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Empirical evidence on the nature of accounting goodwill: an interdisciplinary approach

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Resumo/Abstract

The purpose of this paper is to empirically test the relationship between goodwill (intangible capital) and physical capital. Supported by concepts from quantum theory, we maintain that goodwill alone is not able to generate residual incomes. Instead, the elements that make up goodwill act, entangled with the company's physical capital (present and future), in pursuit of residual incomes. From this assumption, we build a proxy for the entanglement effect by interacting a measure of physical capital (property, plant and equipment) with a measure of intangible capital (managerial ability). Before carrying out the interaction between the variables, we found a positive association between intangible capital and physical capital. We argue that this positive relationship represents: (i) a conversion of intangible capital into physical capital and (ii) the renewal of intangible capital for future conversion. After carrying out the interaction between the variables and controlling for economic and country-year-fixed factors, our findings depict that the entanglement effect is statistically significant for a series of tests performed. For example, entanglement is positively related to both physical capital and the value creation of companies. Our findings suggest that the entanglement effect is a real force in organizations. Our approach offers valuable insights that can help regulators, scholars and investors in forecasting firms' performance. The findings remain robust for sensitivity tests and for other measures of intangible capital.

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Abstract

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Keywords: Goodwill, Managerial Ability, Intangible Capital, Quantum Mechanics

1. Introduction

Academic literature has long reached a consensus that the value of accounting goodwill is the expected present value of a going business's future residual incomes or "superprofits" (Leake, 1921; Martins, 1972; Colley & Volkan, 1988). This consensus, however, does not exist when it comes to an understanding of the nature of goodwill, which in turn defines how it should be accounted for in financial statements. The controversial nature of goodwill has puzzled the accounting community for over a century (Baboukardos & Rimmel, 2014) and remains in evidence (Wen & Moehrle, 2016; Rubio, Martínez & Mazón, 2021; Iatridis, Pappas & Walker, 2021). Garzella et al. (2020) state that a univocal definition of the very nature of goodwill remains an open issue.

Our purpose in this paper is to shed new light on this issue. Supported by quantum physics and economics, we hold that the nature of goodwill is directly related to the residuals (positive or negative) generated in each managerial decision that occurs in the company's daily life. These economic residuals occur from intangible capital acting not alone, but in entanglement with physical capital. From this perspective, goodwill is considered a set of forces that act as drivers of excess profit, rather than an accounting item capable of generating residual income on its own. In other words, we hold that the intangible elements that make up goodwill are intrinsically "entangled" in the organization's present (implemented decisions) and future (decisions not yet implemented) physical capital.

Oliveira and Lustosa (2022) provide new theoretical discussion about the nature of goodwill. The authors use concepts from quantum mechanics and economics to propose that intangible capital and physical capital are entangled, and this entanglement forms the economic value of a company. Briefly, entanglement is an odd phenomenon in which seemingly separated quantum systems behave as one (Bruza, Busemeyer & Gabora, 2009). Oliveira and Lustosa's proposal regarding goodwill considers its coexistence with physical capital. In a going concern,

the two wealth states coexist "intra-actively",[1] because intangible assets need to be combined with other assets to create value (Kaplan & Norton, 2004). In this paper, we expand this proposition to the empirical field. We examine the relationship between intangible capital and physical capital in different research frameworks, using a broad sample of firms over a wide range of time.

Due to the issue of endogeneity among financial variables, our empirical strategy starts with the search for an external variable that can be used as a proxy for accounting goodwill. Since we are claiming that the nature of goodwill is directly related to the residuals of managerial decisions – the "economic events" addressed in Oliveira and Lustosa (2022) – the variable that comes closest to our proposal on the nature of goodwill is managerial ability. The current fair value of goodwill is a function of management's future actions, including managers' conceptualization and implementation of firm strategy (Ramanna & Watts, 2012). Superior managers are better able to effectively select and execute positive net present value projects (Demerjian, Lev & McVay, 2012), thus differences in managerial ability can have important effects on shareholder wealth (Hayes & Schaefer, 1999).

In particular, we follow the managerial ability approach adopted by Demerjian, Lev and McVay (2012). First, we merge the CRSP/Compustat merged (CCM) database with Demerjian, Lev and McVay's database on managerial ability.[2] Next, we merge it with other databases (Execucomp and Research Quotient from Wharton Research Data Services (WRDS), and indicators from the World Bank database). To create a proxy that indicates the entanglement between intangible capital and physical capital, we select net property, plant and equipment (Compustat item: ppent) as a representative of physical capital; Demerjian, Lev and McVay's (2012) managerial ability score is used as a representative of intangible capital. The proxy of the entanglement effect arises through the interaction between these two variables.

First, we examined the association between intangible capital and physical capital, and found it to be positive and statistically significant. We maintain that this positive relationship indicates two findings, namely: (i) conversion of intangible capital into physical capital; and (ii) renewal of intangible capital for future conversions. Next, we examine the entanglement effect. After controlling for economic and country-year-fixed factors, our main findings demonstrate that the coefficient of the interaction of managerial ability and property, plant and equipment – the entanglement effect (entang) – is positive and statistically significant for a series of tests performed. For example, entang is positively related to firms' physical capital, market value and market return. Our findings suggest that entanglement is a real force in organizations and that investors incorporate the entanglement effect when making decisions. It is observed that entanglement is present in most of the economic sectors investigated. Our findings remain robust for other measures of intangible capital. For example, we used a research quotient[3] measure as a proxy for intangible capital, and the findings remained very consistent.

This paper makes some contributions that may be of special importance to scholars, investors and regulators. First, by deepening the discussion on the nature of goodwill we can take a further step towards a better understanding of this highly controversial topic. Understanding goodwill value correctly is important for investors, auditors and regulators (Hayn & Hughes, 2006). Second, the literature has shown that less than half of all mergers and

[1] Intra-action is a neologism that refers to the mutual constitution of entangled agencies and assumes that different agencies do not precede one another, but emerge through their intra-action (Barad, 2007 p. 33).

[2] We are grateful to the authors for publicly sharing their database. Data are available at: https://peterdemerjian.weebly.com/managerialability.html

[3] Research Quotient (RQ) is the Firm's R&D productivity (created by Anne Marie Knott) – that is, the output elasticity of R&D (discussed in detail in the robustness section). Available at WRDS: www.wharton.upenn.edu/.

acquisitions (M&As) are successful. Understanding the role of goodwill as an item capable of generating future residual incomes in this process is of fundamental importance to the accounting research community. Third, we are dealing with a topic that has not previously been covered. Our findings shed light on this topic and open many avenues for future studies, especially for those using quantum physics tools.

2. Literature review and hypothesis development

2.1. Is accounting goodwill an asset?

There is already extensive literature discussing goodwill as an asset. Since both the prevalent literature and current accounting regulations have a widely agreed understanding that goodwill is an asset, we focus this section on the scarce literature that argues just the opposite. The point is that the prevailing trend in the literature is to recognize these competitive advantages as intangible assets of indefinite useful life (Tearney, 1973; Lev, 2004). We, on the other hand, follow the literature that questions goodwill as an asset.

