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The influence of knowledge and intellectual capital on the economic outcomes of academic spin-offs: Evidence from Italy

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ABSTRACT

This study explores the relationship between intellectual capital and the economic performance of academic spin-offs (ASOs). ASOs are hybrid ventures, distinct from more typical startups and small and medium enterprises because their founders pursue both research and market objectives. Using a sample of 295 Italian ASOs over a 10-year period, the study examines the impact of human, relational, and structural capital, extending the latter to include the adoption of digital technology as a critical factor in business performance. The findings suggest that human capital, especially experience accumulated over time, contributes substantially to improved economic outcomes. Adopting digital technology also emerges as a critical driver of performance, increasing operational efficiency and scalability. Conversely, external equity participation and patent ownership—both traditionally regarded as valuable relational assets—are negatively associated with economic success, suggesting a potential misalignment between the needs of stakeholders and ASOs. These insights highlight the strategic importance of capitalizing on digital technologies and building internal capabilities, while carefully assessing external funding sources and intellectual property strategies. This study contributes to the literature on academic entrepreneurship and intellectual capital by offering new empirical evidence on how intangible assets shape ASOs performance and by challenging conventional assumptions regarding patents and external investors in knowledge-intensive ventures.

Introduction

Academic spin-offs (ASOs) form a distinctive category of entrepreneurial ventures, originating from universities and research institutions to commercialize scientific research output. Unlike conventional start-ups and small and medium enterprises (SMEs), ASOs pursue both academic and commercial objectives, embodying a hybrid identity that blends scientific inquiry with the demands of the market (Meoli et al., 2019; Hahn et al., 2024). While traditional entrepreneurial initiatives tend to prioritize financial returns, ASOs are often motivated by broader goals beyond immediate financial gain, such as advancing scientific knowledge, enhancing institutional reputation, or responding to societal challenges (Hayter, 2015). Despite their potential to drive innovation and technological development, ASOs face substantial challenges that can threaten their survival and performance.

A key distinguishing factor of ASOs, in contrast to startups and SMEs, is their strong reliance on intangible resources rather than tangible assets (Greco et al., 2013). In an environment where traditional sources of capital have become more accessible and replicable, organizations derive their true value from the unique combination of talents, expertise, and intellectual resources of their employees, collaborators, and stakeholders (Bontis, 1998). Due to their research-intensive nature, ASOs depend on the efficient management of these intangible assets to promote innovation and sustain competitiveness (Elia et al., 2017; Pedro et al., 2025). Furthermore, although the role of intangible resources has been widely studied in large firms and SMEs, their impact on ASOs remains underexplored (Pedro et al., 2025).

Many ASOs struggle to secure funding, due to their high levels of technological and market uncertainty, which tend to deter risk-averse investors (Prokop, 2021). Long development cycles, dependence on external resources, and difficulties in transitioning from research to commercial application further compound their fragile position within the entrepreneurial ecosystem (Wright & Phan, 2018). As a result, while some ASOs thrive, making a strong economic and technological impact, others fall short of expectations or cease operations entirely (Civera et al., 2024). However, the underlying causes of these disparities remain insufficiently examined, particularly in relation to the factors that shape ASOs' economic performance and their ability to sustain growth (Caputo

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et al., 2022).

Given the central role of intangible resources in the functioning and development of ASOs, it is essential to investigate whether—and how—these assets account for the marked variation observed in their economic performance. This raises a key research question:

Why do ASOs exhibit different economic outcomes? To what extent do intangible assets shape these differences?

