Do board characteristics matter in the relationship between intellectual capital efficiency and firm value? Evidence from the Nigerian oil and gas downstream sector

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Abstract

Purpose The purpose of this study is to investigate the moderating effects of board characteristics such as board size, chief executive officer duality, number of board meetings, and diversity, on the relationship between intellectual capital efficiency and firm value in the Nigerian oil and gas downstream sector.

Design/methodology/approach We collected time-series cross-sectional data from eight (8) downstream-sector oil and gas companies quoted on the Nigerian Exchange Group for the period 2004–2020. We analysed the data using Prais–Winsten regression with panel-corrected standard errors.

Findings Overall, our results show no significant direct relationship between the modified value-added intellectual coefficient and our two measures of firm value (Tobin's Q and Price Earnings Ratio (PER)). However, the board size is found to moderate the intellectual capital efficiency–PER relationship significantly and negatively, whereas board diversity significantly positively moderates the association between the modified value-added intellectual coefficient and PER. Our multi-theory framework, which blends clean surplus, agency, stakeholder, and resource-based theories is found to be relevant in underpinning this study.

Research limitations/implications The research relies on 17-year panel data for eight downstream-sector oil and gas companies. Consequently, future research within intellectual capital efficiency in Nigeria could incorporate related sectors like midstream and upstream to enable comparability and expand generalization.

Practical implication Policymakers may adopt the study findings to serve as a robust empirical base to demand improved board diversity as a catalyst for boosting the potency of the intellectual capital efficiency-firm value relationship.

Originality/value Firstly, to the best of our knowledge, this study is the pioneer attempt to use board characteristics as moderators of the relationship between intellectual capital efficiency and firm value. Secondly, we develop and use a novel theoretical framework that combines clean surplus, agency, stakeholder, and resource-based theories to underpin the study.

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Introduction

Prior studies on corporate governance emphasise its critical role of giving investors the information they need for efficient decision-making. On this premise, business success is notably linked to its corporate governance structure [24]. Maintaining high levels of efficiency requires an aggressive, well-designed, and efficient corporate governance framework. However, achieving such a framework involves a complicated and wide range of board processes. Corporate governance, through the choices and activities of a board of directors, is crucial in developing company strategy, leading and overseeing policy execution, and ensuring the attainment of corporate objectives. One such purpose seen to be at the forefront is to increase the market value of a corporate entity. The board of directors of an entity directs and regulates the effective management and utilization of various organizational resources to ensure goals are achieved. In recent years, intellectual capital has emerged as an essential organizational resource with a fast-rising value. On this note, the literature reviewed reveals that intellectual capital studies are soaring in Asia and developed countries, while developing economies are relatively obscure. Additionally, the just-exited COVID-19 pandemic has taught businesses in developing nations the need to evaluate, assess and manage intellectual capital resources to, at least, lessen the shock of such occurrences and multiplier effects in the future. Thus, [23, p. 368] maintains that intellectual capital implies "the possession of the knowledge, applied experience, organizational technology, customer relationships, and professional skills". In other words, intellectual capital is the aggregate of a company's intangible and knowledge-related capital used to produce value [58]. Moreover, [26] posit that a vital component of the nexus between intellectual capital and firms' performance is corporate governance. Consequently, our paper is based on the argument that even though corporate annual reports and accounts do not explicitly communicate information about intellectual capital, pieces of information on the matter can be gathered to facilitate its computation and measurement [91].

Furthermore, a wide range of studies on the direct relationship between intellectual capital efficiency and firm value have no consensus in the literature. For instance, intellectual capital, proxied by the modified value added intellectual coefficient, is found not only positively impact firms' current performance [14, 15, 59, 103], but also their future performance [90]. In this

regard, [58] further reveals that corporate goodwill and average net profit per employee positively affect firm value; and so is the aggregate intangible assets. Consistent with these findings, [70] posit that not only competitive advantage is achieved and maintained through intellectual capital efficiency, but also greater firm performance. On the contrary, some studies fail to show sufficient evidence of a positive association between the variables in question [52, 82]. Similarly, the results of this study reveal the importance of board characteristics in stimulating the relationship between intellectual capital efficiency and firm value. This is because prior to the introduction of board characteristics in our estimation, there existed no direct relationship between intellectual capital efficiency and firm value. However, with the interaction effect, moderation was found at least in two instances. Moreover, Nigeria's downstream oil and gas companies' managements need to deploy critical decisions that affect their aggregate modified value-added intellectual coefficients. This is particularly required to harness state-of-the-art resource capabilities, as well as employ strategies and policies that enhance employees' tactical contributions to achieve defined organizational goals to meet the ever-changing business environmental challenges.

The choice of Nigerian oil and gas downstream sector is on the premise that as the African most populous country, Nigeria largely depends on its petroleum products as the major source of export, hence, its critical importance. Furthermore, restricting the study to NGX-listed oil and gas companies in the country hinges on the fact that the interpretation of the modified value-added intellectual coefficient results across different sectors is normally problematic [83]. On this note, the value relevance of accounting information, employed by this study is justified, as [28] opined that ascertaining the appropriate value of a firm involves the determination of its book value of equity, abnormal earnings as well as other information (replaced in this study with the aggregate modified value-added intellectual coefficient). Also, the secondary data for this study were sourced from selected firms' annual reports and accounts, African markets as well as Nigerian Exchange Group (NGX) websites. From the foregoing, and through the lenses of our multi-theory framework (which combines clean-surplus, resources-based, agency, and stakeholder theories), we begin by investigating the direct association between intellectual

capital efficiency and firms value. This is then followed by the introduction of board characteristics in the indirect relationship as moderating variables. The rationale is to support this assertion by utilizing varied and distinctive proxies to make meaningful contributions to the existing literature.

To strengthen the outcomes of our estimations, this study incorporates firm-specific characteristics, including firm size, firm age and leverage as control variables based on relevant literature. However, board characteristics are measured through board size, board meetings, chief executive officer duality, and board diversity. Relatedly, a study conducted on the Indonesian listed firms, found corporate governance variables to weaken the intellectual capital—firms performance relationship [48]. However, [21] found corporate governance mechanisms such as board size and frequency of audit committee meetings to significantly affect firms' performance, whereas [5] found board size and board meetings to have a negative and significant impact on intellectual capital performance. Hence, this paper focuses on examining whether board characteristics play a pivotal role in ensuring that intellectual capital performance contributes to the creation and growth of oil and gas downstream sector firms' value.

Nowadays, next to water, hydrocarbons are the most depleted resource in this world. On this note, nineteenth century marks the beginning of a universal reliance on hydrocarbons as critical energy sources. This has significantly improved human general well-being and increased global wealth, but with a heavy price being paid in terms of environmental degradation, resource curse and price volatility effects. Despite sustained efforts to shift from fossil fuels to cleaner energy sources, the former remains the dominant energy source globally. Recent statistics supporting this assertion reveal that 85% of global energy is sourced from hydrocarbons, with oil and gas constituting 35.3% and 20.5% respectively [79]. More specifically, efforts to shift from fossil fuel consumption in Nigeria are still at an early stage [63, 73]. Furthermore, an array of studies on Nigeria's energy sector focuses on issues like energy demand and its supply based on population dynamics and carbon emissions [53], inadequate local refineries and erratic capacity utilization [66], with [64] acknowledging that the country's abundance of natural gas, as a transition energy, that hold immense potential for supporting sustainable growth. However, [18] stresses the country's overreliance on fossil fuel and its significant environmental, health, political, and economic consequences amidst rapid population growth. Thus, it follows that, given the relative importance of the oil and gas downstream sector as an immediate supplier of energy to consumers in Nigeria, an empirical analysis focusing on the relationship between intellectual capital efficiency and firm value as well as the moderating effect of board characteristics in this specific sector is strongly justified.

The rest of the paper consists of; Sect. 2 deals with the literature review, hypothesis development and theoretical framework, whereas Sect. 3 is research methodology and is followed by Sect. 4 which showed results and discussion of the study, and Sect. 5 concludes the study.

Literature review and hypotheses development
The effect of intellectual capital efficiency (ICE) on firm performance

Intellectual capital studies that use modified value-added intellectual coefficient as a proxy for intellectual capital efficiency on firms performance mainly document a significant positive relationship (see Table 1). Yet, only a few studies found a significant negative or no relationship between these variables (see [52, 98]). Furthermore, a substantial number of recent research concentrated on Asia and a few on developed and developing economies, but they largely focused on financial, manufacturing, healthcare/pharmaceutical, and/or information technology sectors (see [14, 30, 35, 47, 59, 88, 96]). Based on the aforementioned, [98] suggests further research on intellectual capital efficiency and firms' performance, especially in emerging economies. In addition, empirical studies on intellectual capital efficiency on firms' performance in the energy sector are very few (see [82, 98]). Thus, Table 1 presents a summary of representative studies on this subject.

