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Evaluating Corporate Governance Risk: A Fuzzy logic approach

Abstract

Assessment of the corporate governance risk of firms is made based on a subjective evaluation of the important attributes that characterize the monitoring mechanisms. The evaluation process relies on the rule of thumb, is inherently characterized by vagueness and imprecision and, is often expressed in terms of the linguistic constructs for the governance variables. This paper explores the possibility of applying fuzzy logic theory for handling vagueness and imprecision that characterize the decision making process. To prevent the exponential growth of rules with a large set of input attributes, hierarchical fuzzy logic framework is developed to carry out the required analysis for arriving at the governance rating of the firms.

Keywords: Hierarchical Fuzzy logic, Corporate Governance, Fuzzy Sets

1. Introduction

Assessing corporate governance risk is important for rating agencies and various institutional investors. Decision makers use linguistic concepts to describe the governance variables of the firms. For example, the natural way for the decision makers to express the adverse impact of the low institutional ownership on the ownership structure risk of the firms would be "*If* institutional ownership is *low then* the ownership structure risk is *high*." The use of such linguistic features as "high" or "low" is an inherent characteristic of the human reasoning process. The lack of objectivity and the lack of unanimity among the experts regarding the definitions of the governance variables and their influence on the governance risk forces the decision makers to incorporate heuristic information, rely on the rule of thumb and on their personal intuition while characterizing the state of the governance variables. One distinctive methodology appropriate for characterizing the imprecision and vagueness inherent in such subjective assessments is the fuzzy logic framework.

Fuzzy based decision making method is founded upon the fuzzy sets of Zadeh (1965) and approximate reasoning of Zadeh (1975a, 1975b, 1976), Dubois (1989). The fuzzy logic approach to decision-making uses fuzzy sets to represent the decision-maker's subjective assessments for the attributes. The fuzzy sets gainfully employ the existence of ambiguous situations whereby the boundaries of the sets, due to the lack of formal definitions, are not crisply defined; instead the sets have overlapping and inexact boundaries. Membership function is framed for every linguistic state in the set of states defined for each of the governance variables. Membership functions define the

extent to which a value in the domain of the governance variable belongs to a certain fuzzy set. The values in the domain of the governance variables for which there is no ambiguity regarding the linguistic state it belongs to, the membership grade of such values is assigned 1 to the fuzzy set that represents the said linguistic state. This restricts the membership to only one particular set. Thus, the membership grade for all other states is null. However the values for which there is ambiguity regarding the state to which it belongs to, the membership grade only defines the extent to which it can belong to a particular state. For example there is unanimity amongst the financial and economics experts in believing that a board size of 2 is "low" as it is not only illegal to have less than 3 directors on the board of public companies but also affects the quality of discussion adversely. Hence a board of size 2 belongs to the fuzzy set "low" with a membership grade of 1 and belongs to the fuzzy set "high" and "medium" with a membership grade of 0. In other words a board of size 2 completely belongs to the fuzzy set "low" and is not even remotely related to the fuzzy sets "high" and "medium". On the other hand there is conflicting opinion regarding a board of size 6. Say 4 out of 10 experts would concur that a board size of 6 is definitely "low" while the remaining 6 experts would agree that a board size of 6 is definitely not "low". Such ambiguous definitions result in the board size of 6 belonging to the fuzzy set "low" only to the extent of 0.4. Thus, the membership grade of a board of size 6 in the fuzzy set "low" is 0.4 only. This way the threshold till which it is conventionally accepted that a governance variable completely satisfy the characteristics of becoming a member of a fuzzy set, the membership grade is granted 1 with respect to the said set and the membership grade is granted 0 with respect to all the other fuzzy sets. The fuzzy logic reasoning then carries the deductive inference based on the ambiguous premises underlying these sets.

The conventional method of corporate governance risk rating is the scoring model. The models identify a set of indicators appropriate for evaluating the corporate governance risk. Weights are then assigned to each of the indicators based on their relative importance in determining the corporate governance risk. Companies are then evaluated across each of these parameters. The overall corporate governance risk is then calculated by weighting the evaluated value of each of the attributes with the relative importance of the attributes. Such inference mechanisms of the classical scoring models often lack the ability to deal with linguistic inexactness and to incorporate imprecise knowledge of the decision makers. This is what makes the fuzzy logic framework an attractive and a natural choice for determining corporate governance risk. The intent of the present work is not to make a comparative assessment of the developed fuzzy model with the existing scoring models but is only to provide a ***new approach*** i.e., rational fuzzy logic framework for assessing the corporate governance risk[1].

[1] A company with highly effective corporate governance structures will have low corporate governance risk

In section 2 we discuss the constructs for corporate governance risk analysis. We summarize the basic fuzzy concepts for corporate governance risk analysis along with the computational experience in section 3. Section 4 concludes the paper by giving some useful future research directions.

2. Corporate Governance

In the words of Berle and Means (1932), the separation of ownership from management leads to agency costs. The literature on corporate governance enumerates various internal and external control mechanisms to contain these agency costs incurred by the shareholders. Broadly the internal control mechanisms comprises of managerial ownership, the board structure, leadership structure and the managerial compensation. On the other hand, the external control mechanisms comprises of the market for corporate control and the legal environment dealing with protection of the minority shareholders. Prior empirical work in this area has documented the evidence that these mechanisms reduce the agency cost to the shareholders and this in turn leads to value maximization. A few of the important studies related to corporate governance mechanisms are discussed below.

The most important finding about the relationship between *managerial ownership* and firm performance (when the managerial ownership is considered exogenous) is that of Morck et al (1988). They argue that at lower levels of managerial ownership (at 1%), the managers like to earn more profits and hence align their interests with that of the shareholders. This, in the literature, is known as the alignment effect. But at higher levels of managerial ownership (at 5%) the entrenchment effect and the empire building effect is higher than the alignment effect, and at still higher levels of managerial ownership (30%) alignment affect dominates the entrenchment effect. Findings by Hermalin and Weisbach (1988) corroborate the findings of Morck et al (1988). In the Indian context, Sarkar and Sarkar (2000) study the role of large shareholders in corporate governance. The authors conclude that, except for the Indian Institutional investors, the increase in stake of all large shareholders beyond the threshold limit of 25% increases the company value (the alignment effect).

