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Abstract

Purpose – The purpose of this paper is to explore whether intellectual capital affects the probability that a particular firm will default. The authors also test whether including intellectual capital performance in bankruptcy prediction models improves their predictive ability.

Design/methodology/approach – Using a sample of US public companies from the period stretching from 1985 to 2015, the authors test whether intellectual capital performance reduces the probability of bankruptcy. The authors use the VAIC as an aggregate measure of corporate intellectual capital performance.

Findings – The findings show that the intellectual capital performance is negatively associated with the probability of default. The findings also indicate that the bankruptcy prediction models that include intellectual capital have a superior predictive ability over the standard models.

Research limitations/implications – This paper contributes to prior research on intellectual capital and firm performance. To the best of the knowledge, this is the first study to show that the benefits of intellectual capital extend from superior performance to long-term financial stability. The research can also contribute to bankruptcy studies. By using a time frame covering decades, the findings suggest that intellectual capital performance measures can be included in bankruptcy prediction models and can effectively complement traditional performance measures.

Originality/value – This paper highlights that intellectual capital is associated with long-term financial stability and a lower bankruptcy risk. Firms realising the potential of their intellectual capital can produce a virtuous circle between higher performance and greater financial stability.

Keywords Performance, VAIC, Intellectual capital, Bankruptcy prediction

Paper type Research paper

1. Introduction

This paper explores whether a firm's intellectual capital performance reduces the probability of default and can help to predict bankruptcy. In a knowledge-based economy, intellectual capital plays a crucial role when it comes to increasing a firm's competitiveness and performance (Lev, 2000; Seetharaman *et al.*, 2002; Massaro *et al.*, 2015). Several studies show that intellectual capital has a positive impact on a firm's financial performance and market value and that they could be considered an indicator of future financial performance (e.g. Bontis, 1998; Pew Tan *et al.*, 2007; Cabrita and Bontis, 2008; Zéghal and Maaloul, 2010; Clarke *et al.*, 2011; Dženopoljac *et al.*, 2016).

Recent research suggests that intellectual capital can also have a relevant impact on a firm's long-term financial health and credit rating (Guimón, 2005). In this respect, bankruptcy studies acknowledge but do not investigate the relevance of intellectual capital. Most of the accounting-based bankruptcy prediction models have not been changed since decades. Recent studies suggest that these models can be improved to properly take into account the intellectual capital, which is crucial to nowadays economy (Beaver *et al.*, 2005; Lev and Gu, 2016).

Nonetheless, to the best of the authors' knowledge, no prior studies have investigated whether intellectual capital affects a firm's long-term financial stability or its probability of default. This paper aims to fill this research gap. Filling this gap through this investigation is relevant in the management's perspective. Proper management of intellectual capital could help firms to achieve a higher credit rating, lower the cost of debt, boost performance and increase market value (Dumay and Tull, 2007).

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More broadly, the use of intellectual capital indicators to predict default could help to reduce the likelihood of misclassifying bankrupt firms as ones that are healthy. This error causes the misallocation of financial resources, economic value destruction, job losses and overall negative social consequences (Berk *et al.*, 2010). Considering intellectual capital in bankruptcy prediction can help to allocate financial resources to firms that manage their intellectual capital and invest it properly. Such firms drive economic and social growth in contemporaneous knowledge-based economies.

This research uses a sample of US public companies from the period stretching from 1985 to 2015 and make use of the VAIC as an aggregate measure of corporate intellectual capital performance (Pulic, 2000). The VAIC can be calculated using publicly available financial statements. It is built on measures that are based on commonly accepted accounting standards and audited by external auditors for every company. Thus, it is suitable for studies about bankruptcy, requiring very large samples and comparable data.

The authors hypothesise and find that the intellectual capital performance is negatively associated with the probability of default, measured using Ohlson's (1980) model and Altman's *Z*-score. Therefore, firms with lower intellectual capital performance display a higher probability of bankruptcy. The authors also evaluate the model in terms of accuracy using a table classification approach and an ROC (receiver operating characteristic) curve to assess whether the intellectual capital indicator improves the model's predictive ability. The findings support the hypothesis that the bankruptcy prediction model with intellectual capital proxy has a superior predictive ability over other standard bankruptcy prediction models.

This paper contributes to prior research on intellectual capital and firm performance. To the best of the authors' knowledge, this is the first study to show how intellectual capital can play a key role in the assessment of a firm's future solvency and long-lasting value creation. This research suggests that firms realising the potential of their intellectual capital can produce a virtuous circle between higher performance and greater financial stability. Besides its theoretical implications, this paper provides an empirical contribution to the literature on intellectual capital and firm performance and value. Unlike prior research using shorter periods, this paper uses 30 years of US data covering the entire time frame starting from when firms began attempting to manage intellectual capital for value creation (Sveiby and Risling, 1986; Zambon, 2003). This long time frame also allows significantly robust bankruptcy prediction (Altman *et al.*, 2010).

This research can also contribute to bankruptcy studies. Measures of intellectual capital are often neglected in financial analysis and credit scoring. The findings suggest that intellectual capital performance measures effectively complement traditional performance measures and improve bankruptcy prediction models.

This study can have relevant practical implications for banks, investors and analysts interested in bankruptcy prediction. New explanatory variables related to a firm's intellectual capital help to avoid the misclassification of bankruptcy firms as "healthy." Improving bankruptcy prediction helps to allocate financial resources and rewards healthy and profitable firms for properly managing and investing their intellectual capital.

