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How to keep renewable energy enterprises to reach economic sustainable performance: from the views of intellectual capital and life cycle

Xin-long Xu[1] and Cheng Kun Liu[2*]

Abstract

Background: Intellectual capital can not only help companies to obtain sustainable competitive advantage, but also serve as a key factor in corporate performance improvement and value creation. For knowledge-intensive and technology-intensive renewable energy companies, the effective management of intellectual capital is particularly important. However, there is a huge gap between the book value of renewable energy companies and their market value. It will be difficult to establish the most appropriate development strategy for companies by evaluating the corporate performance only based on financial indicators. Therefore, studying the value creation effect of intellectual capital will not only make new energy companies pay more attention to the intellectual capital management, but also help renewable energy companies achieve sustainable corporate performance.

Methods: By choosing the listed renewable energy companies from 2010 to 2016, this paper conducts an empirical research based on the Ohlson model and use quantile regression to analyze the impacts of value-added intellectual coefficient (VAIC) on sustainable performance at different life cycle stages.

Results: The results confirm that increasing the VAIC creates value for enterprises. It also examines the effect of life cycle on this impact, and the result shows that it does not change the significant positive correlation with the economic sustainable performance at different life cycle quantiles. This paper also concludes that value-added human capital coefficient (VAHU) and value-added capital assets coefficient (VACA) are the most important component of intellectual capitals to economic sustainable performance at the growth stage, maturation stage, and decline stage.

Conclusions: Thus, it is suggested that renewable energy enterprises should emphasize on corporate intellectual capital management activities and design intellectual capital management solutions specifically for a certain life cycle stage.

Keywords: Value-added intellectual capital (VAIC), Quantile regression, Enterprise life cycle, Renewable energy enterprises, Sustainable performance

Background

Energy is an important factor for social survival and economic development [1, 2]. The development and utilization of renewable energy sources will play a key role in solving environmental pollution and energy shortages and promoting sustainable economic development [3, 4]. At the same time, with the emergence of new economic forms, the competition pattern of companies has undergone major changes, from the capital-led to the knowledge- and capacity-driven. What contributes the most to companies is no longer the tangible physical capital but the intellectual capital (IC) made up of intangible assets. IC not only helps companies to obtain sustainable competitive advantage, but also serves as the key to corporate performance improvement and value creation [5, 6]. For knowledge-intensive and technology-intensive renewable energy companies, the effective management of IC is particularly important. One of the components of IC, that is, human capital, is even the

* Correspondence: ckliu@must.edu.mo
[2]School of Business, Macau University of Science and Technology, Taipa, Macau, China
Full list of author information is available at the end of the article

main body of technological innovation for renewable energy companies. The quality of human capital determines the quantity and quality of enterprise innovation [7]. Therefore, improving the quality of human capital is an important way to improve corporate performance. However, conditions are not optimistic when it comes to the management of human capital and other intangible capital in Chinese renewable energy companies.

IC is a new concept that has emerged recently. It has become an important factor in the development of core competencies for many companies. Capitalizing on intangible assets like IC has become a focus [6, 8, 9]. Prahalad and Hamel [10] were the first to identify the close relationship between IC and core competitiveness. Sarvary [11] looked into building IC management systems. Civi [12] argued that the ability to manage IC is essential to maintaining competitive advantage. Bloodgood and Salisbury [13] indicated that adoption of specific intellectual management strategies would create core competitive sustainable advantages. Edvinsson and Malone [14] proposed that the gap between market value and book value could be attributable to IC and intangible assets. They believed that IC enables companies to develop their true value, maintain competitive advantage, and achieve goals [15, 16].

Most of the existing researches on IC focused on the concept, composition, and function of IC [17–19], as well as research in combination with industry and region [5, 20, 21]. Thesis researches are all significant and have practical values. Foreign studies on the theory and practice of IC have been mature, while domestic studies on this subject are separate and unsystematic and have not yet formed a complete theoretical analysis framework. In recent years, although domestic research on IC has covered the measurement, evaluation, management, and knowledge transfer of IC, there are only few studies focusing on the relationship between IC and sustainable performance, and even fewer on the sustainable performance driven by IC elements in new energy companies. In addition, most of the literature does not look at how it relates to the life cycle stage of the company. Due to huge variations among business enterprises, traditional regression analysis does not perform well with respect to identifying the dependent variable [22]. Quantile regression analysis provides more reliable information about the relationship between the economic performance and the value of IC [23].

This paper contributes to the existing literatures in the following aspects. Firstly, based on the definition and components of IC in the existing literature, combined with the characteristics of new energy companies, this paper adopted the Ohlson model and VAIC™ method to analyze the impacts of IC on the sustainable performance of renewable energy companies at different stages of life cycle. Secondly, this paper empirically analyzed the factors of IC that influence on sustainable performance of new energy companies, and verified the validity of the model through quantile regression analysis, which not only enriched the research filed of IC, but also provided more references and suggestions for new energy companies to improve the management of IC. The structure of this paper is as follows: the second part is the literature review, the third is the methodology, the fourth is empirical results and analysis, and the last presents the conclusion and suggestions.

Literature review

Value-added intellectual coefficient (VAIC™)

Pulic [24] brought forward VAIC™, which was applied by Austria Research Center for Intellectual Capital (AICRC) as a model to evaluate the IC. The model cites concept of the Skandia model, with the formula as follows:

$$\text{VAICTM}^{\text{™}} = \text{VACA} + \text{VAHU} + \text{STVA} \tag{1}$$

where VACA is short for value-added capital assets coefficient, VAHU is short for value-added human capital coefficient, and STVA is short for structure capital value-added coefficient.