Composition of the board of directors[2] is a vital element for the efficient functioning of a company. Of late, there is much emphasis on the independence of the non-executive directors. The study by Weisbach (1988) finds a positive correlation between stock performance and board dominated by independent directors.

Jensen (1993) argues that the *board size* should be either 7 or 8 for optimal performance of a firm. Larger size of the board leads to communication and coordination problems and hence will negatively affect the firm performance. While a few studies, Brickley et al (1997), Donaldson and Davis (1991) and Boyd's (1995), show that *CEO duality*[3] improves the level of performance of

[2] Board of directors comprise of executive and non-executive directors
[3] CEO is also the Chairperson of the Board of Directors

companies; other studies by Finkelstein and D'aveni (1994), Rechner and Dalton (1991) show the effectiveness of non-dual CEO.

All the above studies relate to the impact of individual corporate governance variable on the firm performance. Studies dealing with the influence of all the governance variables, taken together, on the performance of a firm are limited. Developing the corporate governance index requires studying the combined impact of all the governance variables on the firm performance. In the Indian context, there are only two studies dealing with the corporate governance index. Mohanty (2002) constructs an index of corporate governance by giving weightage to the provisions dealing with the different stakeholders protection. Points for each stakeholder are allocated based on the criteria of the provision being positive, negative or neutral. Shareholders are allocated higher weight factors than other stakeholders. Vedpurishwar and Marishetty (2004) use the S&P rankings to construct the corporate governance index. The authors find that average mispricing of stocks for well-governed companies is lower than poorly-governed companies.

La Porta et al (1999b) construct a Corporate Governance index for 49 countries on the basis of investor protection given through legal structures, enforcement and corporate laws. They empirically evaluate the impact of this index on the financial structure of the respective countries. The main findings of the study are that 'common law' countries like United States, United Kingdom etc. have very high level of investor protection due to which such countries have dispersed shareholdings. On the other hand, in the case of the 'French civil law' countries, the investor protection is weak as a result of which there is a concentration of ownership holding. They further argue that the concentration of holding in the French civil law countries has developed as an alternative to inefficient legal system so as to protect the minority shareholders. They provide equal weights to all the provisions that protect the shareholders.

Gompers et al (2003) construct a governance index to find its impact on the stock returns earned by the investors. The index is constructed based on the shareholders rights protected by the company charter in the event of takeover. They find that the companies with higher shareholder rights will earn abnormal returns of 8.5% more than the companies in which the shareholder rights is low (companies which favor the management by providing poison pills etc. in their charter).

From the description of the literature above it is clear that there exists conflicting opinion on the nature of the impact of the various factors on the level of corporate governance rating. Moreover the literature talks in terms of linguistic constructs such as *higher* level of retrenchment, *lower* level of management ownership etc, which are qualitative and are representative of subjectivity and vagueness. The corporate governance index constructed in the above studies does not deal with the subjectivity, ambiguity and vagueness inherent in such reasoning processes. In our study we propose to address this question and deliver a more accurate index with the help of hierarchical fuzzy logic

framework. Moreover, in the absence of any meaningful literature on the combined impact of the corporate governance variables on the governance risk, we logically deduce the rules that relate to the combined impact of all such variables on the corporate governance risk, the subjectivity of which is taken care of by the fuzzy logic system.

3. Hierarchical Fuzzy Logic Framework For Corporate Governance Risk Assessment

To introduce the fuzzy logic framework for evaluating the corporate governance risk we discuss the hierarchical system, membership functions, linguistic variables and the rule base in the corporate governance context.

3.1. Membership Functions and Linguistic Variables

The relationship between the indicator u and its membership grade $\mu_F(u)$ can have many different forms (for the different forms, see Klir and Yuan (2001)). For the implementation of the fuzzy sets in the present paper both asymmetric and symmetric membership functions are used, though it is restricted to only standard membership functions. For the ease of inference purposes, only triangular and trapezoidal membership functions defined by straight-line equations are considered. For real numbers $0 \le a \le b \le c \le U$, the triangular membership function is defined as:

$$\mu_{F^{Tr}}(u) = \begin{Bmatrix} 0 & if\ u \le a \\ \dfrac{(u-a)}{(b-a)} & if\ a < u \le b \\ \dfrac{(c-u)}{(c-b)} & if\ b < u \le c \\ 0 & if\ u \ge c \end{Bmatrix}$$

While for real numbers $0 \le a \le b \le c \le d \le U$ trapezoidal membership function is defined as :

$$\mu_{F^{Tp}}(u) = \begin{Bmatrix} 0 & if\ u \le a \\ \dfrac{(u-a)}{(b-a)} & if\ a < u \le b \\ 1 & if\ b < u \le c \\ \dfrac{(d-u)}{(d-c)} & if\ c < u \le d \\ 0 & if\ u \ge d \end{Bmatrix}$$

Table 1*: Set of Descriptors*

Evaluation Parameter	Linguistic Variable name	Linguistic Values	Universe of Discourse	Membership function
Institutional Ownership	INSTIOWN	Low	[0,100]	(0, 5, 10)
		Medium		(5, 10, 15)
		High		(10, 15, 100)
Promoter Ownership	PROMOWN	Low	[0,100]	(0, 15, 32.5)
		Medium		(15, 32.5, 50)
		High		(32.5, 50, 100)
Foreign Institutional Ownership	FIIOWN	Low	[0,100]	(0, 2, 6)
		Medium		(2, 6, 12)
		High		(6, 12, 100)
Size of Board	BOARDSIZE	Low	[0,20]	(0, 4, 8)
		Medium		(4, 8, 12)
		High		(8, 12, 20)
Proportion of Independent Directors	INDPDIREC	Small	[0,1]	(0, 0.33, 0.5)
		Medium		(0.33, 0.5, 0.75)
		Large		(0.5, 0.75, 1.0)
CEO-Duality	CEODUAL	Yes	0 or 1	1
		No		0