The remainder of the paper is organised as follows: Section 2 includes the literature review, while Section 3 develops the research hypotheses. Section 4 explains the research methodology, and Section 5 shows the empirical findings. Section 6 discusses the findings and present the conclusions.

2. Literature review

2.1 Intellectual capital literature

The resource-based theory of the firm suggests that firms can be seen as a unique bundle of dynamic, complex, and intangible resources (Penrose, 1959; Wernerfelt, 1984; Barney, 1991).

This set of physical and intangible assets is at the core of the firm's competitive advantage (Grant, 1991). Intellectual capital is seen as a key resource for value creation (Bontis, 2001; Sveiby, 2001).

Prior research suggests that three basic dimensions of intellectual capital can be distinguished: human capital, structural capital and relational capital (Sveiby, 1997; Bontis, 1998). Human capital includes experience, knowledge and employee capabilities. It is essential for innovation and strategic renewal aimed at achieving future profits (Bontis *et al.*, 2000). Relational capital includes relationships with customers and suppliers, as well as reputation and corporate image. Structural capital consists of internal company organisational processes and routines, systems, databases and a corporate culture that support business. "Structural capital arises from processes and organisational value, reflecting the external and internal foci of the company, plus renewal and development value for the future" (Bontis *et al.*, 2000, p. 5).

Most scholars acknowledge that intellectual capital has played an increasingly important role in creating long-term corporate competitive advantage and superior financial performance (Lev, 2000; Kaplan and Norton, 2004). In contemporary economies, intellectual capital is in fact the primary factor responsible for generating new products and services, new technologies and new strategic resources overall (Michalisin *et al.*, 2000; Riahi-Belkaoui, 2003).

A stream of studies within the intellectual capital field empirically investigates whether intellectual capital is associated with firms' current and future financial performance (Chen *et al.*, 2005; Tseng and James Goo, 2005; Wang, 2008). Chen *et al.* (2005) investigate a sample of Taiwanese firms. Using VAIC as a proxy for intellectual capital performance, they find that intellectual capital has a positive relationship with both current and future financial performance. This result is further confirmed by a positive relationship with market values, as investors correctly expected superior future performances from firms realising the potential of their intellectual capital to make profits (Lev, 2000; Wang, 2008).

Riahi-Belkaoui (2003), using a sample of 81 US multinational firms, finds a positive relationship between intellectual capital and financial performance. In a similar vein, Pew Tan *et al.* (2007) investigate a sample of companies listed on Singapore's stock exchange by using the VAIC model. They find a significant positive relationship between intellectual capital and both current and future performance. Massaro *et al.* (2015) find that relational, human and structural capital support the firm's performance measured in terms of product and service diversification. Finally, Dženopoljac *et al.* (2016) find that intellectual capital has a significant effect on financial performance in the ICT industry.

2.2 Bankruptcy prediction studies

In recent years, especially after the global financial crisis, bankruptcy prediction has received increased attention from researchers, analysts and financial institutions. Bankruptcy prediction models are typically built by using accounting ratios from the financial statements (Altman, 1968; Ohlson, 1980; Altman and Sabato, 2007). The classic study by Altman (1968) uses discriminant analysis and financial ratios to predict the insolvency. Specifically, he uses ratios like working capital on total assets, retained earnings on total assets, EBIT on total assets, market value of equity on total debt, sales on total assets. Ohlson (1980) introduces the use of logistic regression and finds that high debt, low liquidity and low profitability increase the probability of default.

Recent researches highlight that the traditional bankruptcy prediction models can be improved, also taking into account also qualitative and non-financial information (Laitinen, 1999; Beaver *et al.*, 2005; Balcaen and Ooghe, 2006). Laitinen (1999) analyses a sample of Finnish companies using several financial and non-financial factors to predict failure. The author finds that factors related to higher bankruptcy prediction are: the number of executives and in the

board, the total number of directors in the board, the directors' personal wealth and personal debt, the relationship with other financially distressed companies, and the firm's "payment history" (e.g. bad debts, number of delayed payments).

Chava and Jarrow (2004) analyse the relationship between industry effect and predictive ability of bankruptcy models. Dividing their sample into three groups, basing on the SIC code (excluding financial firms), they show that the industry dummies have a significant association with financial variables used in the predictive model (e.g profitability ratio and leverage variables). These results suggest that the bankruptcy probability is strongly influenced by industry and can significantly differ for firms in different sectors. More specifically, the likelihood of bankruptcy is associated to lower profitability for manufacturing firms. The likelihood of bankruptcy is associated to higher debt for mining mining and raw material firms.

Finally, Altman *et al.* (2010) explore bankruptcy prediction in a sample of small and medium size firms and examine the role of several qualitative and non-financial factors, including the firm age, the firm size and the auditor's opinion. They find that older and larger firms have lower probability of default. Older firms have gone through learning process for longer periods of time, increasing the probabilities of survival and growth. This might suggest that intellectual capital resources are higher in mature firms and can contribute to reduce the likelihood of default (Pena, 2002).

3. Hypotheses development

According to the resource-based view of the firm, intellectual capital is a strategic asset capable of generating long-term competitive advantage and superior financial performance (Riahi-Belkaoui, 2003; Dženopoljac *et al.*, 2016). Intellectual capital is hardly imitable, is often not even observed and measured in the firm. It cannot be separated and sold. It is thus a type of resource not available in the market.

