Journal of Management and Governance (2020) 24:1115–1145
https://doi.org/10.1007/s10997-019-09494-w

A critical validation of the value added intellectual coefficient: use in empirical research and comparison with alternative measures of intellectual capital

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Published online: 5 December 2019

Abstract

The measurement of intellectual capital (IC) constitutes a major challenge in managing intangible resources. Among the various models proposed in prior literature, the value added intellectual coefficient (VAIC) is used by many studies to measure IC. Assuming a perfectly competitive market, this study decomposes the VAIC and demonstrates that it is not directly related to IC. Conversely, the main components of VAIC are the labor share, physical capital share, and interest rate. These results are extended to a non-perfectly competitive setting through a multivariate analysis of a cross-country panel of 50,310 firm-year observations for 2000–2017. The results show that the VAIC still largely depends on exogenous factors being negatively (positively) associated with the labor (physical capital) share. Nevertheless, in this non-perfectly competitive setting, the VAIC also captures a firm's ability to generate profits, which may be attributable to multiple factors, including IC. To reduce potential measurement biases in empirical research using the VAIC, this study suggests controlling for a firm's interest rate, labor and capital shares. Adopting this suggestion, this study investigates the association between VAIC and firm performance. The results show that this association is significantly weaker when including the interest rate, labor and capital shares. The theoretical and empirical results suggest future researchers to select the VAIC to measure IC after having conscientiously examined the alternative models proposed in recent literature.

Keywords VAIC · Intellectual capital · Value added intellectual coefficient · Labor share · Capital share

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1 Introduction

Intellectual capital (IC) is an important topic in management and governance studies. The continuous attention to IC lies in the growing awareness that intangible resources play a central role in the value creation process. The accurate management of IC critically contributes to a firm's wealth (Zambon et al. 2019). Consequently, measuring and reporting IC constitutes a strategic challenge for firms. Although prior studies identify various models to measure IC (e.g., Stewart 1997; Lev 2001, 2003; Corrado et al. 2004), managerial literature highlights a critical lack of contributions validating or falsifying these models (Pucci et al. 2015). One of the most frequently used measures of IC is Pulic's (2000) Value Added Intellectual Coefficient (VAIC) (Dumay 2014; Pedro et al. 2018). This paper adds to the debate related to IC measurement by providing a validation of the VAIC. Theoretical and empirical results show that the VAIC depends largely on exogenous technological factors that are not usually associated with IC. The study also provides potential avenues to overcome the limitations of the VAIC and to assist researchers in the more careful use of the VAIC to measure IC. Finally, theoretical and empirical results are discussed in light of the alternative approaches to measuring and reporting IC proposed in recent literature.

IC and intangible assets have been studied in the literature on marketing and management (Bontis 1999; Hilmola et al. 2009), organization (Knott et al. 2003), talent management (Sparrow et al. 2014; McCracken et al. 2018), and finance and accounting (Aboody and Lev 2000; Sullivan and Sullivan 2000; Basu and Waymire 2008). In governance studies, prior literature highlights the importance of corporate governance for managing and developing IC (Zambon et al. 2019). Governance mechanisms should be aligned to IC and human capital in particular to contribute to future value creation (Lajili 2015). Directors' human capital positively influences firm performance (Volontè and Gantenbein 2016), board turnover after an incident of fraud (D'Onza and Rigolini 2017), and compensation after IPO (Williams et al. 2018). The level of human capital can also positively influence internationalization (Cerrato and Piva 2012). Finally, relational capital represented by heterogeneous relational ties among the board of directors has a strong impact on a firm's performance (Rossoni et al. 2018).

Among all intangible assets, IC is typically considered strategic because it relates to human resources, customer relationships, customer loyalty, etc. (Lev 2005; Pucci et al. 2015). These assets are fundamental both in the internal managerial focus on value creation processes and the external focus on disclosure and reporting on value creation (Badia et al. 2019; Brosnan et al. 2019). This holds true not only in the private sector but also in the public sector, where some universities adopt performance management systems, including IC management, as a criterion for evaluating their managers (Veltri and Puntillo 2019). Similarly, relational capital fosters collaboration among officers in different ministries as a leading indicator of collaborative governance (Ramadass et al. 2018).

Because IC significantly contributes to value creation, its measurement becomes a primary managerial objective to assess the efficient use and creation of IC (Laing et al. 2010). Badia et al. (2019, p. 299) note that "several attempts have been made to develop measurement and reporting systems for this relevant source of value, but managerial literature has highlighted the limits and difficulties of some of those endeavors". Accounting research tends to consider IC as a part of intangible assets, thus emphasizing its financial dimension and the need for a reliable measurement and contribution to future economic benefits (Skinner 2008a, b; Guthrie et al. 2012). Conversely, the managerial literature is interested in understanding how IC contributes to value creation (Johanson et al. 2001; Mouritsen et al. 2001). A more recent approach suggests that IC narratives are strongly relevant, in addition to IC numbers. IC numbers, discourse and disclosure, business models, and financial statements represent a corpus that contributes to the dissemination of the firm's approach to value creation (Mouritsen and Roslender 2009; Nielsen and Roslender 2015). While IC numbers cannot stand alone (Gowthrope 2009), IC measurement remains a fundamental input to internal managerial decision making (Brosnan et al. 2019) and external firm assessment (Badia et al. 2019).

The VAIC model for measuring IC was initially developed by Pulic (2000) and has rapidly become extremely popular in academic research (Dumay 2014; Pedro et al. 2018). Prior literature employing the VAIC focuses on IC performance in the banking sector (Mavridis 2004; Goh 2005; Kamath 2007; Alhassan and Asare 2016), the relationship between IC and market value (Chen et al. 2005), the association between IC and financial performance (Sharabati et al. 2010; Komnenic and Pokrajčić 2012), and the relationship between organizational capital and cost stickiness (Mohammadi and Taherkhani 2017). One reason prompting many researchers to select the VAIC as a proxy for IC is that the VAIC intends to measure the capacity of a firm to transform its stock of IC into value added (Pulic 2008; Iazzolino and Laise 2013). Additionally, the VAIC measures IC by relying on accounting numbers, which provides researchers with an easy and ready-to-use proxy.

Despite these undeniable advantages, prior studies challenge the validity of the VAIC as a measure of IC. For example, Ståhle et al. (2011) argue that the VAIC strongly depends on labor and physical capital investments and thus constitutes a poor measure of IC. In an attempt to reconcile the debate around the validity of the VAIC, Iazzolino and Laise (2013) suggest that the VAIC is more of a multidimensional measure rather than a direct proxy for IC. While prior literature establishes the limitations of the VAIC as a measure of IC, a systematic theoretical and empirical validation is missing. Consequently, researchers and professionals are left with no guidance regarding the use of the VAIC due to the lack of papers suggesting potential solutions to overcome its inherent limitations. This paper fills this gap in four steps.

First, this study reflects on the critical decomposition of the VAIC provided in Ståhle et al. (2011). By assuming a perfectly competitive setting in which profit is equal to zero, this study theoretically demonstrates that the VAIC is a function of labor share, physical capital share, and interest rate. Moreover, the relationship between the VAIC, the labor share, and the physical capital share is nonlinear. These theoretical results imply that the VAIC is not directly related to IC when markets are perfectly competitive. Consequently, they contribute and advance prior knowledge on the critical decomposition of the VAIC.

Second, this study extends the validity of theoretical findings with a multivariate analysis using archival data. In this setting, the hypothesis of perfect competition is relaxed, and the firm's profits are allowed to differ from zero. Under this scenario, the VAIC also captures the ability of a firm to generate profits, which may be attributable to multiple factors, including IC. By using a cross-country dataset of 50,310 firms observed over the 2000–2017 period, the multivariate analysis confirms that the VAIC is negatively (positively) associated with the labor (physical capital) share. The model controls for the time-invariant characteristics for any country, industry, and firm by including firm fixed effects and clustering standard errors at the firm level. Despite the absence of perfect competition, these empirical results show that the VAIC still depends largely on exogenous technological factors that are not usually associated with IC. Hence, they inform the empirical IC literature on the need to control for technological factors to avoid endogeneity bias in multivariate analysis.

