent** with probability 0.66.
2. **Strong Safeguards** (λ_{1EB} = 9, Probability of its presence = 0.9) with **two** attributes being **present** with increasing likelihoods, and two attributes being **absent** with probability 0.66.
3. **No Safeguards** (λ_{1EB} = 1, Probability of its presence = 0.5) with **three** attributes being present with increasing likelihoods, and **one** attribute being **absent** with probability 0.66.
4. **No Safeguards** (λ_{1EB} = 1, Probability of its presence = 0.5) with **two** attributes being **present** with increasing likelihoods, and **two** attributes being **absent** with probability 0.66.

Figure 7: Effectiveness of BOD as a function of the strength of Attributes with different levels of the strength of Safeguards.



1. **Moderately strong Safeguards** ($\lambda_{1EB} = 4$, Probability of its presence = 0.8) with all the **four Attributes** being **present** with increasing likelihoods.
2. **Strong Safeguards** ($\lambda_{1EB} = 9$, Probability of its presence =0.9) with **only three** Attributes being **present** with increasing likelihoods, and **one** known to be **absent** with probability 0.66.
3. **No Safeguards** ($\lambda_{1EB} = 1$, Probability of its presence = 0.5) with all the **four** Attributes being **present** with increasing likelihoods.
4. **No Safeguards** ($\lambda_{1EB} = 1$, Probability of its presence = 0.5) with **only three** Attributes being **present** with increasing likelihoods and **one** known to be **absent** with probability 0.66.

Figure 1A: Generic Evidential Diagram for n sub-assertions