For computation purposes, we require three fuzzy operators-union, intersection and complementation. If A_1 and A_2 are two fuzzy sets defined over the universe of discourse U, then union of A_1 and A_2 is a fuzzy set denoted by $A_1 \bigcup A_2$ with the membership function $\mu_{A_1 \cup A_2}(u) = \mu_{A_1}(u) \vee \mu_{A_2}(u)$, where $a \vee b$ means $\max(a,b)$. Intersection of A_1 and A_2 is a fuzzy set denoted by $A_1 \bigcap A_2$ with the membership function $\mu_{A_1 \cap A_2}(u) = \mu_{A_1}(u) \wedge \mu_{A_2}(u)$, where $a \wedge b$ means $\min(a,b)$. The complement $\overline{A}_1$ of A_1 is a fuzzy set with the membership function $\mu_{\overline{A}_1}(u) = 1 - \mu_{A_1}(u)$. For each of the fuzzy sets defined over the discourse of the input variables, complements of the sets are also defined. Table 1 gives the entire set of descriptors used in the present analysis.

The fuzzy sets are assigned after scanning the existing literature on corporate governance and from values derived from a sample set of companies. Thus, the domain knowledge is essential for defining the fuzzy sets over the range of the governance variables. For example Hartzell and Starks (2003) provide evidence that institutional investors not only are good monitors but also ensure appropriateness of executive compensation contracts. They show that higher institutional ownership results in lower risk to the shareholders as they effectively monitor the remuneration paid to the managers. To scientifically assign the values of the membership functions to ownership structures, we randomly select 40 companies from Prowess. Out of the 40 companies, complete information of the ownership structure is available for 38 companies only. The ownership data of sample companies for the financial year ended 2003 is provided as Annexure I, at the end of this paper. For each

component of the ownership structure Quartile-1 (Q1), Median and Quartile-3 (Q3) are calculated. Based on the Q1, Median, and Q3 we obtain the values for the membership functions. With respect to the institutional ownership, we find that the median shareholding is 10% (the figures are rounded-off to the nearest integer), Q1 is 5% and Q3 is 15%. This data suggests that the institutional ownership can be considered as definitely low if the share holding is below 5%, medium if the share holding is *around* 10% and high for a value greater than 15 %. It is for these reasons that three linguistic values - low(L), medium(M) and high(H) are used to define the percentage of the Indian institutional ownership in the firms. Since $u_{instiown} \in [0,100]$, the fuzzy sets L, M, H have the following membership functions:

$\mu_L(u_{instiown})=(0,5,10)$,
$\mu_M(u_{instiown})=(5,10,15)$,
$\mu_H(u_{instiown})=(10,15,100)$.

The membership functions of the linguistic variables related to the INSTIOWN variable is depicted in figure 1. The vagueness inherent in the assessment is reflected through the gradual transition of the membership values from 0 to 1 and vice versa, for each of the fuzzy sets. μ_L, μ_M and μ_H convey the vagueness arising from incorporating the semantics of the natural language (for example use of the word *around* 10%) in the decision making framework.

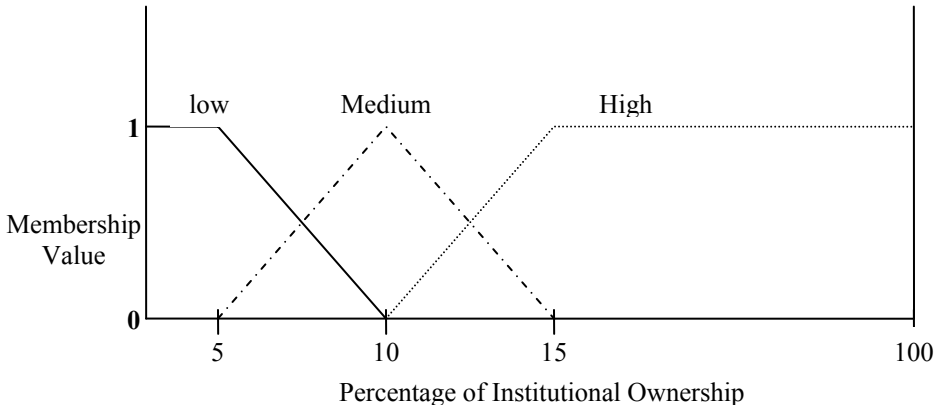

Figure 1 *: Membership Functions for INSTIOWN*

In the context of Indian companies, Sarkar and Sarkar (2000) find that the foreign shareholding and company performance are positively related. For the period 2001 to 2003, Bhattacharyya and Rao (2005) find that ownership by foreign institutional investors reduces the agency costs of the Indian companies, corroborating the results obtained by Sarkar and Sarkar (2000). There is no incentive for the foreign institutional investors to monitor if their shareholding is low. Based on Q1, Median and Q3 values obtained from the sample, foreign institutional shareholding can be called as

low for values less than 2 %, medium for value around 6 % and high for above 12%. The membership functions of the foreign institutional ownership are shown in figure 2.

Morck et al (1988) find that the managerial ownership is positively related to firm performance if their shareholding below 1% (the alignment effect), negatively related when their shareholding is between 1% to 5% (the entrenchment effect), again positively related from 5-20% (alignment effect), and thereafter negatively related. Mudambi and Nicosia (1988) confirms the curvilinear relationship in their study on the financial services industry in the United Kingdom. However, in the Indian context, Sarkar and Sarkar (2000) provide evidence in support of positive relationship between insider ownership and company value beyond 25% of insider ownership and is negatively related to the performance of companies upto 25%. Annexure I provides information on Q1, Median and Q3 of the promoter ownership. Based on this data, we can classify the promoter ownership as low if shareholding is less than 15 %, medium for shareholding around 32.5% and high for shareholding above 50%.