According to added value created by VAIC™, Pulic [24] advanced to differentiate the parts created by VACA and the parts created by intellectual potential (VAIP), of which the former was divided into real and financial assets, while the latter was the salary of employees. Both VACA and VAIP are results of service or labor provision by employees and have to rely on creation and maintenance of employees. Thus, employees are important elements to create an enterprise's VAIP [25]. But, not all VAIPs are created by employees, as the enterprise itself will accumulate its own value. Such self-equipped economic performance will not be derogated due to leaving or staying of employees.

According to Skandia's IC classification, Pulic [26] modified its VAIC™ proposed in 1998, and added STVA in the previous model. Thus, he classified use efficiency of added value created into VACA, VAHU, and STVA. He also categorized IC except the human resources into structure capital; thus, STVA = intellectual capital (total added value) − human capital, which meant that the structure capital was negatively and symmetrically correlated to the human capital. In addition, the bigger those added value coefficients were, the better an enterprise's smart power became. By modifying the model of IC and adding the structure capital, Pulic [26] provided sufficient basis for enterprises' management to evaluate use efficiency of their internal resources. VAIC proposed by Pulic and Bornemann [27] is a standard and consistent measurement basis, which is applicable to any industry because its indicators are designed to evaluate use efficiency of enterprises' resources. Those indicators are relatively objective, with materials easily obtained. Schneider and Samkin [28] believed that as the information used in the course of VAIC calculation were information related to financial statements, an enterprise's external investors, debtors, or other interested parties could obtain information related to measurement indicators within the lowest cost. The VAIC calculation method is easy to understand.

This paper cites the VAIC™ proposed by Pulic [26], which can reflect efficiency of added value created by an enterprise with the same resources. An enterprise which has higher VAIC™ will have better ability to more efficiently use its resources. Such ability is IC. In addition, such measurement method can direct the investors to measure their IC with the simplest method. Thus, this paper uses the VAIC™ to measure the IC of enterprises.

Enterprise life cycle

The enterprise life cycle is by reference to the concept of product life cycle in the marketing and individual economics [29, 30]. Ji [31] discussed capital market value relationship with the number of patent rights approved by the Intellectual Property Office at each life cycle stage. Using Ohlson [32] accounting valuation model, Ji [31] found that patent rights were significantly positively correlated to stock price. The number of patent rights held at the growth stage had a larger influence on stock price than at the maturation and declining stages. Zhang [33] looked at capital market value compared to brand value at each life cycle stage and selected sales growth rate, ad expenses, research and development expenses, capital expenditure, ratio of dividend distribution, and company age as factors. Empirical results confirmed that brand value was significantly positively correlated to stock price. Brand value in the growth stage had a larger influence on stock price than in the maturation and declining stages. Hong [34] divided the enterprise life cycle as set forth in the past literature into four categories: factor-cluster analysis method, quantile method, definition method, and questionnaire measurement method.

Based on the quantile method by Hong [34] for classification of enterprise life cycle, this paper selects four variables namely net profit, sales growth rate, capital expenditures ratio, and company age to divide the enterprise life cycle.

VAIC and economic sustainable performance

In our growing economy, developing IC has become very important [6, 35, 36]. Financial statements prepared under GAAP (generally accepted accounting principles) do not account for intangible assets such as IC [37, 38]. Being unable to measure and evaluate IC limits the company's ability to optimize management [39]. Pulic [24] introduced the VAIC to the Austria Research Center for IC. It categorizes capital assets and IC by the value they add to the company. The former (GAAP) includes enterprise entities and property assets, while the latter (VAIC) differentiates salary paid to the employees. Since measuring IC in the past has been very subjective and did not incorporate current knowledge [40], Pulic [26] modified the VAIC to classify IC according to the value added by capital assets, human capital, and structural capital. This model classified capital other than human as structural capital whose value was the difference between intellectual and human capital. Structural capital has an inverse symmetrical relationship with human capital. The VAIC method proposed by Pulic [24] has reduced the amount of subjective judgment involved in measuring the influence of IC and allowed for a more objective measure of the input and output relationship.

In summary, scholars have already realized that IC gradually evolved into the critical resource for enterprises maintaining competitive advantages and core competitiveness. Scholars studied the relationship between IC and corporate performance in perspective of enterprise life cycle. Studies showed that IC are the important source for enterprises' sustainable development. On the basis of enterprise life cycle theory and IC theory, scholars suggested to developing enterprises' IC dynamically. They also explored the corporate features at different stages, characteristics of IC, and strategies of developing IC. However, currently, a majority of studies focus on the relationship between IC and corporate performance. Most studies target at high-tech enterprises, such as enterprises in information technology and manufacturing industries. Some scholars analyzed only for a given year in the transverse direction, and some established the studies only on one industry. Some scholars conducted empirical studies in both transverse and longitudinal directions. In general, former scholars mainly explored the relationship between IC and corporate performance through empirical analysis, horizontally or vertically.

Methods

Proposed hypotheses

IC components are value-added capital assets (VACA), value-added human capital (VAHU), and structural capital value-added (STVA) according to Edvinsson and Malone [14]. VAIC is used as a proxy variable for IC to measure performance relevance. This paper makes the following assumptions with respect to economic sustainable performance:

Hypothesis 1: VAIC is positively correlated to economic sustainable performance

i. Hypothesis 1-1: VACA is positively correlated to economic sustainable performance.

ii. Hypothesis 1-2: VAHU is positively correlated to economic sustainable performance.
iii. Hypothesis 1-3: STVA is positively correlated to economic sustainable performance.

