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Enhancing financial sustainability: the power of intellectual capital in India's renewable energy industry

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The main objective of this research article is to examine the effect of intellectual capital (IC) and its dimensions on the financial performance (FP) of the Indian renewable energy industry, guided by the Resource-Based View (RBV). The study employed data from 36 solar and 39 wind sector companies for six years, from 2017 to 2022. Moreover, the modified value added intellectual coefficient (MVAIC) model was used to measure the company's IC. Further, the paper uses panel data regression analysis to examine the above-mentioned objectives. The results showed that IC improves the earnings and profitability of solar sector companies, while for wind sector companies, it only helps boost their profitability. Contrary to the expectation, human capital efficiency (HCE) failed to show any effect on the FP of the Indian solar sector companies. However, HCE positively moderates the relationship between structural capital efficiency (SCE) and FP, as well as relational capital efficiency (RCE) and FP. For the wind sector companies, HCE significantly and positively affects the FP; however, HCE negatively moderates SCE and profitability while positively for capital employed efficiency (CEE) and FP. This research adds new data from an industry that has previously received little attention (i.e. Indian renewable energy industry), thus broadening the research on the relationship between IC and FP. Moreover, the study may provide in-depth insights into the MVAIC dimensions as it discovers the moderating effect of human capital in boosting the company's FP.

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Introduction

From the economic and environmental debate perspective, the renewable energy industry is at the forefront due to the worldwide urgency of shifting towards sustainable energy systems. The junction of intellectual capital (IC) and financial performance (FP) in the solar and wind energy fields gains critical relevance in an Indian setting, a country with rapidly increasing energy consumption and a decarbonizing commitment. Understanding the complex links between IC and FP is crucial for stakeholders hoping to promote sustainable practices and economic sustainability as the Indian renewable energy sector experiences rapid expansion and transition.

The IC is mainly related to the company's non-tangible resources. In the period of industrial production, tangible assets traditionally constituted the primary factors of production. However, technological advancements have shifted the predominant production factors from physical assets to non-material ones. These non-tangible resources encompass employee competencies and experiences, brainstorming capabilities, research and development (R&D) initiatives, systems and databases, and relationships with diverse interested parties. Collectively, these elements form IC. Notably, despite not being explicitly reflected in conventional financial statements, IC is essential to improving the overall performance of businesses (Weqar et al. 2021b). Researchers worldwide believe that when IC is applied successfully and efficiently, it improves the FP of the corporate organization, which, when applied to the renewable energy sector, helps achieve the firm's sustainable growth and ultimately benefits the country. Therefore, it is imperative to comprehensively understand the Indian renewable energy sector by scrutinizing the association between their IC and FP.

Indian renewable energy sector. Climate change drives global emphasis on sustainability and environmental considerations, posing a severe existential threat to humanity as global temperatures rise (Chen et al. 2022). There is overwhelming evidence of climate change across the globe (Smith et al. 2009). Greenhouse gases (GHGs), including CO2, CH4, and N2O, released into the atmosphere by humans are the leading cause (IPCC 2022). Because these gases trap heat, the greenhouse effect causes global warming and other climatic consequences. The momentous "Paris Agreement 2015" united all nations to fight climate change and adapt to its repercussions.

The agreement aims to lower world temperatures by 1.5°–2 °C Celsius below pre-industrial levels (Nations U 2020). According to the Global Carbon Project Report (2023), India produced 2.71 billion metric tons of CO2 (7.30%) in 2021, ranking third behind China (11.47 billion, 30.90%) and the US (5.01 billion, 13.49%) (Ritchie et al. 2023). Countries worldwide are establishing a carbon neutrality target by switching to zero CO2 emission vehicles and power generation by adopting clean energy (wind and solar). According to the "International Energy Agency (IEA)", renewable energy's portion in the global energy mixture is anticipated to abruptly upsurge from the existing 11 percent to over 20 percent by 2040 (Shanker 2021).

India, in contrast to many other nations, has the potential to produce more than 1000 Gigawatt (GW) of renewable energy. It now ranks fourth globally for installed renewable energy capacity (including large hydro), fourth for wind power, and fourth for solar power (Report 2022). As of October 2023, India's renewable energy sources (including large hydropower) stood at 178.79 GW, divided into Wind Power (42.6 GW), Solar Power (66.7 GW), Bio-Power (10.2 GW), Small HydroPower (4.94 GW), Large hydro (46.85 GW), accounting for 42% of the nation's total installed power capacity. By 2030, the Indian government targets 450 GW of renewable energy installed, of which 280 GW (or more than 60%) would come from solar power (NIP&FA 2023). Indian renewable energy has shown great promise and progress. India emphasizes renewable energy to lower greenhouse gas emissions, enhance energy security, and foster sustainable development. As technology improves and costs decrease, the renewable energy sector is expected to contribute substantially more to the global energy shift toward sustainability.

The "Ministry of New and Renewable Energy (MNRE)" was the first in the world to be established in 1980 in India. The government has taken numerous initiatives to develop clean energy sources from time to time, like introducing the new solar park, reducing the solar tariff, installing solar pumps, providing financial assistance with ease, and installing rooftop solar panels on various government buildings. To achieve the target, promote efficient solar energy use, and lessen reliance on fossil fuels, India was instrumental in forming the International Solar Alliance (ISA) in 2015 (Mishra and Srikanth 2022). ISA aims to mobilize more than 1000 billion USD of investment required by 2030 to position solar energy (India G of 2021).

Therefore, in this backdrop, with an emphasis on India's renewable energy sector, this article intends to deliver empirically supported perceptions of the relationship between IC and the FP of solar and wind energy projects only. The research aims to determine how IC (as measured by the "Modified Value Added Intellectual Coefficient (MVAIC)" model)—which includes aspects of "human capital (HC), structural capital (SC), relational capital (RC) and capital employed (CE)"—affects the sustainability of renewable energy projects from a financial standpoint. Additionally, the study explores the complex moderating influence of HC on the well-established association between IC and FP, elucidating the function of HC in determining economic consequences.

The selection of IC as the primary focus of the study stems from its recognized but underexplored role as a strategic resource in the renewable energy industry. By assessing its effects on FP, this research fills a significant knowledge vacuum that prevents the sector from making well-informed decisions. The study's investigation is further enhanced by adding HC as a moderating element, which recognizes the complex character of intellectual assets.

This research has several implications for policymakers, practitioners in the sector, and academics. The research provides actionable insights for decision-makers to enhance IC and FP. It highlights the significant role of HC in shaping financial outcomes, urging refined strategies in human capital management. The study advocates integrating economic and environmental considerations for sustainable practices in the Indian renewable energy industry. Policymakers can leverage these findings to create regulations supporting intellectual capital growth and environmental sustainability.