According to Martins (2020), the problem of whether to conceptualize goodwill as an asset or not should be analysed primarily from the definitions of assets themselves. First, whether goodwill can be interpreted as an economic resource or not. Second, which right represents goodwill? Brouwer, Hoogendoorn and Naarding (2015) state that "Although future economic benefits may be expected, goodwill consists of unidentified items and not of rights that are controlled by the entity" (p. 153). Therefore, goodwill is not a right to receive future residual income. This is an expectation that may or may not be fulfilled. Actually, the highest probability is an absence of residual earnings, as the literature considers that most M&A agreements are unsuccessful (Cartwright & Schoenberg, 2006; Calipha, Tarba & Brock, 2010).

Perhaps due to the uniqueness of these elements (managerial ability, creativity, organizational IQ, etc.), several scholars argue that goodwill is not an asset. For example, Johnson and Petrone (1998) assert that goodwill has the capacity "**in combination with other assets**" (p. 6, our emphasis) to contribute to cash flows. However, goodwill lacks the capacity to singly contribute directly to future net cash inflows. Market penetration and a superior operating team are not rights which could be described as being controlled by an entity (Booth, 2003). Intangibles are frequently embedded in physical assets, leading to considerable interactions between physical and intangible assets in the creation of value (Lev, 2001).

In this paper we propose that goodwill alone cannot generate residual incomes. Instead, it is entangled with a firm's physical capital in pursuit of such profits. Thus, we propose goodwill as a kind of intangible raw material for organizations. This intangible raw material progressively transforms into real wealth, or physical capital, as time passes and new assets' exchange transactions with the external environment are carried out by the firm in the form of purchasing, sales, production and environmental changes.

We argue, therefore, that the intangible elements that form goodwill cannot be represented as assets either in isolated form or in groups (as goodwill). They are the forces that drive future sales and residual earnings. Existing research has already carried out this kind of investigation, but has taken a theoretical approach. This study conducts an empirical investigation of the relationship between the goodwill and physical capital of firms. Our core objective is to show that the organizational virtues that characterize goodwill produce economic benefits not in isolation, but because they are entangled with the company's physical capital.

2.2. The formation of economic residuals giving rise to goodwill

We consider that the intangible elements that form goodwill (or intangible capital) do not have economic value just by virtue of "existing" in an organization. In fact, the monetary effect of those virtues that characterize goodwill would be incorporated into both the value of existing physical assets and the value of those that will exist in the future, if they were measured by

economic criteria. What we mean by this is that daily business decisions are the facts that generate residual earnings. For example, the decisions to (i) manufacture (rather than buy) a certain item, (ii) spend surplus cash on a certain investment, (iii) negotiate raw material under better conditions than competitors and (iv) obtain a loan on favourable terms.

Our proposal is based on Gecon,[4] which is a thought experiment that conceives the firm's information system as an economic accounting model in which each managerial decision that implies an exchange of assets with the market is measured by the opportunity costs (Coase, 1937; 1990) of the resources involved, which in turn define the economic value of the asset obtained in the decision. Thus, each managerial decision (based on opportunity cost) may generate an economic residual that can be positive (surplus) or negative (loss). The sum of these residuals[5] is the final portion of the firm's goodwill (or badwill).

It should also be highlighted that some authors maintain that goodwill can be derived from liabilities (see Martins & Martins, 2015 and Martins & Santos, 2017). At this point, we make some remarks. We maintain that, actually, it is the effect of managerial actions becoming entangled with items from liabilities that produces economic residuals. For this reason, we assert that goodwill is not "originated" from debt, but is only "detected" by the authors in this way. Actually, it is originated by intangible capital (managerial ability, intellectual capital, etc.), and is materialized in physical capital (financing agreements). Both forces (intangible and physical) act entangled with one another in order to originate economic residuals. This entanglement effect is the very nature of goodwill. Each force acting alone is unable to generate residual income. No company can finance itself advantageously at random.

2.3. Managerial ability

In this study, we predict that managerial ability is closely related to physical capital, acting as a booster mechanism for residual earnings. We employ the measure of managerial ability developed by Demerjian, Lev and McVay (2012), as it has been widely used in recent empirical studies (Doukas & Zhang, 2020; 2021; Banker, 2013; Sun, 2016; Andreou, Philip & Robejsek, 2016; Andreou et al., 2017; Hasan, 2020; Baik, Choi & Farber, 2020). We hold that this managerial ability measure is suitable for our research setting mainly because we hold that managers' skills act entangled with physical capital (to generate residuals). Indeed, manager-fixed effects matter for a wide range of corporate decisions, especially in acquisition or diversification decisions (Bertrand & Schoar, 2003).

Demerjian, Lev and McVay (2012) introduce a measure of managerial ability based on managers' efficiency in generating revenues. The authors build their model in two steps: (i) they first use data envelopment analysis (DEA) to estimate relative efficiency within industries. They use seven stock and flow variables as inputs: net property, plant and equipment (PP&E); net operating leases; net research and development (R&D); purchased goodwill; other intangible assets; cost of inventory; and selling, general and administrative expenses (SG&A), which contribute to the generation of revenue (output). They use DEA to solve the following optimization problem:

$$\max_v \theta = \frac{\text{Sales}}{v1\text{CoGS} + v2\text{SG\&A} + v3\text{PP\&E} + v4\text{Op.Lease} + v5\text{R\&D} + v6\text{Goodwill} + v7\text{Ot.Intang}} \quad (1)$$

[4] The economic management information system Gecon is a theoretical model of the nature of organizations that was developed at the University of São Paulo by professor Catelli between the late 1970s and the early 2000s.

[5] This is a simplification, as the Gecon approach also considers the residuals of the change of conjuncture (economic, monetary, etc.), the cost of equity and the value of money in time, among other factors.

Since such a measure captures both firm- and manager-specific efficiency factors, Demerjian, Lev and McVay (2012) then proceed to the second step: (ii) they regress the total firm efficiency measure using a tobit model on the firm characteristics that affect firm efficiency (size, market share, cash availability, life cycle, business segment concentration and the presence of foreign currency transactions):

$$\text{Firm Efficiency} = \beta_0 + \beta_1 \ln(\text{Total Assets})_i + \beta_2 \text{Market Share}_i + \beta_3 \text{Free CashFlow Indicator}_i + \beta_4 \ln(\text{Age})_i + \beta_5 \text{Business Segment Concentration}_i + \beta_6 \text{Foreign Currency Indicator}_i + \text{Year Fixed Effects}_i + \varepsilon_i \quad (2)$$

The residual term derived from this second step (tobit regression) is the element reflecting managerial ability score. This measure of managerial ability captures the ability of managers to generate revenue "through efficient exploration of resources through decisions and choices encompassing capital, labor, investment, and other revenue-generating practices" (Andreou et al., 2017, p. 110). The managerial ability measure effectively separates the managerial effect from the firm effect as well as capturing the overall ability of the management team (Hasan, 2020; Doukas & Zhang, 2020).