Once acquired, firms can combine intellectual capital with tangible resources to obtain long-term sustainable competitive advantage (Zambon, 2003). That is, firms with innovative knowledge can register patents creating entry barriers; firms with relational capital can deliver customised quality services (as intangible component of the product), ensuring differentiation advantage (Grant, 1991). The barrier to imitation of resources, especially those intangibles, creates the premise for long-term superior performance and resilience to environmental changes. Prior research finds empirical evidence that intellectual capital is associated to superior financial performance (Riahi-Belkaoui, 2003; Massaro *et al.*, 2015; Dženopoljac *et al.*, 2016).

Moving from the linkage between intellectual capital and financial performance, recent studies are exploring whether intellectual capital affects a firm's financial health and solvency. Sriram (2008) explains that "long-term financial stability depends not only on the ability to raise equity but also on the ability to effectively and efficiently manage a firm's assets – tangible as well as intangible assets". Investors evaluate long-term value by assessing growth in revenues, profits and the repayment of debt, among others. Financial stability and the timely repayment of debt can result in a reduced credit risk desirable by both investors and lenders because a lower cost of debt can further boost profits and overall value creation in the long term. Therefore, it is relevant to analyse whether intellectual capital contributes to a firm's financial health.

Guimón (2005) investigates whether intellectual capital reporting has an impact on credit risk. He suggests that intellectual capital reports disclose information about a firm's competitiveness that banks and financial institutions take into account during their credit risk analyses. This information can help firms receive higher credit ratings and thus have a lower cost of debt. Extra information about intangibles is meaningful to credit decisions (Catasús and Grojer, 2003).

Using a sample of US firms, Sriram (2008) finds that the information about intangible assets improves financial health evaluation by external investors and lenders. Focussing on a sample of German SMEs, Alwert *et al.* (2009) test the impact of intellectual capital reporting on credit risk analysis. They find that intellectual capital reports provide information that is useful for a credit rating. Their research suggests that integrating financial data with intellectual capital indicators could improve rating reliability and allow firms to lower their cost of debt. In a similar vein, Iazzolino and Laise (2013) suggest the non-financial indicators of intellectual capital can be used to improved credit scoring models based on multiple discriminant analysis.

Overall, the abovementioned studies suggest that intellectual capital is an indicator of future financial performance and has the potential to ensure greater long-term financial health. Based on these arguments, this research suggest that investors and lenders prefer to allocate their resources to firms fully realising their intellectual capital potential because they have a greater ability to generate future profits and repay their debts. If such firms are awarded with long-term financial stability, they would be in a better position to create long-term value and should display lower probabilities of bankruptcy. The following hypothesis is formulated:

H1. Intellectual capital is associated with a lower probability of bankruptcy.

Accounting-based bankruptcy prediction literature acknowledges the importance of intellectual capital but does not investigate it. Recent studies highlight the opportunity to improve accounting-based prediction models taking into consideration the firm's intellectual capital (Beaver, 2005). In a similar vein, Lev and Zarowin (1999) argue that traditional financial ratios fail to reflect enterprise value and performance, as highlighted by the decreasing value relevance and usefulness for investors of reported earnings. Lev and Gu (2016) report on the declining relevance of financial documents with respect to investors' decisions; according to them, the relevance that is lost relates to the "surge" in intellectual capital.

Financial reporting users are becoming increasingly aware of the financial statements' weakness in displaying the firm's value creation process through reported earnings. Amir *et al.* (2003) report that financial analysts compensate for information deficiencies by adjusting their forecasts for intangible-intensive companies, assuming intellectual capital is not reflected in financial reports. Nevertheless, they suggest that financial analysts do not compensate for all the information deficiencies.

Sougiannis (2015) finds that market participants increasingly value intangible corporate assets such as employee satisfaction, firm reputation and celebrity status because they are associated with future earnings. Yosano and Koga (2008) report that Japanese financial institutions are paying increasing attention to intellectual capital non-financial indicators, specially for small and medium-sized firms. The authors also suggest that these indicators are often directly gathered by financial institutions and impact on credit conditions.

The abovementioned studies suggest that the inclusion of intellectual capital measures can help develop better models to predict the firm's probability of a future default. Importantly, it can help reduce the misclassification of bankrupt firms as healthy firms and make the allocation of financial resources more efficient. The misallocation of financial resources causes value destruction, job losses and a wide range of negative social consequences. More consideration of intellectual capital in bankruptcy prediction can reward firms that manage and invest their intellectual capital with a higher credit rating. Poor or no consideration could disadvantage intellectual capital – intensive firms that drive economic and social growth in contemporaneous knowledge-based economies.

In this paper, the authors hypothesise that intellectual capital proxies will improve the predictive ability of the accounting-based bankruptcy prediction model. The following hypothesis is formulated:

H2. Including an intellectual capital measure in bankruptcy prediction models improves their predictive ability.

4. Research methodology

4.1 Sample description

The empirical analysis uses data obtained from the Compustat North America database. The authors first downloaded the financial statements data for active and inactive US firms available on Compustat North America. Then, the authors merged these data with bankruptcy information gathered from CRSP, which provides information about the reasons for a firm's delisting. The initial sample consisted of 307,994 firm-year observations during the 1985-2015 period. After excluding the firm-year observations without complete data to calculate the VAIC and other control variables, a final sample of 28,915 firm-year observations is obtained.

4.2 Regression model and variables used in the research

This research uses Ohlson's (1980) model in the main analyses and Altman's Z-score in the robustness checks to study the relationship between intellectual capital and bankruptcy prediction. The following model is used:

$$\text{Bankruptcy} = \beta_0 \times \text{intercept} + \beta_x \times (\text{Intellectual Capital}) + \beta_z \times (\text{Financial Ratios}) + \beta_l \times (\text{Controls}) + \varepsilon$$

Since the bankruptcy prediction equation's explanatory variables are neither linear nor normally distributed (Ohlson, 1980), this paper uses the logistic regression (the logit model), where the dependent variable is binary; 1 if the firm is bankrupt, and 0 otherwise.

