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How Intellectual Capital Combination Method Can Improve Corporate Performance in China's Information Technology Industry

WEIDONG ZHU, XIAOYA DAI, YUFEI TIAN, XUE HU, AND ZHANG CHAO
School of Management, Hefei University of Technology, Hefei 230009, China

Corresponding author: Xiaoya Dai (daixiaoya900924@163.com)

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ABSTRACT This study aims to illustrate how intellectual capital (IC) dimensions can improve corporate performance, and explore ideal IC combination methods in diversified firm situations to distribute IC dimensions effectively with limited resources. A universal theoretical framework based on Balanced Scorecard (BSC) theory is proposed to illustrate the way in which IC dimensions can enhance corporate performance from the perspective of stakeholders. Then, the rough set method is introduced to empirically explore ideal IC combination methods in diversified situations using 539 valid samples from China's information technology industry. The theoretical analysis shows that IC dimensions work as a combination rather than as isolated parts to affect corporate performance, and different levels of corporate performance can be achieved by different IC combination methods under diverse firm factors. Ideal IC combination method is obtained through empirical study. Relational capital is the most important IC dimension, whereas leverage is the most important influence factor. This study extends IC management theory by profoundly illustrating the internal logical between IC dimensions and corporate performance through the theoretical framework. Additionally, this study introduces the rough set method to IC empirical research to explore ideal IC combination methods. Findings will deepen insight of practitioners about the essence of IC dimension combinations to corporate performance, and how they can apply the IC combination results to effectively distribute IC resources in diversified firm situations. The theoretical and practical research of this study extends both the third and fourth stages of IC research.

INDEX TERMS Intellectual capital (IC), IC combination method, balance scorecard (BSC), IC dimension and corporate performance theoretical framework, the rough set method.

I. INTRODUCTION

The information technology industry has become the growth engine of China. As a fast-growing industry, the lack of corporate performance will make information technology enterprises lose competitive advantage. Given that information technology is an intellectual capital (IC)-intensive industry, the improvement of corporate performance mostly depends on the promotion of effective IC management. However, how China's information technology industry can effectively combine IC resources still needs further exploration in theoretical and practical aspects. This lack of research causes inadequate understanding, blind distribution and waste of IC resources. Therefore, deepening the understanding of the effective use of IC and its use in diversified firm situations from the perspective of theory and practice is necessary. The significance of IC for improving corporate performance grows with the development of the knowledge economy era, especially for IC-intensive industries. Scholars have accomplished studies on the relationship between IC and company performance. Although the conclusions are diverse, the positive effects of IC on the performance of enterprises have been verified [1], [2].

IC management should consider more about IC combination method which means effective ways to combine IC dimensions with limited IC resources, rather than considering only the correlation between IC and corporate performance. Dumay and Garanina noted that IC-related research should

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emphasise the use and full mobilisation of IC [3]. Previous studies showed that the relationship between IC dimensions is synergistic rather than simple linear in affecting corporate performance [4]. Therefore, focusing only on the relationship between IC and corporate performance is insufficient in achieving the effective use of intellectual resources. The impact of IC on corporate performance usually relies on several specific combination methods of IC dimensions. Some studies explored the combination problems of IC, opining that a good combination of intellectual resources can significantly improve corporate performance [5]. Nevertheless, more theoretical studies on the logical relationship between IC dimensions and corporate performance need to be explored. These insufficient studies lead to a lack of solid theoretical foundation in research on the IC combination method, and insufficient relevant empirical investigations also have difficulties in guiding decisions on the IC combination method.

Research on IC combination method is still further needed on both theoretical and practical aspects. Theoretical research has obtained results about IC dimensions and corporate performance, such as human capital needs to work through organisational capital, and subsequently, through relationship capital which affects corporate performance [6]. However, the paths that produce the same result are diverse and equivalent, and there is always no single method can be used in complicated and uncertainty reality conditions. In order words, the result is usually due to multiple concurrent complex causal relationships. Besides, the Balance Scorecard (BSC) acts as a useful tool for IC management and is suitable to illustrate the relationship between intangible knowledge assets and tangible financial results, such as IC and corporate performance [7]. Nevertheless, BSC theory is always used as an evaluation method of IC efficiency in the management of IC [8]. Other uses of BSC as an IC strategy management method do not involve the discussion of IC combination method of IC dimensions to improve corporate performance [9].

The practical shortcoming of the IC combination method is mostly due to the limitations of research methods related to IC research. Traditional statistical methods, such as regression and structural equation modelling, are usually used for exploring the correlation or structural problems of IC and corporate performance. However, these analytical methods can only examine linearity, and single causality and symmetric relationships between variables and prior assumptions need to be made. These limitations are inconsistent with the nonlinearity, complex causality and asymmetry conditions that are prevalent in reality, such as IC combination problems. Other methods are complicated in extracting IC combination rules and guide IC dimension combination decisions. This study introduces a rough set method for exploring the high-performance IC combination method. The rough set method is a mathematical tool for knowledge discovery under uncertainty and incomplete situations without making priori assumption. The rough set method can also handle nonlinearity, complex causality and asymmetry relationships between variables that are suitable for exploring the ideal IC combination method, but only a few studies have covered IC management research.

In general, two main problems are encountered in the research on IC combination method and corporate performance. Firstly, without considering multiple concurrent complex causal relationships, insufficient theoretical research on the IC dimensions and corporate performance make a solid theoretical basis with adequate understanding for the study of the IC combination method difficult. Secondly, inappropriate analytical methods make the exploration of nonlinearity, complex causality and asymmetry IC combination method under uncertainty and incomplete situations challenging. In view of these problems, the following research purposes are formulated.

1. How IC dimensions can improve corporate performance theoretically?

2. Which kind of method for combining IC dimension in diversified firm situations can achieve high corporate performance practically?

This study proposes a universal theoretical framework to analyse how IC dimensions can improve corporate performance. By using rough set theory, the IC combination methods in diverse situations, which can achieve high performance, are explored empirically using 539 samples from China's information technology industry.

This study makes the two main contributions. Firstly, the proposed theoretical framework extends IC management theory by illustrating the inter logic between IC dimensions and corporate performance on the basis of BSC from the perspective of stakeholders. Secondly, the rough set method is first introduced to IC empirical research to explore ideal IC combination method which is important to guide IC distribution. The theoretical and practical research of this study extends both the third and fourth stages of IC research.

This study is structured as follows. Section 2 introduces a brief review of the literature regarding basic definitions and main research status, and comments existing in the current research are made. Section 3 presents the proposed theoretical model. Section 4 illustrates empirical method and makes a comparison with other methods, condition attributes and decision attributes are also presented. In Section 5, an empirical example is presented and analysed, and the findings are subsequently interpreted. In Section 6, implications for practice are made. Finally, Section 7 provides concluding remarks and future research opportunities.