Table 1 above shows that an overwhelming number of studies document a significant positive link between intellectual capital efficiency and firm performance. Obviously, this finding aligns with the resource-based theory which refers to intellectual capital as a strategic resource and a modern-day driver of firm value [15]. In a similar context, this routine positive relationship is consistent with stakeholder theory which relatedly advocates improved firm value via strengthening firm's internal and external relations [72]. The aggregate modified value-added intellectual coefficient, as a measure of intellectual capital performance, vis-à-vis human capital efficiency, structural capital efficiency, relational capital efficiency, and capital employed efficiency portrays organizations' intellectual potentials and capabilities. Specifically, this study seeks to test whether intellectual capital efficiency, proxied by modified value-added intellectual coefficient, has a significant impact on firms' value in the first instance. Thus, we hypothesize that:

> *H1: Oil and gas firms with better aggregate measures of modified value-added intellectual coefficients have better market values.*

Table 1 Representative studies on MVAIC and firms' performance

Author(s) and Year	Years range	DV, IV measurement and sector	Main findings	Country
[93]	2005–2011	DV: ROA and ROS IV: e-VAIC Sector: Pharmaceutical	Positive and significant	India
[59]	2011	DV: M/B, ROA and Margin IV: MVAIC Sector: Technology	Positive and significant	ASEAN
[94]	2002–2013 (12-years)	DV: ROA, ROE and ROS IV: E-VAIC Sector: Healthcare	Positive and significant	India
[54]	2001–2014 (14-years)	DV: ROA IV: MVAIC Sector: Pharm. and Chemical	Positive and significant	India
[90]	2007–2014 (8-years)	DV: ROA, ROE M/B and PER IV: MVAIC Sector: Mixed Theory: RBT	Positive and significant	Indonesia
[82]	2010–2017 (8-years)	DV: MBV and ROA IV: MVAIC Sector: Mixed Theories: SHT and RBT	ICE had a significant and positive impact on ROA. However, ICE has no significant impact on MBV	Indonesia
[88]	1999–2015 (17-years)	DV: ROA and ROE IV: MVAIC Sector: Banking Theory: RBV	Positive and significant	India
[14]	2012–2016 (5-years)	DV: ROA, ROE and TQ IV: MVAIC Sector: Banking Theory: RBT	Positive and significant	GCC
[97]	2012–2016 (5-years)	DV: EBIT, ROA, NPM, and ATO IV: MVAIC Sector: Manufacturing	Positive and significant	China
[100]	2012–2017 (6-years)	DV: EBITDA, ROA, ROE and ATO IV: VAIC and MVAIC Sector: Manufacturing	Positive and significant	China and South Korea
[102]	2007–2018 (12-years)	DV: ROA, NOM, and ATO IV: MVAIC and VAIC Sector: Financial Theories: RBV and KBV	Significant U-shaped relationship	Pakistan
[15]	2012–2016 (5-years)	DV: ROA, ROE and TQ IV: MVAIC Sector: Banking Theory: RBT	Positive and significant	GCC
[30]	2013–2018 (6-years)	DV: EBIT, NPM, GPM, EPS, ROIC, ROA, ROE, SG, ATO and M/B IV: MVAIC Sector: Pharma Theory: RBV	Positive and significant	China
[35]	2004–2018 (15-years)	DV: OE IV: MVAIC Sector: Financial	Positive and significant	India
[38]	2008–2017 (10-years)	DV: ROA and ROE IV: BFP and VAIC Sector: Banking	Positive and significant	Nigeria
[87]	2009–2018 (10-years)	DV: ROA and CPM IV: MVAIC Sector: Healthcare Theory: RBT	Positive and significant	India
[89]	2011–2018 (8-years)	DV: ROA and ROE IV: MVAIC Sector: Financial and Non-financial	Positive and significant	Vietnam

Table 1 (continued)

Author(s) and Year	Years range	DV, IV measurement and sector	Main findings	Country
[96]	2009–2018 (10-years)	DV: ROA and ATO IV: MVAIC Sector: Banking Theory: RBT	Positive and significant	India
[98]	2012–2016 (5-years)	DV: EBIT, ROA, ROE and ATO IV: MVAIC Sector: Manufacturing Theory: Signaling	Positive and significant	China
[99]	2013–2018 (6-years)	DV: ROA, ROE, ATO and M/B IV: MVAIC Sector: Manufacturing Theory: RBT	Positive and significant	South Korea
[52]	2013–2018 (6-years)	DV: FC, GP, GIP and GNIP IV: MVAIC Sector: Renewable energy Theory: CCC	An inverted U-shaped and no-relationship	China
[47]	2011–2015 (5-years)	DV: ROA, ROE and VC IV: MVAIC Sector: Mixed	No relationship	Europe, Asia, Africa and USA
[103]	2013–2018 (6-years)	DV: EP, ROA, ROE, and M/B IV: MVAIC Sector: Textile and Apparel	Positive and significant	China
[77]	2014–2020	DV: Internal Control Weaknesses IV: Intellectual Capital, Social Capital Components	Negative and significant	Iran
[55]	2009–2021	DV: ROA and OM IV: HC Sector: Business sectors	Negative and significant	Turkey
[61]	2005–2018	DV: VAIC IV: %Bureaucrat, Ln BureaucratYear Sector: Private Banks	Positive and significant	Turkiye
[76]		DV: Innovation IV: IC and Social Capital Sector: Mixed	Positive and significant	Iran
[80]	2012–2018	DV: VAIC IV: BSIZE, GCEO, CEO Change, Size, LEV Sector: Mixed	Positive and significant Negative and significant	Iran and Iraq
[78]	2012–2018	DV: GEND IV: Work Experiences and Education Sector: Mixed	Positive and Insignificant	Iran

Source: Authors Compilation, 2024

DV Dependent variable, *IV* Independent variable, *VAIC* Value Added Intellectual Coefficient, *MVAIC* Modified Value Added Intellectual Coefficient, *e-VAIC or E-VAIC* Extended and Modified VAIC, *IC* Intellectual Capital, *ICE* Intellectual Capital Efficiency, *ROA* Return on Asset, *ROE* Return on Equity, *ROS* Return on Sales, *PER* Price Earnings Ratio, *SGR* Sustainable Growth, *GIP* Green Innovation Performance, *MBV or M/B* Market to Book Value, *RBT* Resource Based Theory, *RBV* Resource Based View, *KBV* Knowledge Based View, *SHT* Stakeholder Theory, *TQ* Tobin's Q, *GPM* Gross Profit Margin, *NPM* Net Profit Margin, *ATO* Asset Turnover Ratio, *EBIT* Earnings Before Interest and Tax, *EBITDA* Earnings Before Interest, Taxes, Depreciation, and Amortization, *NOM* Net Operating Margin, *OE* Operational Efficiency, *EPS* Earnings Per Share, *ROIC* Return on Invested Capital, *SG or SGR* Sales Growth, *BFP* Boardroom Female Participation, *CPM* Cash Profit Margin, *FC* Financial Competitiveness, *GP* Green Patent, *GIP* Green Invention Patent, *GNIP* Green Non-Invention Patent, *CCC* Corporate Core Competitiveness, *EP* Employee Productivity

In specifics:

H1a: Oil and gas firms with better aggregate measures of modified value-added intellectual coefficients significantly affect Tobin's Q

H1b: Oil and gas firms with better aggregate measures of Modified Value-Added Intellectual Coefficients significantly affect Price Earnings Ratio

In addition, recently, most studies conducted on intellectual capital and firm performance employ moderating or mediating variables to unveil further insights into the relationship. While some use moderating variables that are different from board characteristics (see [18, 45, 49, 86]), others employ corporate governance variables (see for example; [33]). Indeed, very few studies utilize a single board characteristic (see [2, 7, 38] in

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Table 2 Representative studies on intellectual capital and firms' performance with a moderator

Author(s) and Year	Years range	DV, IV measurement and sector	Main findings	Publisher
[41]	1992–2000	DV: ROA, ROE, ROI, MVA and MR IV: IC MV: Environment Sector: High-Tech Industry Theory: KBV and Contingency	There is evidence of moderation	USA
[49]		DV: EPS, AOR, Global Agility and Global Innovation IV: HC, SC, and RC MV: TC and PC Strategies Sector: Manuf. and Service	There is evidence of moderation	Taiwan
[2]	2008–2010	DV: Board Diversity IV: VAIC MV: Board Meetings Sector: Banking Theory: RDT and Upper Echelon	There is evidence of moderation	GCC
[60]		DV: PBV, ROA, ROE and NPM IV: VAIC MV: ROE Sector: Manufacturing	There is evidence of moderation	Indonesia
[86]		DV: Innovativeness IV: OC, HC and Social Capital MV: Firm Size Sector: SMEs Software Development Theory: RBT	There is evidence of moderation	Kenya
[75]	2010–2014	DV: ATO, ROA, ROE, and ROI IV: HC, RC, InnC and PrC MV: HC Sector: Agribusiness	There is evidence of moderation	Emerald
[33]	2012–2014	DV: ROA, ROE and Tobin's Q IV: VAIC MV: CG Index Sector: Mixed Theory: Agency Theory	There is evidence of moderation	Saudi Arabia
[50]	3-Weeks	DV: Org. Perf. and Mkt. Perf IV: HC, CC and OC MV: Business Ties Sector: Tourism Theory: SCT	There is evidence of moderation	Taiwan
[3]		DV: ROA, ROE, EPS, and SGR IV: VAIC MV: KA Sector: Real Estate, Energy and Fin Theory: RBV and KBV	There is evidence of moderation	Australia
[45]	2010–2015	DV: ROA and CFLOW IV: VAIC MV: GOV Sector: Mixed Theory: RBT	There is evidence of moderation	Malaysia
[67]	2012–2016	DV: ROA IV: VAIC MV: Technical Intensity (TI) Sector: Technology Manufacturing	There is evidence of moderation	Italy
[16]		DV: Innovation Performance IV: Internal RC, External RC, and Trust Capital MV: IT Practices Sector: Mixed	There is evidence of moderation	Taiwan
[19]	2007–2010	DV: Social Venture's Perf IV: Age, Educ. Level, Prestigious Univ., Functional background MV: PSE and PCE Sector: Manufacturing and Services Theory: Human Capital Theory	Findings of the study show that prior social experience (PSE) and prior commercial experience (PCE) significantly and positively moderate human capital and firms' performance relationship	Korea

Table 2 (continued)