The main goal of this research is to analyse the relationship between the efficient use of intellectual capital and the probability of bankruptcy. This study uses the value-added intellectual coefficient that Pulic (2004) suggests to measure the contribution of intellectual capital to value creation. The higher the intellectual capital performance is, the lower the probabilities of a firm's bankruptcy will be.

Zambon (2003) classifies intellectual capital measurement methods following two dichotomies: atomistic orientation vs holistic orientation; monetary vs non-monetary measurement. The first dichotomy refers to the attitude of the measurement method to measure an individual intangible compared to the measurement or representation of the whole intellectual capital available to an organisation. The VAIC is classified as monetary holistic method[1]. The theoretical roots of monetary holistic methods are in the resource-based view of the firm, which acknowledges a key importance to the contribution of intangibles, knowledge and learning processes in the value creation (Wright *et al.*, 2001; Villalonga, 2004). The VAIC is among the models born in the 1990s to evaluate the firm's performance highlighting the contribution of intellectual capital "invisible factors linked to non-financial dimensions" (Zambon, 2003, p. 157).

The VAIC has been widely utilised in empirical research as a measure of intellectual capital performance (Chen *et al.*, 2005; Nazari and Herremans, 2007; Pew Tan *et al.*, 2007; Laing *et al.*, 2010; Greco *et al.*, 2014). Some studies highlight limitations of the VAIC (Maditinos *et al.*, 2011; Ståhle *et al.*, 2011), including: it is based on financial reports, indicators of past strategy; it does not take into account the synergies among its various components; it does not take into account the holistic aspect of IC. Despite these criticisms, the VAIC has become widely accepted in the academic and professional community

as a valuable indicator of intellectual capital performance (Zéghal and Maaloul, 2010; Dženopoljac *et al.*, 2016).

Recent literature highlights that most of the criticism levelled at the VAIC derives from a misunderstanding of Pulic's original idea (Iazzolino and Laise, 2013). Pulic's VAIC maintains its logical coherence and validity when it is correctly interpreted as an indicator of the contribution of intellectual capital to value creation. The VAIC should not be used as a proxy for the "stock" (or the value) of the intellectual capital that the firm has amassed nor for the complex set of characteristics of the firm's intangible resources, e.g. capabilities, skills etc. (Iazzolino and Laise, 2013, p. 552).

Using the VAIC for this research has several advantages. First, reliable bankruptcy prediction requires very large samples and comparable data. Because it is based on publicly available financial statements, the VAIC is built on measures mandatorily based on commonly accepted accounting standards and audited by eternal auditors for every company. Intellectual capital reports are not available for every company; furthermore, they offer non-comparable performance measures and are often unaudited. Hence, intellectual capital reports still appear to be unfit for bankruptcy prediction.

Pulic (2004) defined the VAIC as a measure of the value added (VA) by a firm's human capital efficiency (HCE), structural capital efficiency (SCE) and capital employed resources (CEE). The starting point to calculate the VAIC is to compute the VA. VA is the sum of operating profit (OP), employee costs (EC), depreciation expenses (DP) and amortisation expenses (AM):

$$\mathrm{VA} = \mathrm{OP} + \mathrm{EC} + \mathrm{DP} + \mathrm{AM}$$

The first component of the VAIC determines the firm's HCE, which is computed as follows:

$$\mathrm{HCE} = \mathrm{VA}/\mathrm{HC}$$

In the formula above, HC refers to employees' wages and salaries. HCE captures the contribution of human resources to the creation of valued added. SCE captures those elements of the company that positively affect the employees' productivity, e.g. software and hardware, trademark, patents and other assets (Dženopoljac *et al.*, 2016). SCE is obtained as follows:

$$\mathrm{SCE} = \mathrm{SC}/\mathrm{VA}$$

SC is the structural capital obtained by subtracting HC costs from VA. Thus, SC considers all the value created besides the contribution of the human resources. IC efficiency is the sum of HC and SC efficiencies:

$$\mathrm{ICE} = \mathrm{HCE} + \mathrm{SCE}$$

The last component of the VAIC is the CEE or efficiency of the physical and financial capital used in the company, which is the ratio between VA and net assets (capital employed (CE)):

$$\mathrm{CEE} = \mathrm{VA}/\mathrm{CE}$$

The VAIC is the sum of ICE and CEE. It measures the firm's total efficiency using IC, physical and financial capital (Pulic, 2008). "In other words, the VAIC approach focusses on determining the relative contribution of IC, physical and financial capital to the creation of value" (Dženopoljac *et al.*, 2016, p. 381):

$$\mathrm{VAIC} = \mathrm{CEE} + \mathrm{HCE} + \mathrm{SCE}$$

In the model, the authors include the most common financial ratios that bankruptcy studies use (Bellovary *et al.*, 2007; Altman *et al.*, 2010). The return on equity (ROE) as a measure of profitability is included. As indicators of liquidity, the authors include the working capital

on total assets (WC_TA), the current liabilities on total assets (CA_TA), the cash on total assets (Cash_TA) and the retained earnings on total assets (RE_TA). The authors also include the firm's leverage (LEVERAGE), which is measured as the financial debt on total assets. Finally, the authors control for industry effects (using the first two digit of the SIC code) and time effects (with year dummies).

5. Empirical findings

5.1 Descriptive statistics

Table I displays the descriptive statistics for the explanatory variables used in our analysis. Panel A provides the descriptive statistics for non-bankrupt firms, Panel B shows the descriptive statistics for bankrupt firms, while Panel C reports the summary statistics for the full sample.