II. THEORETICAL BACKGROUND

A. IC, IC DIMENSIONS AND FOUR EVOLUTION STAGES

John Kenneth Galbraith first introduced the concept of IC in 1969. Galbraith believes that IC is not simply pure intelligence but also includes intellectual action. Scholars extensively discussed IC in the 1990s and regarded IC as the most critical asset in a knowledge-based economy. Several researchers defined IC as the knowledge that can turn information into value, consisting of intellectual property,

professional skills, customer relationships and organisational technology [10]. The Organization for Economic Co-operation and Development (OECD) described IC as the value of human capital and structural capital, and Roos stated that IC is a combination of knowledge and ability, which enhances the continuous competitiveness of companies [11]. Along with the development of knowledge economy, the concept has gradually expanded to take into account other stakeholders. Edvinsson and Dumay believed that IC's principle is borrowed from stakeholders [12], [13]. Although no universally accepted definition of IC exists, its essential role is confirmed.

The main classifications of IC include two-, three- and multi-dimensional categorisation. Edvinsson and Sullivan [14] and Roos and Roos [11] argued that IC can be divided into human and organisational capital. Stewart and Ruckdeschel [10] and Bontis [6] deconstructed IC into three elements, namely, human, structural and relational capital. Scholars also subdivided IC into four or more elements. Although the classifications of IC differ, the substance is consistent. In addition, the three-dimensional categorisation of IC is gradually being accepted as a universally applicable method.

As one of the three-category classification of IC, human capital related to all human capital-related attributes work through employees. Human capital includes all forms of an individual's knowledge, such as competence, education, attitude and experience, and cannot be replaced by machines [14]. Organisational capital is embedded in daily corporate operations [6], which are performed inside a company, differs from human capital and contains technological elements, procedures, processes, strategies and routines. Relational capital refers to the knowledge embedded in external relations with customers, agents, suppliers and governments [15].

The evolution of IC research can be divided into four main stages [16]. The first stage was characterised by the research of 'grand theories' on raising awareness on IC's potential for improving and maintaining competitive advantage [17]. The second wave of IC research was focused on investigating IC's influence on corporate performance, and continued to focus on developing the measure, report and taxonomy of IC [3]. The third stage of IC research focused on how to manage and adapt IC in companies. The second and third stages are devoted to the management of IC in companies, which can be classified as bottom-up and top-down research. In the fourth stage, the social feature of IC, such as the interdependencies of each kind of stakeholder, is taken into account. Additionally, the boundaries of IC extended to wide ecosystems, such as communities, cities and countries [3], [16].

B. IC AND CORPORATE PERFORMANCE

The positive impacts between IC and corporate performance have been verified in different countries and industries. For example, Lu et al. concluded that integrated IC plays an indispensable role in enterprises using the truncated regression approach and data from China's insurance industry [18]. Using a regression method and employing samples from biotechnology and pharmaceutical firms, Sydler found that high investment of IC leads to an ideal return on assets (ROA) [5]. Similarly, by using multiple regression analysis and samples from technology firms, Nimtrakoon confirmed that IC has a positive relationship with corporate performance, and an excellent value of IC will generate high market value [19]. Several other researchers have drawn similar conclusions.

Many scholars also studied the relationship between IC dimensions and corporate performance. Employing samples from the Pakistan electrical and electronics manufacturing industry and using the multiple regression analysis, Khalique and Bontis found that IC dimensions have a positive relationship with corporate performance [20]. Nasif and Ozkan used data from banks in Turkey and regression models and concluded that ROA is strongly affected by human capital [21]. Similar conclusions were drawn by Cabrita and Bontis, who examined the Portuguese banking industry by using the partial least-squares regression [22]. By applying specific regression models and using samples from nonfinancial companies of the Bucharest Stock Exchange, Sumedrea revealed that ROA, return on equity (ROE) and the growth rate of a business is influenced by human capital and organisational capital [23]. Using regression analyses, Andreeva and Garanina asserted that a company with high levels of human and structural capital has a high corporate performance [24]. Using regression models, Chan also stated that structural capital played a notable role in improving market valuation, ROA, ROE and profitability [25]. Furthermore, the direct impact of relational capital on firm performance is supported by Huang and Hsueh [26]. Shakina found that relational and structural capital play an important positive role in the long term, whereas human capital becomes increasingly relevant in the short term [27].

Previous studies assert that the impact of IC on corporate performance is affected by several factors. Among these, firm size, firm age and leverage are three of the most important factors commonly used in empirical research as control or moderating variables [19], [28]. Growth and profitability are also recognised as vital factors in the relationship between IC and performance [29]. In addition to these corporate factors, Chen and Asiaei believed that industry factors are also an important control variable that cannot be ignored [30]. Furthermore, national or regional factors, like regional growth [32], are also necessary considerations [31]. Alfaro also showed that economic variables like economic growth will broaden the differences of IC's impact between countries [33]. Zulkifli found that government ownership is a moderating element in the association between IC efficiency and corporate performance [34]. The impact of IC on corporate performance in different nations vary. For instance, using data from 51 countries, Ståhle and Bounfour found that IC has varying effects on a nation's gross domestic product growth [35].

C. IC CONFIGURATION AND CORPORATE PERFORMANCE

Scholars are beginning to notice the importance of IC combination method which means combining IC with limited resources. An ideal combination of IC dimensions is believed to enhance corporate performance effectively [5].

Prior studies show that the improvement of corporate performance does not depend on any single type of IC dimension, but rather jointly and interact with specific IC structures. By using structural equation modelling and data from emerging clusters in Latin America, Carlos asserts that human capital is the primary component of IC, and 'human capital generates structural capital and structural capital generates relational capital' to improve corporate performance [36]. The empirical study by Chung-Fah and Sung-Lin using structural equation modelling reveal that human capital significantly affects structural, relational and human capital affects sales growth and profit growth and gross operating profit via relational capital [37]. Similarly, Tseng and Jia found that human capital could act on organisational capital and relationship capital to impact Tobin's q and Market/Book value by using structural equation modelling [38].

Other studies show that the IC combination method can effectively improve corporate performance, but further researches are needed to guide decision making in diverse circumstances. For example, Hussinki used data from Finland and categorised corporations into four groups, and stated that different amounts of integrated IC yield diverse performance outcomes, but IC dimensions were not considered [39]. Cricelli separated high- and low-corporate performance groups by using cluster analysis and compared their different combinations of IC dimensions after excluding the impact of size [40]. Cabrilo and Dahms used fuzzy set qualitative comparative analysis (fsQCA) to explore IC combination and concluded that high corporate performance is achieved through multiple combinations of human capital, organisation capital and relational capital [41]. Castro et al. obtained similar results by using the fsQCA method and data from technology-based firms in Spain [42].