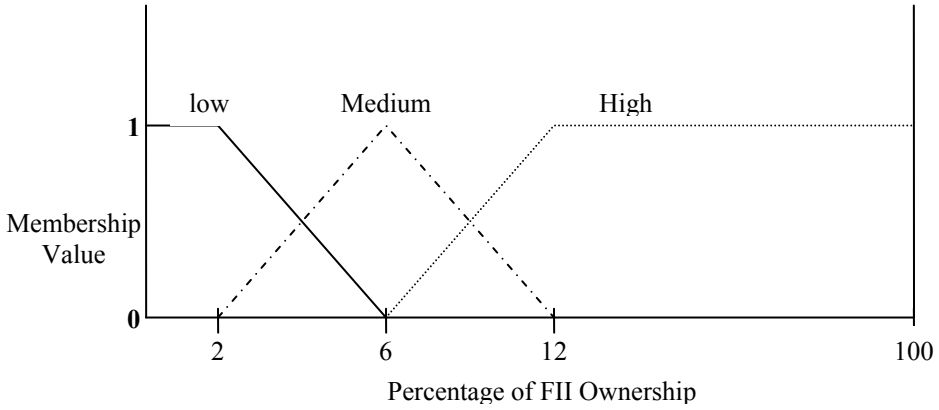

Figure 2 : Membership Functions for FIIOWN

An appropriate structure of the board of directors is imperative for the enhanced performance of any company. Independent directors, due to their expertise, bring in objective judgment in strategic and financial decisions. Having little or no conflict of interest with the company, they strive for excellence in their occupation. A Board with higher proportion of the independent directors is successful in monitoring the managers than a Board with lower proportion of independent directors. The results of Weisbach (1988) support the argument that boards with more independent directors would increase the stock performance. According to the Kumaramangalam Birla Committee atleast 1/3rd of the directors should be independent. It is for these reasons that we define that proportion of independent directors in the Board as low if it is below 33.33%, medium if it is between 33.33% and 75% and, high beyond 75%. For each of the components of the ownership structure we take minimum as 0% and maximum as 100%.

The informal power of the CEO to misappropriate funds increases when he is also the chairperson of the board. The results of Finkelstein and D'aveni (1994), Rechner and Dalton (1991) corroborate this argument. They find that companies where the posts of CEO and chairperson of board of directors are held by separate persons perform better than companies where CEO is also the chairperson of board of directors. Based on these arguments we purport that companies with no CEO duality will have lower risk, while those with CEO duality will have higher risk.

The board size is an important component of the board structure. Jensen (1993) argues that the ideal size of the board should be either 7 or 8. Too few members dilute the ability of the board to provide a strategic direction to the company. Too many members, on the other hand, prove costly and ineffective to the company. Therefore board size is considered low for below 4 members, medium around 8 and high above 12 members. The maximum members permitted to be on the Board of directors of any company is 12, and it can be increased to 20 with the prior approval of the Central Government.

3.2. Hierarchical Inference Process

The proposed fuzzy inference system has 6 input variables - foreign institutional ownership (FIIOWN), promoter ownership (PROMOWN), institutional ownership (INSTIOWN), size of the board (BOARDSIZE), proportion of independent directors (INDPDIREC), CEO-duality (CEODUAL). Consideration of even a modest number of fuzzy sets for each of these input variables will result in an abruptly high number of fuzzy rules. For example, defining three fuzzy sets for each of the variables will require 3^6 rules, many of which may be insignificant. Therefore, increasing the number of variables and/or the number of fuzzy sets will result in combinatorial explosion in the number of fuzzy rules. Such a problem is called the "curse of dimensionality".

Moreover, designing such a huge knowledge base would be a tremendously cumbersome process. One solution to this problem is to decompose the entire problem into logical and more manageable subsystems. The component modules are hierarchically distributed and are logically connected to one another such that the output of one subsystem forms the input to the next higher level of subsystem. Such hierarchical decomposition of the inference process into multi level rule base makes the problem more manageable. Figure 3 shows the proposed hierarchical architecture for assessing the corporate governance risk. The overall inferential mechanism is hierarchically decomposed into three fuzzy blocks. Fuzzy block 3 receives its input from the output of the fuzzy block 1 and 2. Computing corporate governance risk requires assessing risk that arises on account of ownership structure and composition of the board. The input variables that define the ownership structure, therefore, are grouped under the ownership structure inference module and the input variables that define the composition of the board are grouped together in the board structure inference module. Each of these component module is shown separately in figure 4, 5 and 6.