Bankrupt firm-year observations comprise 1.4 per cent of the total observations. The average VAIC for the full sample is 2.020 and ranges from −1.55 to 6.40. The average VAIC for bankrupt firms is 1.736, whereas for non-bankrupt firms it is 2.025. The average ROE for the full sample is 6.5 per cent. Bankrupt firms have an average ROE of 1.8 per cent, whereas for non-bankrupt firms it is similar to the full sample mean. Bankrupt firms also appear to be

Variables	*N*	Mean	SD	Min.	Max.
Panel A – descriptive statistics for non-bankrupt firms					
VAIC	28,511	2.024696	1.739861	−1.559879	6.403979
ROE	28,511	0.0661691	0.3907932	−0.6608902	0.9625989
WC_TA	28,511	0.1193418	0.1830714	−0.0769043	0.5836974
Leverage	28,511	0.5151226	0.2109145	0.1738059	0.8856779
RE_TA	28,511	−0.3554471	0.8400896	−2.343655	0.3672223
CL_TA	28,511	0.2330242	0.1312357	0.085384	0.5389051
Cash_TA	28,511	0.084963	0.0986629	0.0047989	0.3293127
Panel B – descriptive statistics for bankrupt firms					
VAIC	404	1.736202	1.352806	−1.509405	5.796622
ROE	404	0.0180221	0.528531	−0.6608902	0.9625989
WC_TA	404	0.1149747	0.1952109	−0.0769043	0.5836974
Leverage	404	0.5942427	0.22607	0.1738059	0.8856779
RE_TA	404	−0.466448	0.7967582	−2.343655	0.3672223
CL_TA	404	0.3102009	0.1448428	0.085384	0.5389051
Cash_TA	404	0.0741133	0.0902174	0.0047989	0.3293127
Panel C – descriptive statistics for full sample					
VAIC	28,915	2.020665	1.73536	−1.559879	6.403979
ROE	28,915	0.0654964	0.3930787	−0.6608902	0.9625989
WC_TA	28,915	0.1192808	0.1832437	−0.0769043	0.5836974
Leverage	28,915	0.5162281	0.2113337	0.1738059	0.8856779
RE_TA	28,915	−0.356998	0.8395876	−2.343655	0.3672223
CL_TA	28,915	0.2341025	0.1317445	0.085384	0.5389051
Cash_TA	28,915	0.0848114	0.0985567	0.0047989	0.3293127

Notes: This table shows descriptive statistics of the variables included in the model, as specified in Equation (1). The sample period stretches from 1 January 1985 to 31 December 2015. The intellectual capital measure ("VAIC") and its components ("CEE", "HCE" and "SCE") are calculated following Pulic. Financial ratios are calculated from annual data. Return on equity (ROE) is measured as the net income on ordinary equity. WC_TA is measured as working capital divided by total assets. Debt ratio (LEVERAGE) is computed as total liabilities on total assets. RE_TA is measured as retained earnings on total assets. CL_TA is measured as current liabilities deflated by total assets. Cash_TA is measured as cash on total assets. SCORE is a dummy variable that assumes the value 1 if the firm is bankrupt and 0 otherwise. Details on the variable definition and construction are contained in Section 3.2

Table I.
Descriptive statistics

more indebted: The average leverage is 0.59 vs the non-bankrupt mean leverage of 0.51. Higher debt also appears in the short-term liabilities. The current liabilities of bankrupt firms are worth 31 per cent of the total assets (0.31) vs 23 per cent of non-bankrupt firms.

5.2 Univariate analysis

Table II displays the Spearman correlation analysis. The dummy identifying bankrupt firms (SCORE) has a negative significant association with the VAIC and two of its components: the HCE and the SCE. Also, it has negative significant associations with the ROE, retained earnings (RE) and with the firm's cash (CASH). The VAIC has a positive significant association with the ROE and RE. The latter result indicates that the VAIC is strongly positively associated with the accumulated earnings produced by the firms (correlation coefficient 0.63 with p-value < 0.05), which potentially increases the firm's financial stability and reduces the likelihood of insolvency.

5.3 Multivariate analysis

Table III displays the main analyses (logit models), including industry and time fixed effects. Across the models, the maximum VIF is below 3.

Model 1 displays the regression of the bankruptcy-dependent variable (SCORE) on the VAIC plus the control variables. The VAIC has a negative, highly significant association with bankruptcy (coefficient significant at the 1 per cent level). This result suggests that firms with higher intellectual capital performance shows a significantly lower probability of going bankrupt. These findings provide support for *H1*.

The correlation coefficient signs of the control variables are in the expected direction. The ROE has a significantly negative association with bankruptcy. The current liabilities (CL_TA) have a positive significant association with the likelihood of going bankrupt, whilst firms with higher retained earnings (RE_TA) are less likely to fail. The working capital (WC_TA) has a positive association with the probability of default. Firms with solvency problems may have an abnormal working capital. This could be related to factors like i.e. excessive stocks accumulated due to dwindling sales or to the inability to collect receivables from customers. Such expansion of the working capital lowers the operating cash flow impairing the ability to repay debts.

The analysis is replicated using each component of the VAIC as an independent variable. In Table III, Model 2, the HCE has a negative significant association with bankruptcy (coefficient significant at the 1 per cent level). The higher the HCE, the lower the probability of going bankrupt. By contrast, low HCE (e.g. below 1) means the VA does not cover wages and salary, SCE is negative, and there is value destruction and a greater probability of going bankrupt.