Related IC management theory research is necessary for building a solid foundation to explore good IC combination method. Through literature review, Inkinen and Henri stated that IC improves corporate performance through the combination and interaction of IC dimensions [15]. Bonties theoretically analysed and concluded that human capital need to work through organisational capital, and organisational capital needs to work through relationship capital to affect corporate performance [6]. BSC is a powerful tool to manage IC and link IC with corporate performance [7]. From the perspective of IC management by evaluating IC performance, BSC has been used as a measurement tool [43], for example, Skandia Company measures IC from the four perspectives of BSC theory. Bontis and Bart also set indicators for each perspective of BSC in evaluating and managing IC by using the case study of the Fosters Brewing Group [8]. From the perspective of guiding management activities, other researchers have considered the more in-depth management of IC based on BSC, from aspects such as vision, mission and strategy of corporations. Using a case study and information from a car dealer in Taiwan, Anne Wu integrated IC with a BSC and illustrated the vital role of BSC in directing the formation, creation and management of IC [9]. Ramírez analysed the strategic management system of Jaume I University through strategic goals, mission, vision and the vital factors for success to manage IC on the basis of BSC [44].

D. COMMENT ON THE LITERATURE REVIEW

1) The analysis method used in prior studies on IC research is unsuitable to explore IC combination method. Regression analysis methods, which are commonly used in exploring the correlation between IC and corporate performance, are unsuitable for dealing with IC combination method problems. Structural equation modelling is the most commonly used analytical tool for conducting research related to IC structure. However, structural equation modelling can only explore the one-way causality of IC dimensions, and this approach ignores the possibility that multiple combinations of IC dimensions can achieve the same result. In general, these two methods only consider the linearity, one-way causality and symmetric relationships between variables. They also require prior hypothesis. All these limitations are not in line with the nonlinearity, multiple concurrent complex causal, asymmetry and uncertainty and complicated conditions that exist in reality [45]. Additionally, these two methods are unsuitable for exploring multiple combinations that can achieve the same result. Besides, when it comes to the research of IC combination method and corporate performance, the results obtained by using the cluster method are challenging to apply in the conclusion without rule extraction. Moreover, the fsQCA does not filter unimportant conditional variables before exploring the combination.

2) Researchers usually give less consideration to different IC combination method under diverse corporate situations or simply take into account a few influence factors. However, under diverse enterprise situations, IC combination method may show different effects on corporate performance. Thus, when exploring the IC combination approach method to improve corporate performance, the impact of the firm situation should be fully considered

3) Prior studies on IC and corporate performance, especially enterprise-related empirical research, are mostly based on the interests of shareholders that are not in line with IC's concept and the fourth stage of IC research. The dimension of IC contains human, organisational and relational capital. Hence, the capital investment of enterprises includes not only the input of shareholders, but also the investment of employees, government and other stakeholders. Compared with only considering the shareholder, the concept of IC should take into account other stakeholders. The fourth stage of IC research also emphasises the need to consider other stakeholders [12]. However, prior studies that focused on IC and corporate performance are mostly from the perspective of shareholders, and selected corporate performance

indicators, such as ROA and ROE, tend to reflect the interests of shareholders, especially research related to firms.

4) On the basis of BSC theory, research did not delve into how IC dimensions can improve corporate performance through internal relationship between each perspective. Early BSC-based management of IC usually focused on evaluating the IC performance of corporate through BSC to enhance the use of IC. However, the early management of IC is more conducive for improving corporate performance than the later evaluation. Later, based on BSC theory, studies that aim to guide IC management activities were mainly targeted to a specific company through case studies and may be inapplicable as a universal model.

5) On the whole, the theoretical research on the IC combination method is more lacking than the empirical research, and less considering of multiple causal situations. The theoretical research on the structure of IC mostly focuses on one-way causality of IC dimensions, but seldom pays attention to multiple concurrent complex causal of IC dimensions. In other words, possibility that there are many IC combination method can achieve the same result in a diverse environment should be taken into consideration. This perspective is not helpful to build a solid basis and sufficient understanding of the research on IC combination method.

III. IC DIMENSIONS AND CORPORATE PERFORMANCE THEORETICAL FRAMEWORK

A universal theoretical framework is proposed to clearly illustrate how IC dimensions can improve corporate performance theoretically based on BSC theory from the perspective of stakeholders. Through the result analysis, the corporate performance is improved by combining the IC dimensions rather than relying on any single IC dimension and different IC combination methods will generate diversified corporate performance under diverse corporate situations is verified.

A. BSC, IC AND CORPORATE PERFORMANCE

BSC theory is introduced to scrutinise the internal logic of IC dimensions and corporate performance. BSC theory is especially suitable for explaining the process of transforming intangible assets like IC into tangible results like corporate performance from learning and growth, internal processes and customer and financial perspectives. Moreover, using BSC theory as a management tool enables enterprises to maintain the consistency of their business activities with corporate strategies. Therefore, BSC theory is perfect as a foundational tool for analysing the internal logic of IC dimensions and corporate performance.

Furthermore, this study proposed the theoretical framework from the perspective of stakeholders. Considering IC dimensions contain human, organisational and relational capital which means the concept of IC related to investment by stakeholders such as employees, government and other stakeholders, rather than just shareholders.

B. IC DIMENSIONS AND CORPORATE PERFORMANCE THEORETICAL FRAMEWORK

The IC dimensions and corporate performance theoretical framework follows a specific process. Under the similar strategic themes in each perspective, enterprises determine various strategic goals according to different influencing factors, which lead to different combinations of IC dimensions. Then, different corporate performance can be achieved by a different IC combination method.

Although enterprises have different situations, their strategic themes are similar. Consequently, this study illustrates IC dimensions and corporate performance in a universal theoretical framework instead of merely analysing individual enterprises (FIGURE 1). According to Kaplan's strategic map template, the strategic themes of the learning and growth perspective consist of business climate, strategic capabilities and strategic technologies. The strategic themes of the internal process perspective are composed of environmental, customer management, innovation, operational and regulatory processes. The strategic themes of the customer perspective consist of corporate image, stakeholder relationships and product and service quality. The financial perspective places much emphasis on the concept of value-added.

