Intangible assets evaluation: The machine learning perspective

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ABSTRACT

The lack of regulations and disclosures regarding intangible capital has made it rather difficult for investors and creditors to evaluate a firm's intangible value before making the associated investment and loan decisions. This study represents an initial attempt to compare/contrast different types of machine learning techniques and identify the optimal prediction model for intangible assets. In addition, this paper shows that machine learning can be used effectively for the problem of intangible assets evaluation. To be specific, five classification algorithms are considered: decision trees (DT), artificial neural networks (ANN), naïve Bayes, support vector machines (SVM) and k-Nearest Neighbors (k-NN). Consequently, thirty prediction models are constructed for comparison, including five single classifiers, boosting and bagging based classifier ensembles, and the combination of k-means clustering, single classifiers and classifier ensembles. The experimental results show that prediction models combining k-means with boosting/bagging based classifier ensembles perform much better than the other methods in terms of prediction accuracy, ROC Curve, as well as Type I and II errors. In particular, while the best single classifier, k-NN provides 78.24% prediction accuracy, k-means+bagging based DT ensembles provide the best performance to predict intangible assets with a prediction accuracy of 91.60%, 96.40% of ROC Curve and 18.65% of Type I and 6.34% of II errors, respectively.

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1. Introduction

In the knowledge-based economy era, companies have to pay attention to the capability and efficiency for the creation, expansion, and application of knowledge [31]. The primary method available for creating firm value has changed from traditionally physical production factors to intangible knowledge. Given this fact, a large part of a firm's value may be reflected in its intangible assets. However, financial reporting cannot adequately reflect intangible asset value, because of fewer regulations and less disclosure in the area of intangible capital and creates an information gap between insiders and outsiders [59]. In order to provide other useful information different from financial statements for investors or creditors to measure the firm's value in investment opportunities or loans, and also to assist them make more accurate decisions more effectively, it is important to build a more effective and reliable intangible assets value evaluation or prediction model.

Related studies in many business domains have shown that machine learning techniques, such as neural networks and support vector machines, are superior to traditional statistical methods. They can be used to discover interesting patterns or relationships from a given dataset and predict or classify new unknown instances [13,28,7]. Therefore, the aim of this study is to examine the performances of single classification, classifier ensembles, and hybrid classifiers techniques in terms of intangible assets prediction. Specifically, five well-known classification techniques, including multilayer perceptron (MLP) [26], decision trees (DT) [47], naïve Bayes [4], support vector machines (SVM) [58], and k-Nearest Neighbor (k-NN) [14] methods are employed to develop the prediction models.

Since economic development has become more dependent on intangible assets, it is important to investigate the role of intangible assets in terms of a firm's market-based value. For this reason, the contribution of this study is two-fold. Firstly, this research represents an initial attempt to employ several different data mining techniques including single classifier, hybrid classifiers, and classifier ensembles to identify the optimal prediction model for evaluating intangible assets. From the technical point of view, the performance of these

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techniques has not been fully assessed in the domain of intangible assets evaluation. Otherwise, many prior researches have examined the impact of different factors in developed countries [19,36], but they did not consider the extent to which the degree of various factors affects intangible assets in emerging countries. As [39] indicate that the capital markets are less developed and ownership concentration is higher in the emerging market, these researches for firms head-quartered in emerging countries could offer different results for the relationship between various factors and intangible assets. Emerging markets are attention of the whole world since their current high growth rates and potentials for the future. Taiwan is one of those emerging countries with its fast growing economy. Thus, this study extends the prior work by examining the impact of different factors on intangible assets in the emerging market context.

Secondly, in practice, since fewer regulations and less disclosure of intangible capital is the norm, financial reporting cannot actually be utilized to reflect the value of intangible assets or recognize intangibles. The issue of recognizing intangible assets is the subject of active debate in the current literature from the conventional statistical point-of-view [3,29]. This study applies data mining technology and demonstrates that it can be used effectively to evaluate intangible assets as well as provide additional information which is not ever disclosed in financial statements. Due to the lack of regulations about recognizing intangible assets, outsiders cannot use financial statements alone to accurately assess the market-based value of a firm prior to making decisions for new investment in general, or evaluate initial public offerings (IPO) firms in particular. This study will help investors and creditors to better evaluate the potential of new investment or lending opportunities, and also assist them to make the relevant decisions more precisely.