Author(s) and Year	Years range	DV, IV measurement and sector	Main findings	Publisher
[38]	2008–2017	DV: ROA and ROE IV: BFP and VAIC MV: BFP Sector: Banking Theory: RDT	The study found the interaction of BFP with VAIC to significantly and positively influence firms' market performance	Nigeria
[51]		DV: Social Capital IV: IC MV: Managerial Ties Sector: Hospitality Theory: IC Theory and SCT	Findings of the study reveal that managerial ties (i.e., business ties and government ties) moderate the IC–Hotel firms' performance relationship	China
[70]	2000–2013	DV: ROA IV: ICE MV: Family Management Sector: Manufacturing SMEs Theory: RBT and KBT	The moderating role of family management is found to be a double-edged sword depending on the type of intangible resources	Spain
[4]	2017	DV: OR IV: Foreign Markets MV: Ethnic Minority Ownership Sector: High-tech Manufacturing	The study found ethnic minority owners to significantly and positively moderate the relationship between foreign markets and operating revenue (OR) performances	US
[8]	2016–2018	DV: Dividend Policy = SHV IV: IC MV: CEO = Gender, Age, and Educ Sector: Mixed Theory: Agency Theory	The study avers that when the CEO is a woman and has a lower age, it significantly and positively moderates the relationship between IC and dividend policy	China
[19]		DV: Performance IV: SC, HC, and CC MV: Age and Gender Sector: Theory:	Age and gender are found to significantly and positively moderate the relationship between IC and firms' performances	India
[39]	2011–2017	DV: Organizational Sustainability IV: IC MV: SMM Sector: Educational Theory: Psychological Ownership Theory and RBT	The findings of the study report that SMM does not significantly moderate the relationship between IC and sustainability of private higher education organizations in East Java	Indonesia
[48]	2014–2018	DV: FP IV: VAIC MV: ACI Sector: Theory:	On the moderating effect of audit committee independence, the study found it to weaken the relationship between VAIC and firms' performance	Indonesia
[44]	2011–2018	DV: SC, RC, and HC IV: Board Independence MV: Firm Size Sector: Electronics industry Theory: Agency Theory and RBV	A cubic S-curve relationship is found between board independence and ICE variables, whereas firm size is revealed to moderate the nonlinear effects relationship between IC and board independence	Taiwanese

Source: Authors Compilation, 2024

MV Moderating variable, *HC* Human Capital, *SC* Structural Capital, *RC* Relational Capital, *EPS* Earnings Per Share, *AOR* Average Operational Revenues, *ROI* Return on Investment, *MVA* Market Value Added, *MR* Market Return, *RDT* Resource Dependency Theory, *PBV* Price-to-Book Value, *OC* Organizational Capital, *INN* Innovation Capital, Process Capital, *CG* Corporate Governance, *CC* Customer Capital, *ORG. PERF.* Organzational Performance, *MKT PERF.* Market Performance, *SCT* Social Capital Theory, *KA* Knowledge Asset, *CVCB* Consumer Value Co-Creation Behaviour, *FSEIB* Frontline Service Employee Innovative Behaviour, *CFLOW* Cash Flow, *GOV* Government, *SHV* Shareholders Value, *CEO* Chief Executive Officer, *SMM* Social Media Marketing, *FP* Financial Performance, *ACI* Audit Committee Independence, *OM* Operating Margin, *INCP* Intellectual Capital, *BSIZE* Board Size, *BGND* Board Gender, *BESO* Board Shareholding, *GCEO* CEO Gender

Table 2) and, a possible limitation to such an approach relates to a lack of consensus on the effect of the individual board characteristics variables on intellectual capital efficiency. So, capitalizing on this lacuna, our study examines the moderating effect of a range of board characteristics including the board size, number of board meetings, chief executive officer duality, and board diversity, on the relationship between intellectual capital efficiency, proxied by a modified value-added intellectual coefficient, and firm value. On this note, [42] argues that board characteristics increasingly influence firm value, because the board ensures proper deployment and application of intellectual capital resources. For this reason, we suspect that the board

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size, number of board meetings, chief executive officer duality and board diversity might indirectly affect firm value. This agrees with agency theory which in this context proposes that principal-agent conflict management can play a significant role through the board activities to affect firm value [31]. Likewise, consistent with agency theory, [95] contends that board size varies between entity complexity with numerous organizational managers and other major stakeholders seeing board diversity as a must in a firm value framework [17]. Not only is the diversity of the board essential but also their meetings. In this regard, the code of Nigerian corporate governance provides for at least quarterly meetings. Board meetings are an integral part of corporate co-existence and serve as leverage for ideas crossbreeding that leads firms to prosperity. Therefore, board characteristics could determine future earnings [1], and is therefore a strategic tool that influences firms' operating behaviour and value. Table 2 summarizes some recent intellectual capital efficiency studies that employed moderator(s).

Based on Table 2 above, as well as the relevant literature reviewed, we propose the following research hypotheses:

H2 Oil and gas firms' Board Characteristics moderate the aggregate measures of Modified Value-Added Intellectual Coefficient and firms' value.
In specifics:
H2a Board of Directors' size moderates the relationship between aggregate modified value-added intellectual coefficient and Tobin's Q in the Nigerian oil and gas downstream sector.
H2b: CEO duality moderates the relationship between aggregate modified value-added intellectual coefficient and Tobin's Q in the Nigerian oil and gas downstream sector.
H2c Number of board meetings moderates the relationship between aggregate modified value-added intellectual coefficient and Tobin's Q in the Nigerian oil and gas downstream sector.
H2d Board diversity moderates the relationship between aggregate modified value-added intellectual coefficient and Tobin's Q in the Nigerian oil and gas downstream sector.
H2e Board of Directors' size moderates the relationship between aggregate modified value-added intellectual coefficient and price-earnings ratio (PER) in the Nigerian oil and gas downstream sector.
H2f CEO duality moderates the relationship between aggregate modified value-added intellectual coefficient and price-earnings ratio (PER) in the Nigerian oil and gas downstream sector.

H2g Number of board meetings moderates the relationship between aggregate modified value-added intellectual coefficient and price-earnings ratio (PER) in the Nigerian oil and gas downstream sector.
H2h Board diversity moderates the relationship between aggregate modified value-added intellectual coefficient and price-earnings ratio (PER) in the Nigerian oil and gas downstream sector.

Theoretical framework
Our research focuses on the moderating effect of board characteristics on the relationship between intellectual capital efficiency and firm value. We adopt, modify and extend [6]'s multi-theory framework. Accordingly, four theories are found to be relevant to this study; they are clean surplus theory, resource-based theory, stakeholders' theory, and agency theory. Similarly, clean surplus theory underpins the value relevance of accounting information disclosed in the statements of comprehensive income and that of financial position. The theory advocates the separation of accounting information in the two financial statements and proposes that they have independent information content [84]. It further states that transactions resulting from the relationship between an entity and its owners are not passed through the statement of comprehensive income to keep it *clean*. Thus, such transactions are treated in the statement of changes in equity as an extension of the statement of financial position. Moreover, enshrined within the value-relevance of accounting information framework underpinned by the clean surplus theory, the link between human capital efficiency, structural capital efficiency and capital employed efficiency, and firm value is supported and explained by the resource based theory. However, within the same clean surplus theory framework, the association between relational capital efficiency and firm value is underpinned by the stakeholders' theory (see [6]).

Therefore, our study extracts accounting information from both statements to compute the modified value-added intellectual coefficient, which is hypothesized to determine firm value. Consequently, it follows that clean surplus theory operationalises the roles of accounting information (obtained from the statements of comprehensive income, financial position, and changes in equity) in explaining firm value. Consistent with clean surplus theory, most of the study's explanatory variables such as book value of equity (BVE), abnormal earnings (AE), modified value-added intellectual coefficient (which aggregates human capital efficiency, structural capital efficiency, relational capital efficiency, and capital employed efficiency), and board characteristics are extracted from annual
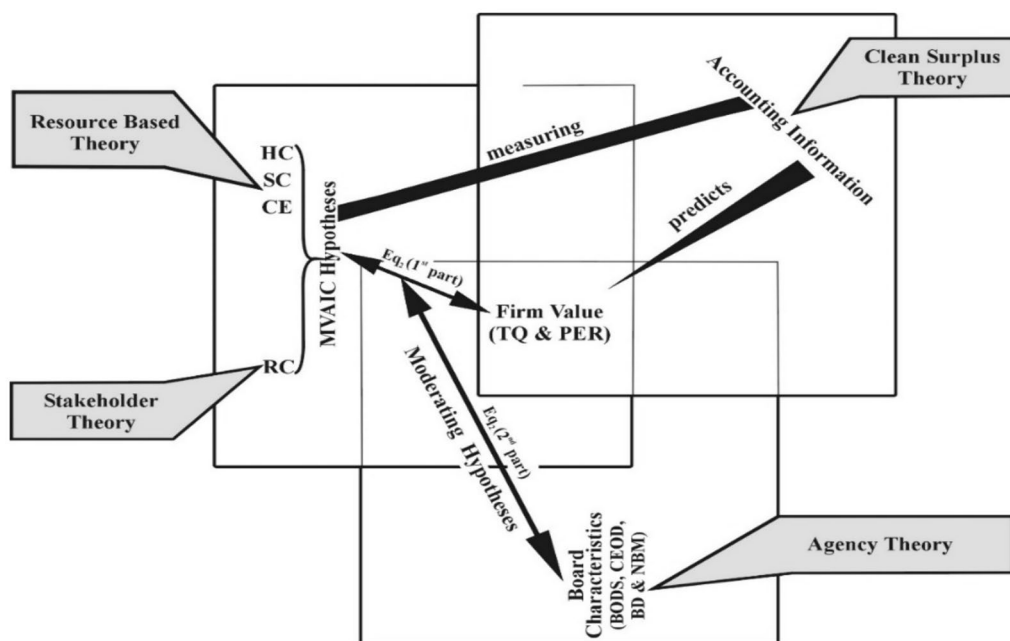
Fig. 1 Theoretical framework (Authors own construction, 2024—as modified from [6]'s multi-theory framework): Where: *HC* Human Capital, *SC* Structural Capital, *RC* Relational Capital, *CE* Capital Employed, *MVAIC* Modified Value-Added Intellectual Coefficient, *TQ* Tobin's Q, *PER* Price Earnings Ratio, *BODS* Board of Directors' Size, *CEOD* Chief Executive Officer Duality, *BD* Board Diversity, *NBM* Number of Meetings

reports and accounts of the sampled firms. Thus, in this study, board characteristics are considered as the moderating variables, because most board members are simultaneously shareholders and have privileged access to unpublished records, and that translates to their investment in the company. In this light, [27, 62, 104] maintain that firms' prospective profitability vis-à-vis value, is a product of the book value of equity, current earnings (i.e. abnormal earnings), and items of other information, for which we substituted value-added coefficient, an aggregate of human capital efficiency, structural capital efficiency, relational capital efficiency and capital employed efficiency in this study. Likewise, the study opines that resource-based theory and stakeholders' theory, on the one hand, and agency theory, on the other, are compatible in terms of facilitating efficient use of intellectual resources to create value. Thus, blending the three theories, within the framework of clean surplus theory, to derive hypotheses; H2a to H2h is justified. Besides that, it is worth noting that the entire tangible and intangible resources domiciled in an enterprise are directly acquired and utilized by the board of directors, and they make policies that direct and control how the resources are managed. Likewise, the board of directors designs and sees to the implementation of appropriate policies in which intellectual capital is acquired, harnessed, and utilized for the growth and sustainability of firm and increase

in value. However, both the entity's managers and the board of directors are agents of the owners but in two different capacities.