These influencing factors can be considered from the micro-level of the enterprise, the medium level of the industry and the macro level of the country (FIGURE 1). From the enterprise level, the main influencing factors are company size, establishment time, leverage, profitability and growth. Furthermore, industry factors also play an important role; different industries involve various regulations and competitive characteristics and thus, discrepancies arise in the achievement of strategic goals. In addition, national factors, such as politics and law, economy, social culture and technology also influence strategic goals. Diversified strategic goals are formulated given these diverse corporate situations [9]. In the learning and growth perspective, resource investment is manifested in human capital and organisational capital. Investment in strategic capabilities is expressed as human capital, whereas investment on the business climate and strategic technologies involves organisational capital. In the internal operational perspective, investment in the customer-management process is manifested in relational capital, and investment in environmental, innovation, operational and regulatory processes is expressed as organisational capital. All investments in the customer perspective are manifested in relationship capital. At the same time, the role of physical capital should not be neglected because IC sometimes functions above the physical capital. Also, investment in IC will affect financial results, which reflect corporate performance.

C. IC DIMENSIONS AND CORPORATE PERFORMANCE

The IC dimensions invested in each perspective combine to improve corporate performance rather than rely on a single correlation because the four perspectives operate as a whole, and their relationships are interrelated and mutually

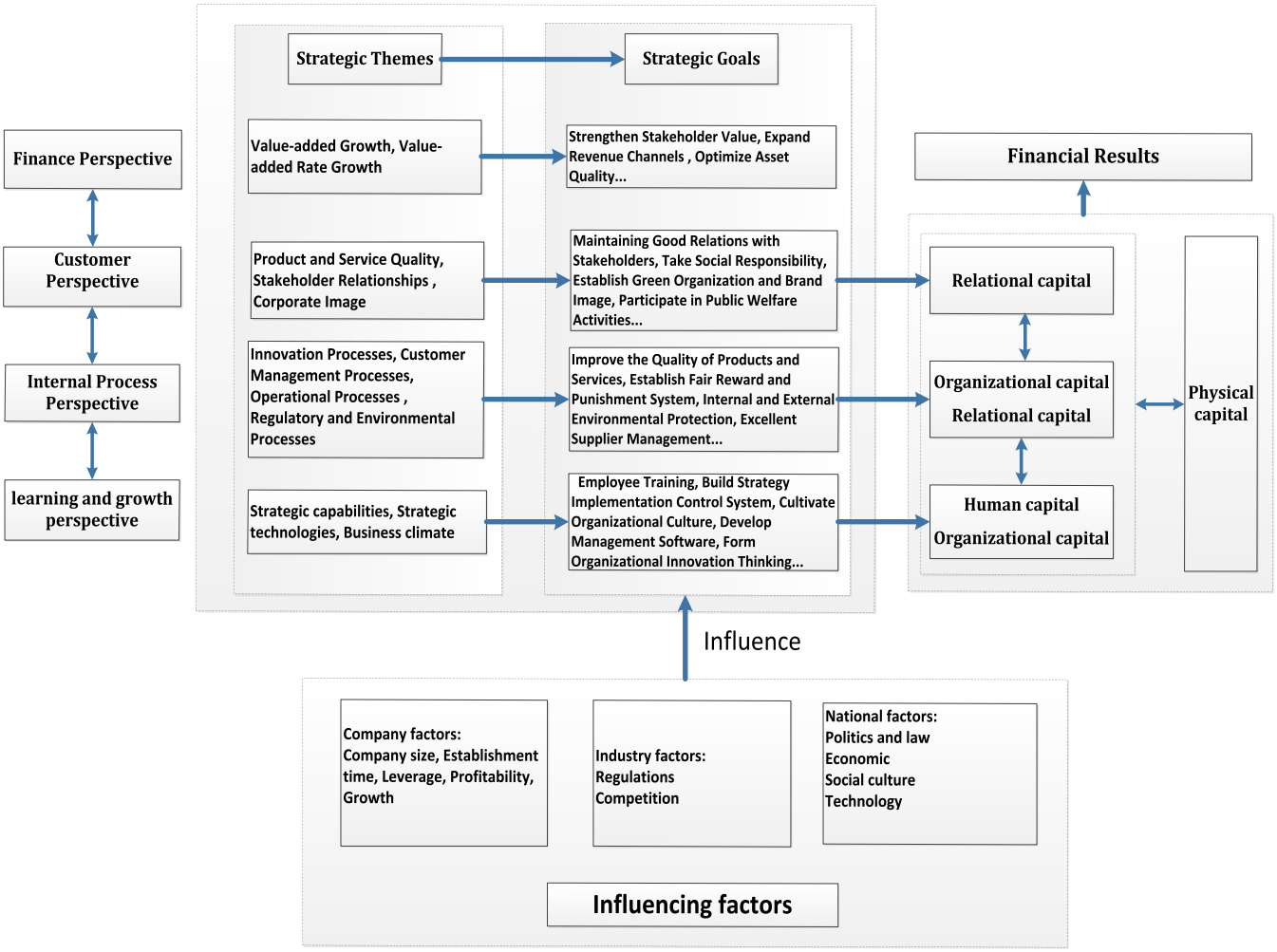

FIGURE 1. **IC dimensions and corporate performance theoretical framework.**

influential [46]. The customer perspective is the key, the internal process perspective is the foundation, whereas the learning and growth perspective is the core and the finance perspective is the goal. The strategy of these combined perspectives ultimately guarantees the realisation of financial indicators. Thus, the input of intellectual resources manifested by IC in each perspective is also expressed as a combination relationship and results in the realisation of corporate performance. Therefore, the combination relationship of IC dimensions to improve corporate performance is illustrated through the interaction relationship between each perspective.

Furthermore, different IC combination methods will generate diversified corporate performance on the basis of various strategic goals under diverse corporate situations. Affected by influencing factors such as leverage and company size, enterprises will make different strategic goals at each perspective [47]. On the basis of diversified strategic goals, different combination methods of IC will be selected to realise strategic goals of companies, which will finally lead to various corporate performances.

Different IC combination methods of enterprises that induce various corporate performances have been analysed from the theoretical aspect. However, the realistic IC combination methods that can be used to improve corporate performance have not received much attention from the empirical aspect, which is beneficial for company operation. Therefore, this study intends to explore ideal IC combination method, which can achieve high corporate performance empirically.

IV. THE ROUGH SET METHOD, CONDITIONAL ATTRIBUTES, AND DECISION ATTRIBUTE

The rough set method is chosen to explore the high-performance IC combination methods from an empirical perspective. Physical capital, human capital, organisational capital, relational capital, company size, establishment time, leverage, profitability and growth and economic area are selected as the condition attributes. Asset value-added rate, which considers the interests of stakeholders, is used as the decision attribute.