Barth, Beaver, and Landsman [41] believed that an enterprise in the growing stage had greater IC than in the declining stage. Bender [42] pointed out that the biggest growth potential is seen in start-ups, followed by a slow decline from the growth stage to the maturation stage. It is difficult for newly established enterprises to attract foreign (and domestic) investors. Funds are most often provided by their founders. In the growth stage, they tend to generate better returns and can attract more investors. As enterprises decline, investors tend to show much less interest. Our paper hypothesizes that in different life cycle stages the following coefficients are positively related to economic sustainable performance.

Hypothesis 2: In different life cycle stages, dummy value-added intellectual capital (DVAIC) coefficient is positively correlated to economic sustainable performance

i. Hypothesis 2-1: In different life cycle stages, dummy value-added capital assets (DVACA) coefficient is positively correlated to economic sustainable performance.
ii. Hypothesis 2-2: In different life cycle stages, dummy value-added human capital (DVAHU) coefficient is positively correlated to economic sustainable performance.
iii. Hypothesis 2-3: In different life cycle stages, dummy structure capital value-added (DSTVA) coefficient is positively correlated to economic sustainable performance.

Modeling

Based on the Ohlson model, quantile regression analysis was used to find the correlation between the VAIC and economic sustainable performance at different life cycle stages. The model is divided into two parts:

Correlation among intellectual capital and economic sustainable performance

The influence of IC on ROA is measured. The model is constructed as follows:

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \alpha_0 + \alpha_1\mathrm{CPI}_{it} + \alpha_2\mathrm{R}_{it} + \alpha_3\mathrm{DA}_{it} \\ & + \alpha_4\mathrm{VAIC}_{it} + \alpha_5\mathrm{LD}_{it} + \alpha_6\mathrm{OP}_{it} \\ & + \alpha_7\mathrm{TA}_{it} + \varepsilon \end{aligned} \tag{2}$$

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \alpha_0 + \alpha_1\mathrm{CPI}_{it} + \alpha_2\mathrm{R}_{it} + \alpha_3\mathrm{DA}_{it} \\ & + \alpha_4\mathrm{VACA}_{it} + \alpha_5\mathrm{LD}_{it} + \alpha_6\mathrm{OP}_{it} \\ & + \alpha_7\mathrm{TA}_{it} + \varepsilon \end{aligned} \tag{3}$$

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \alpha_0 + \alpha_1\mathrm{CPI}_{it} + \alpha_2\mathrm{R}_{it} + \alpha_3\mathrm{DA}_{it} \\ & + \alpha_4\mathrm{VAHU}_{it} + \alpha_5\mathrm{LD}_{it} + \alpha_6\mathrm{OP}_{it} \\ & + \alpha_7\mathrm{TA}_{it} + \varepsilon \end{aligned} \tag{4}$$

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \alpha_0 + \alpha_1\mathrm{CPI}_{it} + \alpha_2\mathrm{R}_{it} + \alpha_3\mathrm{DA}_{it} \\ & + \alpha_4\mathrm{STVA}_{it} + \alpha_5\mathrm{LD}_{it} + \alpha_6\mathrm{OP}_{it} \\ & + \alpha_7\mathrm{TA}_{it} + \varepsilon \end{aligned} \tag{5}$$

where ROA, return on assets; VAIC, value-added intellectual capital; VACA, value-added capital assets; VAHU, value-added human capital; STVA, structure capital value added; OP, operating profit; DA, debt-asset ratio; LD, loan-deposit ratio; CPI, growth rate of local consumer price index; TA, total assets; R, change rate of interest rate of the deposit with a term of 3 months; i, renewable energy companies; t, year; and ε, residual error of the model.

Correlation of intellectual capital with economic sustainable performance in different life cycle stages

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \beta_0 + \beta_1\mathrm{CPI}_{it} + \beta_2\mathrm{R}_{it} + \beta_3\mathrm{DA}_{it} \\ & + \beta_4\mathrm{VAIC}_{it} + \beta_5\mathrm{LD}_{it} + \beta_6\mathrm{OP}_{it} \\ & + \beta_7\mathrm{TA}_{it} + \beta_8\mathrm{DVAIC}_{it} + \xi \end{aligned} \tag{6}$$

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \beta_0 + \beta_1\mathrm{CPI}_{it} + \beta_2\mathrm{R}_{it} + \beta_3\mathrm{DA}_{it} \\ & + \beta_4\mathrm{VACA}_{it} + \beta_5\mathrm{LD}_{it} + \beta_6\mathrm{OP}_{it} \\ & + \beta_7\mathrm{TA}_{it} + \beta_8\mathrm{DVACA}_{it} + \xi \end{aligned} \tag{7}$$

$$\begin{aligned}\mathrm{ROA}_{it} = {} & \beta_0 + \beta_1\mathrm{CPI}_{it} + \beta_2\mathrm{R}_{it} + \beta_3\mathrm{DA}_{it} \\ & + \beta_4\mathrm{VAHU}_{it} + \beta_5\mathrm{LD}_{it} + \beta_6\mathrm{OP}_{it} \\ & + \beta_7\mathrm{TA}_{it} + \beta_8\mathrm{DVAHU}_{it} + \xi \end{aligned} \tag{8}$$

$$\begin{aligned}ROA_{it} = {} & \beta_0 + \beta_1\mathrm{CPI}_{it} + \beta_2\mathrm{R}_{it} + \beta_3\mathrm{DA}_{it} \\ & + \beta_4\mathrm{STVA}_{it} + \beta_5\mathrm{LD}_{it} + \beta_6\mathrm{OP}_{it} \\ & + \beta_7\mathrm{TA}_{it} + \beta_8\mathrm{DSTVA}_{it} + \xi \end{aligned} \tag{9}$$

where DVAIC, dummy value-added intellectual capital coefficient; DVACA, dummy value-added capital assets; DVAHU, dummy value-added human capital; DSTVA, dummy structure capital value added; and ξ, residual error of the model.