Notwithstanding, the agency relations between the managers and owners, the two compete to maximize their shares of financial gains realized though information asymmetry which places the management in a more advantageous position than the other owners. For this reason, [46] affirms that information asymmetry exists where executive management, as the agents of the owners, manages firms' resources on behalf of shareholders. Alas, information is power, and managements usually have motives to suppress or twist their private knowledge for personal gains. Thus, the board of directors is also an agent of the owners in the context of the traditional agency theory, as it is there to reduce information asymmetry and protect the interest of the shareholders. This, therefore, validates the nexus between the study's hypotheses and the multi-theory framework we develop to underpin it. Additionally, Fig. 1 below diagrammatically illustrates the connection between the four theories.

Methodology.

The study employs a deductive research strategy which entails the derivation and test of hypotheses. Within the framework of this research approach, we employ time-series cross-sectional (TS-CS) dataset from 2004 to 2020, which allows for the collection of past data used to examine the moderating effect of board characteristics

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on the relationship between the modified value-added intellectual coefficient and firm value for the listed downstream oil and gas companies in Nigeria. In addition, the descriptive-correlational research design used in the study allows for hypothesizing and estimating the connection between the modified value-added intellectual coefficient, board characteristics and firm value. According to [32, p. 215] descriptive-correlational designs "may be used to develop theory, identify problems with current practice, justify the current practice, make judgements, or determine what others in similar situations are doing". Descriptive-correlations design is suitable for testing the relationships between two or more variables as the case in this study.

Sample of the study, data collection and analysis

To test our hypotheses, we employed panel data from 8 listed oil and gas companies within the years, 2004 to 2020 consisting of 136 firm-year observations. The total number of listed firms on the floor of NGX from all sectors is small, as the entire population of the listed Nigerian oil and gas companies are 10. The 80% sampled is selected based on accessibility and sufficiency of financial information. The strongly balanced panel data were extracted manually from the published annual report and accounts and portals of the sampled firms, in addition to the NGX and African markets websites. Furthermore, while testing the study's hypotheses, a 1% winsorization was applied to deal with the issues of extreme outliers on aggregators of modified value-added intellectual coefficient and price-earnings ratio [71, 74]. Furthermore, this study utilizes [90]'s modified value-added intellectual coefficient model to first measure the relationship between intellectual capital efficiency and firms' value, then followed by the test of the moderating variable (that is, board characteristics) on the direct relationship. Though fascinatingly the research employed the [62] model, following various studies (see, [6, 28, 85]), the model's fundamentals book value of equity and abnormal earnings, which [28] opined to have a positive association with firm value are retained, whereas, modified value-added intellectual coefficient replaces the other information (OI) of the original value relevance of accounting information model.

Variables of the study and their measurements

The two main research hypotheses and ten sub-hypotheses were tested using Tobin's Q and Price Earnings Ratio as the dependent variables, and the modified value-added intellectual coefficient is a composite index as mentioned earlier for human capital efficiency, structural capital efficiency, relational capital efficiency, and capital employed efficiency as independent variables, while, moderating variable consists of board size, number of board meetings, chief executive officer duality and board diversity. Similarly, we employed three firms' characteristics; firm size, firm age, and leverage as control variables (see, [6, 40]), alongside [62] fundamentals, that is, book value of equity and abnormal earnings. Hence, Table 3 below presents variables of the study and their measurement.

Models of the study

The study's model depicted in Fig. 2 indicates the composite index of modified value-added intellectual coefficient as it links to the firm value, measured by (Tobin's Q and Price Earnings Ratio). It further exhibits the moderating and control variables as each associates with the dependent variable.

Now, to empirically test the postulated hypotheses in the earlier section and to deal with issues associated with time-series cross-sectional (TS-CS) dataset [13], the micro panel data was analysed using OLS regression with pairwise panel corrected standard errors (PCSE). Furthermore, following the works of [27, 62], we modelled the value-relevance equation as follows:

$$mv_{it} = \delta_{0i} + \delta_1 bve_{it} + \delta_2 ae_{it} + \delta_3 oi_{it} + \varepsilon_t \tag{1}$$

where mv_{it} = market value of a firm i at time year t, bve_{it} = book value of equity shares of firm's i at the year t end, and ae_{it} = abnormal earning of firm i at a time t period. [62] as cited in [6] measures the variable as net income minus 12% charge for the use of equity capital. *Note*: 12% is the long-term rate of return on equity [36]. oi_t = firm's i other information at time t orthogonal to its earning. ε_t = stochastic error term.

Similarly, following the works of [7], the other information in Eq. (1) above is replaced with the aggregators of modified value-added intellectual coefficient, that is; human capital efficiency, structural capital efficiency, relational capital efficiency and capital employed efficiency as independent variables, while firms' characteristics; firms' size, firm age, and leverage are introduced as control variables, yet retaining the [62] constants, that is the book value of equity and abnormal earnings in the direct relationship. Likewise, in the indirect relationship, interactions of the aggregator, the modified value-added intellectual coefficient with board characteristics are further added while maintaining the [62] constants and the study's control variables. Accordingly, Eqs. (2) and (3) present the econometric models of the direct and indirect relationships, respectively:

Table 3 Variable measurement

Variables	Labels	Measurement	Reference(s)
Dependent Variables			
Firm value	TQ	$\dfrac{\text{Market value of equity} + \text{Book value of liability}}{\text{Book value of total assets}}$	[6, 20]
	PER	$\dfrac{\text{Market capitalization}}{\text{Net earnings}}$	[10, 37]
Independent Variables			
Modified value-added intellectual coefficient	VA	Value added (VA) of the firm consists of: $OP + EC + I + T + D + A$ *Where:* OP = operating profit; EC = employee costs; I = Interest Expenses; T = Taxes; D = depreciation; A = amortisation	[56]
	HCE	VA/HC *Where:* HC = Human capital (Wages and salaries)	[43]
	SCE	SC = VA–HC; and SCE = SC/VA *Where* SC = Structural capital	[43]
	RCE	RC/VA *Where:* RC = Advert expenses + selling and distribution expense + marketing	[6, 62]
	ICE	HCE + SCE + RCE	[14, 59, 82]
	CEE	VA/CE *Where:* CE = physical capital + financial assets	[43]
	MVAIC	HCE + SCE + RCE + CEE	[15, 30, 47, 82]
Moderating Variables			
Board characteristics	BODS	Total number of directors on the board	[92]
	NBM	The number of board meetings held by the board members in the financial year	[92]
	CEOD	Scored 1 where the CEO is simultaneously the board chair otherwise it will be scored 0	[57]
	BD	$\dfrac{\text{Total female board members}}{\text{Board size}}$	[38]
Control Variables			
	LEV	$\dfrac{\text{Total debt}}{\text{Total assets}}$	[57]
	FSIZE	Natural logarithm of total assets	[57]
	FAGE	the logarithm of the number of years since the firm was incorporated	[33]
[62]'s (1995) model constant	BVE	BVE at time *t*, measured as the beginning BVE in a particular year	[6]
	AE	Abnormal earning at time *t*. This variable is measured as net income minus 12% charge for the use of equity capital. Note that 12% is the long-term rate of ROE	[6, 62]

Source: Authors Compilation, 2024

TQ Tobin's Q, *PER* Price Earnings Ratio, *HCE* Human Capital Efficiency, *SCE* Structural Capital Efficiency, *RCE* Relational Capital Efficiency, *CEE* Capital Employed Efficiency, *MVAIC* Modified Value-Added Intellectual Coefficient, *BODS* Board Size, *NBM* Number of Board Meetings, *CEOD* Chief Executive Officer Duality, *BD* Board Diversity, *LEV* Leverage, *FSIZE* Firm Size, *FAGE* Firm Age, *BE* Book Value of Equity, *AE* Abnormal Earnings

$$
\begin{aligned}
MV_{it} = \delta_0 &+ \delta_1 bve_{it} + \delta_2 ae_{it} + \delta_3 MVAIC_{it} \\
&+ \delta_4 HCE_{it} + \delta_5 SCE_{it} + \delta_6 RCE_{it} \\
&+ \delta_7 CEE_{it} + \delta_8 FSIZE_{it} \\
&+ \delta_9 FAGE_{it} + \delta_{10} LEV_{it} + +\varepsilon_{it}
\end{aligned} \tag{2}
$$

$$
\begin{aligned}
MV_{it} = \delta_0 &+ \delta_1 bve_{it} + \delta_2 ae_{it} + \delta_3 MVAIC_{it} \\
&+ \delta_4 BODS_{it} + \delta_5 NBM_{it} + \delta_6 CEOD_{it} \\
&+ \delta_7 BD_{it} + \delta_8 MVAIC * BODS_{it} + \delta_9 MVAIC * NBM_{it} \\
&+ \delta_{10} MVAIC * CEOD_{it} + \delta_{11} MVAIC * BD_{it} \\
&+ \delta_{12} FSIZE_{it} + \delta_{13} FAGE_{it} + +\delta_{14} LEV_{it} + \varepsilon_{it}
\end{aligned} \tag{3}
$$