A. THE ROUGH SET METHOD

The rough set method, which was formulated by Pawlak in 1982, has become a mathematical tool for multi-criteria decision-making under uncertainty and incomplete situations [48], [49]. The method can deal with complex questions with nonlinear, interdependent relationship, multiple concurrency and asymmetric characteristics. Also, the rough set can handle the original data rather than need prior hypothesis. These advantages make the rough set method more in line with complex situations in the real world. The rough set method first removes irrelevant attributes and then identifies potential combination methods. Thus, it can explore variables that achieve results after removing redundant information. The method is in line with the purpose of this study to explore high-performance IC combination methods and make effective IC combination decision. This method has been widely applied to areas such as knowledge discovery, feature selection, data analysis, granular computing and pattern recognition [50], [51] However, only a few studies have utilised the method in economic management and IC management [52].

By using the rough set method, one can avoid the disadvantages of traditional statistical analysis and other analysis methods. Compared with other commonly used methods in IC research, the strengths of the rough set method are as follows:

1) The rough set method focuses on solving nonlinear problems rather than linear problems, which keeps up with complex and uncertain situations in reality. As the environment changes, the challenges faced by organisations become increasingly complicated and uncertain. Traditional statistical analysis methods, which emphasise linear relationships between variables, are difficult to use if one seeks to offer a reasonable and comprehensive explanation in diverse circumstances. Most problems, in reality, are often nonlinear problems. Therefore, the study of management problems should shift from a simple linear problem to a nonlinear problem.

2) Under uncertain and fast-changing circumstances, the rough set method does not require any prior hypothesis beyond the dataset. The rough set method is based on the given sample set; hence, the description or processing of the uncertain problem is objective and exhaustive compared with regression analysis and structural equation models. With the increasing complexity of the environment, proposing an exhaustive priori hypothesis that reflects all interactions between variables is difficult. Such hypothesis is needed by traditional statistical analysis methods like regression analysis and structural equation models.

3) The rough set method focuses on the interdependent relationship and the 'configuration effect' analysis from a holistic perspective, whereas traditional regression analysis focuses on the unique 'net effect' of individual variables from an atomic perspective. The traditional regression analysis technique utilises the marginal analysis technique of economics to seek optimal equilibrium in the static state. Variables are assumed to be independent in the marginal analysis of regression, but the interdependence of organisational attributes (independent variables) and possible 'chemical reactions' are ignored. The unique effects of each variable in marginal analysis of regression may be affected by their interrelationship. The rough set method conducts a case-oriented comparative analysis from a holistic perspective, and each case is considered a 'configuration' of condition variables. When the conditional configuration is holistically analysed, the interdependence relationship assumption has been taken, which is more in line with social phenomena.

4) The rough set method considers that the same result can be achieved by different combination methods (paths), and these combination methods are equivalent. In other words, the reason for the result is multiple concurrent and complex. In contrast, traditional statistical analysis methods such as regression analysis and structural equations models consider only a single causal relationship between results and causes, which is not supported by the complex environment and management practice;

5) The rough set method assumes that the cause–result relationship is asymmetric, whereas traditional statistical methods assume a symmetric relationship. For example, traditional statistical analysis methods believe that high performance is achieved by high human capital investment; thus, low human capital investment will correspondingly result in low performance. However, low human capital can achieve high performance when interacting with other conditions. Asymmetric conditions are more prevalent in the complicated world.

6) The rough set method combines the advantages of qualitative and quantitative analyses. Traditional qualitative analysis focuses on the overall and in-depth analysis of the case, but the external promotion is poor. Quantitative research focuses on the discovery of patterns that can be promoted from large samples, but is not enough to analyse the uniqueness and depth of the case. The rough set analysis method integrates the advantages of qualitative and quantitative analyses, and is suitable for small- (10 or fewer cases), medium- (10 or 15 to 50 cases) and large-sized samples (more than 100 cases).

7) Compared with the cluster method, the rough set method can merge and reduce all rules to obtain the most simplified rules that are instructive and conducive for decision-making. The cluster method can only explore differences in the features of IC among different groups, but cannot combine and reduce the elements of the attributes. The rough set method can reduce attributes, which are beneficial to guide IC dimensions combined with decision-making.

8) Compared with the QCA method, the feature selection of rough set theory can remove irrelevant attributes while preserving the necessary attributes from large datasets first. In real-world applications, data can expand quickly, and large amounts of diverse attributes are stored in databases. After the feature selection process, simplified and understandable combination methods are then produced without redundant attributes, thereby making them instructive for decision-makers.

TABLE 1. Comparison of fuzzy set and other methods of IC research.

	Regression analysis	Structural equations model	Case study	Cluster	QCA	Rough Sets Method
Linear / Nonlinear problem	Linear	Linear	Nonlinear	Nonlinear	Nonlinear	Nonlinear
Prior hypothesis	Required	Required	Not required	Not required	Not required	Not required
Variable relationship	Independent	Independent	Interdependence	Interdependence	Interdependence	Interdependence
Cause and result causality	Single causal	Single causal	Multiple concurrency	Multiple concurrency	Multiple concurrency	Multiple concurrency
Cause and result relationship	Symmetric	Symmetric	Asymmetric	Asymmetric	Asymmetric	Asymmetric
Sample size	Large-sized sample	Large-sized sample	Small-sized samples	No data volume restrictions	No data volume restrictions	No data volume restrictions
Rule simplification	×	×	×	×	●	●
Non-significant variable reduction	×	×	×	×	×	●

A dotted circle (●) means that the method satisfies the given condition, whereas a crossed-out circle (×) means that the method does not satisfy the condition.

On the basis of the strengths highlighted above, the rough set method is ideal for exploring the IC combination method to achieve high corporate performance in decision-making. TABLE 1 provides a list of the advantages of the rough set method compared with other methods.

The following definitions are listed to explain the application of the rough set method:

Definition 1: S represents information system = (U, A, V, f), where U is a nonempty set called the universe; A denotes a nonempty set that contains conditional and decision attributes; V represents the value of each attribute; f is an information function and $\forall u_i \in U$, such that if $a \in A$, then $f(ui, a) \in Va$.

Definition 2: $IND(P) = \{(x_i\ x_j) \in U \times U | f(x_i, a) = f(x_j, a), \forall a \in P\}$.

IND(P) denotes denotes P-indiscernible, which means $x_i, x_j \in P$, and they have the same value of all attributes called indistinguishable objects; a denotes each attribute of P, and P is the nonempty subset of A; x_i, x_j are P-indiscernible. All indistinguishable objects with the same attributes are called the equivalent set. Furthermore, U/IND(P) denotes the set of all equivalence classes.