The idea that supports Demerjian, Lev and McVay's proposal is that high-ability managers better foresee business opportunities, better understand technology and industry trends, reliably predict product demand, invest in higher-value projects and manage their employees more efficiently than low-ability managers. For this reason, we choose mascore as a measure of (or proxy for) intangible capital. Firms with more able managers are more capable of effectively selecting and executing positive net present value projects that yield superior performance. This is because more able managers have better knowledge of the trends in and the ongoing environment of the industry, and they are likely more capable of achieving significant cost reductions (Demerjian, Lev & McVay, 2012; Andreou et al., 2017; Chen & Lin, 2018; Hasan, 2020).

Previous research has related managerial ability to characteristics that point to the generation of abnormal earnings. For example, the impact of managerial ability on the profitability of M&As (Chen & Lin, 2018); earnings quality (Demerjian et al., 2013), value relevance of earnings (Francis et al., 2019) and CEO relative peer quality (Francis et al., 2016). These studies have provided insights into our proposal, which aims to investigate the cause-and-effect relationship between intangible capital and physical capital. From the aforementioned, we predict that there is a statistically significant relationship between them. However, as we are jointly examining several firms from different sectors – some demanding more innovative capacity and others not so much – there is no way to predict the direction of the force that will prevail in this relationship, making it an empirical question.

H1. Intangible capital (mascore) has a statistically significant association with a firm's physical capital.

A positive relationship indicates that, on average, intangible capital is strong enough to convert itself into physical capital and still maintain its growth (or renewal). This is an expected behaviour in those sectors that demand high innovative capacity. On the other hand, a negative value indicates that, on average, physical capital "absorbs" more intangible capital than intangible capital can renew itself.

2.4. Quantum entanglement

Oliveira and Lustosa (2022) dialogue accounting with quantum mechanics, economics and general systems theory to elucidate the nature of goodwill. They seek support from agential realism (Barad, 2007; 2010; 2014) to answer the question "how is goodwill able to generate

residual income?" The authors propose the entanglement of physical capital and intangible capital. Entanglement implies the existence of global states of composite systems which cannot be described as a product of the states of individual subsystems (Horodecki et al., 2009). "The entangled states are linear superpositions of the internal states of the system which cannot be separated into product states of the individual atoms" (Ficek & Tanás, 2002, p. 369).

The quantum approach followed by the authors has been gaining notoriety in the social sciences in recent years. Sociophysics and econophysics are approaches which use ideas, models and conceptual methods of physics applied to socioeconomic phenomena (Kutner et al., 2019). However, we observe very few studies linking accounting and quantum physics (with all of those that do addressing a theoretical perspective). We quote Demski et al. (2006), who explore a connection between quantum information and its conceptual applications to accounting.

In another example, Fellingham and Schroeder (2006) discuss the relationship between quantum information (quantum entanglement, quantum interference and quantum probability) and double entry accounting. Abreu (2016) advocates the relevance of physics to accounting. The author develops a firm value model based on econophysics concepts, and holds that some laws of physics have important implications for firm valuation. Moore (2017) uses the approach of quantum entanglement to present an alternative to the concept of accounting entity.

Oliveira and Lustosa (2022) conclude that the qualities and virtues of human actions are value drivers for physical capital. Therefore, physical capital and intangible capital are entangled in a symbiotic relationship in which each depends on the other to generate superior gains. From this perspective, we created our main research hypothesis, which considers the entanglement proposed by the authors.

Despite the fact that we are jointly examining several firms from different sectors, we can predict, supported by the theory addressed in this study, a direction of the force that will prevail in this relationship. Since going concern firms, on average, tend to earn positive gains from their operations, we can predict that the entanglement effect is positively influencing firms in general regardless of their economic sector. Therefore, we expect to find a positive coefficient on the variable that represents the entanglement effect.

H2. There is a positive entanglement effect on companies, which is capable of creating physical capital and generating value for them.

Haven and Khrennikov (2013) indicate many potential research fields relating quantum mechanics to areas such as economics and finance. We contribute to this growing literature by providing empirical evidence of the entanglement effect. In other words, we provide an empirical underpinning that supports comprehension of the dynamics of goodwill with the company's physical capital.

3. Research methodology

First, we examine the cause-and-effect relationship between intangible capital and physical capital. To do this, we follow the specification from Equation (3). We expect to find a statistically significant relationship between the two forms of capital, albeit without predicting the direction of the force that will prevail. Regardless of the direction, a statistically significant relationship would suggest that the cause of physical capital (physcap) is intangible capital (intcap).

$$\text{physcap}_t = f(\text{intcap};\ \Delta\text{intcap})_t + \sum_n \beta_n\ \text{Control Factors} \qquad (3)$$

Control factors are variables related to firm factors, macroeconomic factors, and year and country effects. Thus, Equation (3) can be rewritten to the following specification:

$$\text{physcap}_t = f(\text{intcap};\ \Delta\text{intcap})_t + \sum_a \beta_a\ \text{Company Factors}_{it} + \sum_b \beta_b\ \text{Macroeconomic Factors}_{it} + \text{year fixed effects}_{it} + \text{country fixed effects}_{it} + \varepsilon_{it} \quad (4)$$

Oliveira and Lustosa (2022) hold that physical capital represents management decisions already implemented – that is, ideas, plans and strategies made material in assets and liabilities. In this regard, we consider that physical capital can be represented by the comprehensive income of the firm. Aggregate comprehensive income is theoretically defined as a measure of all changes in the value of net assets (equity) of an entity that result from recognized transactions and other economic events of the period, except for transactions with owners (Hodgson & Russell, 2014; Black, 2016).

We include two variables in the regression model in order to control the isolated influence of both physical and intangible capital. We select net property, plant and equipment (ppenet) to control the isolated influence of physical capital, and goodwill to control the isolated influence of intangible capital. To avoid a possible autocorrelation with the other RHS variables (which are scaled by total assets), we choose to scale goodwill by shares outstanding. We include two variables (size and leverage) to control for the presence of unobserved heterogeneity at the firm level. We also control for macroeconomic factors. Finally, we control for the presence of unobservable heterogeneity both across countries and over time in our panel data by including year and country fixed effects.

$$\text{compincat}_{it} = \beta_0 + \beta_1\text{mascore}_{it} + \beta_2\text{ppenet}_{it} + \beta_3\text{gdwlshrout}_{it} + \beta_4\text{size}_{it} + \beta_5\text{leverage}_{it} + \beta_6\text{spglobeq}_t + \beta_7\text{rintrate}_t + \beta_8\text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (5)$$

where compincat is the comprehensive income of firm *i* in year *t* scaled by total assets, mascore is the managerial ability score, ppenet is net property, plant and equipment (Compustat item: ppent) scaled by total assets, gdwshrout is the book value of goodwill (Compustat item: gdwl) scaled by total shares outstanding, size is the natural logarithm of total assets, leverage is total liabilities scaled by total assets, spglobeq is the Standard & Poor's global equity index for each country, rintrate is the real interest rate for each country, and gdpgrowth is the gross domestic product (GDP) growth for each country.