Third, reflecting on theoretical and empirical findings, this study proposes to control for a firm's labor share, capital shares, and interest rate to reduce potential measurement biases in empirical research. The present study adopts this solution to investigate the association between IC, proxied by the VAIC, and financial performance. The results show that the VAIC is positively and significantly associated with financial performance when the labor share, capital share, and the interest rate are not included in the model. To ensure that these results are not driven by the technological components of the VAIC and the interest rate, the model is augmented by controlling for these factors. The results from these tests highlight that the association between the VAIC and financial performance is significantly weaker after controlling for its inherent technological components and the interest rate. As a result, this study prompts a careful interpretation of empirical analysis in prior literature when controls for technological factors are missing.

Fourth, the paper discusses the VAIC in light of the theoretical and empirical validation proposed in this study. The VAIC, which claims to represent IC in numbers only, is compared to alternative models of IC reporting by drawing on a multidimensional and performative approach (e.g. Mouritsen 2006; Gowthrope 2009; Melloni 2015; Nielsen and Roslender 2015; Melloni et al. 2016; Bini et al. 2017; Corbella et al. 2019). In empirical research, when properly tuned according to the validation proposed in this paper, the VAIC is capable of serving as a leasing indicator of some *potential* relation between IC and the main dependent variable of interest. However, the VAIC does not allow a deeper investigation on the dimensions of IC (e.g., relational, structural, or human capital) that influence the variable of interest. Similarly, the VAIC cannot explain how IC contributes to value creation. While not discouraging the use of VAIC, this paper suggests empirical literature to select alternative measures of IC that may be more capable of identifying meaningful associations.

The theoretical and empirical findings from this study are important because the VAIC is extensively used in empirical analyses. Researchers are urged to control for the labor share, capital share, and interest rate and to cautiously interpret the results based on the VAIC as a measure of IC. In fact, empirical studies that do not consider these variables as important determinants of the VAIC may suffer from important endogeneity problems. Additionally, the discussion stemming from the results of this paper leads to a reflection on the use of the VAIC in comparison to alternative models of IC reporting.

The remainder of the paper proceeds as follows. Section 2 describes the VAIC model, its underlying assumptions, and results from prior literature adopting this model. Section 3 proposes a decomposition of the VAIC in a perfectly competitive market and theoretically demonstrates that the VAIC is a function of exogenous technological factors that are not usually associated with IC. Section 4 illustrates the methodology and the results of a multivariate analysis that extends the theoretical findings to a non-perfectly competitive setting. In the spirit of assisting researchers in overcoming the VAIC limitations, Sect. 5 proposes and applies a potential solution for tuning the VAIC to more carefully measure IC. Section 6 offers a discussion of the main findings, outlines the limitations of this study, and provides avenues for future research.

2 Review of the literature on the VAIC model

2.1 The VAIC model

The VAIC model intends to offer a methodology to measure intellectual work efficiency and, therefore, IC efficiency (Pulic 2008; Iazzolino and Laise 2013). The formula of the VAIC is obtained through the following line of reasoning (Pulic 2005; Ståhle et al. 2011). First, value added (*VA*) is a function of the structural capital (*SC*) and the human capital (*HC*) employed; *VA* is defined as follows:

$$VA = OP + D + A + C, \tag{1}$$

where *OP* is the operating profit, *D* is depreciation, *A* is amortization, and *C* is all employee-related costs. According to Eq. (1), *C* identifies the *HC*, while ($OP + D + A$) measures *SC*. Thus, Eq. (2) can also be expressed as follows:

$$VA = SC + HC. \tag{2}$$

The second step to derive the VAIC formula defines human capital efficiency (*HCE*), structural capital efficiency (*SCE*), and capital employed efficiency (*CEE*) as follows:

$$HCE = VA/HC, \tag{3}$$

$$SCE = SC/VA, \tag{4}$$

$$CEE = VA/CE, \tag{5}$$

where *CE* represents the physical capital employed. It is worth noting that *HCE* focuses on the contribution of human resources to *VA* creation, while *SCE* measures the efficiency of all other components in creating *VA* (Dženopoljac et al. 2016).

Finally, VAIC is the sum of these three efficiency measures:

$$VAIC = HCE + SCE + CEE. \tag{6}$$

Thus, in its aggregated form, the VAIC emphasizes a firm's total efficiency, decomposed into IC efficiency ($ICE = HCE + SCE$) and financial efficiency (CEE).

2.2 Empirical literature using the VAIC model

Pedro et al. (2018) document that the VAIC was used in 11% of their reviewed papers, resulting in the most popular proxy for IC.[1] Prior literature initially concentrated on understanding the determinants of VAIC, its variation over time and across countries. Goh (2005) finds that commercial banks in Malaysia show higher human capital efficiency than structural and capital efficiencies. Additionally, they document that domestic banks were generally less efficient than foreign banks and that public banks improve their IC efficiency during the 3 years covered in their study. These results are confirmed for Indian firms operating in the banking and pharmaceutical industry (Kamath 2007, 2008), Japanese banks (Mavridis 2004), and ASEAN countries (i.e., Indonesia, Malaysia, Philippines, Singapore, and Thailand) (Nimtrakoon 2015). However, firms operating in different segments show significant differences in their VAIC (Mavridis 2004; Kamath 2007). Similarly, firms operating in different countries tend to differently emphasize the components of the VAIC (Nimtrakoon 2015). Finally, El-Bannany (2008) documents that profitability and risk are the main determinants of the VAIC for a sample of UK firms during the 1999–2005 period.

Another strand of research concentrates on analyzing the relationship between the VAIC and firm performance. The results from these empirical studies are mixed. Chen et al. (2005) document a positive impact of the VAIC on the market value and financial performance of Taiwanese listed firms. They also highlight that the VAIC is a leading indicator of future financial performance. These results are confirmed for financial firms in different countries (Ting and Lean 2009) and non-financial firms worldwide (Díez et al. 2010; Vishnu and Gupta 2014; Nimtrakoon 2015). Additionally, some studies suggest that a specific component of the VAIC has a stronger correlation with financial performance than other components (Chu et al. 2011; Clarke et al. 2011).

Although the above-reported studies point towards a positive relationship between VAIC and financial performance, other studies document inconsistent and, sometimes, opposite results. Some studies support a positive relationship between the VAIC and financial performance for specific industries only (Zeghal and Maaloul 2010; Pucar 2012), for human capital only (Maditinos et al. 2011; Komnenic and Pokrajčić 2012; Joshi et al. 2013), or for capital-employed efficiency only (Dženopoljac et al. 2016). Other studies show mixed associations between

[1] More details on the VAIC method and prior empirical literature employing VAIC can be found in Pulic (2000, 2008), Ståhle et al. (2011), Iazzolino and Laise (2013), Dumay (2014) and Pedro et al. (2018).

the components of the VAIC and financial performance (Firer and Williams 2003; Kamath 2008; Ghosh and Mondal 2009; Mehralian et al. 2012). Sardo and Serrasquiero (2017) highlight that these mixed results for the components of the VAIC depend on their ability to impact financial performance in the short or long run. Bayraktaroglu et al. (2019) identify moderating variables in the relationship between the VAIC and financial performance. Moreover, in their study on Brazilian real estate companies, Britto et al. (2014) show a negative relationship between VAIC and both market value and return on invested capital. Similar findings are documented in different countries (Dženopoljac et al. 2017) and in the public sector (Morariu 2014).

Finally, other studies concentrate on the potential use of the VAIC as a management tool. In their study on the Australian hotel industry, Laing et al. (2010) find that managers can use the VAIC model as a robust tool for assessing the efficient use of IC in their organizations. Additionally, Mohammadi and Taherkhani (2017) document no relation between the VAIC and cost stickiness.

3 Theoretical decomposition of the VAIC in a perfectly competitive setting

Despite the widespread use of the VAIC, prior studies challenge its validity as a measure of IC by critically analyzing its constructs. In particular Ståhle et al. (2011), suggest that the VAIC depends on labor and physical capital investments. This study elaborates on this intuition and provides a theoretical decomposition of VAIC in a perfectly competitive market.