ASOs are often viewed as extensions of university culture and dynamics, which influence their business practices and value-creation mechanisms. Because these ventures typically lack substantial tangible assets, their success largely depends on the effective management of intellectual capital (IC; Elia et al., 2017; Martín-de Castro et al., 2019). Drawing on intellectual capital theory, we conceptualize intangible assets as comprising three core dimensions: human capital (workers' skills, expertise, and knowledge), relational capital (i.e., partnerships and collaborative networks), and structural capital (i.e., organizational procedures, systems, and intellectual property; Bontis, 1998; Elia et al., 2017). Although this framework has rarely been applied to academic entrepreneurship, existing studies suggest that well-managed IC can improve productivity, stimulate innovation, and strengthen stakeholder relationships, ultimately increasing competitiveness across a range of contexts (Pedro et al., 2025).

Prior research has established that SMEs cannot be regarded merely as scaled-down versions of large firms (Marzo & Scarpino, 2016) and that the management of IC in SMEs tends to be somewhat more varied than in larger organizations (Durst & Edvardsson, 2012). More recent studies further suggest that the efficient use of IC can influence both performance and growth prospects in technology-based firms such as ASOs (Elia et al., 2017; Sardo & Serrasqueiro, 2018), as well as affecting strategic outcomes, innovation capacity, and corporate performance in startups and SMEs (Demartini & Beretta, 2020; Nigam et al., 2021).

To assess the role of IC in shaping the economic performance of ASOs, this study analyzes a data set of 295 Italian ASOs tracked over a 10-year period (2013–2022), resulting in 2950 observations. Logistic regression analysis is employed to examine how different dimensions of IC influence ASOs' economic outcomes, controlling for variables such as firm age, ownership structure, university ranking, and the adoption of digital technologies.

This study makes three main theoretical contributions. First, it applies an established conceptual framework to examine a new organizational model (i.e., ASOs), testing its relevance in a context heavily reliant on intangible resources. Second, it moves beyond a static viewpoint by adopting a variance-based approach to account for differences in ASOs' economic trajectories rather than concentrating on the process-oriented evolution of a single entity (El-Awad et al., 2022). This methodological shift increases the reliability of our findings by taking into account the dynamic interplay between IC dimensions. Third, this study also extends the traditional IC framework by incorporating digital technologies as a key element of structural capital, offering new insights into how technological capabilities influence ASO performance. Ultimately, this research bridges two important streams of literature—intellectual capital theory and academic entrepreneurship—advancing both theoretical understanding and managerial practice.

Thus, the following sections will first establish the conceptual foundations by revisiting the IC framework in light of the specific dynamics of ASOs, providing a revised conceptualization of its three core dimensions—human, relational, and structural capital—within a hybrid academic-commercial context. This theoretical approach is then tested using a substantial longitudinal data set of Italian ASOs covering a 10-year period. The methodology section details the empirical strategy and introduces a variance-based approach to capture the dynamic interactions among the various dimensions of IC. The results of the empirical analysis, followed by the discussion, contextualize the findings within broader debates on academic entrepreneurship.

Background

Intellectual capital theory and economic performance

In a knowledge-driven economy, the ability of organizations to create, mobilize, and sustain intangible assets has become central to gaining a competitive advantage and ensuring long-term success (Dumay et al., 2020). IC, as a theoretical construct, encapsulates the knowledge-based resources that organizations use to create value; these include human expertise, relational networks, and organizational structures (Martín-de Castro et al., 2019). Although it has traditionally been viewed as elusive and difficult to quantify (Pedro et al., 2018), IC is increasingly recognized as a key factor in explaining firm-level differences in performance outcomes, particularly in knowledge-intensive contexts (Martín-de Castro et al., 2019).

IC provides a framework for systematically analyzing intangible assets and cognitive resources that, although not included in standard financial statements, strongly contribute to value creation and innovative capacity (Choong, 2008). Over the past two decades, extensive research has explored how IC affects different aspects of firm performance, including innovation capabilities, market responsiveness, and financial outcomes (Inkinen, 2015; Pedro et al., 2018; Faraji et al., 2022; Martín-de Castro et al., 2019). Economic performance, typically measured by return on assets or net income, is particularly relevant in sectors where knowledge assets outweigh physical assets (Sciarelli et al., 2022; Pedro et al., 2018). Empirical findings generally show that IC positively influences economic performance, but the magnitude and consistency of these effects remain contingent on industry- and firm-specific factors (Demartini & Beretta, 2020; Sardo & Serrasqueiro, 2018).