Life cycle factors

Anthony and Ramesh [43] described enterprise life cycles using net profit, sales growth rate, capital expenditures ratio, and company age. Samples were split according to growth, maturation, and declining stages. The characteristics of each company's life cycle stage were described. The life cycle groups of the samples using univariate analysis are detailed in Table 1. Growth stage is defined as 0, maturation stage as 1, and decline stage as 2.

Table 1 Judging factor for life cycle

	Net profit	Sales growth rate	Capital expenditure ratio	Company age
Growth stage	High/above 25%	High/above 25%	High/above 25%	0–25
Maturation stage	Medium/11–20%	Medium/11–20%	Medium/11–20%	26–50
Decline stage	Low/0–10%	Low/0–10%	Low/0–10%	50–100

Results and discussion

Results

Data sources are semi-annual reports during 2010 through 2016 from the listed renewable energy enterprises including wind power industry and solar photovoltaic industry. In Table 2, ROA is a dependent variable and other factors are independent variables. Mean values are 4.34 for VAIC, 0.07 for VACA, 4.12 for VAHU, and 0.49 for STVA.

Pearson correlation analysis found from analysis of coefficients is shown in Table 3. ROA displays a statistically significant positive correlation coefficient with respect to VAIC 0.315 ($P < 0.01$), VACA 0.715 ($P < 0.01$), VAHU 0.209 ($P < 0.05$), and STVA 0.331 ($P < 0.1$).

ROA is negatively correlated to the growth rate of local consumer price index (coefficient = – 0.156, $P < 0.1$), the local change rate of interest rate of the deposit with a term of 3 months (R) (coefficient = – 0.013, $P < 0.1$), the debt-asset ratio (coefficient = – 0.255, $P < 0.1$), the loan-deposit ratio (coefficient = – 0.125, $P < 0.1$), and the total assets (coefficient = – 0.082, $P < 0.1$).

It has a positive correlation with operating profit with a value of 0.154 ($P < 0.1$) and can be used to represent the economic sustainable performance. Before conducting quantile regression, the Hausman test was applied to determine whether to use a fixed effect model or random effect model. From Table 4, P values of all models are significantly greater than 0.1, the random effect model was adopted.

From Table 5, the generalized least square method ($P = 0$) was used to correct for the heteroscedasticity and auto correlation. Quantile regression analysis was applied against the model, without considering the enterprise life cycle coefficient. From Table 6, in the Ohlson model, VAIC displays a regression coefficient (RC) with a value of 1.83 at a significant level of 10% and has a positive relation with ROA. For companies with quantile of 25, VAIC is positively correlated with ROA at a significant level of 10%, with a value of 1.77 ($P < 0.1$) for regression coefficient. In the Ohlson model 1, VAIC's influence is weakened; for companies with a quantile of 50, VAIC is positively correlated with ROA at a significant level of 1%, with a value of 4.33 ($P < 0.01$) for RC; for companies with a quantile of 75, VAIC is not significantly correlated with ROA, with a value of 0.85 for regression coefficient. The adjusted R^2 is 56.77%, which means that VAIC can create value for a company. Hypothesis 1 stands. In quantile cases, hypothesis 1 is partially valid. Adj R^2 of model 2 (VACA) in the Ohlson model is 71.33%, indicating that VACA can create value for a company. Hypothesis 1-1 stands. In the quantile case, hypothesis 1-1 is wholly valid; adj R^2 of model 3 (VAHU) is 57.27%, confirming that VAHU can create value for a company and hypothesis 1-2 stands. In the quantile cases, hypothesis 1-2 is partially valid; adj R^2 of model 4 (STVA) is 55.97%, which means that STVA cannot create value for a company so that hypothesis 1-3 does not stand; in the quantile cases, hypothesis 1-3 is also invalid.

From Table 7, it exhibits the results of the Ohlson model and quantile regression model where the enterprise life cycle is considered. As the subject in this paper is renewable energy industry, life cycles of the enterprises will not be compared in pairs.

Adding the dummy variables of life cycle stage allows VAIC of model 5 to maintain a positive relationship with ROA, while failing to reach a significant level (RC = 1.34). DVAIC has a positive relationship with ROA at a significant level of 5% (RC = 2.42 with $P < 0.05$).

For companies with quantile of 25, VAIC continues to maintain a positive relationship with ROA, while failing to reach a significant level (RC = 1.45). DVAIC has a positive relationship with ROA at a significant level of 5% (RC = 2.52, $P < 0.05$).

Table 2 The descriptive statistics of variables

Variables	Min.	Max.	Mean	Std. Dev.
ROA	– 0.019	0.027	0.007	0.006
OP	15.974	22.037	19.334	5.79
TA	19.761	26.794	24.941	7.17
CPI	– 0.013	0.025	0.004	0.005
R	– 0.912	1.169	– 0.005	0.306
DA	0.368	0.996	0.909	0.112
LD	0.152	103.021	2.289	10.425
VAIC	– 31.781	33.236	4.343	6.753
VACA	– 0.018	0.035	0.071	0.007
VAHU	– 7.586	32.257	4.121	5.479
STVA	– 31.811	1.938	0.491	3.344

ROA return on assets, *VAIC* value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added, *OP* Ln (operating profit), *DA* debt-asset ratio, *LD* loan-deposit ratio, *CPI* growth rate of local consumer price index, *TA* Ln (total assets), *R* change rate of interest rate of the deposit with a term of 3 months