Because the VAIC computation is based on the relationships between *VA* and its components, this study first recalls some results related to these relationships in perfectly competitive markets with a standard specification of the production function. In particular, it is assumed that the final output results from three different inputs (human capital, physical capital, and an intermediate good) and a traditional Cobb–Douglas production function, as follows:

$$Y = F(H, K, I) = AH^{\alpha}K^{\beta}I^{\gamma}, \quad with\ \alpha, \beta, \gamma > 0, \tag{7}$$

where Y is the total output, A is the state of technology, H is the stock of human capital, K is the stock of physical capital, I is the flow of the intermediate good, and α, β, and γ are the elasticity coefficients of human capital, physical capital, and an intermediate good, respectively. In general, an elasticity coefficient indicates the percentage change in the production level when the corresponding input changes by one percentage point. Given Eq. (7), the profit (Π) function is:

$$\Pi = pY - wH - rK - p_I I, \tag{8}$$

where p is the price level of the final output, w is the nominal wage level, r is the interest rate, and p_I is the price of the intermediate input. Because markets are perfectly competitive, the firm is a price-taker in all markets. From Eq. (8), the amount of *VA* the firm generates can also be derived:

$$\text{VA} \equiv pY - p_I I = \Pi + wH + rK. \tag{9}$$

Equation (10) provides the extended expression of the VAIC:

$$\text{VAIC} \equiv \underbrace{\frac{VA}{wH}}_{HCE} + \underbrace{\frac{VA - wH}{VA}}_{SCE} + \underbrace{\frac{VA}{K}}_{CEE}. \tag{10}$$

Using Eq. (9) yields:

$$\text{VAIC} = \frac{\Pi + wH + rK}{wH} + 1 - \frac{wH}{\Pi + wH + rK} + \frac{\Pi + wH + rK}{K}. \tag{11}$$

In the long run, the assumption of a perfectly competitive market for the final good implies no profits (i.e., $\Pi = 0$). Therefore, Eq. (11) becomes:

$$\text{VAIC} = 1 + \frac{rK}{wH} + 1 - \frac{wH}{wH + rK} + \frac{wH}{K} + r. \tag{12}$$

Because firms want to maximize their profits, the first-order conditions (FOCs) of Eq. (8) must be computed. In particular, the FOCs for H and K lead to the following redistributive results: $wH = \alpha pY$ and $rK = \beta pY$. This result also implies that $\alpha = wH/pY$ and $\beta = rK/pY$, which means that human and physical capital elasticities (α and β) are equal to the labor and capital share, respectively (wH/pY and rK/pY). Moreover, the relation $(wH)/(rK) = \alpha/\beta$ can be written. By inserting these basic results into the operative definition of VAIC, the following equation can be obtained:

$$\text{VAIC} = \underbrace{1 + \frac{\beta}{\alpha}}_{\text{HCE}} + \underbrace{1 - \frac{\alpha}{\alpha + \beta}}_{SCE} + \underbrace{\frac{\alpha}{\beta} r + r}_{CEE}. \tag{13}$$

When markets are perfectly competitive and in long-run equilibrium, Eq. (13) demonstrates that the VAIC is a function of the elasticity coefficient of human capital (α), the elasticity coefficient of physical capital (β), and the interest rate (r). In particular, both the *HCE* and the *SCE* components negatively depend on α and positively depend on β, while the opposite is true for the *CEE* component. Thus, while the relationship between the VAIC and r is certainly positive, the relationship between the VAIC and the elasticity coefficients is ambiguous.

To further investigate the relationship between the VAIC, the elasticity coefficient of human capital (α), and the elasticity coefficient of physical capital (β), this study numerically simulates Eq. (13) by assuming reasonable values for the study parameters (i.e., α and β range between 0 and 1). Figures 1, 2, 3 and 4 report different VAIC functions for different interest rate levels (1%, 5%, 10% and 20%). According to Figs. 1 and 2, the relationship between the VAIC and the elasticity coefficients is increasing in β but decreasing in α. In contrast, a nonlinear relationship between the VAIC and coefficients appears when the interest rate increases (Figs. 3 and 4). In particular, Fig. 4 shows that the VAIC first decreases with small elasticity coefficient values and then increases.

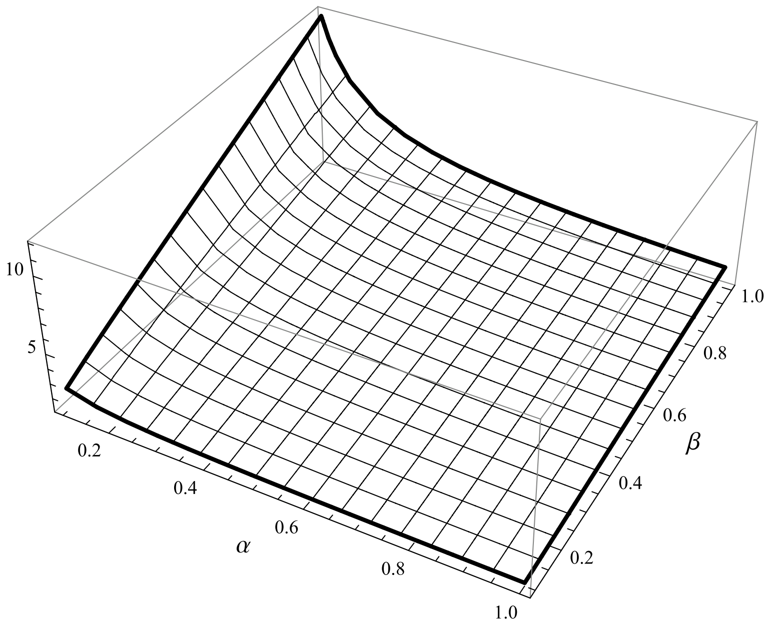

Fig. 1 VAIC function (*r* = *1%*)

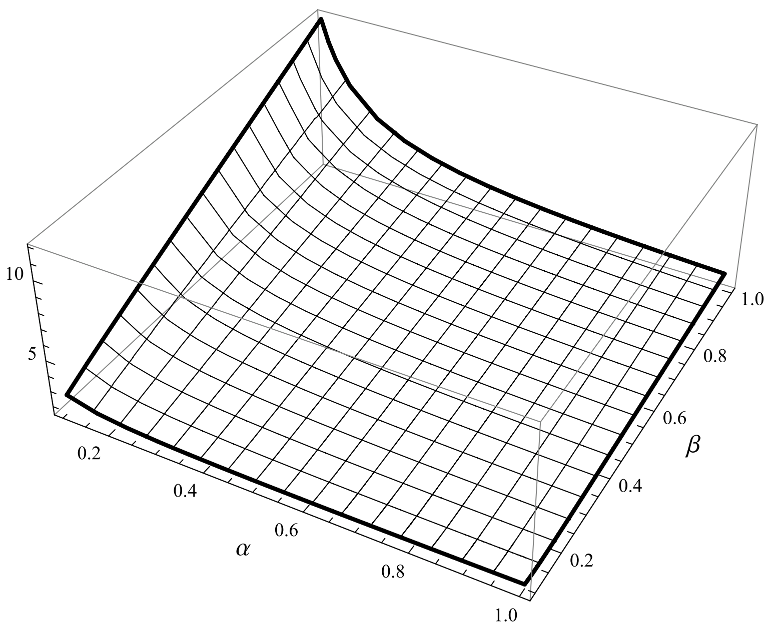

Fig. 2 VAIC function (*r* = *5%*)