The next sections of this paper are organized as follows: In the "Literature review" section, the theoretical underpinnings of the investigation are established through an extensive analysis of the relevant literature, followed by the development of study objectives and hypotheses. The "Research methodology" section explains the research methodology, including the steps in gathering data, the variables, and the study's regression models. The empirical results are then presented in the "Results and discussion" section, together with a brief discussion. The "Conclusion" section concludes the paper, followed by research implications, limitations, and guidelines for future research.

Literature review

IC definition and measurement. Xu and Li (2019b) in their studies mentioned that Galbraith (1974) was the first to establish the idea of IC, although many authors (Chu et al. 2011; Gupta et al. 2020) reported that the IC was initially described by the economist Nassau William Senior in the year 1836. However, Galbraith (1974) opined that IC is the summation of all the non-tangible resources of an organization that can be employed for value addition. Edvinsson and Malone (1997) defined IC as "knowledge that can be converted into value". Further, Stewart (1997) and Bontis and Fitz-enz (2002) believed that IC is an impalpable resource that can be leveraged to create wealth and value for the business organization. Meles et al. (2016) pointed out that Itami and Roehl (1991), in their book, described IC as the accumulation of intangible resources like technology, reputation, brand, etc., that helps in attaining the competitive edge of the organization. Mavridis (2004) defines IC as "an intangible asset with the potential to create value for the enterprise and the society itself". It is rooted in employee behavior and skill sets and has a big impact on business performance (Xu and Wei 2023). From the existing definition of IC, we can extract its three elementary characteristics: non-tangibility, the potential to add value, and the ability to deliver a competitive edge to the organization (Weqar et al. 2020).

Numerous literatures provide the dichotomous and trichotomous classification of IC. However, Sydler et al. (2014) believed that the trichotomous classification of IC provides a detailed view. Hence, the most commonly used taxonomy of IC used by eminent researchers are "human capital, structural capital, and relational capital" (Bontis 1998; Edvinsson and Malone 1997; Edvinsson and Sullivan 1996; J. Roos et al. 1998; Stewart 1997; Sveiby 1997).

Human capital (HC) is an employee's knowledge, skills, and experience, to name a few (Cabrita and Bontis 2008; Johan Roos et al. 1997; Weqar and Haque 2020b). Structural capital (SC) is the non-tangible resources created and owned by a business, such as systems, databases, intellectual property rights, procedures, routines, information systems, strategy, concepts, models, etc. (Bontis et al. 2000; Chu et al. 2011; Weqar et al. 2021a). SC results from employees' past performance (Al-Musali and Ku Ismail 2016). Relational capital (RC) is the network of relationships a company has with external parties that can create value for the organization (Cabrita and Bontis 2008; Meles et al. 2016).

Despite the importance of IC in wealth and value creation, its lack of tangibility creates difficulty in their identification, assessment, and reporting (Dženopoljac et al. 2018). Clarke et al. (2011) identified three focal complications in the IC measurement: first, quantification of intangibles in monetary terms; second, the IC elements are qualitative and are based on judgment; third, the outsiders cannot access the critical information. Due to these complications, there is no universal measurement tool for IC. However, numerous researchers have evolved various methods and models for IC measurement. The prominent ones are "Balanced Scorecard" by Kaplan and Norton (1996), "Skandia Navigator" by Edvinsson (1997), "Calculated Intangible Value (CIV)" by Stewart (1997), "Intangible Asset Monitor" by Sveiby (1997), "Value Added Intellectual Coefficient (VAIC)" by Pulic (1998, 2000b), "Intangible-Driven Earnings (IDE)" by Lev (2001) and "Corrado-Hulten-Sichel (CHS)" by Corrado et al. (2005) to name a few. Among all these methods, Pulic (2000b) VAIC methodology has been employed extensively in IC research.

The VAIC methodology measures the efficiency of IC and financial capital by using the value added (VA) as an indicator of organizational growth (Vishnu and Gupta 2014). It uses audited financial data from easily accessible statements to compare firms, sectors, and countries. Furthermore, Iazzolino and Laise (2013), by critically exploring the VAIC methodology, opined that neither it alters nor opposes any fundamental accounting principles. Thus, due to its comparability, uncomplicatedness, reliability, and subjectivity, it has been extensively employed in IC research around the globe, like in the US (Riahi-Belkaoui 2003; Meles et al. 2016), the UK (El-bannany 2008; Zéghal and Maaloul 2010), Australia (Clarke et al. 2011; Joshi et al. 2013), Italy (Ginesti et al. 2018), Serbia (Komnenic and Pokrajčić 2012), Arab region (Al-Musali and Ku Ismail 2016; Dzenopoljac et al. 2017a), Iran (Mehralian et al. 2012), India (Kamath 2008; Mondal and Ghosh 2012; Smriti and Das 2018; Weqar et al. 2020) and China, Hong Kong, and Taiwan (Chen et al. 2005; Ting et al. 2020; Xu and Li 2019b; Xu and Liu 2020).

Despite its benefits, the VAIC approach has been criticized for measuring labor and capital efficiency instead of IC efficiency (Stahle et al. 2011). Moreover, The VAIC model may fail in companies with negative operating profit because it reduces "value added" (Chu et al. 2011). The VAIC approach also assesses how much each dimension of IC adds value but ignores how tangible and non-tangible assets work together (Xu and Li 2019a). Lastly, Chen et al. (2005) and Dzenopoljac et al. (2017) argued that the VAIC model denies the presence of relational capital (RC) along with innovation capital. Therefore, Nazari and Herremans (2007) added RC to the VAIC model and termed it the Modified VAIC (MVAIC) model to address its drawbacks. Many studies have since used this MVAIC model (Nimtrakoon 2015; Tiwari and Vidyarthi 2018; Xu and Li 2019a; Weqar et al. 2020). Hence, in line with previous findings, this research also employs the MVAIC model, which will be explained in the methodology section.

IC and firm financial performance (FP). IC and FP have garnered remarkable attention from researchers in the past two decades and have got divergent results. Firer and Williams (2003) found that HCE adversely affected South African firms, while SCE and CEE improved profitability and market valuation. Riahi-Belkaoui (2003) established that IC enhanced the FP of US transnational companies. In Taiwan, Chen et al. (2005) reported that VAIC, HCE, and CEE had a significant positive impact on FP indicators, including market-to-book (MB) ratio, return on assets (ROA), return on equity (ROE), growth in revenue (GR) and employee productivity (EP). Gan and Saleh (2008) found that the performance of Malaysian technology-intensive firms relied heavily on CEE, with HCE, CEE, and VAIC positively influencing ROA and assets turnover (ATO) but had an insignificant effect on MB.