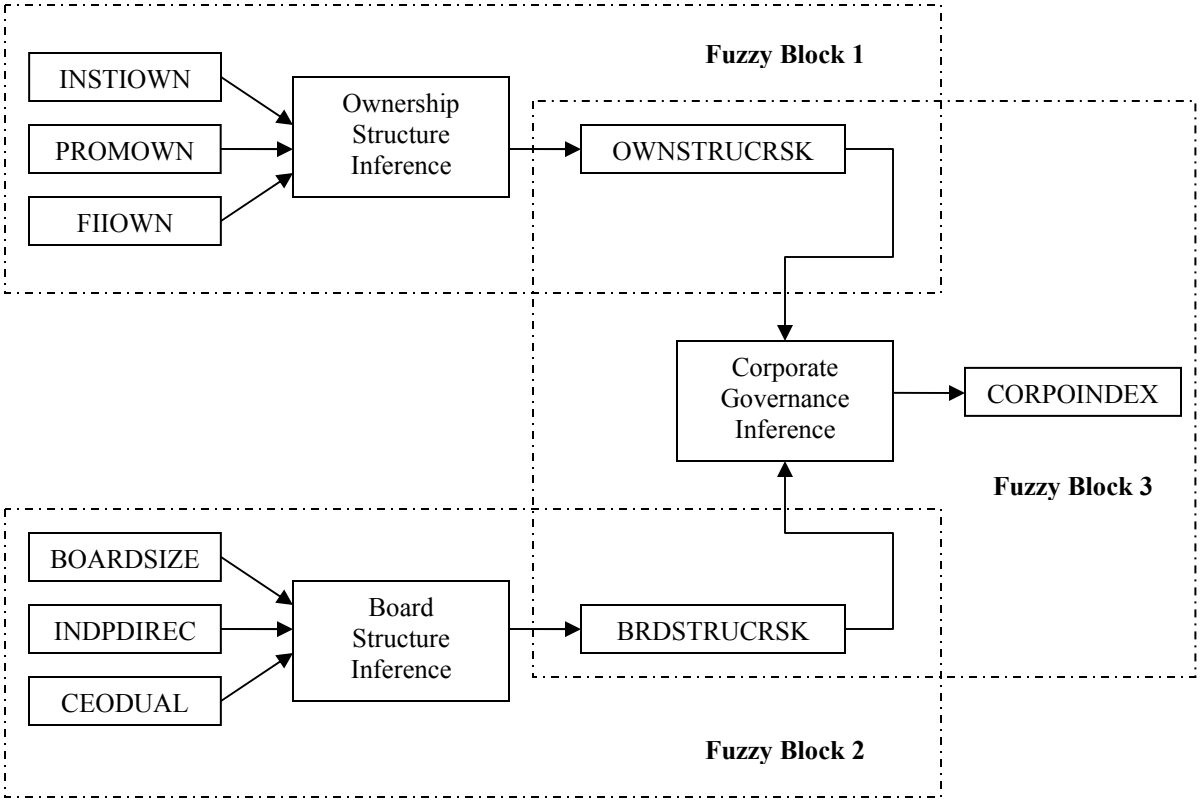

Figure 3: Hierarchical Corporate Governance Risk Inference Process

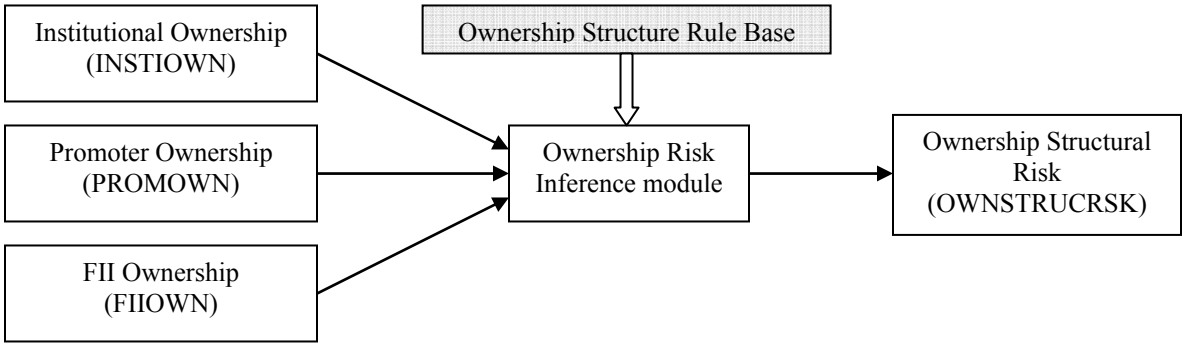

Figure 4: Ownership Structure Risk Inference Process

Figure 4 shows the ownership structure risk inference process. Since the three variables- institutional ownership, promoter ownership and foreign institutional investor ownership define the ownership structure, the values of these variables form input to the Ownership Risk Inference

module–the output of which is a measure of the risk that arise due to the composition of the ownership in the company.

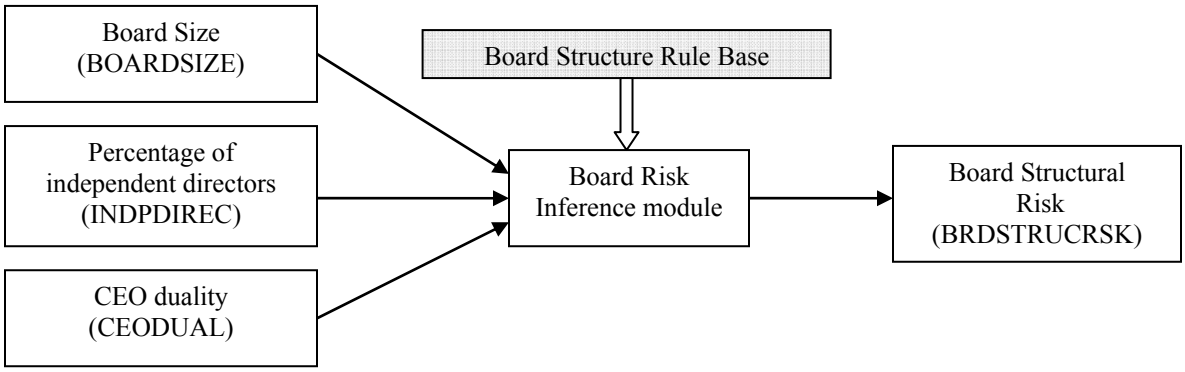

Figure 5: Board Structure Risk Inference Process

Similarly, Figure 5 represents diagrammatically the board structure risk inference process. Since the three variables–the size of the board, the percentage of independent directors and CEO-duality define the structure of the board, the values of these variables, therefore, would affect the risk that arise on account of the composition of the board. The outputs-ownership structure risk (OWNSTRUCRSK) and the board structure risk (BRDSTRUCRSK) from fuzzy blocks 1 and 2 respectively form inputs to the fuzzy block 3, which is the corporate governance risk inference module. Based on the inputs of the values of OWNSTRUCRSK and BRDSTRUCRSK, the corporate governance risk inference module deduces the overall corporate governance risk for the firm.