Intellectual capital theory provides a structured framework for analyzing how IC creates value at the firm level, positioning it as a central perspective in this field (Pedro et al., 2025). It defines value creation through the interactions of three core dimensions: human, relational, and structural capital (Elia et al., 2017; Martín-de Castro et al., 2019).

Despite its widespread application, much of the existing literature examines these dimensions separately, often using static and cross-sectional data, thus overlooking their interdependencies and evolutionary nature (Pedro et al., 2018; Faraji et al., 2022). This limitation diminishes the theory's ability to explain how IC components dynamically interact to produce tangible economic outcomes, such as profitability and growth (Elia et al., 2017). Moreover, structural capital remains undertheorized, especially regarding the impact of digital technologies, which are now essential to modern knowledge infrastructures (Cirillo et al., 2023; Ferreira et al., 2019). While IC research has traditionally focused on large corporations and SMEs, it is also relevant in knowledge-intensive environments, such as ASOs (Demartini & Beretta, 2020; Nigam et al., 2021; Sardo & Serrasqueiro, 2018).

ASOs, developed by academic institutions to commercialize research, present a promising but underexplored opportunity to test and expand intellectual capital theory. Due to their reliance on intangible assets, their limited resources, and their hybrid academic-commercial nature, ASOs provide an ideal environment to analyze how IC influences firm performance. Exploring IC in ASOs is both theoretically relevant and empirically novel, providing valuable insight into how IC frameworks can be applied and adapted in knowledge-intensive and resource-constrained environments (Pedro et al., 2025; Wright & Phan, 2018).

IC dimensions and academic spin-offs

ASOs play a key role in transferring technological and scientific knowledge from universities to markets, promoting innovation and economic development (Evertsen & Rasmussen, 2024; Fernández-Alles

et al., 2015). They are an essential factor in accelerating the development of new technologies, promoting innovation across different industries, and increasing the competitiveness of national economies (Meoli et al., 2019). Their contribution extends beyond commercializing inventions; they are key agents in technology transfer and collaboration between industry and academia (Criaco et al., 2024). However, the literature shows mixed results on the effectiveness of ASOs in creating a sustainable competitive advantage (Abreu & Grinevich, 2024; Dabić et al., 2022).

Research indicates that while ASOs often outperform traditional firms in terms of innovation, they frequently struggle to achieve economic scalability (Colombo & Piva, 2012; Li et al., 2022; Modina et al., 2024; Sciarelli et al., 2021). These challenges arise from structural constraints, strategic limitations, and the academic backgrounds of their founders, who typically possess considerable technical skills but lack entrepreneurial and managerial expertise (Diánez-González et al., 2021). Consequently, many ASOs have difficulty matching their technological advancements with market needs, often resulting in groundbreaking innovations that have limited commercial viability (Belitski et al., 2019; Roche et al., 2020). In light of these dynamics, the role of IC in shaping the successful performance of ASOs merits closer scrutiny.

IC is widely acknowledged as a key driver of value creation in both academic and non-academic settings (Mariani et al., 2018; Nigam et al., 2021; Prencipe et al., 2023; Secundo et al., 2017). Given that ASOs are intrinsically knowledge-intensive enterprises, adopting an IC-based perspective, particularly one grounded in intellectual capital theory (Elia et al., 2017), offers a pertinent framework through for understanding their performance dynamics. Drawing on Bontis' (1998) classic framework, the following subsections examine the role of each IC dimension to ASO performance.