An analysis of the Indian pharmaceutical and drug industries by Kamath (2008) found no significant effect of HCE, SCE, or CEE on the ROA, ATO, or M/B of the companies. In the following year, Ghosh and Mondal (2009) demonstrated that while the Indian software and pharmaceutical industries' IC increased their profitability, it had little effect on their productivity or market value. Zéghal and Maaloul (2010) found that IC positively impacts UK companies' economic and FP but only enhances the firm's market valuation in high-tech industries. Clarke et al. (2011) argued that VAIC and HCE had a substantial positive bearing on all four indicators viz-a-viz, ROA, ROE, RG, and EP of Australian companies, while SCE had an insignificant effect, and CEE helped enhance ROA, ROE, and EP. Chu et al. (2011) confirmed that CEE is the most important component in enhancing the FP of Hong Kong companies.

In Italy, Veltri and Silvestri (2011) found that HCE and SCE positively affect the share price of financial sector companies. However, HCE has an indirect effect on share price through SCE.

Mehralian et al. (2012) found that only CEE improves firm profitability in the Iranian pharmaceutical industry, while HCE and SCE have a non-substantial influence on ROA, ATO, and MB. Meanwhile, the firm's MB is significantly improved by the VAIC, while ROA and ATO remain insignificant.

Similarly, Joshi et al. (2013) demonstrated that HCE, SCE, and VAIC had no noteworthy effect on the ROA of 33 Australian financial firms, while CEE had a favorable outcome. The primary factor influencing value-generating capabilities was HCE, and investment firms had the highest VAIC values, while insurance firms had the lowest VAIC values and highest CEE values. Vishnu and Gupta (2014) reported that IC significantly and positively impacts the ROA and ROS of Indian pharmaceutical companies, while relational capital (RC) has an insignificant impact on the company's FP. Nimtrakoon (2015), using the same MVAIC model, found that HCE, CEE, and MVAIC strongly enhanced the MB, Margin ratio, and ROA of technology firms in five ASEAN countries, while RCE (relational capital efficiency) had no effect. Meles et al. (2016) conducted a study on 5749 US commercial banks and concluded that HCE and VAIC significantly enhance banks' FP, while SCE failed to do so.

Scafarto et al. (2016) found that RC is the most significant element of IC in international seed and agrochemical companies, followed by process capital (PrC), and that performance and innovation capital (InnC) have a connection that HC moderates. However, Chowdhury et al. (2018) found that CEE and HCE are the most and least significant dimensions of VAIC in the Bangladeshi textile industry.

A study by Ginesti et al. (2018) on non-listed Italian companies found that HC and SC significantly positively and negatively affect a firm's reputation, respectively, while CEE and VAIC showed no impact. Moreover, HCE adversely affects the Italian firms' ROA, ROE, ROI, and ATO, while all other independent variables help enhance most of the FP indicators. Smriti and Das (2018) found that VAIC and SCE/CEE had a substantial constructive impact on ATO, ROA, Tobin's Q, and SG of 710 Indian listed companies, but HCE had no appreciable effect. Oppong et al. (2019) reported that HCE, CEE, and VAIC of Ghana's insurance companies play a significant role in augmenting its productivity, while SCE had no role to play. Oppong and Pattanayak (2019) found that a few dimensions of IC significantly enhance the productivity of Indian commercial banks.

Xu and Liu (2019) by using quantile regression, analyze the impacts of IC on sustainable performance at different life cycle stages. The results demonstrated that IC, HC, and capital employed (CE) had a significant positive impact on the ROA of the renewable energy companies. Moreover, they also found that HC and CE are the most vital components of IC in all the three stages of the life cycle i.e., at the growth stage, maturation stage, and decline stage.

Xu and Li (2019b) found that in the Chinese manufacturing industry, CEE is the most significant value generator for both high-tech and non-high-tech SMEs, while RCE is the least important. Conversely, Ting et al. (2020) found that HCE and SCE positively impact firm performance in Taiwan's electronic industry, while CEE and VAIC negatively impact it. They also found that changes in HCE and VAIC significantly positively impact changes in firm performance. Tran and Vo (2020) found that Vietnamese financial firms had higher IC and MVAIC-boosted performance than non-financial firms, where SCE was the most influential component and HCE had no significant effect. CEE and RCE had a strong positive impact on financial firms' ROA and ROE.

Liu et al. (2021) assessed how IC and its components affect Chinese renewable energy businesses' financial competitiveness and green innovation. They reported that IC impacts financial competitiveness in an inverted U-shaped pattern, but not green innovation efficiency. Among the IC components, HC, SC, and RC boost financial competitiveness. Moreover, HC hurts green patents, but innovation capital helps. Additionally, physical capital drives green innovation performance.

Xu et al. (2021) examined how IC and its components affect business sustainable growth in China's agricultural, tourism, and renewable energy sectors. The whole sample revealed that businesses' IC and all four components (HC, SC, RC, and CE) positively affected sustainable growth. When analyzed independently, RCE and SCE are insignificant for agriculture and tourism, but IC and all its components greatly boost the renewable energy industry's sustainable growth.

Ni et al. (2021) found that average net profit per employee, goodwill, and intangible assets positively impact firm value in Taiwan. Prasojo et al. (2022) found that VAIC and two components, HCE and CEE, strongly enhance Islamic banks' performance, while SCE has the least significant impact.

Faruq et al. (2023) studied Bangladesh's banking industry and found that MVAIC and SCE strongly impact the banks' ROA, ROE, and EP. Moreover, HCE, CEE, and RCE showed substantial positive effects on only one of the firm's FP indicators. Awwad and Qtaishat (2023) found that IC and competitive advantage significantly enhance the FP of Jordanian banks. Competitive advantage also mediates the relationship between IC and FP. Asutay and Ubaidillah (2023), using data from 49 Islamic banks found that MVAIC positively affects the bank's ROA but not ROE and ATO. Among the MVAIC components, CEE was the most significant in enhancing Islamic banks' performance, followed by HCE. SCE and RCE had a non-significant impact.

The prevailing literature on IC showed mixed and varied findings. On the one hand, many studies concluded that IC aids in boosting and enhancing the FP of business organizations (Weqar et al. 2021b; Prasojo et al. 2022; Weqar and Haque 2022; Faruq et al. 2023), while on the other hand, studies like Joshi et al. (2013) and Tran and Vo (2018) failed to show the favorable results. Also, only a few studies focused on the renewable energy sector, and that too in China. Moreover, because the economic, social, technical, political, and financial factors vary from nation to nation, this relationship must be confirmed in every sector of the world's economy. Lastly, the authors find only one article by Scafarto et al. (2016), who examined the moderating effect of HC. These reasons motivated the authors to conduct the current study. The objectives of the current study have been stated further.

Research objectives. Based on the gaps identified in the literature review, the following objectives have been framed:

1. To examine the effect of intellectual capital on the financial performance of the Indian renewable energy sector.
2. To examine the effect of each intellectual capital dimension on the financial performance of the Indian renewable energy sector and identify the most significant element of IC that helps improve the firm's financial performance.
3. To examine the moderating effect of human capital on the financial performance of the Indian renewable energy sector via other components of intellectual capital.