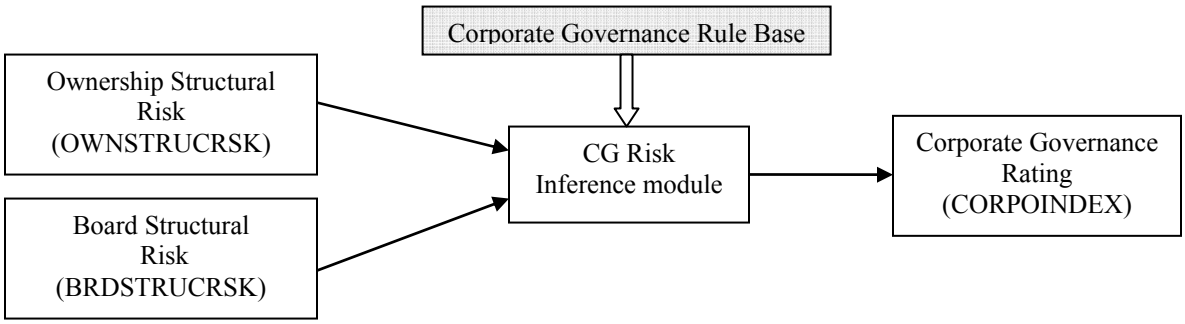

Figure 6: Corporate Governance Risk Inference Process

3.3. Rule Base

The fuzzy variables are combined into a set of rules. The set of rules are formulated based on extensive study of the literature on corporate governance and elaborate discussion with other academicians. Each rule has a number of antecedent terms but only one consequent term. These rules capture the semantic imprecision of the human language. Tables 2, 3 and 4 gives a few characteristic examples of the fuzzy rules used in the present decision making process.

Table 2: Rules expressing the risk due to ownership structure

Foreign Institutional Ownership (FIIOWN)	Institutional ownership (INSTIOWN)	Promoter Ownership (PROMOWN)	Ownership Structure Risk (OWNSTRUCRSK)
Low	Low	Low	High
Low	Low	Medium	High
High	High	High	Low
High	High	Medium	Low
High	Medium	High	Low
High	Medium	Medium	Medium
Medium	High	Low	Medium
Medium	Medium	High	Medium
High	Low	High	Medium
High	Medium	Low	Medium
Medium	High	High	Low
Low	Medium	High	Medium

In table 2 a representative set of rules that reflect the effect of different ownership structure on the ownership risk is shown. Higher levels of promoter and foreign institutional ownerships have a positive impact on the performance of the company (Sarkar and Sarkar (2000)) (Rule 5) and vice-versa. Companies with low promoter and foreign institutional shareholding may not perform well because the promoters may not have the monetary incentive to improve the performance; and at the same time the foreign institutional investors do not have adequate motivation to monitor the managers and hence the ownership risk in this case is high (Rule 1). Other rules can be interpreted in a similar manner.

Table 3: Rules expressing the risk arising due to board composition

Board Size (BOARDSIZE)	CEO Duality (CEODUAL)	Independent Directors (INDPDIREC)	Board Structure Risk (BRDSTRUCRSK)
Low	No	Low	Medium
Low	No	Medium	Low
Low	No	High	Low
Low	Yes	Low	Medium
Low	Yes	Medium	Medium
Low	Yes	High	Medium
Medium	No	Low	Medium
Medium	No	Medium	Medium
Medium	No	High	Low
Medium	Yes	Low	High
Medium	Yes	Medium	Medium

Medium	Yes	High	Medium
High	No	Low	Medium
High	No	Medium	Medium
High	No	High	Medium
High	Yes	Low	High
High	Yes	Medium	High
High	Yes	High	Medium

Table 3 gives a set of rules that is used to infer the board structure risk. A board with high number of independent directors, medium size (Jensen (1993)) and a non-dual CEO (Rechner and Dalton(1991)) will have lower board structure risk as all these components enhance the performance of the company (for example Rule 9). On the other hand, companies with high board size, CEO duality and low proportion of independent directors will be poorly governed. This is because, the CEO being the chairperson of the board possess high informal power. Furthermore, as the proportion of independent directors is low, the board may not be able to monitor the activities of CEO effectively. Hence, in this case we expect that the board structure risk will be high (for example Rule 16). Similar interpretations hold for other rules.

The ownership structure risk and the board structure risk together determines the overall corporate governance risk of a company and is shown in table 4. Low ownership structure risk together with low board structure risk reduces the overall corporate governance risk of the company (Rule 1). Low ownership structure risk is characterized by high promoter ownership and high institutional ownership. Low board structure risk is characterized by high proportion of independent directors, CEO non-duality and medium size board. Lower board structure risk implies efficient board capable of providing strategic directions to the company. On the other hand, a company with high ownership structure risk and high board structure risk inevitably has higher corporate governance risk (Rule 9).