	Score	VAIC	CEE	HCE	SCE	ROE	WC_TA	Leverage	RE_TA	CL_TA	Cash_TA
SCORE	1										
VAIC	−0.033*	1									
CEE	−0.000	0.646*	1								
HCE	−0.038*	0.907*	0.439*	1							
SCE	−0.047*	−0.104*	−0.596*	−0.030*	1						
ROE	−0.029*	0.364*	0.289*	0.346*	−0.041*	1					
WC_TA	−0.013*	0.082*	0.154*	0.016*	−0.017*	−0.169*	1				
LEVERAGE	0.039*	0.078*	0.071*	0.183*	−0.274*	0.290*	0.441*	1			
RE_TA	−0.036*	0.639*	0.630*	0.5867*	−0.261*	0.314*	0.180*	0.039*	1		
CL_TA	0.071*	−0.124*	0.025*	−0.1369*	−0.183*	0.175*	−0.257*	0.423*	−0.156*	1	
Cash_TA	−0.012*	−0.161*	−0.023*	−0.223*	0.031*	−0.156*	0.508*	−0.281*	−0.152*	−0.008*	1

Notes: This table contains the correlation coefficients among the variables used as default probability determinants; *p-value < 0.05 (two-tailed)

Table II. Spearman correlation analysis

Variables	Model 1	Model 2	Model 3	Model 4
VAIC	−0.350*** (0.0533)			
HCE		−0.275*** (0.0562)		
SCE			0.211 (0.155)	
CEE				−0.887*** (0.135)
ROE	−0.254** (0.118)	−0.316*** (0.118)	−0.388*** (0.119)	−0.267** (0.119)
WC_TA	1.733*** (0.415)	1.702*** (0.418)	1.627*** (0.422)	1.774*** (0.414)
LEVERAGE	0.348 (0.365)	0.609* (0.370)	0.424 (0.371)	−0.164 (0.370)
RE_TA	−0.259*** (0.0899)	−0.371*** (0.0863)	−0.529*** (0.0802)	−0.259*** (0.0889)
CL_TA	2.983*** (0.501)	2.903*** (0.501)	3.095*** (0.502)	3.540*** (0.506)
Cash_TA	−0.794 (0.757)	−0.695 (0.756)	−0.566 (0.753)	−0.793 (0.753)
Constant	−2.155 (1.120)	−2.665** (1.104)	−3.129*** (1.078)	−2.702** (1.071)
Observations	28,915	28,915	28,915	28,915
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: This table shows the estimated coefficient from the following logit model: Model 1, Bankruptcy = f (VAIC, financial ratios, control variables); Model 2, Bankruptcy = f (HCE, financial ratios, control variables); Model 3, Bankruptcy = f (SCE, financial ratios, control variables); Model 4, Bankruptcy = f (CEE, financial ratios, control variables). Standard errors are in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table III.
Main findings

SCE does not show a significant association with bankruptcy (Table III, Model 3). Iazzolino and Laise (2013) explain that SCE can be expressed as 1-(1/HCE). This means that for firms creating value, SCE growth is much smaller than HCE growth. Thus, SCE growth could have a non-significant impact on bankruptcy. This finding could be consistent with the prior one on HCE. Taken together, they suggest that the productivity of knowledge workers measured by HCE is fundamental to reducing the likelihood of bankruptcy. When there is no such productivity, there is value destruction, and SCE is not relevant.

In Table III, Model 3, the capital employed efficiency (CEE) shows a significant negative association with the likelihood of bankruptcy (coefficient significant at the 1 per cent level). The combined efficiency of intellectual, physical and financial capital contributes significantly to reducing the likelihood of bankruptcy.

5.4 Model evaluation

Previous bankruptcy prediction literature identified two types of errors. The model may predict that a firm is not bankrupt when, in fact, it is. This error corresponds to the assignment of a high credit score to firms that default (type-I error). A type-II error occurs when the model misclassifies a non-bankrupt firm as one that is bankrupt.

The authors evaluate the model in terms of accuracy using a table classification approach and an ROC (receiver operating characteristic) curve approach. The table classification approach is used to assess whether the intellectual capital indicator improves the predictive ability of bankruptcy prediction reducing the type-I error, which is costlier than a type-II error (Lee *et al.*, 2002). The analysis begins by running both a logit model without intellectual capital proxy and a bankruptcy model with the VAIC; next, it defines the classification matrix. Table IV shows the predictive ability of the estimated models.

A model's sensitivity describes the probability that the model classifies a firm as bankrupt (+), given a specified probability (cut-off point), when it is bankrupt (D). A model's specificity is the probability that the model classifies a firm as non-bankrupt (−) when it is non-bankrupt ($\sim D$). Since the panel sample is unbalanced, the authors adjusted the cut-off point as a percentage of bankruptcy firm-year observations scaled by total firm-year observations in the sample. The authors use a cut-off of 0.022 to calibrate the accuracy.

In terms of classification accuracy, the findings show that the model with intellectual capital proxies provides a higher sensitivity rate (lower type-I error) than models without them. Particularly, the results provide evidence that the bankruptcy model with the VAIC is the best model in terms of both sensitivity (81.70 per cent) and correct classification rate (76.54 per cent), which indicates that this model is particularly good at identifying bankrupt firms. These findings support the hypothesis that the inclusion of the VAIC improves the predictive ability of the bankruptcy prediction model (*H2*).

The authors also examine the models using an ROC approach. The ROC curve assesses the model's performance over the whole range of possible cut-off points, measuring the trade-off between type-I and type-II errors (Figure 1).