- Human capital is the dimension of IC that most directly reflects the academic origins of ASOs. It is their primary driver because most of their innovative activities derive from the expertise and experience of the founders and research teams (Sciarelli et al., 2021). These ventures are typically created by individuals with highly specialized scientific knowledge acquired in research institutions (Rasmussen, 2011). However, the ability to translate this cognitive capital into a sustainable economic activity depends largely on the presence—or purposeful cultivation—of entrepreneurial, managerial, and strategic skills (Knockaert et al., 2011; Visintin & Pittino, 2014). Vohora et al. (2004) identify a number of critical junctures in ASO development, among which one of the most important is the transition from a scientific to a market logic, requiring the integration of distinct knowledge bases. In this context, complementarity between scientific and managerial profiles—often achieved by appointing external CEOs or providing targeted entrepreneurship training—is essential to overcome the limitations of a one-dimensional human capital base (Zahra et al., 2007).

Although the early development of these ventures often derives from an unfair advantage rooted in specialized competencies, knowledge, and know-how, ASOs must continually expand and adapt their skill sets and capabilities to ensure the long-term sustainability of their business (De Cleyn et al., 2015; Vohora et al., 2004). In this respect, the age of a spin-off correlates positively with its capacity to accumulate and refine critical capabilities, thereby increasing overall business performance. Older spin-offs tend to have a broader set of competences, increasing their chances of sustained success (Cho & Sohn, 2017).

In the early stages of spin-off development, human capital plays a crucial role in attracting investors and forming strategic partnerships (De Cleyn et al., 2015; Fernández-Alles et al., 2022). Research shows that gender diversity broadens the range of perspectives within teams, strengthening a company's resilience and responsiveness to the needs of an increasingly diverse market (e.g., Prencipe et al., 2023; Sciarelli et al., 2021; Tagliazucchi et al., 2021). Although women continue to be underrepresented in STEM-related entrepreneurship—particularly in ASOs—, evidence suggests that their involvement is associated with greater potential for organizational success (Alsos et al., 2017).

- Relational capital refers to the network of actual and potential relationships an organization maintains with external actors, such as investors, customers, suppliers, research institutions, and other stakeholders (Hormiga et al., 2011). In ASOs, relational capital is deeply embedded in the university ecosystem. Angrisani et al. (2023) emphasize the role of academic innovation ecosystems as a form of relational capital, in which collaboration between universities, spin-offs, and external stakeholders fosters knowledge transfer and helps ASOs overcome challenges arising from resource limitations (Paoloni et al., 2019). In particular, the involvement of external shareholders, such as venture capitalists or corporate investors, and the direct participation of universities increase the likelihood of firms gaining access to financial, technical, and strategic resources (El-Awad et al., 2022; Ortín-Ángel & Vendrell-Herrero, 2014).

Relationships with experienced partners and mentors improve strategic decision-making, accelerate time-to-market, and facilitate a more efficient scaling process (Paoloni et al., 2019). Furthermore, Martínez-Martínez and Ventura (2020) highlight that the reputation of the academic institution is a powerful signal of credibility, reducing perceived risks and aiding in the building of strategic partnerships.

This process of credibility transfer from the university to the spin-off is widely acknowledged as a key driver of resource acquisition and network development (Mustar et al., 2006; Shane, 2004). The institutional prestige of a university can improve the chances of access not only to financial capital but also to highly skilled personnel and opportunities for collaboration with established firms (Zucker et al., 1998).

Thus, ASOs that benefit from strong ties with their parent universities, whether through formal support mechanisms or informal reputational spillovers, are more likely to gain early-stage legitimacy and attract external stakeholders. At the same time, however, excessive reliance on academic networks hinder ASOs in developing more market-oriented and autonomous business models, restricting their capacity to diversify their networks and integrate into industry-driven innovation systems (Abbate & Cesaroni, 2017).