Table 4*: Rules for calculating Corporate Governance risk*

Ownership Structure Risk (OWNSTRUCRSK)	**Board Structure Risk (BRDSTRUCRSK)**	**Corporate Governance Risk (CORPOINDEX)**
Low	Low	Low
Low	Medium	Medium
Low	High	Medium
Medium	Low	Medium
Medium	Medium	Medium
Medium	High	Medium
High	Low	Medium
High	Medium	Medium
High	High	High

3.4. Evaluation

The process of combining the effects of several fuzzy rules is called fuzzy inferencing. During the evaluation process the inferential engine of the model tries to capture the imprecision associated with a partial match between the antecedent terms of the rules with the input data. Mamdani inference principles are applied in the proposed decision making framework (for review of other inference principles like TSK see Klir and Yuan (2001)). Input aggregation, also called *matching*, is done based on the min operator. Since all the inputs are scalars quantities, thus if $u_{instiown}$ takes the input $u'_{instiown}$ then a partial match is performed by carrying out the operation $(1 \wedge \mu_F(u'_{instiown}))$, where F is the fuzzy set. Owing to the fact that the inputs are always singletons the matching operation would always return the membership value of $u'_{instiown}$ in the set F, that is $\mu_F(u'_{instiown})$. Result aggregation is done by applying the max operator. Thus if $u'_{instiown}$, $u'_{promown}$ and u'_{fiiown} are the inputs to the fuzzy inference system 1 and where $k \in N$ denotes the k^{th} rule, then aggregation is done according to the equation:

$$R^N = \vee_k R^k \tag{1}$$

$$\mu_R^k(u'_{instiown}, u'_{promown}, u'_{fiiown}) = \vee_k(\mu_{F_{instiown}}^k(u'_{instiown}) \wedge \mu_{F_{promown}}^k(u'_{promown}) \wedge \mu_{F_{fiiown}}^k(u'_{fiiown})) \tag{2}$$

In other words, logical AND operator is used to connect the various antecedent terms of a rule and the implication method based on the min operator is used to draw conclusions. Finally the max operator is used to aggregate the different rules. Different rules contribute differently towards the output membership function. Thus, a fuzzy envelope over the output variable range represents the combined effect of all the rules. By means of defuzzification, a single value of the CORPOINDEX variable is obtained, from the combined membership function that is got over the range of the CORPOINDEX variable. As the output surface resulting from the fuzzy inference process is due to the geometrical aggregation of the fuzzy sets, the geometrical center of the output membership surface takes into consideration even the slightest contribution of any of the sets. Therefore, we adopt the center of area (COA) method for defuzzification (for other methods see Klir and Yuan (2001)). The COA method calculates the center of area of the combined output membership function $\mu(u_{corpoindex})$ of the variable $u_{corpoindex}$ as follows:

$$u_{COA} = \frac{\int_S u_{corpoindex} * \mu(u_{corpoindex}) du}{\int_S \mu(u_{corpoindex}) du} \tag{3}$$

Where S stands for the ranges of values $u_{corpoindex}$ covered by the combined output surface, also called the *support* of $u_{corpoindex}$.

The inference blocks were designed according to the concepts of the fuzzy logic described above and was implemented in the computational environment of Fuzzytech 5.54m. The results of four of the test cases that we experimented with are shown below in table 6. We explain how the 'matching' step is carried out in the fuzzy block 1 with the example of Bajaj Auto Ltd. In this case we observe that the input values $u'_{instiown}$ =6.69, u'_{fiiown} =12.99 and $u'_{promown}$ =28.57 are scalar quantities-that is non-fuzzy. From table 1 we get the membership values of the three basic terms of INSTIOWN to be $\mu_{low}(6.69)$ = 0.662, $\mu_{medium}(6.69)$ = 0.338, $\mu_{high}(6.69)$ = 0. As already mentioned, the inputs being scalar quantities, the matching step returns the corresponding values to be min(1, 0.662)= 0.662, min(1, 0.338)=0.338, min(1, 0)= 0 respectively. Likewise the membership grade for the three linguistic values of FIIOWN are $\mu_{low}(12.99)$ = 0, $\mu_{medium}(12.99)$ = 0 and $\mu_{high}(12.99)$ =1. The matching step in a similar manner returns min(1, 0) = 0, min(1, 0) = 0, min(1, 1) = 1 respectively. Similarly, the membership grade for the three terms of PROMOWN are $\mu_{low}(28.57)$ = 0.225, $\mu_{medium}(28.57)$ = 0.775, $\mu_{high}(28.57)$ = 0 and the matching step returns the following values min(1, 0.225) = 0.225, min(1, 0.775) = 0.775, min(1, 0) = 0 respectively. Combining these grades with the antecedents of the rules listed in table 2, we get table 5. For example, the antecedent of the first rule from table 2 is 'FIIOWN = low and INSTIOWN = low and PROMOWN = low' then from equation 2 we get: $\mu_R^{k=1}(6.69, 28.57, 12.99) = (0.662 \wedge 0.225 \wedge 0.0)$. To connect the various antecedent terms of the rule, we compute: min(0.662,0.225,0.0) = 0. Continuing with rule 1 in table 2, for the 'implication' step we compute $\mu_{F_{G'}}(v) = \min(0, \mu_{F_G}(v))$ where $F_{G'}$ is the approximate fuzzy outcome for the given set of input data and F_G is one of the many fuzzy sets G defined on the range of output values. This gives rise to fuzzy sub-envelope. The fuzzy sub-envelopes obtained this way from different rules of table 2 is aggregated using the max operator (denoted in equation 2 by $\vee_k$) to get the ultimate outcome-one complete fuzzy set over the range of output values of the ownership structure risk (OWNSTRUCRSK). This together with the board structure risk (BRDSTRUCRSK) computed in a similar manner, forms input to the Corporate Governance risk inference module which again in a similar manner computes the Corporate Governance risk. The only difference while calculating the Corporate Governance risk (CORPOINDEX), the inputs as defined by ownership structure risk (OWNSTRUCRSK) and board structure risk (BRDSTRUCRSK) would be fuzzy as opposed to the scalar inputs of INSTIOWN, FIIOWN and PROMOWN while calculating the OWNSTRUCRSK.