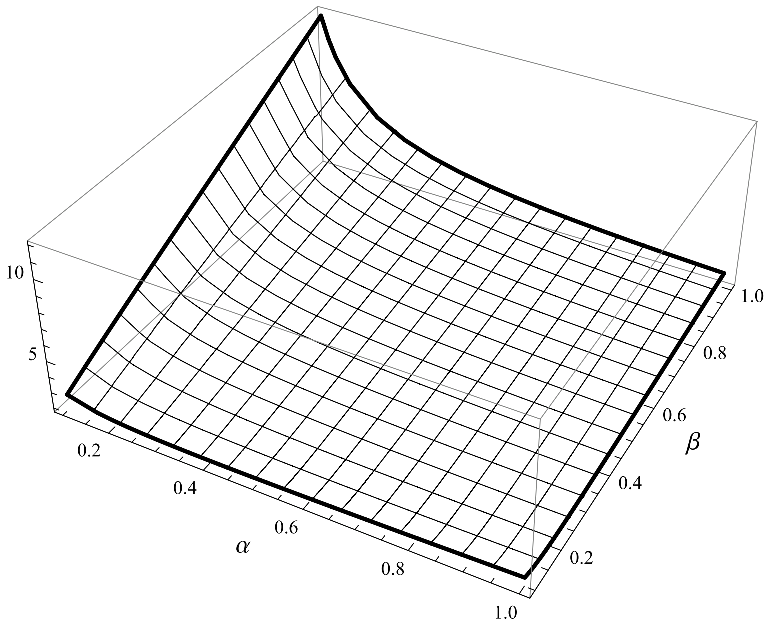

Fig. 3 VAIC function ($r = 10\%$)

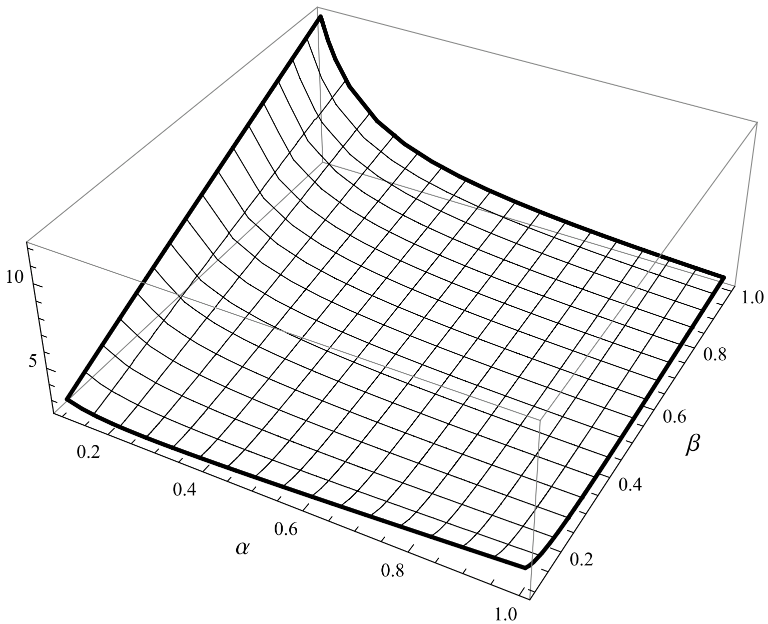

Fig. 4 VAIC function ($r = 20\%$)

To conclude, this analysis shows that the VAIC may have ambiguous behavior when the elasticity coefficients (especially the elasticity coefficient of human capital) are relatively low. *Ceteris paribus*, efficient firms adopting human capital-intensive technologies could show lower VAIC levels only as a result of their higher *HCE*. In contrast, the VAIC tends to be higher if a firm pays higher interest rates on physical capital. These relations imply that two firms with the same stock of IC and managerial capabilities may show different VAIC levels due to their technological constraints.

4 Empirical analysis of the decomposition of VAIC

The decomposition of the VAIC in Eq. (13) assumes a perfectly competitive market, which in the long run is inherently characterized by the absence of supernormal profits (i.e., the excess profit above the minimum return necessary to keep an organization in business). Under this assumption, the value added is completely exhausted by the factors of production, meaning that the VAIC captures only technological parameters and the cost of physical capital. However, real markets may violate perfect competition, with firms exhibiting non-zero supernormal profits. In this scenario, the VAIC also captures the ability of a firm to generate profits due to multiple factors, including IC. This section extends the validity of theoretical findings with a multivariate analysis employing archival data. In the empirical analysis, we test the association between the VAIC and firm performance while controlling for the capital share, labor share, and cost of capital.

4.1 Empirical model

This study draws upon previous literature (Goebel 2015) and regresses the VAIC performance on the interest rate, human and physical capital elasticity.[2] The following regression model is estimated (firm subscripts are suppressed):

$$\begin{aligned} VAIC_t = \theta_0 + \theta_1 LABOR_t + \theta_2 CAPITAL_t + \theta_3 R_t \\ + \theta_4 INTANGIBLES_t + \theta_5 R\&D_t + \theta_6 LEV_t + \theta_7 PAYMENT_t \\ + \theta_8 SIZE_t + \text{Firm FE} + \text{Year FE} + \varepsilon_t \end{aligned} \tag{14}$$

Consistent with prior literature (e.g., Nimtrakoon 2015; Dženopoljac et al. 2016; Mohammadi and Taherkhani 2017), the study measures the dependent variable *VAIC* (i.e., Pulic 1998, 2000) as the sum of *HCE*, *SCE*, and *CEE*. Further details on the calculation of these variables are provided in Sect. 2 and in Appendix. With respect to the main variables of interest, *LABOR* and *CAPITAL* represent measures of labor and capital elasticity, respectively, and are proxied by staff expenses

[2] For clarity in designing the model, we replace the notations α, β, and r in Eq. (13) with *LABOR*, *CAPITAL*, and *R*, respectively.

(*LABOR*) and capital expenditures (*CAPITAL*) divided by total sales.[3] Similarly, *R* represents the interest rate proxied by the cost of debt capital. To further investigate the relationship between *LABOR*, *CAPITAL*, *R* and *VAIC*, Eq. (14) is also estimated by replacing VAIC with its components (*HCE*, *SCE*, and *CEE*). The study expects to find a negative association between both *HCE* and *SCE* and *LABOR* and a positive association with *CAPITAL*, while the opposite will be true for the *CEE* component.

Following previous literature, the study also includes some additional firm-level controls that can influence the VAIC (Goebel 2015). Accordingly, this study controls for the level of intangible assets (*INTANGIBLES*), the level of research and development expenses (*R&D*), the leverage ratio (*LEV*), the mean industry-year level of staff expenses (*PAYMENT*), and the natural logarithm of total sales (*SIZE*). Finally, the study also considers country, industry, and firm time-invariant characteristics and cross-sectional variation by adding firm and year fixed effects and clustering standard errors at the firm level. Continuous variables are winsorized at the 1% and 99% levels, except *SIZE,* which is expressed as a natural logarithm. Appendix provides additional information about variable definitions and their sources.

4.2 Sample description

The sample includes all firm-year observations available in COMPUSTAT Global[4] for the 2000–2017 period. The study drops firm-year observations with missing accounting information required to estimate Eq. (14). Singleton groups (i.e., groups with only one observation) are removed, as prior literature demonstrates that including these observations can inflate the statistical significance (Correia 2015). In addition, observations with a negative book value of equity and a negative *VAIC* are removed, as a negative value of "value-added" does not generate a meaningful analysis (see Firer and Williams 2003; Shiu 2006; Chan 2009; Chu et al. 2011; Pal and Soriya 2012). Consequently, the final sample consists of 50,310 firm-year observations (i.e., 8401 firms across 81 countries).

Panel A of Table 1 reports the sample distribution by industry-year. Most observations are clustered in the information technology (11,041), industrials (11,120), materials (7624), consumer discretionary (7755), and healthcare (5454) industry sectors. Panel B of Table 1 reveals that most observations are from India (8815), Taiwan (4767), the UK (4519), China (3253), and Germany (2994).

4.3 Descriptive statistics and univariate analysis

Table 2 reports the descriptive statistics for the dependent and independent variables entering the multivariate analysis. The mean (median) *VAIC* measure is 7.52 (2.7), while the mean (median) values of *HCE*, *SCE*, and *CEE* are 6.43 (1.81), 0.55

[3] We recall from Sect. 3 that α is the elasticity coefficient of human capital from Eq. (7) and is equal to the labor share (*wH/pY*). Similarly, β is the elasticity coefficient of the physical capital from Eq. (7) and is equal to the capital share (*pY/rK*). Thus, from now on, we use the terms "labor share" and "capital share" to refer to the elasticity coefficients of intellectual and physical capital.