where Market value (MV) is a continuous dependent variable proxied by Tobin's Q (TQ) and Price Earnings Ratio (PER) as interchanging dependent variables, Eq. (2) is estimated chronologically. Initially, the nexus of modified value-added intellectual coefficient aggregators alongside control variables (firms' size, firm age, and leverage) and firm value is analysed, then followed by modified value-added intellectual coefficient, interactive effects of board characteristics and control variables on firm value are examined. Note that, Tobin's Q, Price Earnings Ratio, Modified Value-Added Intellectual Coefficient (MVAIC), Firms' Size (FSIZE), Firm Age (FAGE), and Leverage
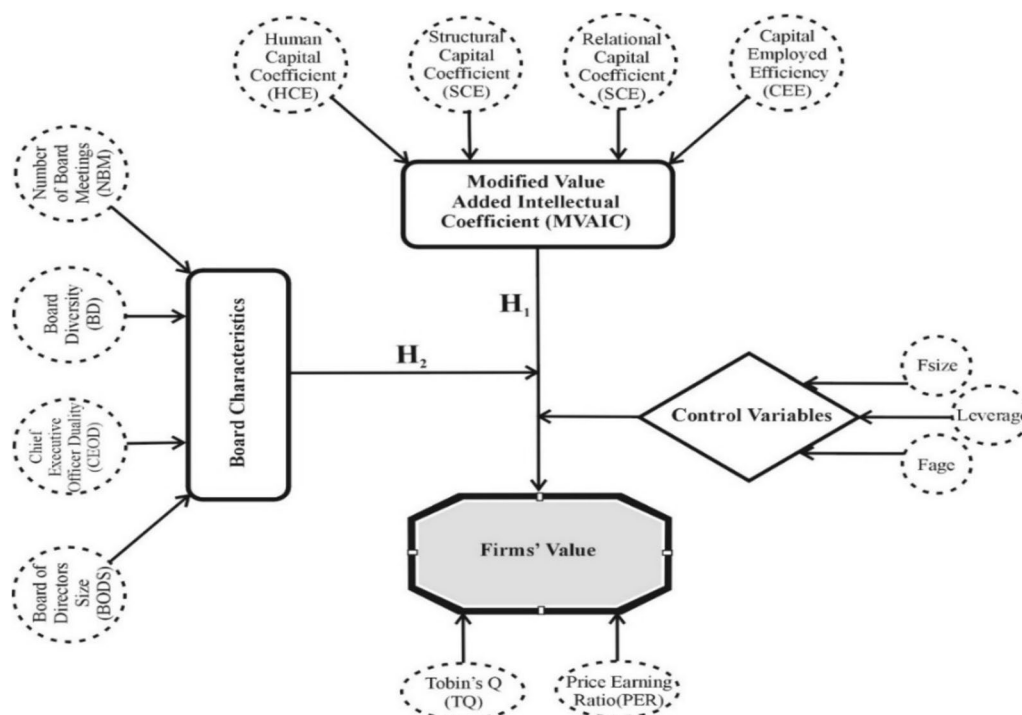
Fig. 2 Conceptual and statistical model of the study

(LEV) are continuous variables for firm's *(i)* at period *(t)*. The δ_0 is a constant and δ_{1-10} is the slope of the independent and control variables of Eq. (2), while δ_{1-14} in Eq. (3) is the slope of the aggregator of independent variables, the moderators, the moderator's interaction and control variables. Equally, Table 3 above provides a summary of the variables' measurements. Furthermore, take note, in the main value relevance model, share price (SP) is the conventional dependent variable (see, [6, 27, 28, 62]).

Results and discussion

Descriptive statistics and correlation matrix

Table 4 of this study presents descriptive statistics, it shows the mean price-earnings ratio has the highest value compared to Tobin's Q. This indicates that NGX-listed oil and gas firms' income/value is generated from investors' forecasts of future growths of earnings based on current earnings rather than expected future earnings concerning anticipated book value. The higher price-earnings ratio is believed to be a motivator for entities to increase investments, because, such would trigger investors to acquire more of the firms' shares to benefit from future earnings growth. In a nutshell, the high price-earnings ratio reveals investors' willingness to rely on future earnings growth although current earnings are low (see, [68]). Similarly, the high standard deviation observed from the price-earnings ratio indicates significant variations in earnings per share compared to book value returns among the sampled firms. The descriptive result further shows that except human capital efficiency among the intellectual capital efficiency variables, the modified value-added intellectual coefficient is the most influential in creating wealth with their greatest mean value of 10.305 and 8.346, respectively. Thus, human capital efficiency is attested to be the main driver of intellectual capital efficiency (see, for example, [96]). Furthermore, among the moderating variables, the board size has the highest mean of 9.015 and it is equally a human resource component, thus, it implies that firms create value essentially through their intangible resources rather than physical and financial. This finding corroborates with the works of [15, 59]. Similarly, the VIF test result indicates the study variables are within the acceptable threshold (see, [34]). Subsequently, the study hypotheses were tested using ordinary least squares (OLS) regression via pairwise panel corrected standard errors (PCSE), while the results robustness test is via feasible generalized least squares (FGLS).

Table 4 Descriptive statistics, pairwise correlation matrix and VIF among all the variables

Variable	Mean	SD	Min	Max	TQ	PER	BVE	AE	HCE	SCE	RCE	CEE	MVAIC	BODS	CEOD	BD	NBM	LEV	FSIZE	FAGE	VIF
TQ	0.914	0.888	0.000	5.179	1.000																
PER	8.956	11.596	−38.382	42.909		1.000															2.01
BVE	27.834	29.511	−44.992	119.074	−0.132	0.115	1.000														1.47
AE	0.010	0.295	−2.169	1.669	0.100	0.056	−0.031	1.000													2.88
HCE	10.305	40.538	−50.126	459.278	−0.103	−0.030	−0.030	0.501***	1.000												1.29
SCE	0.864	0.422	0.252	4.363	−0.074	−0.101	−0.201**	−0.152*	0.023	1.000											1.91
RCE	0.193	0.999	−10.622	1.590	0.101	0.119	0.136	0.135	0.004	−0.781***	1.000										2.67
CEE	0.202	0.212	−0.420	1.643	0.225***	0.133	−0.099	0.455***	0.600***	−0.166*	0.097	1.000									2.13
MVAIC	8.346	6.521	0.718	32.139	−0.095	0.098	0.152*	0.209**	0.524***	−0.001	0.084	0.202**	1.000								2.42
BODS	9.015	2.419	4.000	16.000	−0.097	0.016	0.075	−0.059	0.017	0.035	0.059	−0.296***	0.215**	1.000							2.16
CEOD	0.127	0.334	0.000	1.000	0.530***	0.286***	−0.105	0.114	−0.052	−0.106	0.096	0.282***	−0.116	−0.393***	1.000						1.32
BD	0.126	0.103	0.000	0.375	−0.115	−0.119	0.138	−0.150*	0.011	0.048	−0.138	−0.128	0.055	−0.014	−0.009	1.000					1.72
NBM	3.746	2.287	0.000	10.000	−0.128	−0.022	0.361***	−0.063	0.050	0.029	0.005	−0.167*	0.181**	0.188**	−0.076	0.255*	1.000				1.70
LEV	0.858	0.226	0.023	0.997	0.091	−0.052	0.304***	−0.092	−0.071	−0.021	0.031	−0.099	0.023	0.352***	−0.104	0.284*	0.341***	1.000			5.85
FSIZE	17.654	1.328	13.101	20.796	−0.050	0.129	0.469***	−0.076	0.044	−0.044	0.062	−0.182*	0.344***	0.425***	−0.121	0.397***	0.641***	0.606***	1.000		4.37
FAGE	3.650	0.442	2.303	4.234	0.237***	0.246***	0.564***	0.025	−0.070	−0.166*	0.107	0.092	−0.056	0.120	0.282***	0.270*	0.360***	0.500***	0.606***	1.000	
Mean VIF																					2.42

Source: Stata 16.0 output

Firm-year obs. = 136, ***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$

TQ Tobins' Q, *PER* Price Earnings Ratio, *BVE* Book Value of Equity, *AE* Abnormal Earnings, *HCE* Human Capital Efficiency, *SCE* Structural Capital Efficiency, *RCE* Relational Capital Efficiency, *CEE* Capital Employed Efficiency, *MVAIC* Modified Value-Added Intellectual Coefficient, *BODS* Board of Directors' Size, *CEOD* Chief Executive Officer Duality, *NBM* Number of Board Meetings, *BD* Board Diversity, *FSIZE* Firms' Size, *FAGE* Firm Age, *LEV* Leverage

Table 5 Prais–Winsten regression results on MVAIC and firm value (TQ and PER)

Variables	PCSE		FGLS for robustness test	
	TQ model	PER model	TQ model	PER model
	t-stat (Prob.)	*t*-stat (Prob.)	*t*-stat (Prob.)	*t*-stat (Prob.)
BVE_{it}	− 3.65*** (0.003)	− 0.34 (0.321)	− 3.28*** (0.003)	− 0.26 (0.041)
AE_{it}	1.03 (0.284)	0.21 (5.979)	1.10 (0.268)	0.35 (3.716)
HCE_{it}	− 2.89*** (0.002)	− 1.69* (0.043)	− 2.74*** (0.003)	− 2.03** (0.036)
SCE_{it}	0.21 (0.249)	0.17 (2.875)	0.29 (0.178)	0.20 (2.465)
RCE_{it}	1.85* (0.329)	2.46*** (4.742)	1.70* (0.358)	2.35** (4.963)
CEE_{it}	2.15** (0.468)	1.40 (9.099)	2.01** (0.498)	1.84* (6.901)
$MVAIC_{it}$	1.65* (0.011)	1.22 (0.204)	1.25 (0.014)	1.25 (0.991)
LEV_{it}	1.17 (0.411)	− 2.78*** (4.972)	1.22 (0.396)	− 2.52*** (5.481)
$FSIZE_{it}$	− 1.67* (0.089)	1.45 (1.416)	− 1.43 (0.104)	1.43 (1.440)
$FAGE_{it}$	2.74*** (0.265)	0.78 (3.821)	2.39** (0.303)	0.71 (4.198)
R^2	0.284	0.184		
F-value/Wald Ch^2	4.452***	2.518***	48.89***	27.65***
F-Sign/Prob Ch^2	0.000	0.009	0.000	0.002