Table 3 Correlation analysis

	ROA	CPI	R	DA	VACV	VAHU	STVA	VAIC	LD	OP	TA
ROA	1										
CPI	− 0.156*	1									
R	− 0.013*	0.301	1								
DA	− 0.255*	0.088	0.072	1							
VACA	0.715***	− 0.049*	− 0.065*	− 0.418	1						
VAHU	0.209**	0.102*	− 0.016*	0.303	− 0.027*	1					
STVA	0.331*	0.129*	− 0.022	0.573*	0.116*	0.612*	1				
VAIC	0.315***	0.104	− 0.017*	0.316	− 0.021*	0.099*	0.633*	1			
LD	− 0.125*	0.004	− 0.029*	0.112*	− 0.216*	0.089*	0.144	0.092*	1		
OP	0.154*	0.067	− 0.112	0.429	0.165*	0.173*	0.581*	0.189*	− 0.121*	1	
TA	− 0.082*	0.051	− 0.102	0.456	− 0.123**	0.076*	0.371*	0.087	− 0.087	0.928*	1

ROA return on assets, *VAIC* value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added, *OP* operating profit, *DA* debt-asset ratio, *LD* loan-deposit ratio, *CPI* growth rate of local consumer price index, *TA* total assets, *R* change rate of interest rate of the deposit with a term of 3 months
**P* value < 10%; ***P* value < 5%; and ****P* value < 1%

In companies with quantile of 50, VAIC also has a positive relationship with ROA and reaches a significant level of 1% (RC = 2.77, $P < 0.01$). DVAIC has a positive relationship with ROA at a significant level of 1% (RC = 3.82, $P < 0.01$). The result in quantile of 75 is the same as that in quantile of 50.

The adj R^2 of model 5 is 58.51%, suggesting that VAIC can create value for a company and DVAIC (combined with the dummy variable of the life cycle) is positively correlated to ROA. Hypothesis 2 is supported in this case and also in the case of quantile regression, shown in Table 7.

Adj R^2 of model 6 is 59.57%, and DVACA shows a significant positive relationship with ROA; hypothesis 2-1 is supported. Both VACA and DVCA have a significant positive relationship with ROA at the quantile of 75.

Adj R^2 of model 7 is 58.61%, and DVAHU is positively related to ROA. Hypothesis 2-2 stands, and both VAHU and DVAHU have a significant positive relationship with ROA at the quantile of 50.

Adj R^2 of model 8 is 57.35%, and DSTVA is positively related to ROA. However, it fails to reach a significant level, and hypothesis 2-3 does not stand.

Discussion

The emergence of IC has changed the ways and approaches of value creation. The relationship between IC and performance has been also a favorite topic of academia. In recent years, lots of literatures are involved in this topic. But most of them focus on the conventional high-tech field, which indicates that the current studies on IC are still very narrow. In this paper, starting from the life cycle theory, we try to explore the relationship between performance and components of IC at different life cycle stages of renewable energy enterprises. Data in this paper were divided into three groups according to the life cycle theory, namely growth stage, maturation stage, and decline stage. We explore the relationship between IC and performance respectively at the three stages.

According to the resource-based view, the competitive advantage comes from own resources or disposable resources, such as land, equipment, capital, and human resource. Enterprises at different sizes and with various combinations of resources produce different operating efficiency [44]. However, since the market tends to be more mature, some tangible components, such as land, equipment, and even human resource, could be obtained through equivalent exchange in market. Therefore, there is no direct cause-and-effect relationship between competitive advantage and tangible resources. In fact, it is the capacity of distributing and utilizing resources that brings bout the competitive advantage. This capacity is the core competency of enterprise. The knowledge-based theory believes that the enterprise's core competency depends on corporate knowledge and cognitive learning. Accordingly,

Table 4 Hausman test

Model 1 (VAIC)	$\chi^2 = 8.2$	Prob > χ2 = 0.315
Model 2 (VACA)	$\chi^2 = 10.05$	Prob > χ2 = 0.172
Model 3 (VAHU)	$\chi^2 = 5.14$	Prob > χ2 = 0.654
Model 4 (STVA)	$\chi^2 = 5.15$	Prob > χ2 = 0.415

VAIC value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added

Table 5 The results of generalized least square method

Model 1 (VAIC)	$\chi^2 = 163.51$	Prob > $\chi^2 = 0.00$
Model 2 (VACA)	$\chi^2 = 2056.42$	Prob > $\chi^2 = 0.00$
Model 3 (VAHU)	$\chi^2 = 224.35$	Prob > $\chi^2 = 0.00$
Model 4 (STVA)	$\chi^2 = 256.86$	Prob > $\chi^2 = 0.00$

VAIC value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added

Table 6 The results of quantile regression without the life cycle coefficient

Model 1	RC	$Q=25$	$Q=50$	$Q=75$
VAIC	1.83*	1.77*	4.33***	0.85
Adj R^2	0.5677	0.5145	0.5012	0.4394
Model 2	RC	$Q=25$	$Q=50$	$Q=75$
VACA	6.51***	4.22***	9.26***	6.11***
Adj R^2	0.7133	0.5535	0.5802	0.5721
Model 3	RC	$Q=25$	$Q=50$	$Q=75$
VAHU	2.05*	1.88*	4.43***	0.88
Adj R^2	0.5727	0.5143	0.5011	0.4383
Model 4	RC	$Q=25$	$Q=50$	$Q=75$
STVA	1.21	1.15	1.32	0.68
Adj R^2	0.5597	0.5122	0.4883	0.4331