[4] Accessed via WRDS on September 16, 2018.

Table 1 Sample distribution

Panel A: Sample distribution by Global Industry Classification Sector (GIC) and year

GIC sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
10—Energy	10	18	18	30	36	37	51	70	72	79	84	83	88	91	105	104	93	77	1146
15—Materials	155	168	197	211	238	235	322	414	436	486	494	508	510	609	706	715	690	530	7624
20—Industrials	224	253	276	287	332	252	422	617	661	714	753	750	769	870	989	1066	1026	859	11,120
25—Consumer discretionary	110	151	178	179	195	208	274	411	484	481	511	551	573	671	727	750	737	564	7755
30—Consumer staples	69	79	109	120	136	132	180	243	265	292	284	287	299	302	326	357	345	278	4103
35—Health care	120	144	165	180	203	165	233	326	348	361	358	366	373	394	452	455	448	363	5454
40—Financials	6	6	10	17	18	7	10	19	18	20	19	19	14	15	14	12	10	7	241
45—Information technology	171	201	226	275	284	198	333	531	573	596	622	638	647	1051	1208	1234	1211	1042	11,041
50—Telecom services	10	14	17	21	25	18	26	37	41	43	43	50	49	48	45	42	38	35	602
55—Utilities	22	28	32	32	41	40	43	73	75	84	74	84	76	83	89	97	97	85	1155
60—Real estate	2	2	3	2	3	2	3	4	5	3	1	4	2	6	6	7	8	6	69
Total	899	1064	1231	1354	1511	1294	1897	2745	2978	3159	3243	3340	3400	4140	4667	4839	4703	3846	50,310

Panel B: Sample distribution by country and year

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Argentina	0	0	0	0	0	0	0	2	2	1	2	1	3	5	6	6	5	6	39
Australia	4	6	13	18	28	31	91	113	141	135	140	136	132	140	141	141	121	109	1640
Austria	9	7	5	8	12	8	20	34	36	30	31	37	34	37	39	40	36	33	456
Bangladesh	0	0	0	0	0	1	3	7	12	10	13	18	17	20	20	15	15	26	177
Belgium	10	9	13	16	18	10	23	39	38	41	41	40	41	41	39	39	38	36	532
Bermuda	15	32	38	54	49	31	47	82	87	81	83	79	83	70	77	70	60	50	1088
Brazil	1	0	2	2	2	9	11	30	32	43	43	50	56	57	57	50	48	45	538
Bulgaria	0	0	0	0	1	2	2	2	1	1	2	2	0	1	2	3	3	1	23
Cayman Islands	8	17	29	38	50	47	88	128	182	199	211	230	250	267	270	287	261	243	2805

Table 1 (continued)

Panel B: Sample distribution by country and year

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Chile	0	0	0	0	0	0	0	0	1	7	8	8	9	9	10	12	10	10	84
China	2	15	27	51	49	35	37	49	51	54	57	97	130	149	501	660	661	628	3253
Colombia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	4	3	10
Croatia	1	1	2	2	2	3	3	2	4	4	3	3	3	3	3	2	3	2	46
Curaçao	0	0	1	1	1	1	1	1	2	1	1	1	1	1	0	1	1	2	17
Cyprus	0	0	0	0	1	1	1	3	4	2	4	3	3	3	4	5	4	3	41
Czech Republic	0	1	1	2	3	3	1	3	4	3	3	3	2	3	2	2	2	1	39
Denmark	18	18	25	23	19	18	24	39	37	39	40	44	40	45	44	41	39	35	588
Egypt	0	0	0	0	0	0	0	0	0	0	1	3	4	3	5	7	4	4	31
Estonia	0	0	0	0	0	0	2	4	3	2	2	1	1	1	2	2	1	1	22
Faroe Islands	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	9
Finland	47	56	56	48	53	32	58	77	76	72	76	71	72	73	72	76	71	65	1151
France	61	70	80	93	103	72	90	140	152	173	180	197	186	185	198	195	184	157	2516
Germany	61	77	88	107	120	50	98	213	226	225	236	234	222	227	212	208	203	187	2994
Greece	1	5	11	15	23	25	33	30	39	43	41	37	37	32	30	31	23	22	478
Hong Kong	6	6	9	12	10	9	14	14	20	20	22	27	29	31	35	38	41	33	376
Hungary	0	0	1	0	1	2	2	3	3	1	2	2	2	4	3	6	5	5	42
Iceland	2	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	38
India	211	260	290	287	330	435	525	592	585	627	622	570	538	537	537	579	565	95	8185
Indonesia	5	4	5	8	2	11	11	19	19	22	24	23	22	27	31	30	33	28	324
Ireland	10	12	10	8	8	4	11	12	13	15	13	10	11	10	10	13	13	12	195
Isle of MAN	0	0	0	0	0	0	0	0	0	0	1	1	0	2	3	3	3	2	15
Israel	13	10	16	17	21	22	47	55	69	82	79	79	77	77	78	69	75	61	947

Table 1 (continued)

Panel B: Sample distribution by country and year

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Italy	1	3	5	15	38	23	28	50	66	71	78	80	76	80	77	78	85	68	922
Jersey	3	3	2	3	2	1	1	3	5	5	7	9	13	11	11	11	7	4	101
Jordan	1	1	2	1	2	1	2	0	3	1	1	5	3	5	6	8	9	10	61
Kazakhstan	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Korea Rep.	0	3	1	4	5	4	3	0	0	0	0	0	1	1	1	1	0	0	24
Latvia	2	1	1	0	1	2	1	3	4	5	5	5	6	5	3	5	5	5	59
Lithuania	0	0	0	0	0	0	0	1	3	3	2	3	3	2	2	2	2	2	25
Luxembourg	1	2	3	1	3	1	4	6	7	10	13	12	13	15	13	13	14	10	141
Malawi	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	6
Malaysia	12	19	36	39	44	55	57	122	125	130	131	136	126	129	125	116	100	80	1582
Malta	0	0	0	0	0	1	1	1	2	3	4	2	4	2	2	2	2	2	28
Mauritius	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	6
Mexico	0	0	0	0	0	0	1	3	1	2	1	2	6	6	6	8	9	8	53
Morocco	0	0	0	0	0	1	1	1	0	1	0	1	2	0	0	3	2	1	13
Netherlands	14	14	17	18	24	18	36	43	44	48	47	48	50	49	46	41	36	34	627
New Zealand	0	0	1	1	1	0	5	13	20	23	24	29	26	30	22	18	21	22	256
Nigeria	1	1	2	4	3	2	3	3	2	3	2	1	2	2	2	1	5	5	44
Norway	11	12	14	17	21	11	27	43	39	46	46	39	39	33	38	36	35	34	541
Oman	0	0	0	0	0	1	2	2	1	1	1	0	0	1	1	2	1	0	13
Pakistan	9	12	7	5	3	6	9	22	31	28	21	24	21	18	17	16	17	16	282
Palestine	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	0	0	7
Peru	0	0	0	0	0	0	0	0	0	1	1	2	2	4	4	4	4	4	26
Philippines	1	4	5	5	7	10	9	20	23	25	26	30	27	25	22	24	24	26	313

Table 1 (continued)