Source: Stata 16.0 Output

TQ Tobins'Q, *PER* Price Earnings Ratio, *BVE* Book Value of Equity, *AE* Abnormal Earnings, *HCE* Human Capital Efficiency, *SCE* Structural Capital Efficiency, *RCE* Relational Capital Efficiency, *CEE* Capital Employed Efficiency, *MVAIC* Modified Value-Added Intellectual Coefficient, *FSIZE* Firms' Size, *FAGE* Firm Age, *LEV* Leverage

***$p < 0.01$, **$p < 0.05$ and *$p < 0.1$

The PCSE and FGLS Std. Err.—values are presented in parenthesis while the other figures represent *z*-score

The PCSE and FGLS Statistics—values is in parenthesis are Wald Ch2 and Prob Ch2 while the other figures represent

F-values and *F*-Significant

Direct relationship between the dependent and independent variables

At the initial stage, the research model tests the direct relationship between the dependents and independent variables, the result of which is presented in Table 5, thus, Model 1 is the baseline model, while Models 2 and 3 are the main model of the study, where Tobin's Q and Price-Earnings Ratio are utilized synonymously as dependent variables. The Prais–Winsten regression with PCSE estimation result is depicted in model 2, surprisingly, the aggregate modified value-added intellectual coefficient is marginal (*p* value < 0.1) level of significant positive

effect on firms' value (Tobin's Q) of Nigerian oil and gas firms, but not significant in all other scenarios, hence we fail to accept H1a. This finding is contrary to the work of [101], who empirically attests that the modified value-added intellectual coefficient ensures corporate sustainable growth vis-à-vis, value. Furthermore, no significant direct relationship was observed between aggregators of modified value-added intellectual coefficient and firm value (price earnings ratio), which also leads to the rejection of H1b, similar findings were reported by [82]. Besides, in terms of modified value-added intellectual coefficient sub-components, only human capital efficiency was found to negatively affect market performance (Tobin's Q), whereas, relational capital efficiency and capital employed efficiency are found to positively drive firms' value (Tobin's Q and price-earnings ratio). The result indicates that Nigerian oil and gas companies enhance their value mildly through intangible IC, while other resources play important roles.

With regards to Feasible Generalised Least Squares (FGLS) robustness analysis, similar positive modified value-added intellectual coefficient but insignificant were observed in both modified value-added intellectual coefficients on Tobins' Q and modified value-added intellectual coefficient on price earnings ratio relationships. The empirical results of this study are in agreement with the works of [47], who found no association between the modified value-added intellectual coefficient and the value creation of entities. However, it is divergent from the findings of [14, 30, 51]. In respect of [62]'s constant, only the book value of equity reports a significant negative relationship with firm value (Tobins' Q) for both Panel Corrected Standard Errors (PCSE) models and Feasible Generalised Least Squares (FGLS) robustness test. In addition, in terms of firms' specific control variables, firms' age and firm size were found to respectively have significant positive and negative relationships with Tobins' Q, while leverage indicates a significant negative association with price earnings ratio. Likewise, Feasible Generalised Least Squares (FGLS) robustness analysis reports similar results. Additionally, the subsequent section of this research depicts the moderating effect of board characteristics on the association between modified value-added intellectual coefficient and firm value (Tobins' Q and price earnings ratio).

Moderation effect of board characteristics on Modified Value-Added Intellectual Coefficient and firm value (Tobins' Q and Price Earnings Ratio) relationships

Hierarchical regression was employed to assess the moderating effect of board characteristics on the relationship between intellectual capital efficiency and firm

value. Although, hierarchical regression is a model affinity analysis [25]. Many studies have utilized it (see, for example, [2, 29]). Consequently, we apply hierarchical regression to test the hypotheses H2a to H2h. Thus, we examined (Tobins' Q as the dependent variable), the explanatory aptitude of each set of independent variables of the regression where initially added, [62]'s constant, the modified value-added intellectual coefficient and its component, and the control variables in (Table 6: column 1), then (Table 6: columns 2 and 3), the moderators and interactions were added, respectively. The same relationship was measured using (Price Earnings Ratio as the dependent variable) and the explanatory variables in (Table 6: columns 4, 5 and 6). Furthermore, the feasible generalised least squares robustness test of the aforesaid results was in (Table 6: columns 7, 8, and 9) that relate to Tobins' Q as well as (Table 6: columns 10, 11, and 12) linked to Price Earnings Ratio.

Thus, analyzing the Panel Corrected Standard Errors regression results (TQ as dependent variable) showed that the modified value-added intellectual coefficient (p value < 0.1) is significantly positive (Table 6: Column 1). Likewise, the introduction of board characteristics variables in Column 2 (Table 6) reveals that the modified value-added intellectual coefficient is insignificant. Similarly, with the addition of interaction variables (Table 6: Column 3), the modified value-added intellectual coefficient remains insignificant (p value > 0.1). On the constituents of the modified value-added intellectual coefficient, only relational capital efficiency and capital employed efficiency showed a significant positive relationship with Tobins' Q (Table 6: Column 1), whereas, human capital efficiency is consistently significantly negative (Table 6: Columns 1, 2, and 3), and no relationship was observed with structural capital efficiency. Nonetheless, [62]'s book value of equity and abnormal earnings are consistent among all the models (Columns 1, 2, and 3), although only the book value of equity depicts a significant negative relationship (Table 6) with (p values, < 0.01, < 0.1 and < 0.1), respectively. Abnormal earnings reveal an insignificant relationship. Moreover, on the firms' specific control variables, firms' age (p values < 0.01, < 0.1 and < 0.1 respectively) shows a significant positive relationship across the first three columns (Table 6). Also, leverage (p value < 0.05) showed a significant positive association (Table 6: Columns 2 and 3). Yet, firm size (p value < 0.1) depicts a significant negative (Table 6: Column 1) relationship. Furthermore, among the moderators, board diversity (p values < 0.05) remains uniformly significant but negative (Table 6: Columns 2 and 3) along with number of board meetings (p value < 0.05) in Table 6 (Column 2), while board size and chief executive officer duality showed significant positive (Table 6: Column

2) with (p values < 0.1 and < 0.01), respectively. Even so, none of the moderating interactions board size_modified value-added intellectual coefficient (BODS_MVAIC), chief executive officer duality_modified value-added intellectual coefficient (CEOD_MVAIC), number of board meetings_modified value-added intellectual coefficient (NBM_MVAIC) and board diversity_modified value-added intellectual coefficient (BD_MVAIV) reveals a significant relationship. Based on this result, we reject hypotheses H2a, H2b, H2c and H2d and conclude that board characteristics do not moderate the relationship between modified value-added intellectual coefficient and firm value (Tobins' Q). It is also observed that across columns 1 and 2, the models R2 greatly increases from 23 to 45%, while it relatively increases to 47% (Table 6: Column 3). Thus, we inferred that column 3 which includes the interactions, boosts the model fitness. Similarly, the f-statistics of the coefficients of the three models (Columns 1, 2, and 3) are significant at (p value < 0.01), suggesting fit specification of the models [87, 88].

Estimating the same relationship with Price Earnings Ratio (PER) as the dependent variable in Table 6, the PCSE regression results indicate that, the modified value-added intellectual coefficient is significant and positive (p value < 0.05) when all the variables and interactions were added (Table 6: Column 6). While the modified value-added intellectual coefficient depicts insignificant association in the two penultimate columns (Table 6: Columns 4 and 5). With regards to the modified value-added intellectual coefficient components, only relational capital efficiency maintains a perfect significant positive (p value < 0.01) relationship (Table 6: Columns 4, 5, and 6), although human capital efficiency showed a significant negative (p value < 0.1) in (Table 6: Column 4), however, structural capital efficiency and capital efficiency depict no significant relationships. Further, both [62]'s constants, that is book value of equity and abnormal earnings are steadily insignificant in all the models (Table 6: Columns 4, 5, and 6). Although, in the firms' specific control variables, only leverage, respectively, showed a significant negative (p values < 0.01, < 0.05 and < 0.1) relationship (Table 6: Columns 4, 5, and 6), contrarily, firms' size significant positive (p value < 0.1) relationship occurs at (Table 6: Column 5), while firm age depicts no association with the firm value (price earnings ratio). Nonetheless, of the moderating variables, only board diversity uniformly showed a significant but negative (p values < 0.05 and < 0.01) relationship with firm value (price earnings ratio) in (Table 6: Columns 5 and 6), while board size, chief executive officer duality and number of board meetings depict an insignificant association with firms' value (price earnings ratio). Also, despite the previous stage association, the introduction of the interaction

Table 6 Regression results on the moderating effect of board characteristics on MVAIC and firm value relationship (NEW APPROACH under FGLS)