Table 5:*Results of the ' matching' stage of ownership structure risk inference process in the case of Bajaj AutoLtd.*

Foreign Institutional Ownership (FIIOWN)	Institutional ownership (INSTIOWN)	Promoter Ownership (PROMOWN)
0	0.662	0.225
0	0.662	0.775
1	0	0
1	0	0.775
1	0.338	0
1	0.338	0.775
0	0	0.225
0	0.338	0
1	0.662	0
1	0.338	0.225
0	0	0
0	0.338	0

Of the four cases that we report here, it can be seen that the Corporate Governance Risk index is the least for Novartis India Ltd and the highest for Bajaj Auto Ltd. The reason for this is not too hard to fathom. In the case of Novartis India Ltd, the company has an optimal board size of 8 with no CEO duality. The risk associated with the likelihood of expropriation by the CEO is reduced due to presence of large proportion of independent directors. At the same time the insiders own more than 50% of the shareholding, which enhances the operational performance of the company (alignment effect). Low corporate governance risk of Novartis India Ltd suggests that the company is well governed.

Table 6: Results of the test cases

Company Name[4]	BOARD-SIZE	CEO-DUAL	FIIOWN	INSTIOWN	PROMOWN	INDPDIREC	CORPO-INDEX
Bajaj Auto Ltd	10	1	12.99	6.69	28.57	0.6	6.16
Novartis (I) Ltd	8	0	4.43	18.78	50.99	0.875	1.25
Satyam Comp Ltd	6	0	33.76	19.14	25.6	0.5	3.12
Zee Telefilms	7	1	17.94	6.77	59.61	0.29	5.00

Whereas in the case of Bajaj Auto Ltd, the company is not only characterized by a large size of the board but also has CEO who at the same time is the chairperson of the board of directors. The probability of misappropriation by the CEO increases as a result. Moreover large size of board results in increased communication and coordination problems. Board structure can therefore be easily seen to be not so effective. Additionally, the promoters own only 29% of the shareholding, which may not adequately motivate them to increase the firm value. For these reasons the risk index of Bajaj Auto Ltd. is very high compared to other cases. This suggests that Bajaj Auto Ltd is a poorly

[4] Publicly traded companies in India

governed company. This explanation shows that the ratings derived by the fuzzy index are in sync with desirable values.

Since few studies provide evidence of the ineffectiveness of the Indian Institutional Investors ownership on company performance, we try to calculate the corporate governance risk ratings for the above companies by excluding the Indian Institutional Investors shareholding. The risk ratings in that case would be 6.10, 1.25, 3.10 and 5.00 for Bajaj Ltd, Novartis Ltd, Satyam Ltd and Zee Ltd, respectively. Thus, we find that if we exclude the Indian Institutional Investors ownership from the risk calculations, the corporate governance risk index remains almost the same. This result supports the finding of Sarkar and Sarkar (2000), where they do not observe any effect of Indian Institutional ownership on company performance.

4. Conclusion

In this paper we use the fuzzy logic approach to model the subjective characteristics of human nature in the decision making process involved in assessing the corporate governance risk. Mamadani inference along with the Center of Area method of defuzzification allowed taking into consideration even the slightest influence of a rule. Further research would be needed to conclude the effect of various other fuzzy operators, input aggregation operators, result aggregation operators and defuzzification methods on the final rating.

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Annexure-I

Table 7: Ownership Structure of Sample Companies for the Financial Year Ended 2003

Company Name[5]	BOARD-SIZE	CEO-DUAL	FIIOWN
Arvind Mills Ltd.	38.07	8.77	18.18
Asian Paints (India) Ltd.	42.60	14.26	18.59
Bharat Gears Ltd.	32.46	14.34	2.00
Bharat Petroleum Corpn. Ltd.	66.20	15.01	10.21
Centurion Bank Ltd.	44.22	2.13	18.83
Cholamandalam Invst & Finance Co. Ltd.	48.99	2.40	2.52
Cummins India Ltd.	58.02	15.04	12.00
Emmessar Biotech & Nutrition Ltd.	14.30	10.35	0.00
E-Serve International Ltd.	44.38	11.68	6.27
Essel Propack Ltd.	37.15	10.15	7.52
Grasim Industries Ltd.	20.42	24.12	14.11
Gujarat Ambuja Cements Ltd.	27.51	23.49	14.96
Hero Honda Motors Ltd.	52.00	8.52	22.53
Himachal Futuristic Communications Ltd.	9.07	4.01	6.45
Hindalco Industries Ltd.	24.37	26.50	11.65
I D B I Bank Ltd.	71.39	8.05	1.06
Indian Petrochemicals Corpn. Ltd.	79.98	7.29	1.09
Indusind Bank Ltd.	49.86	3.03	5.44
Kesoram Industries Ltd.	23.87	20.64	1.97
Mahindra & Mahindra Ltd.	26.26	36.43	7.36
Moser Baer India Ltd.	18.54	3.43	15.53
Mphasis B F L Ltd.	0	12.23	9.80
Orchid Chemicals & Pharmaceuticals Ltd.	14.04	6.13	0.05
Pentamedia Graphics Ltd.	1.33	0.77	4.44
Pritish Nandy Communications Ltd.	35.02	5.50	14.38
Pudumjee Pulp & Paper Mills Ltd.	49.37	11.89	2.01
Ray Ban Sun Optics India Ltd.	0.00	2.95	0.03
Saven Technologies Ltd.	13.84	3.00	1.50
Silverline Technologies Ltd.	2.74	0.95	0.39
South Indian Bank Ltd.	4.77	15.20	0.00
Steel Authority Of India Ltd.	85.82	8.73	1.00
T V S Motor Co. Ltd.	58.81	12.72	4.89
Tata Chemicals Ltd.	30.56	26.37	0.02
Tata Power Co. Ltd.	32.54	29.06	6.50
Tata Tea Ltd.	29.48	28.82	7.21
Unichem Laboratories Ltd.	49.47	7.62	3.50
Uniphos Enterprises Ltd.	34.07	23.94	7.93
Vision Organics Ltd.	11.84	2.30	2.00
Quartile-1 (Q1)	***15.36***	***4.68***	***1.62***
Median	***32.50***	***10.25***	***5.86***
Quartile-3 (Q3)	***49.28***	***15.16***	***11.79***

[5] Publicly traded companies in India