In addition to using their academic connections, ASOs should cultivate new business relationships, learn from other organizations, and adapt to changing stakeholder expectations (Fernández-Alles et al., 2022; Paoloni et al., 2019). According to this perspective, relational capital in ASOs should not be understood merely as a passive inheritance from the parent institution but as a dynamic and strategic asset that aids firms' integration into broader innovation networks and increases their ability to mobilize critical resources for growth and sustainability.

- Structural capital refers to the explicit knowledge embedded in an organization. It encompasses organizational routines, procedures, databases, culture, intellectual property, and formal systems that support operational continuity and scalability (Elia et al., 2017). In the context of ASOs, structural capital is particularly strategic because these ventures typically arise from loosely organized academic environments and need to quickly establish formal structures for growth and commercialization (Secundo et al., 2017). Among the components of structural capital, patents have traditionally held a central position. For ASOs, patents are both legal tools that protect innovation and strategic assets that increase firm value, attract investors, and support partnerships (Algieri et al., 2013; Goldenberg & Linton, 2012). By codifying scientific knowledge into legally recognized forms, patents allow ASOs to transform research outcomes into marketable products and services, bridging the gap between academia and industry (Li et al., 2022; Secundo et al., 2020). However, managing intellectual property is resource-intensive and often limited by the legal frameworks of the parent universities, which can

lead to bureaucratic delays and uncertainties in ownership (Shane, 2004; Zhou & Baines, 2024). These complexities may be particularly burdensome for young ASOs lacking dedicated legal expertise or financial resources, potentially deterring investors who may perceive high levels of risk and administrative inefficiency (Levitas & McFadyen, 2009; Mustar et al., 2006).

Therefore, building robust structural capital by formalizing internal processes, developing organizational routines, and codifying intangible assets can be essential for translating scientific potential into operational and economic performance.

Nevertheless, in recent years, the convergence of IC and digital transformation has created new challenges and opportunities for ASOs (Rippa & Secundo, 2019). Integrating digital technologies—ranging from knowledge management systems to digital intellectual property platforms—has been shown to strengthen structural capital by increasing the agility, security, and efficiency of intangible asset management (Rippa & Secundo, 2019; Secundo et al., 2020).

Moreover, fostering a digital organizational culture enables ASOs to align the academic values of openness and collaboration with the operational demands of competitive markets (Caputo et al., 2022). Digital tools not only improve internal coordination but also increase a firm's capacity to build innovation networks and access distributed sources of knowledge and resources (Toniolo et al., 2020). As Evertsen and Rasmussen (2024) argue, digital spin-offs often achieve a better technology–market fit by leveraging flexible digital infrastructures and resource reconfigurations that expand their strategic reach. Ultimately, by integrating IC and digitalization, ASOs gain a strategic advantage, allowing them to transform innovations into sustainable competitive strengths and generate economic value in a digitally driven environment (Broccardo et al., 2024).

ASOs thus provide a particularly fertile ground for advancing intellectual capital theory, both conceptually and empirically. Their knowledge-intensive nature, organizational weaknesses, and distinctive relational dynamics make them an ideal environment in which to examine how different IC dimensions can help explain ASOs' economic performance.

Methodology

Given the complex nature of ASOs, often operating in high-tech and knowledge-intensive environments, it is essential to adopt an approach that accurately reflects both their dynamic characteristics and the impact of IC on their performance outcomes. The application of generalized estimating equations (GEE) is particularly suited to this study because it accommodates the longitudinal nature of the data and accounts for potential correlations in repeated measures over time. This approach ensures robust and reliable coefficient estimates, providing a solid foundation for analyzing the key drivers of success in ASOs.

Data collection

This study examines ASOs originating from Italy's major universities, specifically targeting *Mega Atenei* (large universities) and technical universities (polytechnics), to limit the analysis to institutions with substantial involvement in technology transfer. In doing so, we minimized variations related to nationality and selected ASOs more actively engaged in commercializing research results, ensuring a manageable and representative sample of high-impact spin-offs (Passavanti et al., 2024).