The value of the area under the ROC curve (AUC) can fall between 0 and 1, where an AUC of 1 corresponds to a perfect model. The AUC for the bankruptcy prediction model with intellectual capital proxy (0.8722) is higher than the AUC for the model with only a financial ratio (0.8041). These results are consistent with the findings previously reported.

5.5 Robustness checks

The authors performed robustness checks (Table V) to ensure that endogeneity does not affect the abovementioned results and regressed the one-year lagged VAIC and its components on the dummy identifying bankrupt firms (Models 5-8). In this way, the analysis show that not only current value creation but also past value creation is associated with the likelihood of bankruptcy.

The results suggest that intellectual capital contributes significantly to financial stability in the long term. The VAIC, the HCE and the CEE have significantly negative associations with the likelihood of going bankrupt, whereas SCE does not show any significant associations. The authors obtain the same results using a two-year lagged VAIC and its components.

	Model without VAIC (%)	Model with VAIC (%)
Sensitivity	73.17	81.70
Specificity	71.72	76.41
Correctly classified	71.75	76.54

Notes: This table shows the predictive ability of the estimated models. A model's sensitivity describes the probability that the model classifies a firm as bankrupt, given a specified probability (cut-off point), when it is bankrupt. Its specificity is the probability that the model classifies a firm as non-bankrupt when it is non-bankrupt

Table IV.
Classification tables

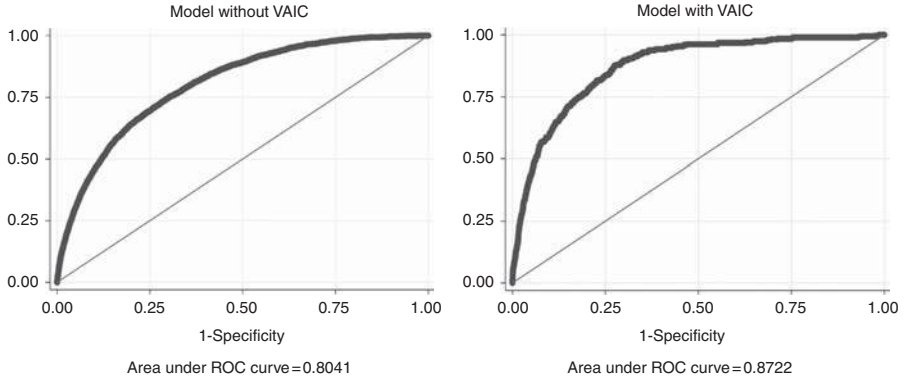

Figure 1.
ROC Curve. These graphs report the area under the ROC curve for both bankruptcy prediction model with only financial ratio (Model 1) and bankruptcy prediction model with intellectual capital proxy (Model 2)

Table V.
Robustness cheques-endogeneity

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$VAIC_{t-2}$	−0.303*** (0.0627)							
HCE_{t-2}		−0.303*** (0.0658)						
SCE_{t-2}			0.318 (0.180)					
CEE_{t-2}				−0.451*** (0.154)				
$VAIC_{t-3}$					−0.243*** (0.0665)			
HCE_{t-3}						−0.285*** (0.0715)		
SCE_{t-3}							0.223 (0.197)	
CEE_{t-3}								−0.154 (0.164)
ROE	−0.431*** (0.137)	−0.454*** (0.136)	−0.509*** (0.137)	−0.472*** (0.138)	−0.359** (0.149)	−0.364** (0.148)	−0.417*** (0.148)	−0.409*** (0.149)
WC_TA	2.946*** (0.485)	2.913*** (0.485)	2.796*** (0.484)	2.870*** (0.484)	3.205*** (0.532)	3.198*** (0.533)	3.142*** (0.533)	3.146*** (0.533)
LEVERAGE	1.346*** (0.418)	1.600*** (0.424)	1.400*** (0.425)	1.070** (0.422)	1.535*** (0.456)	1.772*** (0.463)	1.556*** (0.463)	1.408*** (0.461)
RE_TA	−0.366*** (0.103)	−0.408*** (0.0998)	−0.571*** (0.0933)	−0.479*** (0.100)	−0.445*** (0.110)	−0.446*** (0.108)	−0.615*** (0.102)	−0.608*** (0.109)
CL_TA	2.744*** (0.566)	2.660*** (0.566)	2.859*** (0.570)	3.015*** (0.573)	2.679*** (0.621)	2.608*** (0.621)	2.749*** (0.624)	2.767*** (0.629)
Cash_TA	−1.096 (0.877)	−0.955 (0.874)	−0.803 (0.864)	−0.979 (0.869)	−0.439 (0.926)	−0.314 (0.926)	−0.321 (0.923)	−0.382 (0.924)
Constant	−2.354 (1.323)	−2.763** (1.317)	−3.528*** (1.300)	−3.058** (1.287)	−3.648*** (0.766)	−3.995*** (0.760)	−4.297*** (0.770)	−4.015*** (0.765)
Observations	13,179	13,185	13,185	13,179	10,804	10,812	10,811	10,805
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table shows the estimated coefficient from the following logit model: Model 1, Bankruptcy = *f* (VAIC*t−2*, financial ratios, control variables); Model 2, Bankruptcy = *f* (HCE *t−2*, financial ratios, control variables); Model 3, Bankruptcy = *f* (SCE *t−2*, financial ratios, control variables); Model 4, Bankruptcy = *f* (CEE *t−2*, financial ratios, control variables) Model 5, Bankruptcy = *f* (VAIC*t−3*, financial ratios, control variables); Model 6, Bankruptcy = *f* (HCE *t−3*, financial ratios, control variables); Model 7, Bankruptcy = *f* (SCE *t−3*, financial ratios, control variables); Model 8, Bankruptcy = *f* (CEE *t−3*, financial ratios, control variables). Standard errors are in parentheses. **$p < 0.05$; ***$p < 0.01$

Using three-year lagged data (Models 9-12), the VAIC and the HCE still show significantly negative associations with bankruptcy, whereas the CEE correlation coefficient is negative but non-significant. The findings suggest that HCE can contribute to long-term value creation to a higher extent than physical and financial capital. Overall, these findings are consistent with the results of the main analyses and confirm the hypothesis that endogeneity does not affect the results.