Definition 3: $\overline{P}Y$ denotes the P-upper approximation of Y, and $\underline{P}Y$ indicates the P-lower approximation of Y.

$$\underline{P}Y = \{x \in U | IND(P) \subseteq Y\},$$
$$\overline{P}Y = \{x \in U | IND(P) \cap Y \neq \emptyset\},$$
$$BN_P(Y) = \overline{P}Y - \underline{P}Y.$$

Definition 4: For any subset $X \in U$, C and D are equivalence relations .$POS_C(D)$ represents the C-positive region of D.

$$POS_C(D) = \left\{ \underset{X \in U/IND(D)}{U} \underline{C}X \right\}.$$

Definition 5: $\forall a \in C$, and if $POS_C(D) = POS_{C-\{a\}}(D)$, then a represents a redundant attribute. IF $C' = C - \{a\}$ is a reduction of C, then all reduction outcomes are $RED(C')$.

Definition 6: Rules can be identified according to the reduction results.

$$Des(x) = \bigcap_{a \in RED} (a = f(x, a))$$

Confidence, coverage and support are the three crucial indicators for the judgment of rules. Large numbers represent meaningful conclusions. Confidence indicates the correct probability of reasoning using this rule. Coverage denotes the proportion of the support number of the rule in the corresponding decision set and support represents the number of samples that sustain the rule in the universe.

The rough set method cannot process continuous numerical data, which must be first discretised. The clustering method is more scientific than equal-frequency methods in terms of data discretisation. The discrete method affects the empirical results of the rough set method. Equal-frequency methods, which are commonly used in rough sets, may be too strict for continuous data where values may only differ as a result of noise. Data presenting different features may be classified into one class simply because of an equal number requirement. Relatively, the clustering method ensures that the data in each subset have similar characteristics, thereby rendering the data more in line with their original features and conducive for generating precise and reasonable results [53]. Therefore, this study selects the rough set method for problem analysis, whereas the clustering method is applied for data pre-processing.

B. CONDITIONAL ATTRIBUTES: IC DIMENSIONS AND INFLUENCING FACTORS

Human, organisational, relational and physical capitals (with the exclusion of the enterprise scale) are chosen as the conditional attributes to examine the IC combination method that can improve the performance of a firm. The three-dimensional categorisation of IC has become widely accepted after years of research on IC classification. Given the IC combination method and corporate performance internal logic

model illustrated above, this study posits that corporate performance is induced by human, organisational, relational and physical capital. In addition, considering that the scale of the company affects the value of the capital, this study uses the IC relevant elements that exclude the impact of firm size.

Furthermore, company size, length of establishment, leverage, profitability, growth and economic area are selected as conditional attributes that represent the influencing factors. As discussed earlier in the theoretical framework, the influencing factors can be considered from the micro-level of the enterprise, medium level of the industry and macro-level of the country. At the micro-level of company size, the length of establishment, leverage, profitability and growth are the most notable elements. At the medium level of the industry, all the samples are chosen from a single industry and are all influenced by the same regulations and competitive characteristics. Therefore, given the similarity of industry factors, no medium-level element is considered. At the macro-level of the country, politics and law, economics, social culture and technology are the most vital national elements. The economic area is selected for representing the diversity at the national level owing to the qualitative characteristics of these indexes [29], [34], [54].

C. DECISION ATTRIBUTE: ASSET VALUE-ADDED RATE

The asset value-added rate is chosen as an indicator of the decision attribute. Considering that the concept of IC includes the capital related to human and relational rather than simply considering shareholder, the value-added indicators are more in line with the interest of stakeholders and the concept of IC. The development of IC considers that value is not just monetary but incorporates worth and importance of the products and services to customers and other stakeholders [12]. According to the Marxist political economy, added value represents newly created value, that is, the value achieved by all stakeholders from the input. Relative to profit indicators, which only focus on the value created by shareholders, added-value indicators represent all the wealth created and reflect the interest of stakeholders. Thus, the value-added indicator can provide more useful information for enterprises. Moreover, replacing profit indicators with value-added indicators can effectively enhance the value and promote the development of corporations [55].

Considering that the number of value-added indicators may be affected by the firm size, this study selects the value-added indicator that excludes the influence of the enterprise scale, which in turn, is an asset value-added rate. TABLE 2 presents the calculation method of the asset value-added rate.

V. EMPIRICAL RESULTS AND ANALYSIS

This section uses the rough set method to investigate the high-performance IC combination method from an empirical perspective. FIGURE 2 illustrates the empirical procedure using the rough set method.

TABLE 2. Calculation method of the asset value-added rate.

Indicators	Calculation method
Asset value-added rate	Asset value-added rate = Value-added/ Year-end assets
The value-added	The value-added = Employee income + Government income + Shareholder income + Creditor income + Enterprise income
Employee income	Cash paid to employees + Cash paid for employees + Difference between the end and the beginning of the payable period
Government income	Payments of all types of taxes + Difference between the end and the beginning of the tax payable + Refunds of taxes
Shareholder income	Shares in current year × Dividend per share
Creditor income	Interest expense
Enterprise income	Net profit − Dividend pay out

A. STAGE 1: PROBLEM DEFINITION AND DATA COLLECTION

The empirical study was carried out on the information technology industry in China from 2015 to 2017. Data were obtained from the information transmission, software and information technology service industry under the industry classification of the China Securities Regulatory Commission in the CSMAR database. Aside from omitted, missing and abnormal data, 539 samples were obtained.

Essential IC-related elements and influencing factors were investigated as conditional attributes. The asset value-added rate was evaluated as a decision attribute. IC-related elements included human, organisational, relational and physical capital. Influencing factors consisted of enterprise scale, length of establishment, leverage, profitability, growth and economic area, which were widely accepted as vital influence factors in IC value creation. The influence of corporate size is excluded according to the attributes. TABLE 3 lists the attributes and the chosen calculation method for these attributes [29], [34].

After collecting, all data were randomly divided into training samples (431 samples) and test samples (108 samples) using an 8:2 ratio. Training samples were used to generate rules, whereas test samples were used to verify the accuracy of the rules.

B. STAGE 2: DATA PRE-PROCESSING AND RULE FORMATION

Before the data relationship table can be established, all attributes must be presented in discrete form. The attributes of the information technology industry are all continuous numerical data, and clustering methods are used to discretise these data. All the attributes were clustered according to the dichotomy to differentiate between the high and the low group. TABLE 4 shows the breakpoint set of attributes generated by the clustering method. The said set is stored to discretise the test samples, thereby ensuring the consistency of discretisation of training and test samples.