Panel B: Sample distribution by country and year																			
Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Poland	3	2	3	3	6	8	7	9	17	31	46	63	83	72	72	77	74	64	640
Portugal	0	0	0	0	0	0	2	1	3	5	6	6	7	5	5	5	6	7	58
Romania	0	0	0	1	1	3	1	2	3	4	6	4	4	6	8	5	4	5	57
Russian Federation	1	2	3	3	5	6	11	18	17	20	19	17	21	25	23	24	22	14	251
Saudi Arabia	0	0	0	1	2	1	1	3	3	4	6	8	7	7	7	9	9	9	77
Serbia	0	0	0	0	0	0	1	2	3	2	2	3	2	2	1	1	1	1	21
Singapore	11	19	27	33	40	25	35	73	79	78	64	61	52	61	64	64	62	49	897
Slovakia	1	1	0	0	1	1	0	1	1	1	1	0	1	2	0	1	2	1	15
Slovenia	0	0	0	0	0	1	3	3	2	3	7	6	4	5	4	2	2	2	44
South Africa	13	17	25	25	27	13	33	44	50	54	48	49	48	52	43	46	43	37	667
Spain	1	1	3	5	3	9	14	20	22	27	36	43	48	53	53	55	54	49	496
Sri lanka	2	1	0	0	1	1	5	9	9	10	11	11	12	11	15	17	14	9	138
Sweden	48	52	54	67	69	52	33	78	84	104	97	99	96	82	79	88	94	83	1359
Switzerland	49	43	52	47	46	22	62	83	81	83	91	84	91	81	78	73	73	72	1211
Taiwan	0	1	2	3	8	9	6	7	12	13	35	57	69	783	963	958	953	888	4767
Thailand	0	0	0	0	1	1	0	3	4	5	11	10	15	14	15	17	18	13	127
Trinidad and Tobago	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1	1	1	9
Tunisia	0	0	0	0	0	0	1	2	2	2	1	2	4	4	4	2	4	2	30
Turkey	1	2	2	5	6	27	32	43	52	55	50	74	94	100	98	101	98	95	935
Uganda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Ukraine	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	1	1	1	9
United Arab Emirates	0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	2	2	2	13
United Kingdom	225	236	237	232	228	108	208	302	309	304	301	291	296	275	284	249	241	193	4519

Table 1 (continued)

Panel B: Sample distribution by country and year

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Viet nam	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	4	4	5	16
Virgin Islands	1	1	1	2	3	2	3	5	4	8	8	8	9	10	7	6	5	3	86
Zimbabwe	1	1	1	1	2	2	1	1	2	2	1	1	1	1	1	1	1	0	21
Total	899	1064	1231	1354	1511	1294	1897	2745	2978	3159	3243	3340	3400	4140	4667	4839	4703	3846	50,310

Table 2 Descriptive statistics

Variable	N. Obs.	Mean	St. Dev.	Min	25°	Median	75°	Max
VAIC	50,310	7.527	19.675	0.001	2.098	2.700	4.081	133.759
HCE	50,310	6.435	18.763	− 1.590	1.352	1.806	3.024	125.887
SCE	50,310	0.548	0.609	− 0.994	0.283	0.470	0.702	5.391
CEE	50,310	0.326	0.282	− 0.915	0.151	0.256	0.424	1.665
LABOR	50,310	0.215	0.465	0.001	0.070	0.151	0.260	9.924
CAPITAL	50,310	0.086	0.244	0.000	0.019	0.040	0.084	6.362
R	50,310	0.101	0.242	0.000	0.033	0.056	0.088	2.318
INTANGIBLES	50,310	0.116	0.166	0.000	0.003	0.034	0.166	0.703
R&D	50,310	0.029	0.057	0.000	0.002	0.010	0.031	0.546
LEV	50,310	1.741	2.580	0.006	0.602	1.096	1.938	26.522
PAYMENT	50,310	0.062	0.242	0	0	0	0	1
SIZE	50,310	7.183	2.485	− 1.041	5.452	7.214	8.750	26.890

See Appendix for variable definitions

(0.47), and 0.33 (0.26), respectively. Focusing on the main variables of interest, the mean (median) *LABOR*, *CAPITAL* and *R* values are 0.21 (0.15), 0.09 (0.04), and 0.10 (0.06), respectively. On average (median), intangible assets represent 12% (3.4%) of total assets (*INTANGIBLES*). Related to intangibles, research and development expenditures (*R&D*) are approximately 2.9% (1%). Finally, the leverage ratio (*LEV*) is on average (median) 1.74 (1.1), while only 6.2% of firms in the study's sample have a level of staff compensation higher than the mean value by sector-year (*PAYMENT*).

Table 3 presents the Pearson correlation coefficients for all variables in the multivariate analysis. Consistent with Eq. (13), it is observed that *LABOR* is negatively (positively) and significantly correlated with *HCE (CEE)* ($p<0.01$). Notice that, contrary to theoretical predictions, the association between *LABOR* and *SCE* is positive and statistically significant ($p<0.01$). However, this coefficient may be misleading because it is based on simple, univariate correlations. This fact leads to a negative and significant association between *LABOR* and *VAIC* ($p<0.01$). Fully consistent with the prediction from Eq. (13), *CAPITAL* is negatively correlated with *CEE* ($p<0.01$) and positively correlated with *HCE* ($p<0.01$) and *SCE* ($p<0.01$), resulting in a positive and significant association between *CAPITAL* and *VAIC* ($p<0.01$).

4.4 Multivariate analysis

Table 4 reports the results for the tests regarding the influence of interest rate, labor and capital shares on the VAIC. Column (1) shows the baseline model that includes labor share (*LABOR*), capital share (*CAPITAL*), and the interest rate (*R*) without including firm and year fixed effects. Columns (2) and (3) progressively augment the baseline model with the controls from Eq. (14). The results confirm that the theoretical model based on perfectly competitive markets also remains valid in a non-perfectly competitive setting. In fact, Table 4 shows that the labor

Table 3 Pearson correlation coefficients

		1	2	3	4	5	6	7	8	9	10	11	12
VAIC	1	1											
HCE	2	0.988**	1										
SCE	3	0.234**	0.168**	1									
CEE	4	−0.142**	−0.145**	−0.344**	1								
LABOR	5	−0.108**	−0.126**	0.175**	0.067**	1							
CAPITAL	6	0.021**	0.017**	0.180**	−0.159**	0.432**	1						
R	7	−0.011*	−0.015**	0.037**	0.063**	0.046**	−0.023**	1					
INTANGIBLES	8	0.025**	0.019**	−0.040**	0.514**	0.094**	−0.057**	0.010*	1				
R&D	9	−0.031**	−0.041**	0.101**	0.155**	0.305**	0.023**	0.075**	0.092**	1			
LEV	10	0.002	0.002	−0.016**	−0.032**	−0.003	−0.009*	−0.043**	−0.003	−0.033**	1		
PAYMENT	11	−0.051**	−0.050**	−0.027**	0.012**	−0.011*	0.006	−0.017**	−0.022**	−0.010*	0.030**	1	
SIZE	12	0.106**	0.116**	0.025**	−0.248**	−0.229**	0.020**	−0.104**	−0.128**	−0.279**	0.055**	0.460**	1

Number of observations: 50,310. See Appendix for variable definitions

**, and * denote significance at the 1% and 5% levels, respectively

Table 4 Association between labor share (*LABOR*), capital share (*CAPITAL*), interest rate (*R*), and VAIC

Dependent variable	Column (1) VAIC	Column (2) VAIC	Column (3) VAIC
Constant	8.271*** (43.84)	8.648*** (41.81)	−0.972 (−0.54)
LABOR	−6.068*** (−9.90)	−6.278*** (−5.79)	−5.862*** (−5.44)
CAPITAL	6.715*** (8.67)	2.770*** (3.89)	2.446*** (3.49)
R	−0.177 (−0.61)	−0.098 (−0.27)	0.036 (0.10)
INTANGIBLES			−1.341 (−0.80)
R&D			−2.606 (−1.07)
LEV			0.108** (1.97)
PAYMENT			−12.469*** (−9.25)
SIZE			1.444*** (5.75)
Year FE	No	Yes	Yes
Firm FE	No	Yes	Yes
Observations	50,310	50,310	50,310
Adjusted R^2	0.017	0.363	0.371
F	36.514	11.389	15.851

See Appendix for variable definitions. t statistics are in parentheses and based on clustered standard errors at the firm level

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

share (*LABOR*) has a negative and statistically significant association with *VAIC* ($p < 0.01$), while the capital share (*CAPITAL*) has a positive and statistically significant association with *VAIC* ($p < 0.01$). However, the relation between the interest rate (*R*) and *VAIC* is not statistically significant. As shown in the theoretical derivation, this result occurs because the interest rate enters only the CEE component of VAIC. All other controls are in line with prior literature (e.g., Goebel 2015). The multivariate analysis confirms that, despite not being directly related to a firm's IC, labor and capital shares are two fundamental drivers of *VAIC*.