To complement our analysis, we also investigate a variation, or changed version, of the Equation (5) model. Such a model allows us to examine whether changes in physical capital are also associated with changes in intangible capital. Thus, we rearrange Equation (5) to present the variables as changes (except for economic factors):

$$\Delta\text{compincat}_{it} = \beta_0 + \beta_1\Delta\text{mascore}_{it} + \beta_2\Delta\text{ppenet}_{it} + \beta_3\Delta\text{gdwlshrout}_{it} + \beta_4\Delta\text{size}_{it} + \beta_5\Delta\text{leverage}_{it} + \beta_6\text{spglobeq}_t + \beta_7\text{rintrate}_t + \beta_8\text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (6)$$

where Δ means changes in the variables already specified in the Equation (5) model.

After this first investigation, we created a proxy for the entanglement effect to verify whether there is a positive and statistically significant relationship between entanglement and both firms' physical capital and their value creation. To create a proxy for entanglement we interact managerial ability score with net property, plant and equipment (entang = mascore × ppenet). To examine the role of entanglement in a firm's physical capital, we follow the model proposed in Equation (5). We also examine the entanglement by economic sector according to the Global Industry Classification Standard (GICS).

$$\text{compincat}_{it} = \beta_0 + \beta_1 \text{entang}_{it} + \beta_2 \text{ppenet}_{it} + \beta_3 \text{gdwlshrout}_{it} + \beta_4 \text{size}_{it} + \beta_5 \text{leverage}_{it} + \beta_6 \text{spglobeq}_t + \beta_7 \text{rintrate}_t + \beta_8 \text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (7)$$

Once again, we investigate a variation. From the Equation (7) model we examine whether changes in the entanglement effect are associated with changes in physical capital. Thus, we rearrange Equation (7) to present the variables as changes (except for economic factors).

$$\Delta\text{compincat}_{it} = \beta_0 + \beta_1 \Delta\text{entang}_{it} + \beta_2 \Delta\text{ppenet}_{it} + \beta_3 \Delta\text{gdwlshrout}_{it} + \beta_4 \Delta\text{size}_{it} + \beta_5 \Delta\text{leverage}_{it} + \beta_6 \text{spglobeq}_t + \beta_7 \text{rintrate}_t + \beta_8 \text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (8)$$

where Δ means changes in the variables already specified in the Equation (5) and Equation (7) models.

Finally, we examine the relationship between entanglement and firms' value creation. To do this, we follow the accounting-based valuation model developed by Ohlson (1995). We then consider the following specification:

$$\text{mkvalt}_{it} = \beta_0 + \beta_1 \text{entang}_{it} + \beta_2 \text{ppenet}_{it} + \beta_3 \text{gdwlshrout}_{it} + \beta_4 \text{size}_{it} + \beta_5 \text{leverage}_{it} + \beta_6 \text{spglobeq}_t + \beta_7 \text{rintrate}_t + \beta_8 \text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (9)$$

Where mkvalt is the natural logarithm of the market value of the firm. We also use an alternative measure for market value (mkvalprc) calculated by multiplying the stock price (Compustat item: prcc_f) by the number of shares outstanding (Compustat item: csho). As in the previous case, we use the natural logarithm of this measure. After that, we proceed to the final analysis based on market return (Δmkvalt) as a function of Δentang. We consider the following specification:

$$\Delta\text{mkvalt}_{it} = \beta_0 + \beta_1 \Delta\text{entang}_{it} + \beta_2 \text{ppenet}_{it} + \beta_3 \text{gdwlshrout}_{it} + \beta_4 \text{size}_{it} + \beta_5 \text{leverage}_{it} + \beta_6 \text{spglobeq}_t + \beta_7 \text{rintrate}_t + \beta_8 \text{gdpgrowth}_t + \text{year\_control} + \text{country\_control} + \varepsilon_{it} \quad (10)$$

where Δmkvalt is the market return of the firm measured in six different ways:

$$\text{ret1} = \frac{\text{mkvalt} - \text{mkvalt[\_n-1]}}{\text{mkvalt[\_n-1]}} \quad (11)$$

$$\text{ret2} = \frac{\text{mkvaltprc} - \text{mkvaltprc[\_n-1]}}{\text{mkvaltprc[\_n-1]}} \quad (12)$$

$$\text{ret3} = \frac{\text{prcc\_f} - \text{prcc\_f[\_n-1]}}{\text{prcc\_f[\_n-1]}} \quad (13)$$

$$\text{ret4} = \frac{\text{prcc\_f} + \text{dvpsp} - \text{prcc\_f[\_n-1]}}{\text{prcc\_f[\_n-1]}} \quad (14)$$

$$\text{ret5} = \frac{\text{aj\_prcc} - \text{aj\_prcc[\_n-1]}}{\text{aj\_prcc[\_n-1]}} \quad (15)$$

$$\text{ret6} = \frac{\text{aj\_prcc} + \text{dvpsp} - \text{aj\_prcc[\_n-1]}}{\text{aj\_prcc[\_n-1]}} \quad (16)$$

where prcc_f is the closing stock price, dvpsp is the common dividends paid per share, and aj_prcc is the closing stock price adjusted for stock splits.

4. Sample construction and descriptive statistics

Table 1 depicts the operationalization of all variables used in the study as well as the sample construction. Our sample starts with the entire database from the CRSP merged with Compustat (CCM). The data ranges from 1980 to 2020. First, we merged CCM with Demerjian, Lev and McVay's database on managerial ability.[6] After that, we merged it again with other databases (Execucomp and Research Quotient from WRDS, and indicators from the World Bank Data[7]), which are the source of the other variables used in this study. All data sources were merged in Stata using the combined gvkey-datadate which uniquely identifies each observation. After all merges, our initial sample comprised all firms listed from 1980 to 2020, totalling 167,907 firm-year observations.