Hypotheses development. The following hypotheses have been framed to achieve the above objectives. Hypotheses H1 and H2 are formulated to achieve the study's first objective. Meanwhile, hypotheses H1a to H1d and H2a to H2d are framed to achieve the second study's objective.

H1: MVAIC positively influences the firm's financial performance as measured by Log EBIT.

H1a: HCE positively influences the firm's financial performance as measured by Log EBIT.

H1b: SCE positively influences the firm's financial performance as measured by Log EBIT.

H1c: RCE positively influences the firm's financial performance as measured by Log EBIT.

H1d: CEE positively influences the firm's financial performance as measured by Log EBIT.

H2: MVAIC positively influences the firm's financial performance as measured by ROA.

H2a: HCE positively influences the firm's financial performance as measured by ROA.

H2b: SCE positively influences the firm's financial performance as measured by ROA.

H2c: RCE positively influences the firm's financial performance as measured by ROA.

H2d: CEE positively influences the firm's financial performance as measured by ROA.

Numerous research studies have found that non-tangible assets often have little direct impact on an organization's financial success. Moreover, among the three major components of IC, HC is acknowledged as IC's central component and a crucial driver of sustainable competitive advantage. Moreover, some research studies (Edvinsson and Malone 1997; Sveiby 1997; Cabrita and Bontis 2008; Veltri and Silvestri 2011) have demonstrated that the impact of HC on a firm's performance is indirect rather than directly significant. Therefore, in this backdrop, the following hypotheses have been framed:

H3a: HCE moderates the relationship between SCE and Log EBIT.

H3b: HCE moderates the relationship between RCE and Log EBIT.

H3c: HCE moderates the relationship between CEE and Log EBIT.

H4a: HCE moderates the relationship between SCE and ROA.

H4b: HCE moderates the relationship between RCE and ROA.

H4c: HCE moderates the relationship between CEE and ROA.

The hypotheses (H3a to H3c and H4a to H4c) have been devised to fulfill the third research objective. Notably, the data analysis was conducted by segregating companies into the wind and solar sectors. Thus, each of the 16 hypotheses and their corresponding sub-hypotheses for wind and solar sector companies will be individually formulated and scrutinized.

Research methodology

Sample selection. The samples were split into "solar" and "wind" companies for analysis. These companies' data were collected from the "Prowess" database administered by the "Centre for Monitoring Indian Economy (CMIE)." The Prowess database includes all NSE and BSE-listed enterprises, hundreds of private limited corporations, and thousands of unlisted public limited companies. Data from 36 solar and 46 wind companies from 2017 to 2022 was used for this analysis. The 36 solar and 39 wind companies remain in the study after removing firms with three or more years of missing data. The significance of these companies in combating climate change motivates the researchers to conduct the present study. The study uses cross-sectional and time-series data, making it panel in nature. Thus, the fixed effect and random effect regression models were employed to analyze how IC and its components affected the FP of the Indian renewable energy industry (Baltagi 2005).

Variables

Dependent variables. "Return on assets (ROA)" and "Earnings Before Interest and Taxes (EBIT)" are the two metrics used in the study as the dependent variables, as they are measures of the company's FP. While the latter gauges the firm's ability to generate profits by utilizing its assets or resources, the former represents its earnings. In the realm of IC research, EBIT has been utilized by earlier researchers, namely, Dženopoljac et al. (2018), Ge and Xu (2020) and Weqar (2022). However, to prevent skewness in the data, the logged values of EBIT (i.e., Log EBIT) will be employed for analysis. Likewise, ROA demonstrates the firm's capability to generate profits by utilizing its assets or resources, and it has been employed in numerous IC studies (Chowdhury et al. 2019; Olarewaju and Msomi 2021; Tran and Vo 2020; Weqar and Haque 2020a). The firm's ROA can be computed as follows:

$$ROA = Net\ Income * /Average\ Total\ Assets$$

$$*\text{Net Income} = \text{Profit after Tax (PAT)}$$

Independent variables. The current research treats IC and its dimensions as the study's independent variables. The "Modified Value Added Intellectual Coefficient (MVAIC)" model has been employed to measure and quantify an organization's IC. The MVAIC is a modification of the original "Value Added Intellectual Coefficient ($VAIC^{TM}$)" model developed by (Pulic, 2000a).

Value Added Intellectual Coefficient ($VAIC^{TM}$) model: The $VAIC^{TM}$ assesses firm IC efficiency. Hamdan (2018) asserted that the $VAIC^{TM}$ methodology was created to assess knowledge-based enterprises' finances accurately. However, the $VAIC^{TM}$ approach is currently used in many forms of enterprises, knowledge-intensive or not. Chowdhury et al. (2019), Faruq et al. (2023), Gan and Saleh (2008), Ge and Xu (2020), and Prasojo et al. (2022) use the $VAIC^{TM}$ model in banking, pharmaceutical, and IT sectors, while Chowdhury et al. (2018), Dženopoljac et al. (2018), Scafarto et al. (2016) and Xu and Liu (2020) used it in construction, oil and gas, textile, and manufacturing sectors which require less knowledge as compared to the banking, IT and pharmaceutical sectors.

The $VAIC^{TM}$ model examines data from balance sheets and financial statements to assess how well a firm produces value that can be attributed to and originates from its IC development. As per Pulic (2000b), the $VAIC^{TM}$ model is the summation of "intellectual capital efficiency (ICE)" and "capital employed efficiency (CEE)", considering the model's premise that IC cannot provide value on its own and thus, it needs to blend with the firm's CEE to create value. Thus, the algebraic formula for the $VAIC^{TM}$ model can be shown as below:

$$VAIC^{TM} = ICE + CEE$$

Further, ICE is the combination of a firm's "human capital efficiency (HCE)" and "structural capital efficiency (SCE)." Algebraically,

$$ICE = HCE + SCE$$

Thus, $VAIC^{TM}$ can be shown as

$$VAIC^{TM} = HCE + SCE + CEE$$

Now, to compute these components of the $VAIC^{TM}$ model, a firm's value added (VA) is required. And according to Pulic (2000b), VA is the summation of "operating profit (OP), employee cost (EC), depreciation (D) and amortization (A)".

Algebraically,

$$VA = OP + EC + DA + A$$

After the firm's VA is computed, the VAIC^{TM} and its components can be obtained.