VAIC value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added
*P value < 10%; **P value < 5%; and ***P value < 1%

knowledge eventually becomes the source of competitive advantage [45]. The concept of IC has basically absorbed the core of these theories. And the classification of IC is the concrete manifestation of these theories in practice. Therefore, IC can be considered as the source of competitive advantage. Regarding the relationship between IC and economic sustainable performance at different stages of life cycle, it can be summarized as follows: First, from the results of model 8, the adj R^2 of model 8 is 52.96%; both

Table 7 The results of quantile regression with the life cycle coefficient

Model 5	RC	$Q=25$	$Q=50$	$Q=75$
VAIC	1.34	1.45	2.77***	3.25***
DVAIC	2.42**	2.52**	3.82***	4.33***
Adj R^2	0.5851	0.5335	0.5341	0.4873
Model 6	RC	$Q=25$	$Q=50$	$Q=75$
VACA	5.78***	2.79***	9.12***	7.45***
DVACA	0.26*	0.47	0.79	0.31**
Adj R^2	0.5957	0.5261	0.5635	0.5613
Model 7	RC	$Q=25$	$Q=50$	$Q=75$
VAHU	1.24	1.43	2.18**	3.12
DVAHU	2.36**	2.67**	3.15***	4.73***
Adj R^2	0.5861	0.5351	0.5317	0.4798
Model 8	RC	$Q=25$	$Q=50$	$Q=75$
STVA	1.43	2.38**	1.83	1.17
DSTVA	2.45**	1.79*	2.36**	1.75*
Adj R^2	0.5735	0.5296	0.5135	0.4671

VAIC value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added, *DVAIC* dummy value-added intellectual capital coefficient, *DVACA* dummy value-added capital assets, *DVAHU* dummy value-added human capital, *DSTVA* dummy structure capital value added
*P value < 10%; **P value < 5%; and ***P value < 1%

STVA and DSTVA is positively related to ROA at quantile of 25; therefore, the STVA is the most important component of IC to create corporate value at the growth stage, such as the relationship with government, banks, and suppliers, and corporate market performance. Second, the VAHU is the most important component of IC to improve the economic performance at the maturation stage, because the adj R^2 of model 7 is 53.17% and both VAHU and DVAHU are positively related to ROA at quantile of 50. Third, the VACA of IC has the best efficiency to enhance the economic performance at the decline stage, because the adj R^2 of model 6 is 56.13% and both VACA and DVACA are positively related to ROA at the quantile of 75.

Robustness check

To solve the heterogeneity between samples and make the research conclusion more reliable, this paper conducted a robustness check [46]. This paper selected financial indicator that can reflect the profitability of the company in the DuPont analysis system, namely, the return on equity (ROE), as the measure of corporate performance to perform a new regression analysis. Robustness results are shown in Table 8. Compared with the results in Table 7, the coefficients of each variable are different, but the significance levels have not change, indicating that the empirical conclusions in this paper are robustness.

Conclusions and implications

Conclusions

This paper empirically analyzed the sustainable performance of new energy companies by the Ohlson model [32] combined with the VAIC™ method proposed by Pulic [26]. It is found that VAIC, VACA, and VAHU were positively and significantly correlated with sustainable performance in quantile regression without the life cycle coefficient, but the relationship between STVA and sustainable performance was not significant. In the Ohlson model, VAIC, VACA, and VAHU were positively and significantly correlated with sustainable performance, but the relationship between STVA and sustainable performance was not significant. In the quantile regression with the life cycle coefficient, VAIC, VACA, and VAHU were positively and significantly correlated with sustainable performance, supported by quantile of 25, 50, and 75, but the relationship between STVA and sustainable performance was not significant.

VACA has a significant positive correlation with sustainable performance both in quantile regression without the life cycle coefficient and with the life cycle coefficient, which shows that VACA has an important contribution to the performance of new energy companies. At the same time, it shows that the new energy companies rely mainly on capital assets in the utilization of resources, which is

Table 8 Robustness analysis

Model 5	RC	*Q* = 25	*Q* = 50	*Q* = 75
VAIC	1.07	1.39	2.84***	3.37***
DVAIC	2.26**	2.85**	3.89***	4.51***
Adj R^2	0.5874	0.5359	0.5414	0.4895
Model 6	RC	*Q* = 25	*Q* = 50	*Q* = 75
VACA	5.51***	2.83***	9.45***	7.21***
DVACA	0.23*	0.49	0.82	0.37**
Adj R^2	0.5972	0.5284	0.5652	0.5641
Model 7	RC	*Q* = 25	*Q* = 50	*Q* = 75
VAHU	1.27	1.48	2.16**	3.31
DVAHU	2.29**	2.62**	3.13***	4.68***
Adj R^2	0.5605	0.5343	0.5325	0.4814
Model 8	RC	*Q* = 25	*Q* = 50	*Q* = 75
STVA	1.47	2.21	1.95	1.41
DSTVA	2.24	1.85	2.59	1.88
Adj R^2	0.5759	0.5231	0.5217	0.4694

VAIC value-added intellectual capital, *VACA* value-added capital assets, *VAHU* value-added human capital, *STVA* structure capital value added, *DVAIC* dummy value-added intellectual capital coefficient, *DVACA* dummy value-added capital assets, *DVAHU* dummy value-added human capital, *DSTVA* dummy structure capital value added
**P* value < 10%; ***P* value < 5%; and ****P* value < 1%

related to the current government investment and financial grants.