A genetic calculation method is used to generate the rules. Only high-performance rules were presented given that this study sought to explore the high-performance IC combination

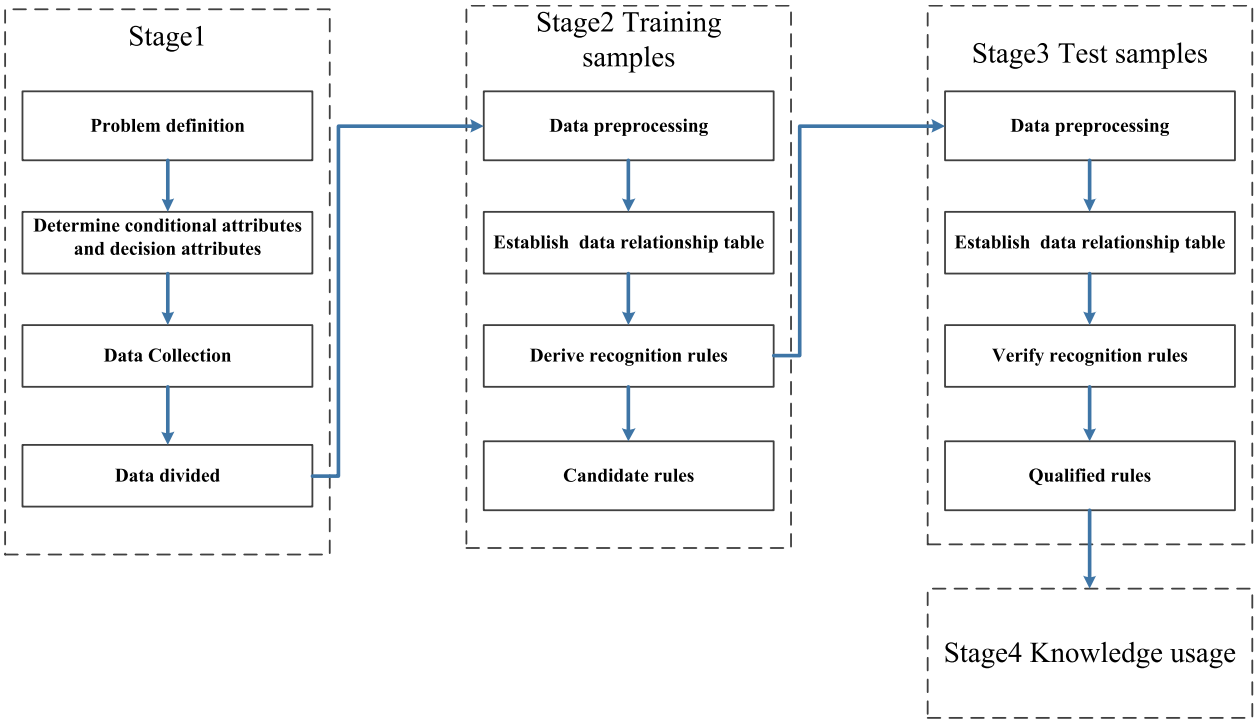

FIGURE 2. Empirical procedure.

TABLE 3. Attributes and the calculation method.

Attributes	Attribute categories	Attribute subcategories	Calculation method
Conditional attributes	Intellectual capital related elements	Human capital	(Cash paid to employees + Cash paid for employees + Difference between the end and the beginning of the payable period) / operating income
		Organizational capital	Management expenses/ Operating income
		Relational capital	Selling expenses/ Operating income
		Physical capital	The book value of net assets/ Operating income
	Influence factors	Enterprise scale	Natural logarithm of operating income
		Leverage	Total liabilities/ Shareholders' equity
		Length of establishment	2018- Establishment year
		Profitability	ROE
		Growth	Net profit growth rate= Net profit for the current year / Last year's net profit
		Economic area	East Region =1 Central Region=2 Western Region=3
Decision attribute	Corporate performance	Asset value-added rate	Value-added/Year-end assets

TABLE 4. Breakpoint set of attributes.

	Minimum point	Intermediate point	Maximum point
Human capital	-5.6549	-1.8325	0.1196
Organizational capital	-6.1192	-1.9324	-0.0772
Relational capital	-6.1658	-2.7952	-0.3371
Physical capital	-3.5267	0.5276	4.3689
Enterprise scale	7.5721	11.6983	17.129
Leverage	0.036	0.36	0.7945
Length of establishment	8	20	34
Profitability	-0.435	-0.0483	0.4499
Growth	-137.3769	-68.0793	41.8384
Economic area	East Region =1	Central Region=2	Western Region=3
Asset value-added rate	-0.3722	0.4669	1.4936

method. After all the samples were checked, a rule with a support level greater than 34, a confidence value higher than 89% and a coverage level greater than 15% were considered a qualified rule. Finally, 10 qualified rules were generated (TABLE 5).

For example, the first rule in TABLE 5 is a rule identified by seven attributes. When the company exhibits the following characteristics of a small scale, low leverage and location in the east area of China, then the company can achieve excellent corporate performance on the basis of high human, organisational, relational and physical capital investment. The support, confidence and coverage for Rule 1 are 46, 0.978723 and 0.264368, respectively. Thus, 46 samples support this rule. The coverage ratio is approximately 26.44% of the high-performance set, and the credibility of this rule is 0.978723.

C. STAGE 3: VERIFICATION OF RULE FORMATION

To test the applicability of the rules generated by the training set samples, test samples were chosen to verify these rules.

TABLE 5. List of the qualified rules of high-performance.

Rule NO.	IC elements				Influence factors						Support	Confidence	Coverage
	HC	OC	RC	PC	ES	LEV	LOE	PRO	GRO	EA			
1	High	High	High	High	Small	Low				1	46	0.264368	0.978723
2.	High	High	High	High	Small	Low		High		1	46	0.264368	0.978723
3	High	High	High	High		Low	Short			1	38	0.218391	0.974359
4	High	High	High	High	Small	Low	Short			1	34	0.195402	0.918919
5	High		High	High	Small	Low		High		1	46	0.264368	0.978723
6	High		High	High	Small	Low			High	1	46	0.264368	0.978723
7	High		High	High		Low	Short	High	High	1	40	0.229885	0.97561
8.	High	High	High		Small	Low	Short			1	35	0.201149	0.897436
9.		High	High	High	Small	Low	Short				34	0.195402	0.971429
10	High		High	High	Small	Low	Short				34	0.195402	0.971429

Table 4 presents the qualified rules of high-performance. HC is human capital, OC is organisational capital, RC is relational capital and PC is physical capital. ES is enterprise scale. LEV is leverage of each company. LOE is length of establishment where PRO is profitability. GRO is growth. EA is economic area of China and 1 denotes Eastern China.