1. Human Capital Efficiency (HCE): HCE is the firm's VA by investing one monetary unit in the firm's human capital (HC). It may be attained by dividing the company's VA with its HC. "Total salaries and wages" are used as a substitution for the firm's HC (Pulic 2000a). Algebraically, $HCE = VA/HC$
2. Structural Capital Efficiency (SCE): Structural capital (SC) results from employees' past performance, and hence, SCE is the efficiency of SC used to create value for the organization. The firm's SC can be achieved by deducting HC from the firm's VA (Pulic 2000a). Algebraically, $SC = VA–HC$
   Considering the above equation, a rise in HC decreases SC, indicating an inverse connection between the two, which contradicts SC's expected nature. To address this discrepancy, Pulic (2000b) proposes the estimation of SCE as follows:
   $SCE = SC/VA$
3. Capital Employed Efficiency (CEE): CEE is the firm's VA by investing one monetary unit of capital. It is the efficiency left out by HCE and SCE (Pulic 2000a), and the computation of CEE involves dividing the firm's value added by its capital employed (CE). Algebraically,
   $CEE = VA/CE$

Advantages of VAIC^{TM} model: In assessing a company's IC, the VAIC model has various benefits. First, it quantifies how efficiently a corporation uses its intellectual resources to create value. The model's simplicity and applicability allow academics and practitioners to compare industries and historical periods. VAIC also incorporates financial performance data to show how IC affects company success and profitability.

Modified Value Added Intellectual Coefficient (MVAIC) model: The VAIC^{TM} model, as originally conceived, overlooks a crucial element of intellectual capital – namely, relational capital (RC) (Stahle et al. 2011; Iazzolino and Laise 2013). An adaptation to the original VAIC^{TM} model incorporating relational capital efficiency (RCE) has been introduced in response to this limitation. It is noteworthy, however, that this augmentation is not unprecedented in IC. Prior to this, various scholars and researchers, such as Gupta et al. (2020), Nimtrakoon (2015), and Xu and Li (2020), have similarly modified the VAIC^{TM} model by integrating relational capital. Furthermore, others, including Chang and Hsieh (2011) and Nadeem et al. (2019), have opted to enhance the model by incorporating innovation capital.

Hence, the MVAIC model is the combination of "intellectual capital efficiency (ICE)" and "capital employed efficiency (CEE)." However, here, the ICE is the summation of a firm's "human capital efficiency (HCE)," "structural capital efficiency (SCE)," and "relational capital efficiency (RCE)." Algebraically,

$$ICE = HCE + SCE + RCE$$

Thus, the formula for MVAIC can be presented as follows:

$$MVAIC = HCE + SCE + RCE + CEE$$

Relational Capital Efficiency (RCE): RCE is the contribution of one monetary unit of the firm's RC in its value addition. RC refers to the cost of maintaining the existing customers and other stakeholders and acquiring the potential customers and stakeholders. Here, in line with the following researchers like Gupta et al. (2020), Nazari and Herremans (2007), Nimtrakoon (2015), and Xu and Li (2020) "Marketing, Selling, and Advertising Expenses" are treated as a proxy of RC. Thus, a firm's RCE can be obtained by dividing the RC with its VA. Algebraically,

$$RCE = RC/VA$$

Control variables. Following the studies of Vidyarthi and Tiwari (2020), Weqar (2022), and Xu et al. (2019), two control variables have been incorporated – Size and Leverage. The firm's "Size," which is used to manage the impact of size on value creation, is determined by calculating the log of the firm's total assets. Meanwhile, "Leverage" measures the firm's total outside liabilities compared to its total assets. The formulas for their computation are as follows:

$$Size = Log\,(Total\ Assets)$$

$$Leverage = Total\ Outside\ Liabilities/Total\ Assets$$

Regression models. For the analysis, six regression models have been developed.

Models (1a) and (1b) scrutinize hypotheses H1 and H2, respectively.

Model 1a: $\text{Log EBIT}_{it} = \alpha + \beta_1 \text{MVAIC}_{it} + \beta_2 \text{Size}_{it} + \beta_3 \text{Leverage}_{it} + \varepsilon_{it}$

Model 1b: $\text{ROA}_{it} = \alpha + \beta_1 \text{MVAIC}_{it} + \beta_2 \text{Size}_{it} + \beta_3 \text{Leverage}_{it} + \varepsilon_{it}$

Model (2a) examines hypotheses H1a, H1b, H1c and H1d, while Model (2b) examines hypotheses H2a, H2b, H2c and H2d.

Model 2a: $\text{Log EBIT}_{it} = \alpha + \beta_1 \text{HCE}_{it} + \beta_2 \text{SCE}_{it} + \beta_3 \text{RCE}_{it} + \beta_4 \text{CEE}_{it} + \beta_5 \text{Size}_{it} + \beta_6 \text{Leverage}_{it} + \varepsilon_{it}$

Model 2b: $\text{ROA}_{it} = \alpha + \beta_1 \text{HCE}_{it} + \beta_2 \text{SCE}_{it} + \beta_3 \text{RCE}_{it} + \beta_4 \text{CEE}_{it} + \beta_5 \text{Size}_{it} + \beta_6 \text{Leverage}_{it} + \varepsilon_{it}$

Model (3a) inspects the hypotheses H3a, H3b and H3c, while Model (3b) inspects hypotheses H4a, H4b, and H4c.

Model 3a: $\text{Log EBIT}_{it} = \alpha + \beta_1 \text{HCE}_{it} + \beta_2 \text{SCE}_{it} + \beta_3 \text{RCE}_{it} + \beta_4 \text{CEE}_{it} + \beta_5 \text{HCE}_{it}{*}\text{SCE}_{it} + \beta_6 \text{HCE}_{it}{*}\text{RCE}_{it} + \beta_7 \text{HCE}_{it}{*}\text{CEE}_{it} + \beta_8 \text{Size}_{it} + \beta_9 \text{Leverage}_{it} + \varepsilon_{it}$

Model 3b: $\text{ROA}_{it} = \alpha + \beta_1 \text{HCE}_{it} + \beta_2 \text{SCE}_{it} + \beta_3 \text{RCE}_{it} + \beta_4 \text{CEE}_{it} + \beta_5 \text{HCE}_{it}{*}\text{SCE}_{it} + \beta_6 \text{HCE}_{it}{*}\text{RCE}_{it} + \beta_7 \text{HCE}_{it}{*}\text{CEE}_{it} + \beta_8 \text{Size}_{it} + \beta_9 \text{Leverage}_{it} + \varepsilon_{it}$

Results and discussion

Descriptive statistics. Table 1 describes solar and wind companies separately. The mean of earnings represented by Log EBIT for both the samples is almost similar (2.512 for solar and 2.521 for wind companies). However, their average profitability for 2017 and 2022 is very worrying and grave. Companies related to the solar sector have an average profitability rate of 0.10%, while those related to the wind sector have a negative profitability rate. Further, the average MVAIC of wind sector companies (19.725) is almost double that of solar sector companies (9.981). The figure indicates that, on average, Indian solar and wind sector companies generate a value of ₹19.725 and ₹9.981, respectively, for every rupee (₹) invested in their IC (represented by MVAIC). Among the dimensions of MVAIC, HCE contributes the maximum, aligning with the most prominent studies (Tiwari 2020; Weqar et al. 2020; Faruq et al. 2023; Xu et al. 2023).