Table 1. Definition of the main variables and sample construction

Acronym	Operationalization	Data source
compincat	Total comprehensive income (compinc) scaled by total assets	CCM database
mascore	Managerial ability score by Demerjian, Lev and McVay (2012)	P.Demerjian website
ppenet	Total net property, plant and equipment scaled by total assets	CCM database
gdwshrout	The book value of goodwill scaled by shares outstanding	CCM database
size	Natural logarithm of total assets	CCM database
leverage	The book value of liabilities scaled by total assets	CCM database
spglobeq	Standard & Poor's global equity indices, by country	World Bank website
rintrate	Real interest rate by country	World Bank website
gdpgrowth	GDP growth by country	World Bank website
entang	Entanglement effect proposed by the authors. entang = mascore × ppenet	---
resquot	Research quotient. A measure of a firm's R&D productivity	CCM database
mkvalt	Market value – total	CCM database
prcc_f	Price close – annual	CCM database
ajex	Adjustment factor for stock splits and stock dividends	CCM database
aj_prcc	Price close adjusted for stock splits and stock dividends (prcc_f / ajex)	CCM database
csho	Common shares outstanding	CCM database
mkvaltprc	Alternative measure for market value by multiplying the stock price (prcc_f) by the number of shares outstanding (csho)	CCM database
ret*	Market return measured by six different forms (See page 8)	---
dvpsp_f	Dividends per share – pay date	CCM database
compensat	Total executive compensation paid	Execucomp database
intanoat	Other intangibles scaled by total assets	CCM database
intangat	Total intangible assets scaled by total assets	CCM database
ppegross	Total gross property, plant and equipment scaled by total assets	CCM database

We have excluded observations whose currency (Compustat item: curcd) was different from the US dollar (2,695 observations in Canadian dollars were excluded). Since Demerjian, Lev and McVay's database excludes financial institutions, our final sample does not have data from these institutions (757 obs excluded). Finally, we also excluded 2,489 firms with negative stockholder equity (Compustat item: teq). The final sample totalled an unbalanced panel, with 161,966 firm-year observations from 1980 to 2020, covering 67 countries.

Since the comprehensive income variable computed by the CCM database has values only from 2009 onwards, we chose to manually construct this variable. To do this, we followed Black (2016), calculating comprehensive income as the sum of Compustat items: *cibegni*, *cisecgl*, *cidergl*, *cipen*, *cicurr*, and *ciother*; if missing, comprehensive income is the sum of

[6] We are grateful to the authors for publicly sharing their database. Recently, Demerjian's website updated the MA score database for the year 2020. Data are available at: https://peterdemerjian.weebly.com/managerialability.html

[7] Available at https://data.worldbank.org/indicator

Compustat items: *ni*, *cisecgl*, *cidergl*, *cipen*, *cicurr*, and *ciother*; if still missing, comprehensive income is the sum of Compustat items: *citotal* and *cimii*.

Table 2 depicts a summary of the variables. Average comprehensive income of the sample is -2.6%. The mean value of managerial ability is .0014 and the median is -.0157 (the values range from -.282 to .697). For comparison purposes, Demerjian, Lev and McVay (2012) found a mean value of -.004 and a median of -.013 (the values ranged from -.415 to .557). Net property, plant and equipment represented on average 28.6% of total assets, and goodwill represented on average 0.5% of total shares outstanding. Despite the extreme values for some variables, for example in the maximum of compincat, gdwlshrout and leverage, we chose neither to exclude outliers nor to winsorize our sample. The average leverage of the companies was about 50% and the compensation paid to executives represented an average of 1.1% of the firms' total assets.

Table 2. Summary statistics

	N	mean	st.dev.	min	p1	p25	median	p75	p99	max
compincat	51,974	-0.0263	0.2842	-12.4602	-0.9836	-0.0427	0.0298	0.0762	0.2957	24.5863
mascore	161,966	0.0014	0.1249	-0.2822	-0.2168	-0.0698	-0.0157	0.0410	0.4931	0.6970
ppenet	161,915	0.2863	0.2335	0	0.0064	0.0988	0.2198	0.4154	0.9018	1.0000
gdwlshrout	117,892	0.0046	0.3784	0	0	0	0	0.0019	0.0311	75.9160
size	161,966	5.2405	2.3200	-5.8091	0.5805	3.5630	5.0948	6.8091	10.8850	13.5896
leverage	161,650	0.5003	0.3477	0	0.0551	0.3093	0.4903	0.6503	1.2459	63.6667
compensat	39,818	0.0109	0.0218	0	0.0003	0.0027	0.0058	0.0119	0.0826	1.9106
resquot	43,179	0.1141	0.0585	-0.5767	0.0108	0.0810	0.1062	0.1375	0.2939	1.9373
spglobeq	121,683	0.0973	0.1868	-0.8423	-0.3849	-0.0154	0.1139	0.2631	0.4789	2.8400
rintrate	155,093	0.0479	0.0260	-0.3531	0.0018	0.0298	0.0492	0.0654	0.0859	0.7762
gdpgrowth	160,894	0.0280	0.0219	-0.2149	-0.0349	0.0188	0.0300	0.0413	0.0786	0.2663

Table 3 shows correlation between the main variables included in the model. The starting points that we call attention to are (i) the positive and statistically significant relationship between comprehensive income (compincat) and the managerial ability variable (mascore) and (ii) the negative and statistically significant relationship between mascore and net property, plant and equipment (ppenet).

Table 3. Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) compincat	1										
(2) mascore	0.12***	1									
(3) ppenet	0.08***	-0.20***	1								
(4) gdwlshrout	0.09***	-0.00	-0.00	1							
(5) size	0.30***	0.08***	0.16***	0.01***	1						
(6) leverage	-0.10***	-0.06***	0.13***	0.01***	0.11***	1					
(7) compensat	-0.03***	0.08***	-0.15***	-0.14***	-0.36***	-0.20***	1				
(8) resquot	0.10***	0.14***	-0.03***	-0.07***	-0.11***	-0.02***	0.08***	1			
(9) spglobeq	0.05***	0.00	0.01***	-0.00	-0.04***	-0.01***	-0.01*	0.07***	1		
(10) rintrate	-0.01*	0.01***	0.09***	0.00	-0.25***	0.03***	0.02***	0.17***	0.13***	1	
(11) gdpgrowth	0.05***	0.01***	-0.01**	0.00	-0.11***	-0.02***	0.02***	0.01	0.14***	0.19***	1

Overall, the variables have low correlation as well as low VIF values (untabulated), indicating that the problem of multicollinearity is unlikely to be a concern for our results. We also conducted a Hausman test that indicated that the fixed effects model is most appropriate. It is also important to emphasize that all results of the regressions performed are based on White's (1980) adjustments (standard errors adjusted for heteroscedasticity).

5. Results

Table 4 shows the results of stepwise multiple regression. Our first results indicate the strength of association between intangible capital, represented by managerial ability, and physical capital (an average of 28%). The last two columns show the full regression with and without year and country controls. The results remain robust even after controlling for firm factors, macroeconomic factors and country-year-specific factors. Our results show that a 1% increase in managerial ability score is associated with a 14.4% increase in physical capital as a proportion of total assets (final column of Table 4). These first findings suggest that our proposition about the relationship between intangible capital and physical capital (H1) appears to be true.

Our empirical findings depict that, on average, the positive relationship between intangible capital and physical capital prevails. We argue that the positive relationship denotes that intangible capital is renewed at a speed greater than it is converted – that is, intangible capital is converted into physical capital and is renewed for future conversions. This finding suggests that, on average, companies seek to maintain strong intangible capital – that is, they invest in innovative managerial ability and in transforming this knowledge and expertise into physical capital, regardless of the sector. A possible negative relationship would indicate that physical capital absorbs more intangible capital than this (the intangible capital) can renew itself. This would represent a scenario in which firms in a given sector have low intangible capital intensity.