After randomly dividing the full set, 108 test samples were obtained. Thirty-five samples among the obtained samples achieved high performance. In the high-performance group, 28 out of the 35 samples were identified as meeting the rules and the recognition rate was 0.8. On the contrary, in the low-performance group, 68 out of the 73 samples could not meet the rules, and thus led to low corporate performance.

Table 6 lists the verified results of test samples. The resulting rules cannot cover low-performance samples because the training set only checked the IC configuration that achieves high performance. The training set is therefore verified through the samples named, 'conform to the rules' and 'does not meet the rules'. The [0.4669, 1.4936] represents the high-performance group and [−0.3722, 0.4669] represents the low-performance group.

TABLE 6. Test sample confusion matrix.

Value interval	(0.4669, 1.4936]	[-0.3722, 0.4669]	Correct rate
Conform to the rules	28	5	0.85
Does not meet the rules	7	68	0.91
Correct rate	0.8	0.93	0.89

Among the samples that conformed to the rules, 28 samples could realise high corporate performance, 5 samples failed to achieve high performance and the correct rate is 0.85. Only 7 samples realised high corporate performance. The other 68 samples could not achieve high performance because the samples that did not meet the rules. Thus, the conclusions obtained in the training set can pass the test in the test samples.

D. STAGE 4: KNOWLEDGE USAGE

TABLE 7 shows the evaluation results of the effect of attribute level on corporate performance. Hit frequency means the total of each attribute and a high value means great importance. TABLE 7 shows leverage as the most critical influence factor, whereas growth is the least important. Relational capital is the most important form of intellectual capital investment. Human and material capitals follow in importance. By contrast, relational capital is not as vital.

TABLE 7. Evaluation of the effect of attribute level on corporate performance.

Factor categories	Attribute	Attribute effect evaluation	
		Hit frequency	Importance ranking
Influence factors	Enterprise scale	321	3
	Leverage	399	1
	Length of establishment	215	4
	Profitability	132	5
	Growth	86	6
	Economic area	331	2
Intellectual capital elements	Human capital	365	2
	Organizational capital	233	4
	Relational capital	399	1
	Physical capital	364	3

As shown in the first four rules in TABLE 5, sufficient investments should be made in all aspects of IC to achieve high corporate performance when the corporate environment presents similar characteristics. Furthermore, as listed in the last six rules in Table 5, investment needs to be made in three dimensions of IC.

In each rule, the scale of all corporations presents small-scale features. Specifically, leverage presents low features, a situation in which corporations rely more on investment from shareholders rather than from debt. All lengths of establishment exhibit short-time characteristics. Profitability and growth have high value. In addition, companies with high performance in each rule are mainly located in Eastern China.

VI. IMPLICATIONS FOR PRACTICE

The findings reported in this study can enhance practitioners' insights into IC dimension combination and firm performance, as well as provide guidance on effective IC combination decisions. Practitioners can use the results in the following ways:

1. Deep insight: Through theoretical analysis of the IC dimension interdependence on corporate performance by using the proposed theoretical framework, practitioners can deepen their understanding of how IC dimensions work and use IC to improve corporate performance. The realisation of excellent corporate performance cannot rely on a particular IC dimension but on the combination of IC dimensions. According to the different situations of enterprises, practitioners should select different kinds of IC combination method of IC dimensions to achieve corporate performance.

2. Combination guidance: Practitioners in the information technology industry in China will generate useful information on IC combination decision-making. With the results of ideal IC combination method, practitioners can combine IC dimensions more effectively instead of blindly investing resources in all aspects of IC or a single dimension, regardless of differences between firms, which will result in waste and inefficient use of resources. Besides, relational capital is a critical IC dimension of the information technology industry in China, which should receive more attention. Leverage, which is the most important enterprise factor, should be noticed when firms make their IC combination decisions.

VII. CONCLUSION

As the growth engine of China, the development of the information technology industry receives attention from the whole society. However, how China's information technology industry can effectively allocate IC resources with limitations to improve corporate performance needs further theoretical and empirical study. Consequently, lack of this knowledge will cause enterprises to distribute IC blindly and lose corporate performance and competitiveness.

In this study, the following two problems have been addressed. How can IC dimensions improve corporate performance theoretically? Which kind of method for combining IC dimension can practically achieve high corporate performance? To address these two questions, firstly, a universal theoretical framework is proposed to illustrate the way IC dimensions can enhance corporate performance from stakeholder perspective. The findings show that IC dimensions work in combination rather than isolation. The combination can affect corporate performance. Under diversified corporate situation, corporate performance can be achieved by different IC combination methods. Then, under different firm situation, ideal IC combination methods are empirically explored by applying a rough set method using an illustrated application of information technology companies in China from 2015 to 2017.

Theoretically, this article contributes to the knowledge of IC management theory by illustrating the internal logic between IC dimensions and corporate performance based on the theoretical framework analysis from stakeholder perspective. In addition, the rough set method is introduced to IC empirical research to explore high-performance IC combination methods. The third and fourth stages of IC research are extended by the theoretical and empirical analysis. Through theoretical analysis, practitioners will derive in-depth insight into the importance of IC combination method to improve corporate performance. Through empirical analysis, practitioners can combine IC dimensions more effectively to achieve sound corporate performance.

Like any empirical investigation, this study has limitations. The results of this empirical study are only applicable to the information technology industry in China. No guarantee can be assured on whether the results can be extended to other industries or countries. Additionally, this study only uses sample data from 2015 to 2017 and does not focus on an extended period. Future studies should pay more attention to samples obtained from diversified situations.

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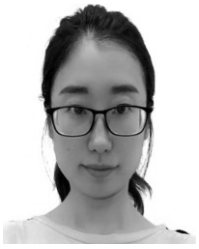
WEIDONG ZHU received the Ph.D. degree in management science and engineering from the Hefei University of Technology. He is currently a Professor with the School of Economics, Hefei University of Technology, where he is also a Doctoral Supervisor with the School of Management. His research interests include value-added accounting, decision support systems, accounting information, and decision making.

XIAOYA DAI is currently pursuing the Ph.D. degree with the School of Management, Hefei University of Technology. Her research interests include intellectual capital, finance and accounting, and value-added accounting.

XUE HU is currently pursuing the Ph.D. degree with the School of Management, Hefei University of Technology. Her research interests include finance and accounting, and value-added accounting.



YUFEI TIAN is currently pursuing the Ph.D. degree with the School of Management, Hefei University of Technology. Her research interests include finance and accounting, and value-added accounting.

ZHANG CHAO received the Ph.D. degree in management from the Hefei University of Technology. He is currently holding a postdoctoral position with the School of Management, Hefei University of Technology. His research interests include decision making, decision support systems, finance and accounting, and value-added accounting.