Table 5 reports the results for the investigation into the influence of *LABOR*, *CAPITAL*, and *R* on the VAIC components. Accordingly, *VAIC* is replaced with *HCE*, *SCE*, and *CEE,* and the model is estimated in Eq. (14). The results show that *CAPITAL* is positively correlated with *HCE* and *SCE*, negatively correlated with *CEE*, and statistically significant at a conventional level ($p < 0.01$). Table 5 also shows that *LABOR* is negatively correlated with *HCE* ($p < 0.01$) and positively correlated *CEE* ($p < 0.05$). Finally, *LABOR* is not linearly correlated with

Table 5 Association between labor share (*LABOR*), capital share (*CAPITAL*), interest rate (*R*), and the components of VAIC

Dependent variable(s):	Column (1) HCE	Column (2) SCE	Column (3) CEE
Constant	−1.903	0.495***	0.540***
	(−1.11)	(9.67)	(22.63)
LABOR	−6.423***	−0.003	0.029**
	(−7.54)	(−0.09)	(2.48)
CAPITAL	2.559***	0.135***	−0.047***
	(4.06)	(3.38)	(−5.96)
R	−0.137	0.036**	0.015***
	(−0.41)	(2.06)	(2.84)
INTANGIBLES	−1.428	−0.064	0.435***
	(−0.89)	(−1.07)	(16.86)
R&D	−2.145	0.596***	0.000
	(−0.96)	(2.88)	(0.00)
LEV	0.087*	0.003	−0.003***
	(1.68)	(1.45)	(−5.24)
PAYMENT	−12.176***	−0.110***	0.069***
	(−9.53)	(−9.09)	(10.58)
SIZE	1.441***	0.004	−0.037***
	(6.04)	(0.57)	(−11.09)
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Observations	50,310	50,310	50,310
Adjusted R^2	0.381	0.480	0.821
F	20.461	15.198	64.891

See Appendix for variable definitions. t statistics are in parentheses and based on clustered standard errors at the firm level

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively

SCE. This lack of correlation may be caused by the linearization of a nonlinear expression. Additionally, *R* is positively correlated with *SCE* and *CEE*. These findings are in line with our theoretical results and confirm that *LABOR*, *CAPITAL* and *R* are important drivers of VAIC and its components (*HCE*, *SCE*, and *CEE*) in a non-perfectly competitive setting.

5 Tuning the VAIC

The preceding two sections demonstrate that the VAIC is largely influenced by exogenous technological factors that are unrelated to IC. While this result constitutes a criticism of the use of the VAIC as a measure of IC, in a non-perfect competitive setting, the VAIC also captures the ability of a firm to generate profits. This ability may be attributable to numerous circumstances, including IC. In the spirit of assisting empirical researchers, this section shows a potential solution for tuning the VAIC to more carefully measure IC.

Stemming from prior section's results, this paper argues that controlling for the interest rate, labor and capital share in an empirical analysis is fundamental to avoiding potential biases. Not including *LABOR*, *CAPITAL*, and *R* as additional controls may lead to serious omitted variable concerns and biased estimations. By contrast, including *LABOR*, *CAPITAL*, and *R* helps in ensuring that *VAIC* does not proxy for exogenous technological factors and the interest rate. Far from perfectly proxying for IC, *VAIC* will then capture the ability of a firm to generate profits and, therefore, time-varying heterogeneity across firms.

To test the potential solution identified above, this study investigates the association between VAIC and financial performance. Drawing upon previous literature (Pal and Soriya 2012; Sardo and Serrasqueiro 2017; Dženopoljac et al. 2019), the following regression model is estimated (firm subscripts are suppressed):

$$\begin{aligned} PERFORMANCE_t = {} & \theta_0 + \theta_1 VAIC_t + \theta_2 LABOR_t + \theta_3 CAPITAL_t + \theta_4 R_t \\ & + \theta_5 INTANGIBLES_t + \theta_6 R\&D_t + \theta_7 LEV_t + \theta_8 PAYMENT_t \\ & + \theta_9 SIZE_t + \text{Firm FE} + \text{Year FE} + \varepsilon_t \end{aligned} \tag{15}$$

where *PERFORMANCE* is return on assets (*ROA*), return on equity (*ROE*), and return on investments (*ROI*), alternatively, and all other variables are as defined earlier. Equation (15) is estimated excluding *LABOR*, *CAPITAL*, and *R*, then excluding *VAIC* and, finally, including all these variables. If not controlling for *LABOR*, *CAPITAL*, and *R* generates biased estimations, the coefficient of VAIC obtained when non-controlling for these variables should be significantly different than that when controlling for these factors.

Table 6 reports the results of the estimation of Eq. (*15*) with alternative measures of financial performance. The results show that the VAIC is significantly associated with financial performance (0.018, Column (1); 0.051, Column (4); 0.079, Column (7); $p<0.01$). Similarly, *LABOR*, *CAPITAL*, and *R* are also associated with financial performance [−6.178, 1.749, and 1.175 Column (2); (−13.597, 5.427, and 2.027, Column (5); (−30.592, 8.743, and 3.884, Column (8)]. Finally, when *VAIC*, *LABOR*, *CAPITAL*, and *R* are included in the estimation of Eq. (*15*), the results show that all these variables are significantly related to financial performance. However, when controlling for *LABOR*, *CAPITAL*, and *R*, the coefficient of *VAIC* is significantly different than when not controlling for these factors.[5] Thus, the estimations produced, including *LABOR*, *CAPITAL*, and *R,* are more careful and ensure that the association between the VAIC and financial performance is not overestimated. When controlling for technological factors, explanatory power varies from 45.7% when using ROE as a measure of financial performance to 66.5% when employing ROI (adjusted r-squared in columns (6) and (9), respectively). This difference can be

[5] A Wald test shows that the difference between the estimated coefficients of the VAIC in Column (1) and Column (3) is statistically significant at $p<0.01$, that between those in Column (4) and Column (6) is statistically significant at $p<0.10$, and that between those in Column (7) and Column (9) is statistically significant at $p<0.01$.

Table 6 Association between labor share (*LABOR*), capital share (*CAPITAL*), interest rate (*R*), VAIC and firm performance

Dependent variable (s):	Column (1) ROA	Column (2) ROA	Column (3) ROA	Column (4) ROE	Column (5) ROE	Column (6) ROE	Column (7) ROI	Column (8) ROI	Column (9) ROI
Constant	7.053*** (5.49)	8.643*** (6.88)	8.652*** (6.89)	22.390*** (5.83)	25.968*** (6.80)	26.000*** (6.82)	39.338*** (6.48)	47.762*** (8.02)	47.800*** (8.03)
VAIC	0.018*** (8.03)		0.010*** (3.67)	0.051*** (5.80)		0.034*** (3.54)	0.079*** (7.53)		0.040*** (2.93)
LABOR		−6.178*** (−7.87)	−6.120*** (−7.76)		−13.597*** (−6.87)	−13.401*** (−6.75)		−30.592*** (−6.17)	−30.359*** (−6.09)
CAPITAL		1.749** (2.44)	1.725** (2.42)		5.427*** (2.85)	5.345*** (2.81)		8.743** (2.30)	8.645** (2.28)
R		1.175*** (2.99)	1.175*** (2.99)		2.027** (2.15)	2.026** (2.14)		3.884** (2.08)	3.882** (2.08)
INTANGIBLES	−5.389*** (−3.90)	−5.491*** (−4.23)	−5.478*** (−4.22)	−8.917** (−2.11)	−9.143** (−2.25)	−9.098** (−2.24)	−17.464** (−2.20)	−18.240** (−2.37)	−18.187** (−2.37)
R&D	−74.400*** (−11.10)	−72.430*** (−11.06)	−72.405*** (−11.05)	−172.330*** (−10.75)	−168.037*** (−10.57)	−167.950*** (−10.57)	−232.512*** (−6.95)	−222.952*** (−6.95)	−222.849*** (−6.95)
LEV	−0.727*** (−14.46)	−0.716*** (−14.14)	−0.717*** (−14.16)	−5.835*** (−14.73)	−5.811*** (−14.67)	−5.814*** (−14.69)	−1.318*** (−7.39)	−1.274*** (−7.17)	−1.279*** (−7.19)
PAYMENT	−0.242 (−0.78)	0.038 (0.13)	0.161 (0.55)	0.237 (0.23)	0.725 (0.73)	1.143 (1.14)	−0.116 (−0.10)	1.404 (1.20)	1.900 (1.62)
SIZE	0.014 (0.08)	−0.052 (−0.30)	−0.067 (−0.39)	−0.194 (−0.36)	−0.350 (−0.66)	−0.398 (−0.75)	−1.708** (−2.07)	−2.092*** (−2.60)	−2.150*** (−2.67)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50,310	50,310	50,310	50,310	50,310	50,310	50,310	50,310	50,310
Adjusted R^2	0.556	0.570	0.570	0.450	0.457	0.457	0.652	0.665	0.665