Correlation matrix. Tables 2 and 3 display the correlation analysis findings for solar and wind sector companies, respectively. In Table 2, all of the independent factors exhibited no link with the dependent variables, except RCE, which is strongly and negatively connected with Log EBIT and ROA. In Table 3, Log EBIT has a

Table 1 Descriptive statistics.

	SOLAR					WIND				
	N	**Mean**	**Min.**	**Max.**	**SD**	***N***	**Mean**	**Min.**	**Max.**	**SD**
Log EBIT	151	2.512	0.579	4.455	0.848	160	2.521	0.221	4.382	0.798
ROA	188	0.001	−0.427	0.342	0.086	198	−0.018	−0.795	0.413	0.130
HCE	191	9.257	−25.000	82.500	16.402	183	18.274	−5.615	98.666	29.963
SCE	191	0.668	−6.135	5.181	1.053	183	0.853	−1.923	3.862	0.725
RCE	167	0.083	−0.431	0.693	0.133	148	0.026	−0.922	0.740	0.262
CEE	195	0.188	−0.081	1.810	0.208	207	0.143	−0.341	0.802	0.162
MVAIC	195	9.981	−23.962	83.519	16.436	207	19.725	−4.906	99.732	29.143
Size	195	3.766	2.083	5.519	0.764	210	3.849	1.322	5.358	0.670
Leverage	195	0.692	0.013	3.243	0.410	209	0.682	0.005	2.112	0.377

Source(s): Authors' compilation.

Table 2 Correlation matrix of the solar sector companies.

	Log EBIT	ROA	HCE	SCE	RCE	CEE	MVAIC	Size	Leverage
Log EBIT	1								
ROA	0.214**	1							
HCE	−0.045	0.042	1						
SCE	0.061	0.063	0.122	1					
RCE	−0.308**	−0.177*	−0.213**	−0.492**	1				
CEE	−0.083	0.004	0.043	0.027	0.073	1			
MVAIC	−0.043	0.041	0.998**	0.182*	−0.236**	0.063	1		
Size	0.918**	−0.034	−0.043	0.119	−0.306**	−0.234**	−0.037	1	
Leverage	−0.114	−0.582**	0.050	0.072	0.113	0.358**	0.059	−0.051	1

** and * indicate significance at 1% and 5% levels, respectively.
Source(s): Authors' compilation.

Table 3 Correlation matrix of the wind sector companies.

	Log EBIT	ROA	HCE	SCE	RCE	CEE	MVAIC	Size	Leverage
Log EBIT	1								
ROA	0.198*	1							
HCE	−0.124	0.109	1						
SCE	−0.084	−0.154*	0.102	1					
RCE	0.400**	0.246**	0.025	−0.441**	1				
CEE	0.397**	−0.080	0.140	−0.017	0.271**	1			
MVAIC	−0.050	0.098	1.000**	0.122	0.024	0.153*	1		
Size	0.803**	0.005	−0.173*	−0.043	0.240**	0.029	−0.108	1	
Leverage	0.205**	−0.491**	−0.018	0.161*	−0.149	0.298**	−0.027	0.008	1

** and * indicate significance at 1% and 5% levels, respectively.
Source(s): Authors' compilation.

significant positive correlation with RCE and CEE, whereas ROA has a substantial positive relationship only with RCE. In both the tables (Tables 2 and 3), the correlation between the HCE and MVAIC was very strong (0.998; 1.000), as HCE is the main component of MVAIC. Since the regression models do not employ both variables at the same time, the multicollinearity issue will not be created. Nevertheless, the authors have conducted the Variance Inflation Factor (VIF) analysis to delve further into the issue of data multicollinearity.

Regression analysis

Diagnostics tests. Before executing panel data regression, the authors performed the VIF test. The results detected no multicollinearity issue in the sample since all VIF values are less than 10. Gujarati and Porter (2010) suggest multicollinearity occurs when VIF exceeds 10. Additionally, the Wooldridge test assessed autocorrelation, and the Breusch–Pagan/Cook–Weisberg test heteroscedasticity. These tests demonstrated that most regression models have autocorrelation and heteroscedasticity. Consequently, robust standard errors, acknowledged for their ability to address these problems, are employed in those regression models that show the above-stated problems.

To select the best regression model, the authors assessed the Fixed Effect Model (FEM) and Random Effect Model (REM) using the Hausman specification test. Furthermore, the choice between the Pooled Ordinary Least Square (OLS) regression model and REM was determined using the Breusch and Pagan Lagrangian Multiplier (LM) test. Results from these tests identified REM as the preferable model for most regression models, while FEM was deemed more suitable for a subset of regression models.

Table 4 Regression results of the models related to the solar energy sector.

	Solar energy sector					
	Log EBIT			ROA		
	Model 1a (REM)	Model 2a (REM)	Model 3a (REM)	Model 1b (REM)	Model 2b (REM)	Model 3b (REM)
Constant	−1.00*** [0.2118]	−1.4386*** [0.1749]	−0.1443 [0.4279]	0.0989** [0.0442]	0.0951* [0.0519]	−0.0207 (0.1036)
MVAIC	0.0036** [0.0017]			0.0005** [0.0002]		
HCE		0.0002 [0.0024]	−1.2921*** [0.3864]		0.0003 [0.0003]	0.1228 (0.1008)
SCE		0.0355 [0.0231]	0.0134 [0.0220]		−0.0023 [0.0070]	−0.0033 (0.0074)
RCE		0.1938 [0.2952]	−0.4192 [0.2837]		−0.0951 [0.0794]	−0.1412** (0.0592)
CEE		1.0317*** [0.3332]	1.0207*** [0.3263]		0.1284*** [0.0461]	0.1052*** (0.0364)
HCE*SCE			1.2905*** [0.3845]			−0.1230 (0.1008)
HCE*RCE			0.3336** [0.1430]			0.0459* (0.0250)
HCE*CEE			−0.0131 [0.0087]			0.0025 (0.0035)
Size	0.9332*** [0.0499]	1.0279*** [0.0350]	1.0356*** [0.0389]	−0.0050 [0.0093]	0.0012 [0.0091]	−0.0011 (0.0113)
Leverage	−0.0727 [0.1509]	−0.2486* [0.1369]	−0.2991** [0.1391]	−0.1205*** [0.0292]	−0.1687*** [0.0367]	−0.1694*** (0.0188)
R^2	0.9074	0.9479	0.9528	0.4596	0.5197	0.5449
F/Wald Chi^2	386.48***	1456.35***	1688.12***	18.28***	77.12***	99.34***
N	151	130	130	188	163	163

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. "()" indicates standard error; "[]" indicates robust standard error. "FEM" stands for Fixed Effect model, while "REM" stands for Random Effect model.
Source(s): Authors' compilation.