Table 4. Regression results for the association between physical capital and intangible capital

compincat	**Model (5)**						
mascore	0.287***	0.283***	0.284***	0.295***	0.274***	0.281***	0.144***
	(19.75)	(19.55)	(19.37)	(19.41)	(18.72)	(18.40)	(18.82)
ppenet		-0.330**	-0.333**	-0.347**	-0.250*	-0.173***	0.0494***
		(-3.10)	(-3.07)	(-3.25)	(-2.40)	(-7.24)	(9.88)
gdwlshrout			-0.193	-1.911***	-1.435***	-1.633***	0.237
			(-1.15)	(-4.29)	(-4.50)	(-5.23)	(1.85)
size				0.0506***	0.0567***	0.0682***	0.0515***
				(4.84)	(5.56)	(15.59)	(80.42)
leverage					-0.378***	-0.359***	-0.241***
					(-22.53)	(-25.61)	(-50.88)
spglobeq						0.0596***	0.0133
						(11.77)	(0.81)
rintrate						0.182**	-0.272*
						(2.82)	(-2.12)
gdpgrowth						0.599***	0.528***
						(12.81)	(3.29)
_cons	-0.0261***	0.0570*	0.0582*	-0.259**	-0.141	-0.264***	-0.233
	(-2703.64)	(2.12)	(2.09)	(-2.85)	(-1.52)	(-9.86)	(-0.00)
Year/Country Control	No	No	No	No	No	No	Yes
N	51,974	51,966	51,630	51,630	51,491	48,532	48,532
R^2	0.02	0.03	0.03	0.04	0.09	0.13	0.19

We also draw attention to the goodwill (gdwlshrout) and fixed assets (ppenet) coefficients. Note that both present negative associations with physical capital in almost all steps. However, when we include country-year-fixed factors, ppenet becomes positive and statistically significant whereas gdwlshrout ceases to be statistically significant (these changes may be related to year and country controls). Finally, firm size has a positive association with physical capital (probably due to scale gains), whereas leverage has a negative association.

We expand our analysis to examine whether changes in intangible capital explain changes in physical capital. Examining whether the association verified in the initial model (Equation (5)) remains in the variation model (Equation (6)) allows us to make more inferences about the cause-and-effect relationship between physical capital and intangible capital. The results in Table 5 show that it does – that is, the association between changes in managerial ability and changes in physical capital is positive and statistically significant in every step.

More specifically, a 1% increase/decrease in managerial ability is associated with an increase/decrease in physical capital (as a proportion of total assets) of about 27.7% (final column). These results seem to confirm hypothesis H1, and suggest that intangible capital is the cause of organizations' physical capital. Interestingly, contrary to the findings in Table 4, changes in ppenet (dppenet) are negatively related to changes in physical capital. Changes in goodwill (dgdwlshrout) are now positively associated with changes in physical capital. This change is probably due to the influence of year and country controls, and not of gdwlshrout itself. Changes in firm size have no statistically significant association with changes in physical capital, whereas changes in leverage have a negative association with physical capital.

Table 5. Regression results for the association between changes in physical capital and changes in intangible capital

dcompincat	**Model (6)**						
dmascore	0.262***	0.264***	0.266***	0.280***	0.262***	0.255***	0.277***
	(9.96)	(9.65)	(9.57)	(7.23)	(7.23)	(11.73)	(26.77)
dppenet		-0.909	-0.910	-0.977	-0.844	-0.250***	-0.242***
		(-1.45)	(-1.43)	(-1.40)	(-1.25)	(-4.60)	(-10.95)
dgdwlshrout			1.112	3.398	3.794	1.728	1.543***
			(1.14)	(1.32)	(1.31)	(1.40)	(5.53)
dsize				-0.141	-0.144	0.00969	-0.00395
				(-0.88)	(-0.90)	(0.43)	(-0.95)
dleverage					-0.554***	-0.446***	-0.392***
					(-6.22)	(-13.13)	(-38.08)
spglobeq						0.105***	0.00462
						(14.48)	(0.26)
rintrate						-0.0245	-0.239
						(-0.33)	(-1.69)
dpgrowth						0.212**	-0.0904
						(2.95)	(-0.51)
_cons	0.00474***	0.00692***	0.00675***	0.0163	0.0225	-0.00434	-0.142
	(74.31)	(4.52)	(3.82)	(1.30)	(1.68)	(-1.89)	(-0.55)
Year/Country Control	No	No	No	No	No	No	Yes
N	44,926	44,916	44,558	44,558	44,382	41,807	41,807
R^2	0.00	0.02	0.02	0.02	0.04	0.07	0.07

We proceed with the analysis since we are interested in showing not a separate relationship between physical and intangible capital, but an entangled relationship between them. Based on the Equation (7) model, we now examine the entanglement effect. The results from Table 6 show that the coefficient of the interaction – that is, the joint effect – is positive and statistically significant, supporting our proposition (H2) about the entanglement effect.

Note that the entanglement coefficient (20.7%) is about 50% as high as the mascore coefficient (see Table 4) even using ppenet as a control for the individual action of physical capital. Thus, a 1% increase in the entanglement effect is associated with an approximately 21% increase in physical capital (as a proportion of total assets). We believe that this represents a true physical–intangible symbiosis that is present in every single organization and is the source of generation not only of ordinary earnings but also of residual earnings.

Interestingly, ppenet alone shows a negative relationship with compincat in most of the stepwise regression, showing a positive association only when we insert year and country fixed effects (last column). Also in Table 6, goodwill (gdwlshrout) presents a negative association with physical capital (without year and country fixed effects). In the model with country-year fixed effects, there is no statistically significant relationship. As Table 6 shows aggregated results for all companies in the sample, we next examine the behaviour of the entanglement effect by economic sector.

Table 6. Regression results for the association between the entanglement effect and physical capital

compincat	**Model (7)**						
entang	0.617***	0.589***	0.589***	0.598***	0.558***	0.570***	0.207***
	(15.74)	(17.15)	(17.25)	(17.48)	(17.42)	(17.66)	(9.64)
ppenet		-0.320**	-0.323**	-0.337**	-0.239*	-0.161***	0.0415***
		(-3.01)	(-2.99)	(-3.17)	(-2.31)	(-6.70)	(8.31)
gdwlshrout			-0.289	-1.939***	-1.454***	-1.660***	0.0485
			(-1.91)	(-4.15)	(-4.43)	(-4.98)	(0.38)
size				0.0484***	0.0547***	0.0662***	0.0526***
				(4.64)	(5.39)	(14.91)	(82.19)
leverage					-0.382***	-0.364***	-0.245***
					(-22.89)	(-25.74)	(-51.41)
spglobeq						0.0617***	0.0140
						(12.10)	(0.85)
rintrate						0.174**	-0.304*
						(2.65)	(-2.36)
gdpgrowth						0.580***	0.545***
						(12.29)	(3.39)
_cons	-0.0244***	0.0561*	0.0577*	-0.246**	-0.128	-0.250***	-0.238
	(-199.48)	(2.10)	(2.08)	(-2.71)	(-1.39)	(-9.18)	(-0.00)
Year/Country Control	No	No	No	No	No	No	Yes
N	51,966	51,966	51,630	51,630	51,491	48,532	48,532
R^2	0.01	0.02	0.02	0.03	0.09	0.12	0.18

Untabulated results indicate that our findings were statistically significant for almost all sectors, with the exception of Communication Services (GICS 50). This suggests that entanglement is a real force in organizations regardless of the economic sector investigated. Although the Utilities (GICS 55) and Real Estate (GICS 60) sectors showed the highest coefficients, the low number of observations for these two sectors should be highlighted. Thus, we draw attention to the sectors: Materials (GICS 15), Health Care (GICS 35) and Information Technology (GICS 45). Our findings suggest that in these three sectors, intangible capital is renewed at a higher rate than it is converted into physical capital.