VAHU has a significant positive correlation with sustainable performance both in quantile regression without the life cycle coefficient and with the life cycle coefficient. The improvement of human capital in new energy companies mainly includes improving the quality of human resource and optimizing the allocation of human resource. Training and recruitment are important ways to improve the quality of human resource, as well as the main channel for human capital investment. Vocational training can enhance employees' ability to acquire knowledge and apply knowledge to practice, improving the technical level of companies. This method can produce high return on investment in a short period of time, which makes it quite suitable for new energy companies. Recruitment is the main way for companies to collect high-end talents. Companies can directly acquire talents with professional background knowledge through recruitment.

STVA has a positive but not significant correlation with sustainable performance in quantile regression neither without the life cycle coefficient nor with the life cycle coefficient. The reasons may be some problems in the management of new energy industry and the insufficient investment on structural capital. Firstly, new energy companies have giant internal organization and many companies are still under the typical pyramidal organizational structure, which is not appropriate for them adapting to the development of knowledge economy. Secondly, new energy companies have not established clear values, which make them fail to develop unique corporate culture. Finally, the new energy industry is an important industry in China. Many new energy companies are state-owned. As independent accounting and self-financing companies, they must maximize profits and at the same time shoulder a huge social responsibility. Because of the combination of state responsibility and the nature of company, new energy companies find it hard to take both into consideration when establishing goals and making choices, which weakens the role of structural capital on corporate performance.

Implications

Based on the above analysis, this paper suggests that new energy companies should pay attention to the role of IC and strengthen the management of IC. Science and technology are the primary productive force. New energy companies should emphasize on the introduction of high-tech talents; strengthen the training of employees' knowledge, skills, and quality; and attach importance to the construction of organizational culture. At present, capital assets still play a pivotal role in the new energy industry. Although human capital and structural capital have certain influence on the corporate performance, they have not achieved the desired effect, indicating that companies still lack systematic and effective management of IC. Companies should further strengthen the management and development of IC, systematically integrate the existing resources, achieve coordinative development of IC and capital assets, and make them jointly improve the corporate sustainable performance.

Future research

The VAIC is used as the proxy variable of IC in this paper; other IC proxy variables may be considered for future research such as market capitalization method, score card, and direct intellectual capital. In addition, in the classification of enterprise life cycle, this paper uses the growth stage, maturation stage, and decline stage of three-quantile method. Cluster method may be used in future research. Finally, future research samples can be divided into renewable energy and non-renewable energy enterprises to compare and analyze the differences in the management of IC.

Abbreviations

CPI: Growth rate of local consumer price index; DA: Debt-asset ratio; DSTVA: Dummy structure capital value-added coefficient; DVACA: Dummy value-added capital assets coefficient; DVAHU: Dummy value-added human capital coefficient; DVAIC: Dummy value-added intellectual coefficient; GAAP: Generally accepted accounting principles; IC: Intellectual capital; LD: Loan-deposit ratio; OP: Operating profit; R: Change rate of interest rate of the deposit with a term of 3 months; ROA: Return on assets; ROE: Return on equity; STVA: Structure capital value-added coefficient; TA: Total assets; VACA: Value-added capital assets coefficient; VAHU: Value-added human capital coefficient; VAIC: Value-added intellectual coefficient; VAIP: Value-added intellectual potential

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions
The manuscript is designed by XLX. The data set was collected by CKL. Analysis of data was performed by XLX. Finally, the manuscript was written by XLX and CKL. Both authors read and approved the final manuscript.

Ethics approval and consent to participate
The submitted paper has not been published previously, that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out.

Consent for publication
If accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

Competing interests
This paper adopted the Ohlson model and VAIC™ method to analyze the impacts of IC on the sustainable performance of renewable energy companies at different stage of life cycle. The authors declare that they have no competing interests.

Publisher's Note

Author details
[1]College of Tourism, Hunan Normal University, Changsha 410081, China. [2]School of Business, Macau University of Science and Technology, Taipa, Macau, China.