Variables	PCSE using Model 2						Variables	FGLS using Model 2 (Robustness Test)					
	TQ with M/V—Model			PER with M/V—Model				TQ with M/V—Model			PER with M/V—Model		
	(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)	(9)	(10)	(11)	(12)
BVE	−3.65*** (0.003)	−1.65* (0.003)	−1.85* (0.003)	−0.34 (0.032)	0.31 (0.037)	−0.30 (0.036)	BE	−3.28*** (0.003)	−1.71* (0.003)	−1.95** (0.003)	−0.26 (0.041)	0.11 (0.042)	−0.02 (0.042)
AE	1.03 (0.284)	0.72 (0.255)	0.69 (0.255)	0.21 (5.979)	−0.07 (6.110)	−0.18 (5.556)	AE	1.10 (0.268)	0.76 (0.242)	0.73 (0.239)	0.35 (3.716)	−0.12 (3.453)	−0.30 (3.307)
HCE	−2.89*** (0.002)	−1.63* (0.003)	−1.52* (0.003)	−1.69* (0.043)	−0.84 (0.047)	−0.99 (0.045)	HCE	−2.74*** (0.003)	−1.67* (0.002)	−1.60* (0.002)	−2.03** (0.036)	−1.16 (0.034)	−1.34 (0.033)
SCE	0.21 (0.249)	0.28 (0.210)	0.26 (0.198)	0.17 (2.875)	0.24 (2.254)	0.41 (2.108)	SCE	0.29 (0.178)	0.37 (0.159)	0.33 (0.159)	0.20 (2.465)	0.23 (2.269)	0.40 (2.199)
RCE	1.85* (0.329)	0.57 (0.300)	1.12 (0.307)	2.46*** (4.742)	2.59*** (4.760)	2.82*** (4.433)	RCE	1.70* (0.358)	0.47 (0.363)	0.89 (0.386)	2.35** (4.963)	2.38** (5.174)	2.34** (5.339)
CEE	2.15** (0.468)	1.32 (0.432)	1.35 (0.446)	1.40 (9.099)	0.76 (9.885)	0.08 (9.349)	CEE	2.01** (0.498)	1.22 (0.468)	1.23 (0.491)	1.84* (6.901)	1.13 (6.671)	0.10 (6.800)
MVAIC	1.65* (0.011)	0.88 (0.011)	−0.18 (0.044)	1.22 (0.204)	0.97 (0.200)	2.29** (0.842)	wMVAIC	1.25 (0.014)	0.72 (0.013)	−0.16 (0.049)	1.25 (0.991)	1.04 (0.187)	2.84*** (0.677)
LEV	1.17 (0.411)	2.25** (0.411)	2.02** (0.440)	−2.78*** (4.972)	−2.06** (5.109)	−1.81* (5.348)	LEV	1.22 (0.396)	2.41** (0.384)	2.34** (0.381)	−2.52*** (5.481)	−1.92* (5.476)	−1.84* (5.271)
FSIZE	−1.67* (0.089)	−0.73 (0.104)	−0.75 (0.104)	1.45 (1.416)	1.52* (1.914)	1.26 (1.839)	FSIZE	−1.43 (0.104)	−0.65 (0.117)	−0.67 (0.117)	1.43 (1.440)	1.73* (1.674)	1.43 (1.615)
FAGE	2.74*** (0.265)	1.51* (0.310)	1.69* (0.318)	0.78 (3.821)	0.81 (4.942)	1.24 (4.843)	FAGE	2.39** (0.303)	1.47* (0.319)	1.65* (0.326)	0.71 (4.198)	0.88 (4.556)	1.33 (4.514)
BODS	1.65* (0.035)	1.49* (0.035)	0.34 (0.057)	−0.40 (0.612)	−0.40 (0.612)	1.31 (0.936)	BODS		1.32 (0.039)	0.31 (0.064)		−0.44 (0.556)	1.39 (0.881)
CEOD		3.64*** (0.319)	−0.09 (1.027)	0.35 (4.015)	0.35 (4.015)	0.04 (8.733)	CEOD		4.21*** (0.276)	−0.13 (0.746)		0.35 (3.937)	0.03 (10.330)
BD		−2.34*** (0.520)	−2.06** (0.824)	−1.93** (9.851)	−1.93** (9.851)	−2.85*** (13.376)	BD		−1.79 (0.691)	−1.58* (1.076)		−1.93** (9.859)	−2.56*** (14.906)
NBM		−2.09** (0.039)	−1.09 (0.060)	−1.36 (0.586)	−1.36 (0.586)	−0.28 (0.818)	NBM		−2.18** (0.037)	−1.13 (0.058)		−1.50* (0.530)	−0.29 (0.804)
BODS_MVAIC			0.29 (0.004)			−2.46*** (0.061)	BODS_MVAIC			0.23 (0.004)			−2.50*** (0.060)
CEOD_MVAIC			1.21 (0.153)			0.59 (1.129)	CEOD_MVAIC			1.84* (0.100)			0.48 (1.390)
BD_MVAIC			0.51 (0.064)			2.06** (1.114)	BD_MVAIC			0.34 (0.095)			1.75* (1.310)
NBM_MVAIC			−0.00 (0.004)			−0.92 (0.062)	NBM_MVAIC			−0.00 (0.005)			−0.89 (0.065)
R^2	0.284	0.448	0.465	0.184	0.252	0.317	Log_likelihood	−139.75	−111.84	−110.13	−463.06	−409.55	−404.48

Table 6 (continued)

Variables	PCSE using Model 2					
	TQ with M/V—Model			PER with M/V—Model		
	(1)	(2)	(3)	(4)	(5)	(6)
R^2 change		0.164***	0.017		0.069	0.065*
F-value	4.452	5.625	4.486	2.518	2.338	2.398
F-Sig	0.000	0.000	0.000	0.009	0.008	0.003

Variables	FGLS using Model 2 (Robustness Test)					
	TQ with M/V—Model			PER with M/V—Model		
	(7)	(8)	(9)	(10)	(11)	(12)
Wald chi2	48.89***	90.93***	97.24***	27.65***	37.79***	51.99***
Prob > chi2	0.000	0.000	0.000	0.0002	0.001	0.000

Source: Stata 16.0 Output

The PCSE and FGLS Std. Err.—values are presented in parenthesis while the the other figures represent z-score

The Log-likelihood, Wald chi2 and Prob > chi2 under the FGLS model was generated from the FGLS model to satisfy the moderation analysis

***p < 0.01, **p < 0.05 and *p < 0.1

variables (Table 6: Column 6), the result showed that board diversity_modified value-added intellectual coefficient (BD_MVAIC) positively and significantly affects price-earnings ratio (p value < 0.05), contrary to board diversity_modified value-added intellectual coefficient (BD_MVAIC) relationship with firms' value (Tobins' Q) which is not significant. Moreover, the chief executive officer duality_modified value-added intellectual coefficient (CEOD_MVAIC) and the number of board meetings_modified value-added intellectual coefficient (NBM_MVAIC) reveal an insignificant relationship with the price-earnings ratio. From the foregoing, the study accepts hypotheses, H2e and H2h while it rejects H2f and H2g. Hence, we deduced that board size and board diversity moderate the relationship between modified value-added intellectual coefficient and firm value (price-earnings ratio).

A swift examination of (Table 6) reveals the models R2 greatly increases from 18 to 25% (Columns 4 and 5) respectively and substantially increases to 32% (Column 6). Accordingly, it implied that column 6 which includes the interactions, enhances the model's suitability. Equally, the combined f-statistics of the coefficients of the three models (Columns 4, 5, and 6) are significant (p value < 0.05), suggesting the model is well specified [87, 88]. As a whole, among the board characteristics proxies, board diversity and board size are, respectively, found to positively and negatively moderate the relationship between modified value-added intellectual coefficient and firm value (price-earnings ratio). Furthermore, results obtained from FGLS robustness are comparable to PCSE. Table 7 below provides a summary of hypotheses and robustness tests result.

Discussions

Nonetheless, intellectual capital efficiency is recognized to have an effect in creating corporate financial performance, increasing competitive advantage in addition to influencing firms' market value. Thus, in the context of Nigeria, this is the pioneering study to consider aggregate modified value-added intellectual coefficient on firms' market value, with board characteristics as a moderator. The regression result suggests no direct association between the modified value-added intellectual coefficient and firms' value in the Nigerian oil and gas downstream sector firms. For instance, the result revealed a mild positive but insignificant direct relationship between modified value-added intellectual coefficient and firms' value (Tobins' Q), contrary to the previous findings of [14, 15, 55, 99, 103] et cetera. Repugnant to multi-theories support that links intellectual capital efficiency and firms' value (see, Fig. 1) as well as intellectual capital efficiency literature empirical evidence (see, for example, [18, 39,

45, 50, 70]), similarly, with price-earnings ratio as the dependent variable, as well as the robustness test models no significant relationship with modified value-added intellectual coefficient was observed, akin to the works of [47, 81, 82]. Consequently, although intellectual capital is assumed to enhance firms' value, our result is to the contrary in Nigeria, thus, other factors are believed to be responsible. Hence, this study further investigates the moderating effect of board characteristics.

Therefore, on the moderating effect of board characteristics, the model explanatory power was enhanced by the addition of the interactions (see, the R2 of Table 6: columns 3 and 6), which signifies the moderating effect of independent variables on the dependent. Conversely, when Tobins' Q is the dependent variable, in-depth analysis of the four interaction terms board size_modified value-added intellectual coefficient (BODS_MVAIC), chief executive officer duality_modified value-added intellectual coefficient (CEOD_MVAIC), board diversity_modified value-added intellectual coefficient (BD_MVAIC), and the number of board meetings_modified value-added intellectual coefficient (NBM_MVAIC) showed an insignificant relationship), i.e., none moderates the relationship between modified value-added intellectual coefficient and Tobins' Q. The findings are in divergent from the works of [9, 34, 38] who found board characteristics to moderate the relationship between intellectual capital efficiency and firms' value. In contrast, when (the price-earnings Ratio is the dependent variable), the board size_modified value-added intellectual coefficient (BODS_MVAIC) in which board size is found to moderate the association between aggregate intellectual capital efficiency and the price-earnings ratio has a significant negative relationship, that is, aggregate intellectual capital efficiency is weakened by size of the board, this implied that Nigerian oil and gas downstream sector investors foresee fairly higher board size as an obstacle that can create bureaucracy in the firms' market value decision-making processes. Inversely, the board diversity, modified value-added intellectual coefficient (BD_MVAIC) in which board diversity moderates the relationship between aggregate intellectual capital efficiency and the price-earnings ratio has a significant positive relationship, meaning, aggregate intellectual capital efficiency is strengthened by board diversity, this finding implies that, investors and other capital market players predict and value Nigerian oil and gas firms' when their board comprises of satisfactory number mixture of men and women members. This result is analogous to [38], where female board directors' interaction with intellectual capital components is found to positively influence Nigerian banking firms' performance.