Once again, we examine the change model. We now are interested in verifying whether changes in the entanglement effect are associated with changes in physical capital (Equation (8)). The results are reported in Table 7 and show that a one-unit change in entanglement is positively associated with a 53% (without year and country fixed effects) and 55% (with year and country fixed effects) change in physical capital. It is important to note that we also performed this analysis by sector with and without country-year fixed effects (untabulated).

Although the entanglement effect suggests that both forces (physical and intangible) act together in generating economic outcomes, the findings suggest a dominant resultant force of intangible capital impacting physical capital. It may be that our findings are influenced by the tools used in this research (linear regressions). This is one of the limitations of our investigation. We do not use the tools of quantum mechanics. The tools of statistical physics or quantum-statistical mechanics turned out to be extremely useful when applied to complex systems (Chakraborti et al., 2011) – and organizations can be characterized as complex systems (Dooley & Van de Ven, 1999; Schneider & Somers, 2006; Scott & Davis, 2007). "Strategy making [...] is probably much closer to a quantum probability wave that changes its shape each time we observe it than it is to a linear and predictable Newtonian equation" (O'Donnell et al., 2003, p. 86).

Table 7. Regression results for the association between changes in the entanglement effect and changes in physical capital

dcompincat	**Model (8)**	
dentang	0.527***	0.553***
	(12.90)	(19.28)
dppenet	-0.231***	-0.228***
	(-4.28)	(-10.27)
dgdwlshrout	1.827	1.621***
	(1.45)	(5.79)
dsize	0.0101	-0.00343
	(0.45)	(-0.82)
dleverage	-0.448***	-0.394***
	(-13.11)	(-38.12)
spglobeq	0.105***	0.00383
	(14.37)	(0.21)
rintrate	-0.00112	-0.281*
	(-0.02)	(-1.98)
gdpgrowth	0.201**	-0.124
	(2.79)	(-0.70)
_cons	-0.00511*	-0.143
	(-2.20)	(-0.55)
Year Control	No	Yes
Country Control	No	Yes
N	41,807	41,807
R^2	0.07	0.06

We next examine whether the entanglement effect has a statistically significant relationship with market variables. First, we examine the association between the entanglement effect and firms' market value according to the specifications of Equation (9). The results are reported in Table 8. We found that the entanglement effect is positive and statistically significant whatever the regression model (columns 1 and 2).

Regardless of the market value measure (mkvalt or mkvaltprc) the association remains significant even after controlling for firm factors, macroeconomic factors and country-year-specific factors. We call attention to the high R-squared observed in the columns with year and country fixed effects (column number 2). The findings observed in Table 8 seem to confirm Oliveira and Lustosa's (2022) proposal that intangible capital and physical capital are entangled, and this entanglement forms the firm's economic value. Furthermore, our findings suggest that investors also incorporate the entanglement effect in their analysis.

Table 8. Regression results for the association between the entanglement effect and a firm's market value

	mkvalt		*mkvaltprc*	
	(1)	(2)	(1)	(2)
entang	2.323***	2.877***	2.271***	2.715***
	(18.29)	(38.70)	(20.92)	(44.10)
ppenet	-0.901***	-0.900***	-0.727***	-0.721***
	(-11.31)	(-56.97)	(-12.23)	(-54.33)
gdwlshrout	-5.745***	-12.52***	-4.685***	-11.13***
	(-4.33)	(-26.52)	(-4.82)	(-26.10)
size	0.863***	0.981***	0.843***	0.963***
	(89.00)	(497.62)	(120.46)	(603.62)
leverage	-0.531***	-0.758***	-0.566***	-0.833***
	(-4.93)	(-68.79)	(-6.52)	(-93.26)
spglobeq	0.779***	0.688***	0.718***	0.378***
	(54.17)	(8.79)	(55.33)	(8.72)
rintrate	0.192	-3.103***	-1.628***	-1.233***
	(0.79)	(-5.26)	(-8.63)	(-4.15)
gdpgrowth	3.641***	5.177***	4.121***	4.435***
	(22.65)	(6.98)	(28.31)	(9.54)
_cons	1.188***	0.787	1.248***	0.866
	(15.97)	(0.00)	(24.61)	(0.00)
Year/Country Control	No	Yes	No	Yes
N	68,853	68,853	104,549	104,549
R^2	0.49	0.84	0.54	0.85

Table 9. Regression results for the association between the entanglement effect and a firm's market return

	ret1	*ret2*	*ret3*	*ret4*	*ret5*	*ret6*
dentang	1.092	1.240	2.952***	2.953***	2.367***	2.378***
	(0.14)	(0.43)	(6.80)	(6.80)	(7.29)	(7.32)
ppenet	0.634	-0.500	-0.0667	-0.0552	-0.183***	-0.173***
	(0.47)	(-1.09)	(-0.96)	(-0.80)	(-3.52)	(-3.35)
gdwlshrout	-12.17	-8.343	0.0371	0.515	-2.856	-2.873
	(-0.30)	(-0.56)	(0.02)	(0.23)	(-1.70)	(-1.71)
size	-0.0504	-0.0174	-0.0765***	-0.0754***	0.00198	0.00571
	(-0.30)	(-0.31)	(-9.04)	(-8.91)	(0.31)	(0.90)
leverage	-0.564	-0.410	0.0861	0.0852	-0.0989**	-0.102**
	(-0.56)	(-1.29)	(1.80)	(1.78)	(-2.76)	(-2.84)
spglobeq	-0.0111	0.382	0.564*	0.563*	0.514**	0.530**
	(-0.00)	(0.24)	(2.34)	(2.33)	(2.85)	(2.93)
rintrate	-0.409	-0.192	-0.721	-0.691	0.0883	0.469
	(-0.01)	(-0.02)	(-0.43)	(-0.42)	(0.07)	(0.38)
gdpgrowth	-9.091	-1.637	-2.967	-2.955	-0.377	-0.330
	(-0.13)	(-0.10)	(-1.15)	(-1.15)	(-0.20)	(-0.17)
_cons	1.064	-0.903	0.200	0.193	-0.309	-0.347
	(0.01)	(-0.04)	(0.06)	(0.06)	(-0.12)	(-0.14)
Year/Country control	Yes	Yes	Yes	Yes	Yes	Yes
N	61,118	96,581	96,614	96,614	96,614	96,614
R^2	0.00	0.00	0.01	0.01	0.01	0.01

Finally, we investigate whether market return is also associated with the entanglement effect. We follow the Equation (10) model. The results are reported in Table 9 and show a positive and significant association for most return measures. Our findings suggest that a variation in the entanglement effect is positively associated with a variation in market return (a mean of 2.7%). It should be highlighted that as our main objective is to examine entanglement rather than to make predictions. The low value of R-squared does not change our findings which suggest that investors also incorporate the entanglement effect when making decisions.