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References

1. Feng Y, Chen HH, Tang J (2018) The impacts of social responsibility and ownership structure on sustainable financial development of China's energy industry. Sustainability 10(2):1–15. UNSP 301. https://doi.org/10.3390/su10020301
2. Xu XL, Chen HH, Feng Y, Tang J (2018) The production efficiency of renewable energy generation and its influencing factors: evidence from 20 countries. J Renewable Sustainable Energy 10(2):025901–025911. https://doi.org/10.1063/1.5006844
3. Zhao X, Luo DK (2017) Driving force of rising renewable energy in China: environment, regulation and employment. Renew Sust Energ Rev 68:48–56. https://doi.org/10.1016/j.rser.2016.09.126
4. Xu XL, Chen HH (2018) Examining the efficiency of biomass energy: evidence from the Chinese recycling industry. Energ Policy 119:77–86. https://doi.org/10.1016/j.enpol.2018.04.020
5. Yaseen SG, Dajani D, Hasan Y (2016) The impact of intellectual capital on the competitive advantage: applied study in Jordanian telecommunication companies. Comput Hum Behav 62:168–175. https://doi.org/10.1016/j.chb.2016.03.075
6. Secundo G, Dumay J, Schiuma G, Passiante G (2016) Managing intellectual capital through a collective intelligence approach: an integrated framework for universities. J Intellect Cap 17(2):298–319
7. Delgado-Verde M, Martin-de Castro G, Amores-Salvado J (2016) Intellectual capital and radical innovation: exploring the quadratic effects in technology-based manufacturing firms. Technovation 54:35–47. https://doi.org/10.1016/j.technovation.2016.02.002
8. Edvinsson L (2002) Corporate longitude: navigating the knowledge economy. BookHouse Publishing, Sweden
9. Greco M, Cricelli L, Grimaldi M (2013) A strategic management framework of tangible and intangible assets. Eur Manag J 31(1):55–66. https://doi.org/10.1016/j.emj.2012.10.005
10. Prahalad CK, Hamel G (1990) The core competence of the corporation. Harv Bus Rev 7:79–91
11. Sarvary M (1999) Knowledge management and competition in the consulting industry. Calif Manag Rev 41(2):95–107
12. Civi E (2000) Knowledge management as a competitive asset: a review. Mark Intell Plan 18(4):166–174
13. Bloodgood JM, Salisbury WD (2001) Understanding the influence of organizational change strategies on information technology and knowledge management strategies. Decis Support Syst 31(1):55–69. https://doi.org/10.1016/S0167-9236(00)00119-6
14. Edvinsson L, Malone MS (1997) Intellectual capital: realizing your company's true value by finding its hidden brainpower. Harper Business, New York
15. Bounfour A, Edvinsson L (2012) Intellectual capital for communities, Routledge
16. Lu WM, Kweh QL, Huang CL (2014) Intellectual capital and national innovation systems performance. Knowl-Based Syst 71:201–210. https://doi.org/10.1016/j.knosys.2014.08.001
17. Edvinsson L, Sullivan P (1996) Developing a model for managing intellectual capital. Eur Manag J 14(4):356–364
18. Edvinsson L (1997) Developing intellectual capital at Skandia. Long Range Plan 30(3):366–373. https://doi.org/10.1016/S0024-6301(97)90248-X
19. Boudreau JW, Ramstad PM (1997) Measuring intellectual capital: learning from financial history. Hum Resour Manag 36(3):343–356. https://doi.org/10.1002/(Sici)1099-050x(199723)36:3<343::Aid-Hrm6>3.0.Co;2-W
20. Xu XL, Yang XN, Zhan L, Liu CK, Zhou ND, Hu MM (2017) Examining the relationship between intellectual capital and performance of listed environmental protection companies. Environ Prog Sustain Energy 36(4):1056–1066. https://doi.org/10.1002/ep.12572
21. Demartini C, Trucco S (2016) Does intellectual capital disclosure matter for audit risk? Evidence from the UK and Italy. Sustainability 8(9):867. https://doi.org/10.3390/su8090867
22. Myers RH (2000) Classical and modern regression with applications. Duxbury, Boston, MA, USA
23. Shiu HJ (2006) Application of the VAIC method to measures of corporate performance: a quantile regression approach. J Am Acad Bus 8(2):156–160
24. Pulic A (1998) Measuring the performance of intellectual potential in knowledge economy 2nd McMaster Word Congress on measuring and managing intellectual capital by the Austrian Team for Intellectual Potential
25. Bornemann M (1999) Potential of value systems according to the VAIC (TM) method. Int J Technol Manag 18(5–8):463–475. https://doi.org/10.1504/Ijtm.1999.002781
26. Pulic A (2000) VAIC™–an accounting tool for IC management. Int J Technol Manag 20(5–8):702–714
27. Pulic A, and Bornemann M. (1999) The physical and intellectual capital of Austrian banks. https://www.researchgate.net/publication/327386301_The_Physical_and_Intellectual_Capital_of_Austrian_Banks
28. Schneider A, Samkin G (2008) Intellectual capital reporting by the New Zealand local government sector. J Intellect Cap 9(3):456–486
29. Mueller DC (1972) A life cycle theory of the firm. J Ind Econ 20:199–219
30. Rink DR, Swan JE (1979) Product life cycle research: a literature review. J Bus Res 7(3):219–242
31. Ji XY, 2002, Study on value relevance of patent right: discussed and analyzed from perspective of enterprise life cycle, National Changhua University
32. Ohlson JA (1995) Earnings, book values, and dividends in equity valuation. Contemp Account Res 11(2):661–687
33. Zhang JQ (2003) Correlation of life cycle to brand value. University, Chung Yuan Christian
34. Hong YC (2004) Enterprise life cycle and financing strategy. The National Taiwan University of Science and, Technology
35. Roos J (1998) Exploring the concept of intellectual capital (IC). Long Range Plan 31(1):150–153. https://doi.org/10.1016/s0024-6301(97)87431-6
36. Subramaniam M, Youndt MA (2005) The influence of intellectual capital on the types of innovative capabilities. Acad Manag J 48(3):450–463

37. Bontis N (2003) Intellectual capital disclosure in Canadian corporations. Journal of Human Resource Costing & Accounting 7(1):9–20
38. Harvey MG, Lusch RF (1999) Balancing the intellectual capital books: intangible liabilities. Eur Manag J 17(1):85–92
39. Huang C, Wang M-C (2008) The effects of economic value added and intellectual capital on the market value of firms: an empirical study. Int J Manag 25(4):722
40. Roslender R, Fincham R (2001) Thinking critically about intellectual capital accounting. Account Audit Account J 14(4):383–399
41. Barth ME, Beaver WH, Landsman WR (1998) Relative valuation roles of equity book value and net income as a function of financial health. J Account Econ 25(1):1–34
42. Bender R (2013) Corporate financial strategy, Routledge
43. Anthony JH, Ramesh K (1992) Association between accounting performance-measures and stock-prices - a test of the life-cycle hypothesis. J Account Econ 15(2–3):203–227. https://doi.org/10.1016/0165-4101(92)90018-W
44. Wernerfelt B (1984) A resource-based view of the firm. Strateg Manag J 5(2):171–180
45. Demsetz H (1988) The theory of the firm revisited. J Law Econ Org 4(1):141–161
46. Wang DL, Sutherland D, Ning LT, Wang YD, Pan X (2018) Exploring the influence of political connections and managerial overconfidence on R & D intensity in China's large-scale private sector firms. Technovation 69:40–53. https://doi.org/10.1016/j.technovation.2017.10.007