The remainder of this paper is organized as follows. Section 2 reviews related studies about intangible assets. Section 3 describes the experimental methodology, and experimental results are presented in Section 4. Finally, in Section 5 some conclusions are offered and their implications.

2. Intangible assets

2.1. Definition

The term "applications of knowledge and information technology" indicates one of the key driving forces that has triggered dramatic changes in/to the operational structure of various companies. These changes, in conjunction with increased customer demands, are constantly challenging companies to shift their attention from tangible to intangible resources. These intangible assets have always played a limited role in the past, and now their systematic handling is seen as being an essential factor for competitiveness [18].

Intangible assets including knowledge, information, intellectual property, and experience represent future growth opportunities and important profitability considerations, which are critical to increasing the market-based value of a firm. Actually, intangible assets have prevailed as measures of core competency and competitive advantage, which can be used to explain the gap between the market-based value and book value of an organization at a time of decreasing usefulness of current financial reporting [25]. As a result, many researchers are interested in describing the structure of intangible assets and are trying their best to define the main component that affects market value. There is, however, no uniformity to addressing this problem in the research environment, although a more generic understanding of the composition of intangible assets is becoming apparent.

Intangible assets and tangible assets must be combined to create the true firm market value. However, the value created by intangible assets is harder to determine than the value of tangible assets since the fewer regulations and disclosure requirements

exist for intangible capital [9]. Therefore, many corporates tend to provide additional information regarding intangible assets on a voluntary basis [8,57]. It is important to build an intangible asset prediction model to provide additional information different from what is available on financial statements for investors or creditors to evaluate investment opportunities or loans, and help them make more effective investment decisions.

2.2. Determiners of intangible assets

According to previous studies, determinants of intangible assets can be classified into several categories, including intangible capital, ownership structure, firm characteristics, industry characteristics and reactions of analysts and customers. In this paper, the most critical factors (i.e. variables or features) for intangible assets found in the study of [56] are employed. A summary of the information is provided in Table 1 shown below.

[34] proved that advertising and R&D stock are statistically significant determinants of a firm's intangible assets. In empirical studies, [48] and [23] showed that innovation and brand loyalty are viewed as investments that can increase a firm's intangible assets and have predictably positive effects on future cash flow and intangible assets. Many related studies indicate that in emerging countries, corporate ownership is tightly manipulated by the controlling shareholders who are family controlling shareholders especially. In this situation, the agency conflict exists between controlling shareholders and minority shareholders and result in severe degradation of the value of intangible assets. [12,38,5].

From another angle, a firm's intangible asset value may be affected directly or indirectly by factors related to the nature of the firm. These natures include the growth in sales revenue, firm size, leverage of firm, pay a dividend, profitability of firm, firm age and multinationality [22,23,33,36,5,56]. In addition to the firm's characteristics, different natures of various industries will certainly affect its intangible assets value. In the knowledge-intensive industries (e.g., high-technology industries) knowledge and innovation are the dominant resources, far more important than physical assets.

Finally, according to the marketing theory (e.g., Heisenberg Uncertainty Principle of Marketing), the more a marketer of a firm understands about why and how a consumer behaves (the decision making process in general and the purchase decision or indecision in

Table 1
The determinants of intangible assets.

Category	Variables	Reference
Intangible capital		
	R&D INTENSITY	[34], [48], [23], [22].
	ADVERTISING INTENSITY	[34], [48], [23], [22].
Ownership structure		
	FAMILY	[62], [38].
	CASH FLOW RIGHT	[62], [12], [38], [5].
	BUSINESS GROUP	[62].
Firm characteristics		
	SALE GROWTH	[62], [33], [5], [22].
	SIZE	[33], [23], [5], [22].
	LEVERAGE	[2], [41], [5], [22].
	DIVIDEND	[2].
	PROFITABILITY	[2], [37], [48], [5].
	AGE	[62], [12], [48], [5].
	EXPORT	[2], [5].
Industry characteristics		
	INDUSTRY	[34], [46], [37].
Reactions of analysts and customers		
	MARKET SHARE	[1], [5], [43].