6. Robustness check

To assess the sensitivity of our results, we included in the model some variables with the potential to impact our findings. We use (i) total compensation paid to executives (compensat), (ii) total intangible assets (intangat) and (iii) other intangible assets (intanoat). We believe that these variables could influence physical capital or market variables. We replaced gdwlshrout sometimes with intangat and sometimes with intanoat. We also replaced net property, plant and equipment (ppenet) with gross property, plant and equipment (ppegross). Non-tabulated results indicate that our findings remain very consistent.[8] We also examine the persistence of the relationship between the entanglement effect and firm value creation. We analyse entang lagged by one year, considering the specifications of Equation (7). Untabulated results show that the positive and statistically significant relationship remains even with entang lagged by one year. We believe that this finding is due to the autocorrelation in earnings (or earnings persistence) between two consecutive years (Lev, 1983; Lipe, 1990; Schipper & Vincent, 2003).

In order to verify whether the results obtained for the variable of interest (entang) remain unchanged, we performed another robustness test by using an alternative variable for intangible capital. We replaced mascore with another measure of intangible capital named research quotient (Knott, 2008). Research quotient (RQ) is a novel firm-level measure of innovation efficiency (Ongsakul, Chatjuthamard & Jiraporn, 2021). In short, RQ indicates the percentage increase in revenue from a 1% increase in R&D. Recent studies link RQ measure with issues such as corporate innovation (Ongsakul, Chatjuthamard & Jiraporn, 2021), economic growth (Knott & Vieregger, 2019), and stock returns (Santi, 2020). We argue that, by measuring the productivity of spending on R&D, RQ becomes a good proxy for a firm's intangible capital. For this reason, we advocate RQ as a good alternative variable for our purpose.

Table 10. Robustness test: Regression results for an alternative measurement of entanglement

compincat	(1)	(2)	(3)	(4)
resquot	0.337***	0.235***		
	(5.39)	(8.28)		
entangrq			0.730**	0.0145
			(2.62)	(0.11)
ppenet	-0.274***	0.0456***	-0.355***	0.0307
	(-6.03)	(4.34)	(-7.41)	(1.90)
gdwlshrout	-1.994***	0.324	-2.095***	0.247
	(-5.26)	(1.56)	(-5.42)	(1.19)
size	0.0501***	0.0363***	0.0478***	0.0367***
	(7.16)	(43.19)	(6.91)	(43.66)
leverage	-0.301***	-0.193***	-0.307***	-0.193***
	(-14.24)	(-30.11)	(-14.38)	(-30.02)
spglobeq	0.0692***	-0.00244	0.0705***	-0.00403
	(9.95)	(-0.12)	(10.14)	(-0.20)
rintrate	0.337***	-0.217	0.319***	-0.215
	(3.73)	(-1.35)	(3.53)	(-1.33)
gdpgrowth	0.781***	0.723***	0.804***	0.742***
	(11.01)	(3.84)	(11.32)	(3.93)
_cons	-0.205***	-0.263	-0.150***	-0.225
	(-4.41)	(-1.21)	(-3.54)	(-1.03)
Year/Country Control	No	Yes	No	Yes
N	17,038	17,038	17,038	17,038
R^2	0.13	0.18	0.12	0.18

[8] Keeping these variables in our model would significantly impact the number of observations from our sample, which is why we chose to use them only for robustness-testing purposes.

We followed the Equation (5) model to perform the regressions. The results are depicted in Table 10 above. The results indicate that our findings remain robust even for alternative measures of intangible capital. First, RQ (resquot) shows a positive association with physical capital (columns 1 and 2), reinforcing our proposition about the conversion from intangible capital (now as resquot) into physical capital (in addition to its renewal for future conversions). Next, similarly to what we proposed for entanglement in Equation (7), we created an alternative proxy of the entanglement effect by interacting RQ with property, plant and equipment (entangrq = resquot*ppenet). Although the results are significant only for the case without country-year controls (column 3), we consider that the results shown in Table 10 reinforce that the entanglement effect is present in organizations' economic reality.

7. Summary and conclusion

The existing literature has suggested that accounting goodwill is made up of different components acting as generators of residual earnings. Another stream of studies has suggested that intangible assets need to be combined with other assets to create value. However, no previous study has examined a simultaneous or entangled relationship between intangible capital and physical capital as an explanatory factor for value creation. Supported by quantum theory foundations and using a large sample of companies in different countries and over a long period of time, this study has examined this issue.

Our findings confirm our two hypotheses. First, our findings show that intangible capital is associated with physical capital. In addition, this association is positive, suggesting a conversion of the first into the second. The positive association also reveals that intangible capital is renewed at a speed greater than its conversion. Second, more importantly, our findings suggest that the entanglement effect is real. We found a positive association between the entanglement effect and physical capital and firm value creation. In other words, when we entangle property, plant and equipment with intangible capital, we find that this "new force" has a statistically significant association with several measures of a firm's economic outcome, such as physical capital, market value and market return.

It has to be considered that we did not investigate whether entanglement creates residual earnings. We consider this a limitation of this study, as well as a suggestion for further research (another limitation, discussed at the end of Section 6, concerns the use of the tools from statistical physics). Nevertheless, this study opens a wide path for further studies that aim to investigate the role of goodwill as a value driver that acts entangled with other assets.

The entanglement effect theoretically proposed by Oliveira and Lustosa (2022) and empirically found in this study gives rise to a challenging scenario for accounting measurement. It is challenging because one of the most significant properties of accounting is binary classification (Pinnuck & Shekhar, 2013). Existing studies in different areas of knowledge have suggested the abandonment of the Cartesian view in favour of the entanglement of things. This study joins this literature. However, we are not trying to propose a new form of measurement, but merely to show, based on physics and economics concepts, that the process of generating value can be better understood if we relax the binary premise.

Reflecting on our findings, we ask: what then is the goodwill paid on a business-combination transaction? We consider it to be the prospect of future profitability of the acquired business. A wealth that is only potential at the present time. This is not an asset, as it is not an acquired right by the entity – and this is even more true in a scenario where most M&A deals are highly unprofitable. As highlighted in the literature review, some scholars still question whether the company has control of these virtues. For all the above, we conclude that goodwill

should be considered a value driver that acts intertwined with a firm's physical capital, rather than an asset in isolation.

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