Table 6 (Continued)

Dependent variable (s):	Column (1) ROA	Column (2) ROA	Column (3) ROA	Column (4) ROE	Column (5) ROE	Column (6) ROE	Column (7) ROI	Column (8) ROI	Column (9) ROI
F	71.243	54.341	56.987	66.551	52.534	51.880	30.580	23.477	27.564
βVAIC 1 vs.3; 4 vs.6; 7 vs. 9	–	–	8.85***	–	–	3.41*	–	–	8.59***

See Appendix for variable definitions. t statistics are in parentheses and based on clustered standard errors at the firm level

***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. We multiplied the dependent variable by 100 for ease of representation. On the basis of a Wald test, the last row shows that the difference between the estimated coefficients of VAIC in Column (1) and Column (3) is statistically significant at $p < 0.01$ ($F = 8.85$), between those and Column (4) and Column (6) at $p < 0.10$ ($F = 3.41$), and between those in Column (6) and Column (9) at $p < 0.01$ ($F = 8.59$)

attributed to the underlying difference in calculating ROE, ROA, and ROI. In fact, ROE and ROA include non-operating items that are not considered when calculating ROI. As VAIC refers to a firm's operations, the explanatory power is higher when using ROI to proxy financial performance than when using ROA and ROE.

6 Discussion and conclusions

The use of the VAIC as a measure of IC is consistently growing due to its reliance on accounting numbers and its ease of calculation. Motivated by prior critiques of the VAIC's validity, this study offers a theoretical decomposition of the VAIC in a perfectly competitive setting and demonstrates that the VAIC is a function of the elasticity coefficient of human capital, the elasticity coefficient of physical capital, and the interest rate. The theoretical results are extended to non-perfectly competitive settings through a multivariate analysis of a cross-country panel of 50,310 firm-year observations covering the years 2000–2017. Reflecting on the theoretical and empirical findings, this study proposes guidance for the use of the VAIC to overcome its inherent limitations. More specifically, this study suggests that future empirical literature control for a firm's interest rate, labor and capital shares to reduce potential measurement biases. In an additional analysis investigating the association between the VAIC and financial performance, the results show that this association is weaker when controlling for the interest rate, labor and capital share, prompting a more careful interpretation of the results.

The results of this study prompt a reflection on the use of the VAIC as a measure of IC and should be interpreted in light of the growing body of literature suggesting a multidimensional and performative approach to IC. This paper suggests that the VAIC construct is unrelated to IC from a theoretical perspective that assumes a perfectly competitive market. Conversely, from an empirical perspective, it shows that when relaxing the perfect competition assumption, the VAIC captures the ability of a firm to generate profits. Hence, the VAIC can be *cautiously* used as a leading indicator of IC. When properly tuned according to the validation proposed in this paper, academic studies may adopt the VAIC in empirical analyses to identify some *potential* relation between IC and the main dependent variable of interest. In case they find a significant relation, they are advised to investigate more deeply in order to identify the component of IC and the mechanisms through which IC affects the main dependent variable of interest.

Conversely, the VAIC can provide little or no information on how IC contributes to the value creation process. In fact, the concept of IC has many dark sides, which cannot be easily captured in the VAIC numbers or other models (Gowthrope 2009). As a result, the correlation between IC numbers is sometimes useless (Mouritsen and Roslender 2009). Hence, recent literature clearly outlines that the metrics of IC cannot stand alone but should be read and interpreted in connection to disclosure following a performative approach (Mouritsen 2006).

Although there is no single solution to measuring and reporting IC, prior literature identifies some practice-based patterns. For example, Corbella et al. (2019) demonstrate that some concepts inspired by the International Integrated Reporting

Council Framework are considered pivotal in defining categories of IC and identifying its contribution to value creation. Nielsen and Roslender (2015) show how business model discourse and disclosure can contribute to improving the information content of financial statements by also including information on IC and its contribution to value creation. Another strand of research concentrates on the interaction between business models and non-financial key performance indicators to obtain a more integrated framework that can provide more relevant and performative disclosure to users (Bini et al. 2017, 2018). While empirical content analysis demonstrates a tendency toward impression management (Melloni 2015; Melloni et al. 2016), integrated reporting, business models, key performance indicators, and IC definitely show a strong link and influence each other in practice (Zambon et al. 2019).

Compared to the VAIC, these approaches are certainly more exhaustive in explaining the contribution of IC to the value creation process. Despite its inherent limitations, the VAIC offers a ready-to-use measure based on accounting numbers. Conversely, collecting and analyzing information conveyed through integrated reporting, business models, and key performance indicators is certainly more complicated and costlier. In the end, the two approaches serve two different purposes. The VAIC provides a superficial tool for measuring IC that can be used to identify some potential relation to value creation while being incapable of any deeper investigation. Conversely, integrated reporting, business models, and key performance indicators allow a granular—albeit time and resource consuming—understanding of the contribution of IC to the value creation process.

Despite its contributions, this study is subject to some potential limitations that generate avenues for future research. First, this study limits its theoretical decomposition of the VAIC to a perfectly competitive setting. Future studies may question the decomposition of VAIC in different settings, such as monopolies, oligopolies, and other market forms. Second, the study empirically validates its theoretical model with a linear regression model. Future contributions could investigate the existence of a nonlinear relationship between the VAIC, labor share, and capital share. Finally, future research could use nonmonetary measures of market competition, such as the *Herfindahl–Hirschman* index or other concentration indices, to test whether these measures moderate the role of VAIC in explaining firms' performance.

Appendix

Variables	Description (Compustat Global code)
VAIC^{w}	Sum of HCE, SCE, and CEE
HCE^{w}	Human Capital Efficiency: VA divided by total staff expenses (XLR)
SCE^{w}	Structural Capital Efficiency: VA minus staff expenses divided by VA (XLR)
CEE^{w}	Capital Employed Efficiency: VA divided by the difference between total assets and the value of intangibles (AT, INTAN)
LABOR^{w}	Labor share: Total staff expenses divided by total sales (XLR, SALE).
CAPITAL^{w}	Capital share: Total capital expenditures divided by total sales (CAPX, SALE)
R^{w}	Interest and related expenses divided by the sum of long-term debt and debt in current liabilities (XINT, DLTT, DLC)
INTANGIBLES^{w}	Total intangibles divided by total assets (INTAN, AT)
R&D^{w}	Research and development expenses divided by total assets (XRD, AT)
LEV^{w}	Total liabilities divided by total common shareholder equity (LT, CEQ)
PAYMENT	Dummy variable that takes the value of 1 if the staff expenses are above the mean value by sector year, 0 otherwise (XLR)
SIZE^{L}	Natural logarithm of total assets (AT)
ROA^{w}	Income before extraordinary items divided by total assets (IB, AT)
ROE^{w}	Income before extraordinary items divided by common shareholder equity (IB, CEQ)
ROI^{w}	Earnings before interest and taxes divided by the difference between total assets and current assets (EBIT, AT, ACT)

^{w}Winsorized the 1% and 99% levels, while ^{L} is the natural logarithm

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