Table 7 Hypotheses test/robustness test

H/No	Diagnostics test	PCSE		FGLS	
		TQ	PER	TQ	PER
H1a	Oil and gas firms with better MVAIC significantly affect TQ	Rejected	–	Rejected	–
H1b	Oil and gas firms with better MVAIC significantly affect PER	–	Rejected	–	Rejected
H2a	Oil and gas firms' BODS moderates the MVAIC and TQ relationship	Rejected	–	Rejected	–
H2b	Oil and gas firms' CEOD moderates the MVAIC and TQ relationship	Rejected	–	Accepted	–
H2c	Oil and gas firms' NBM moderates the MVAIC and TQ relationship	Rejected	–	Rejected	–
H2d	Oil and gas firms' BD moderates the MVAIC and TQ relationship	Rejected	–	Rejected	–
H2e	Oil and gas firms' BODS moderates the MVAIC and PER relationship	–	Accepted	–	Accepted
H2f	Oil and gas firms' CEOD moderates the MVAIC and PER relationship	–	Rejected	–	Rejected
H2g	Oil and gas firms' NBM moderates the MVAIC and PER relationship	–	Rejected	–	Rejected
H2h	Oil and gas firms' BD moderates the MVAIC and PER relationship	–	Accepted	–	Accepted

Source: Authors' Compilation, 2024

TQ Tobins' Q, *PER* Price Earnings Ratio, *MVAIC* Modified Value-Added Intellectual Coefficient, *BODS* Board of Directors Size, *CEOD* Chief Executive Officer Duality, *NBM* Number of Board Meetings, *BD* Board Diversity

Conclusion

Primarily, the study objective is to investigate the moderating effects of board characteristics on the intellectual capital efficiency—firms' value relationship, whether it leads to efficient operations and improves value. Though, there are numerous approaches to intellectual capital measurement, yet, in the context of Nigerian oil and gas sector companies, limited literature exists on the use of [90]'s modified value-added intellectual coefficient on firms' value. Thus, this research investigates intellectual capital efficiency and the value of 8 NGX-quoted downstream sector oil and gas firms from 2004 to 2020, the data generated was analysed using the Prais–Winsten regression via PCSE. Whereas FGLS analysis was carried out for robustness.

Theoretical implications

Based on the results of this study, we heed to [22] advice, guiding intellectual capital research and used a multi-theory framework to support the research hypotheses to accomplish its goals. To measure the modified value-added intellectual coefficient, which was supported by resource-based theory and stakeholders' theory while predicting firms' value in the first segment, as well as clean surplus theory is demonstrated to operationalize accounting information. Moreover, agency theory validates the characteristics of the board while examining its moderating effect on the relationship between the modified value-added intellectual coefficient and firms' value. The findings imply that the value of oil and gas companies in Nigeria is unaffected by the efficiency of intellectual capital as determined by the modified value-added intellectual coefficient. The outcome of the study portrays a divergence with intellectual resources;

as well as stakeholders' inclusion as the key to organizational success. Furthermore, the interaction of board characteristics components with modified value-added intellectual coefficient suggests that a significant female representation on the Nigerian oil and gas companies board strengthens the intellectual capital efficiency impact, as opposed to the size of the board of directors, which weakens the relationship due to the expected existence of bureaucracy. The interaction results reaffirm the agency theories balancing agents' interest for the overall goals attainment of the entity.

Practical implications

Management of downstream oil and gas sector firms in Nigeria could make vital decisions that might influence their entities on aggregate modified value-added intellectual coefficient. For instance, the negative effect of human capital efficiency can be changed by the management to ensure adequate investment in human capital, besides employing strategies and policies that enhance employees' strategic contributions to achieve state-of-the-art organizational goals to meet the ever-dynamic business environmental challenges and remain competitive. Furthermore, the non-significance of structural capital efficiency reveals the inexistence of firms' in-build methods and processes that improve operational capabilities. Turning around these two important intellectual capital elements, in conjunction with relational capital efficiency and capital employed efficiency, the aggregate modified value-added intellectual coefficient will significantly influence the market performance of the enterprises. Furthermore, the study recommends that substantial women directors should be on the firms' boards, for women are bent drivers of firms' intellectual capital efficiency which

Table 8 Summary of diagnostic test

Diagnostics test	Statistics	*p* value	Remark
Time (years) fixed effect	1.16	0.3250	Absent
Oil and Gas Companies (units) fixed effect	6.83	0.0000	Present
Group-wise Heteroskedasticity	2030.25	0.0000	Present
Contemporaneous correlation	1.394	0.0163	Absent
Panel serial correlation	47.082	0.0002	Present
Normality Test Skewness/Kurtosis,			Skewed
Shapiro–Wilk			Not normally distributed
Shapiro-Francia			Not normally distributed

Source: Authors Compilation, 2024

might lead them to greater market value. Similarly, the number of directors should be trimmed to the barest minimum so also, their expertise should be considered.

Limitations and future research

This study has limitations and sets the ground for future investigation. Intellectual capital efficiency is measured using a modified value-added intellectual coefficient. Still, due to recent criticisms of [69]'s approach plus the addition made by [90]'s future researchers can employ other proposed measures, like [9]'s Extended-Value Added Intellectual Coefficient or [65]'s approach. Furthermore, the research focuses only on 8-NGX quoted downstream oil and gas firms, to increase the study sample, other studies can include both midstream and upstream sector companies, though not listed on the NGX to increase generalisation of the findings.

Diagnostics check

In our research, Tobins' Q and Price Earnings Ratio are employed as the dependent variables, we re-estimate both the direct and indirect relationships among the variables. In both cases, Feasible Generalised Least Squares (FGLSs) results are similar to the Panel Corrected Standard Errors (PCSEs) findings, thus, it suggests the robustness of our conclusion. Likewise, due to the nature of the dataset, Table 8 summarizes the diagnostics test conducted, for [12] argued that standard errors are OLS errors. Consequently, the errors will be erroneously estimated if the time-series cross-sectional (TS-CS) dataset exhibits panel heteroskedasticity, contemporaneous correlation and/or panel serial correlation. Prais–Winsten regression via PCSE estimation automatically corrects for the first two but assumes that there is no autocorrelation [12, 13]. However, pair-wise was employed to correct for the panel serial correlation [11].

The result of Table 8 above, confirms our data estimation choices that fix all the issues identified (see, [11]).

Key resources table

Raw data used for the Analysis of the Study was published with Mendeley data: https://doi.org/10.17632/2yns89t5jx.1.

Abbreviations

CG	Corporate Governance
BODS	Board of Directors Size
NBM	Number of Board Meetings
CEOD	Chief Executive Officer Duality
BD	Board Diversity
ICE	Intellectual Capital Efficiency
VAIC	Value-added Intellectual Coefficient
e-VAIC or E-VAIC	Extended VAIC
HC	Human Capital
SC	Structural Capital
RC	Relational Capital
MVAIC	Modified Value Added Intellectual Coefficient
HCE	Human Capital Efficiency
SCE	Structural Capital Efficiency
RCE	Relational Capital Efficiency
CEE	Capital Employed Efficiency
FSIZE	Firm Size
FAGE	Firm Age
LEV	Leverage
DV	Dependent Variable
IV	Independent Variable
ROA	Return on Asset
ROE	Return on Equity
ROS	Return on Sales
PER	Price Earnings Ratio
SGR	Sustainable Growth
GIP	Green Innovation Performance
MBV or M/B	Market to Book Value
RBT	Resource Based Theory
RBV	Resource Based View
KBV	Knowledge-Based View
AT	Agency Theory
SHT	Stakeholder Theory
TQ	Tobin's Q
GPM	Gross Profit Margin
NPM	Net Profit Margin
ATO	Asset Turnover Ratio
EBIT	Earnings Before Interest and Tax
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
NOM	Net Operating Margin
OE	Operational Efficiency
EPS	Earnings Per Share
ROIC	Return on Invested Capital
SG or SGR	Sales Growth

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BFP	Boardroom Female Participation
CPM	Cash Profit Margin
FC	Financial Competitiveness
GP	Green Patent
GIP	Green Invention Patent
GNIP	Green Non-Invention Patent
CCC	Corporate Core Competitiveness
EP	Employee Productivity
MV	Moderating variable
EPS	Earnings Per Share
AOR	Average Operational Revenues
ROI	Return on Investment
MVA	Market Value Added
MR	Market Return
RDT	Resource Dependency Theory
PBV	Price-to-Book Value
OC	Organizational Capital
IC	Innovation Capital
PC	Process Capital
CC	Customer Capital
ORG. PERF	Organisational Performance
MKT PERF.	Market Performance
SCT	Social Capital Theory
KA	Knowledge Asset
CVCB	Consumer Value Co-Creation Behaviour
FSEIB	Frontline Service Employee Innovative Behaviour
CFLOW	Cash Flow
GOV	Government
SHV	Shareholders Value
SMM	Social Media Marketing
FP	Financial Performance
ACI	Audit Committee Independence
BE	Book Value of Equity
AE	Abnormal Earnings
NGX	Nigerian Exchange Group
OI	Other Information
VA	Value Added
OP	Operating Profit
EC	Employee Costs
I	Interest Expenses
T	Taxes
D	Depreciation
A	Amortisation
SC	Structural capital
TS-CS	Time-Series Cross-Sectional
PCSE	Panel Corrected Standard Errors
OLS	Ordinary Least Squares
FGLS	Feasible Generalized Least Squares

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43093-024-00351-3.

Additional file 1

Additional file 2

Availability of data and materials
The raw secondary data is published with Mendeley data: https://doi.org/10.17632/2yns89t5jx.1

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors want to declare that there is no any competing financial, professional, or personal interests from other parties related to the paper.

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