Table 5 Regression results of the models related to the wind energy sector.

	Wind energy sector					
	Log EBIT			ROA		
	Model 1a (REM)	Model 2a (REM)	Model 3a (REM)	Model 1b (REM)	Model 2b (REM)	Model 3b (FEM)
Constant	−0.7678* [0.4225]	−1.5799*** [0.2647]	−1.7928*** (0.4463)	0.1251 [0.1010]	−0.0055 [0.0433]	−0.2247 [0.2358]
MVAIC	0.0027** [0.0012]			0.0003 [0.0002]		
HCE		0.0041*** [0.0012]	0.1411 (0.2712)		0.0008** [0.0003]	0.0082*** [0.0313]
SCE		−0.2295* [0.1253]	−0.2256*** (0.0779)		−0.0044 [0.0140]	0.0046 [0.0170]
RCE		0.1670 [0.5045]	0.5240 (0.3711)		0.0577 [0.0446]	0.0050 [0.0255]
CEE		2.3217*** [0.4261]	2.6094*** (0.3882)		0.0809 [0.1151]	0.0571 [0.1265]
HCE*SCE			−0.1352 (0.2704)			−0.1011*** [0.0315]
HCE*RCE			−0.1044 (0.0758)			−0.0181 [0.0283]
HCE*CEE			0.0002 (0.0168)			0.0384* [0.0212]
Size	0.8129*** [0.1055]	1.0105*** [0.0612]	1.0288*** (0.0850)	−0.0080 [0.0250]	0.0201* [0.0121]	0.0630 [0.0666]
Leverage	0.0627 [0.1777]	−0.2741 [0.1988]	−0.3717 (0.1736)	−0.1649*** [0.0488]	−0.1744*** [0.0360]	−0.2759*** [0.0983]
R^2	0.5212	0.8892	0.8913	0.3523	0.6859	0.7129
F/Wald Chi^2	65.50***	318.27***	248.01***	13.13***	73.52***	18.21***
N	160	93	93	197	130	130

***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively. "()" indicates standard error; "[]" indicates robust standard error. "FEM" stands for Fixed Effect model, while "REM" stands for Random Effect model.
Source(s): Authors' compilation.

Regression results. The findings from panel data regression are outlined in Table 4, focusing on the outcomes pertinent to the solar energy sector, and Table 5 elucidates the results of the wind energy sector.

Table 4 reveals a significant positive impact of MVAIC on the Log EBIT and ROA for solar energy firms, indicating that these companies capitalize on their IC to enhance earnings and profitability. This implies that IC plays a crucial role in enhancing operational efficiency and maximizing the use of assets in the solar industry, where innovation, technology, and strategic partnerships are essential. Our findings align with prior research by Ge and Xu (2020), Weqar (2022), and Xu and Li (2019a, 2020), all of whom empirically demonstrated that IC positively contributes to the FP of their sampled firms.

Consequently, hypotheses H1 and H2 are affirmed for the solar energy sector.

Among the four dimensions of MVAIC, only CEE exhibited a significant positive impact on both Log EBIT (Model 2a) and ROA (Model 2b), thus consistent with the findings by Dzenopoljac et al. (2017b), Ge and Xu (2020) and Prasojo et al. (2022). Consequently, hypotheses H1d and H2d were validated. In contrast, the remaining dimensions (HCE, SCE, and RCE) did not demonstrate noteworthy effects on the dependent variables (Kamath 2008; Mehralian et al. 2012; Chowdhury et al. 2018). As a result, hypotheses H1a, H1b, H1c, H2a, H2b, and H2c were rejected for solar sector companies. This suggests that the main factor influencing FP in solar energy companies is the effective use of capital, but the absence of substantial impacts from HCE, SCE, and RCE suggests that although these components of IC are crucial, FP in this industry may not be directly impacted by them.

Table 4 reveals that in Models 3a and 3b, incorporating interaction terms to assess moderation effects, CEE remains the most impactful factor in MVAIC, positively influencing Log EBIT and ROA. Conversely, HCE and RCE adversely affect Log EBIT (Model 3a) and ROA (Model 3b), respectively. Notably, HCE moderates the relationship between SCE and Log EBIT, as well as RCE and Log EBIT in Model 3a, evidenced by significant positive associations in HCE*SCE and HCE*RCE with Log EBIT. However, in Model 3b, HCE solely moderates the link between RCE and ROA among solar sector companies, remaining non-significant for SCE and CEE. Thus, it may be said that hypotheses H3a, H3b, and H4b are accepted, while H3c, H4a, and H4c are rejected for the solar sector companies.

Moreover, the R^2 values, signifying model explanatory capability, are notably greater in Log EBIT models (Models 1a, 2a, and 3a) than in ROA models (Models 1b, 2b, and 3b). When comparing Log EBIT and ROA models within the solar sector, Model 3a exhibits the highest R^2 in Log EBIT models, whereas Model 3b demonstrates the highest R^2 in ROA models. This suggests that models incorporating interaction variables for moderation effects provide superior explanatory power for the dependent variables than those without such variables.

The outcomes of the wind sector companies are outlined in Table 5. Notably, MVAIC significantly and positively influences Log EBIT (Model 1a), whereas it remains statistically insignificant for ROA (Model 1b). This suggests that instead of maximizing asset utilization (i.e., ROA), IC is more successful at generating short-term profits (Log EBIT). In the context of Log EBIT findings, our results align with those of Ge and Xu (2020), Weqar (2022), and Xu and Li (2019a), all confirming the positive impact of MVAIC on Log EBIT in their respective sampled firms. Conversely, concerning ROA, our results are consistent with Singla (2020) and Weqar (2022), whereas Ge and Xu (2020) and Xu and Li (2019b, 2020) reported divergent outcomes. Consequently, hypothesis H1 is affirmed, while H2 is refuted for wind sector companies.

Table 5 provides an overview of the findings about the MVAIC components. In Model 2a, for wind sector companies, all three components (HCE, SCE, and CEE) significantly impact Log EBIT, with HCE and CEE demonstrating positive effects, while SCE exhibits a negative influence. It underscores the significance of a competent workforce and the effective utilization of capital in generating a company's earnings. Conversely, the adverse effect of SCE on Log EBIT implies that earnings may be impeded by overinvestment or misalignment in organizational structures. On the contrary, in Model 2b, only HCE displays a noteworthy effect on ROA, while the remaining components do not significantly affect the firm's ROA. Consequently, hypotheses H1a, H1d, and H2a are confirmed, whereas H1b, H1c, H2b, H2c, and H2d are not supported for wind sector companies.