The authors perform further robustness cheques by providing a comparison between a traditional *Z*-score model (Altman, 1968) and a *Z*-score with VAIC (*Z*-VAIC). The Altman *Z*-score and the revised *Z*-score (*Z*-VAIC) are estimated as reported in Table VI.

Table VI shows the error classification rates and the accuracy rate of both *Z*-VAIC and the Altman *Z*-score. As abovementioned, the type-I error is the ratio of misclassified cases of actual bankrupt firms declared as non-bankrupt by the model, whilst the type-II error is the ratio of misclassified events of actual non-bankrupt firms declared as bankrupt.

The type-I error rate of *Z*-VAIC is lower than the one of the Altman *Z*-score model: 37.25 per cent for *Z*-VAIC and 51.07 per cent for the Altman *Z*-score. However, type-II error is 33.57 per cent for *Z*-VAIC and 31.65 per cent for the Altman *Z*-score. Therefore, the *Z*-VAIC performs better at classifying the percentage of bankruptcy than the Altman *Z*-score does. The results provide evidence that the *Z*-VAIC is the best model in terms of both sensitivity (62.75 vs 49.03 per cent) and the correct classification rate (68.16 vs 66.40 per cent).

6. Conclusions

In this paper, the authors hypothesise and find that intellectual capital performance is negatively associated with the probability that a firm will default. The authors also find that the bankruptcy prediction models that include intellectual capital performance have a superior predictive ability over standard bankruptcy prediction models.

This paper contributes to prior research on intellectual capital and firm performance. To the best of the authors' knowledge, this is the first study to investigate how intellectual capital affects the likelihood of bankruptcy. The findings suggest that intellectual capital performance is associated with lower probabilities of future default. The benefits of higher intellectual capital performance extend from superior future performances to long-term financial stability. Increased performance allows the timely payment of passive interests and debt, which reduces a firm's credit risk and lowers the cost of debt applied by bond holders and external lenders. A lower credit risk also boosts a firm's profitability and value.

This study shows that intellectual capital indicators can play a key role in assessing a firm's future solvency. In this respect, the research contributes to bankruptcy prediction studies. Prior bankruptcy prediction literature suggests that traditional financial ratios do not fully capture the contribution of intellectual capital to value creation (Beaver *et al.*, 2005). Nevertheless, measures of intellectual capital are neglected in financial analysis and bankruptcy prediction. The findings show that intellectual capital performance indicators can help to develop better models to predict the probability of a future default.

	Altman *Z*-score (%)	*Z*-VAIC (%)
Type-I error	51.07	37.25
Type-II error	31.65	33.57
Correctly classified	66.81	68.67

Notes: This table shows the predictive ability of both Altman Z-score and Z-VAIC. Type-I error is the ratio of misclassified cases of actual bankrupt firms declared as non-bankrupt by the model, whilst the type-II error is the ratio of misclassified events of actual non-bankrupt firms declared as bankrupt

Table VI. Robustness checks-comparison between Altman *Z*-score and *Z*-VAIC

This research has practical implications. The findings of this study can be of interest to analysts, investors, banks and financial institutions. Analysts and investors are now informed that intellectual capital performance can also ensure financial stability for firms and reduce credit risk. Banks and financial institutions could consider intellectual capital measures in their credit rating systems, which are based on the estimation of the probability of future default (see e.g. Altman *et al.*, 2010). Overall, a more efficient allocation of financial resources by investors and lenders award profitable and healthy firms properly managing their intellectual capital and investing on it. Such a type of firm is a key driver of economic and social growth in contemporary knowledge-based economies.

This study also has some limitations. First, the study shares the limitation of the VAIC as intellectual capital measurement. The SCE measurement does not appear to be thoroughly consistent with the way in which the two other components are measured. HCE and CEE are in fact both measured relating VA respectively to human resources costs and capital employed. SCE is instead obtained in a different manner.

Another limitation is that this study does not use indicators of intellectual capital performance from sources other than financial statements, namely intellectual capital reports. However, the use of indicators from intellectual capital reports may cause problems with regard to the comparability and availability of data for reliable bankruptcy prediction, which is usually based on large samples. The VAIC is built on financial reports using a set of commonly accepted accounting principles and are publicly available for every company. Hence, they can be assessed by any external stakeholder, e.g. investors, lenders and employees.

Future research on intellectual capital could help to develop intellectual capital performance measures not based on accounting figures. Commonly accepted, publicly available audited measures could be included in bankruptcy prediction modelling once such measures become widespread and reliable (Catasús and Grojer, 2003). Future research on intellectual capital performance measures could also investigate how firms' investment of their intellectual capital can be rewarded with higher credit scores and lower cost of debt.

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Note

1. In the same group of intellectual capital indicators, Zambon (2003) include: the market-to-book-value, the Tobin's Q, the EVA and Lev's Knowledge Capital (Lev and Mintz, 1999).

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