In Model 3a, incorporating interaction terms reveals substantial positive effects of CEE and significant adverse effects of SCE on the Log EBIT of wind sector companies. These effects align with those observed in Model 2a. However, the previously significant impact of HCE on Log EBIT in Model 2a is now found to be insignificant. Notably, HCE does not moderate the relationship between other MVAIC components and Log EBIT. In Model 3b, HCE moderates the relationship between SCE and ROA in a negative direction, indicating that the affirmative effect of SCE on profitability diminishes or reverses under specific conditions or levels of HCE. Additionally, HCE moderates the relationship between CEE and ROA, suggesting that while CEE alone may not significantly drive ROA, the presence of a skilled workforce (HC) can enhance the impact of capital employed on profitability. Consequently, hypotheses H3a, H3b, H3c, H4a, and H4b are rejected, while H4c is accepted for wind sector companies.

In terms of model explanatory power, the R^2 values are more noteworthy in Log EBIT models (Models 1a, 2a, and 3a) compared to ROA models (Models 1b, 2b, and 3b), thereby favoring outcomes related to solar sector companies, as detailed in Table 4. When comparing Log EBIT and ROA models, Model 3a and Model 3b exhibit the highest R^2 values, indicating that the interaction among MVAIC components enhances the variability in the dependent variable for wind sector companies.

Conclusion

Researchers and academics worldwide recognize IC's impact on business organizations' FP. IC's significance in a firm's value creation is becoming more evident (Weqar et al. 2020). In this backdrop, the data of 36 solar and 39 wind companies in India are employed to verify the above link. Using panel data regression analysis, the authors observed that IC increased solar sector earnings and profitability. For wind industry firms, IC boosts earnings but not profitability. This shows that while IC improves FP in both sectors, its effect on profitability is sector-specific. The nuanced connection between IC and FP emphasizes the necessity of industry dynamics and contextual variables in understanding sector-specific effects.

CEE is the most critical MVAIC component for improving the FP of the Indian renewable energy sector. The favorable influence of physical and tangible assets (CEE) on the FP of the Indian renewable energy sector, particularly solar energy, shows the importance of infrastructure investment. Well-maintained assets assist firms in emphasizing operating efficiency, dependability, and long-term profitability. Based on this correlation, policymakers and investors should promote renewable energy asset development and maintenance strategies.

Moreover, CEE may not significantly impact wind energy sector profitability due to technological advances in wind turbine design, higher maintenance costs, scale, and project financing structures that may prioritize other factors over traditional assets. The high positive effect of human capital (HCE) in regression models implies that worker experience, skills, and knowledge boost profitability. Skilled people who innovate, operationalize, and make strategic decisions in the wind energy business may impact FP more than physical assets. This highlights the wind energy industry's dynamic character and the rising role of human capital in its success.

The insignificant effect of structural capital (SCE) on the earnings and profitability of solar sector companies may be attributed to the solar industry's technology-driven nature, prioritizing advancements in solar panel efficiency over internal organizational structures. Due to project complexity and regulatory concerns, SC may have a higher impact on the wind energy sector, as shown by the considerable negative effect on earnings and the non-significant impact on profitability for wind sector companies. Although SC negatively affects short-term financial outcomes for wind companies, it may not hinder long-term profitability, indicating a need for optimization and adaptation to the specific operational dynamics and regulatory environments within each renewable energy sector.

The moderation effects in solar sector companies, where HCE moderates the relationships between SCE and earnings, as well as relational capital (RCE) and both earnings and profitability, indicate the knowledge-intensive and relationship-driven nature of the solar industry. Skilled professionals may enhance the impact of organizational and relational structures on FP. The lack of moderation in the relationship between CEE and FP suggests that, in the solar sector, the effectiveness of tangible assets may be less dependent on the workforce's skills and knowledge (as mentioned above), emphasizing the importance of technological considerations. Strategic alignment between HC and specific types of capital appears crucial for optimizing financial outcomes in the solar sector.

HCE's moderation impacts on profitability in wind sector companies are subtle, with no moderating between HCE and other MVAIC components. The association between CEE and profitability is favorably moderated by HCE, emphasizing the importance of skilled professionals in enhancing the operational efficiency and FP of tangible assets like wind turbines. Conversely, HCE negatively moderates the relationship between SCE and profitability, indicating that an overfocus on organizational structures in the wind sector may hinder profitability. These findings emphasize HC's asset-specific contributions and strategic decision-making in the Indian renewable industry's distinctive operational challenges.

The regression model includes Size and Leverage as control variables. Size positively influences earnings, whereas leverage undermines the Indian renewable energy industry's profitability. The significant positive effect of Size on earnings suggests that larger companies experience higher earnings, likely due to economies of scale. Conversely, the substantial detrimental impact of leverage on profitability raises the possibility that poorer industrial profitability is linked to greater debt levels.

In the Indian renewable energy sector, IC's importance in wind and solar energy project finances gives critical insights. Decision-makers can improve intellectual property and financial earnings using this knowledge; even though the study is equivocal on whether HC moderates fiscal outcomes, it underlines its importance and prompts companies to improve their HC management techniques. The study suggests combining economic and environmental factors in the sector to align financial strategies with environmental goals and enhance sustainability. Policymakers can leverage these findings to create and refine regulations supporting IC growth in the Indian renewable energy industry, promoting environmental sustainability and financial viability.

Additionally, the policymakers should focus on developing sector-specific strategies. This includes implementing policies to improve CEE in the solar sector and promoting HCE development in the wind sector. In the solar sector, for instance, lawmakers may offer tax breaks, low-interest loans, fast-track approval, and research and development tax credits; while in the wind sector, subsidies for training programs, industry-academia collaboration, and grants for human-centric innovation may contribute to the growth of HCEs. Moreover, policymakers should ensure that structural investments are optimized for profitability. From an investment standpoint, it is best to put money into solar businesses with a high CEE and wind companies with a strong HCE. However, they should be wary of wind companies that have made excessive structural investments that do not result in profitability.

The research will provide references for future IC research, particularly in India. Nonetheless, the study exhibits few limitations. Primarily, the research duration spans only six years, and extending this timeframe could yield more comprehensive and equitable results. Additionally, the analysis is limited to a single sector within a specific national context, the Indian renewable energy sector. Therefore, extending the findings to larger contexts may give more robustness to the study. Moreover, prospective studies might broaden understanding by including a sample of renewable energy companies from other Asian countries. Finally, this study encompasses only earnings and profitability indicators to evaluate financial success. Future studies could include more FP variables for a more comprehensive analysis.

Data availability

The datasets used and analyzed in this study are disclosed in the paper. However, the data used in the study can be available from the corresponding author upon reasonable request.

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Author contributions

FW has participated in the conceptualization, data analysis, writing, and preparation of the original draft. SNS participated in Writing- reviewing and editing, Visualisation, and Validation of the manuscript. While MK contributed to the study's conception, design, research methodology section, and analysis. SN was involved in collecting and sorting the data, interpreting the results, and drafting the manuscript. MKN was involved in methodology formulation, Data curation, and Formal analysis. All authors reviewed the results and approved the final version of the manuscript.

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