The initial database was created using official lists of ASOs available on websites of Italian universities and the national association of Italian spin-offs (NETVAL).[1] To improve the data set, we added descriptions of each ASO's activities from official and public websites and supplemented this with economic and financial data extracted from the Aida database. The initial sample size was 585 ASOs, but we excluded spin-offs that were dissolved, in liquidation, or lacked available financial statements for 2022. Following these criteria, a manual review was conducted to ensure data accuracy and relevance, resulting in a final sample of 295 active Italian ASOs for further analysis.

We gathered longitudinal data on each ASO over the last 10 years, resulting in 2950 observations. This information includes key variables such as the age of each ASO, gender composition of ownership, industry sector, university ranking, and number of shareholders. We also collected data on external shareholders, intellectual property rights, and classified digital ASOs (Evertsen & Rasmussen, 2024).

Dependent variable

The dependent variable used to measure ASO performance in this study is net income. Net income is a widely recognized indicator of a company's profitability because it reflects the difference between total revenues and total expenses, providing insight into an organization's overall economic health and operational efficiency. Net income is especially suitable for assessing ASOs because it provides a clear, quantifiable measure of economic success that aligns with the primary goal of many spin-offs: achieving profitability and long-term sustainability (Ferretti et al., 2019). Unlike metrics focused solely on revenue or cost reduction, net income captures both revenue generation and effective cost management, making it a comprehensive indicator of overall business performance. Furthermore, in the context of ASOs, net income serves as an indicator of a venture's ability to generate sufficient returns to reinvest in innovation, attract investors, and maintain competitive advantage, all of which are critical for their growth and success in high-tech and knowledge-intensive markets (Sciarelli et al., 2021).

In this study, net income was classified as a binary variable, where values were set to one if the ASO reported a positive net income and zero if the net income was negative. This binary approach allows a straightforward assessment of economic success, highlighting whether the ASO achieved profitability in each period

Independent variables and intellectual capital dimensions

The independent variables used in this study were carefully chosen to represent the three main dimensions of IC: human capital, relational capital, and structural capital. Each of these dimensions plays a central role in the growth and performance of ASOs, as suggested in the literature.

1. Human capital reflects the knowledge, skills, and experience of an ASO's team, essential for translating research into market-ready solutions. The age variable reflects accumulated organizational learning because older ASOs typically have more specific competencies and show greater adaptability (Cho & Sohn, 2017). Additionally, gender diversity in the founding teams promotes creativity and resilience, supporting problem-solving and meeting diverse market needs (Prencipe et al., 2023; Tagliazucchi et al., 2021).
2. Relational capital involves the network and external relationships that support ASOs in accessing essential resources and building

[1] NETVAL (Network for Research Valorization) is an Italian association founded in 2007, uniting universities, public research institutions, and medical research centers. Its mission is to support the commercialization of public research through training, technology transfer, and networking.

credibility. External participation captures the role of industrial stakeholders, who can provide resources but may have differing strategic goals (Fini et al., 2011). University participation refers to the direct involvement of the parent university, enhancing credibility and access to valuable partnerships (Ortín-Ángel & Vendrell-Herrero, 2014). Finally, university ranking measures the parent university's reputation, which can attract investors and facilitate strategic alliances (Mustar et al., 2006).

3. Structural capital refers to the organizational assets and systems that allow ASOs to scale and sustain competitiveness. The digital technologies variable refers to the adoption of digital technologies, which streamline operations and improve efficiency (Rippa & Secundo, 2019). Patent ownership, on the other hand, provides legal protection for innovations, enhancing market value and attracting investors, though it requires balanced management due to associated costs (Algieri et al., 2013; Li et al., 2022).

Table 1 lists the independent variables used to operationalize IC in ASOs.

Assessing digital adoption as a component of an ASO's structural capital

For this methodological approach, we chose to include the adoption of digital technologies within the framework of structural capital. Our goal was to evaluate the strategic relevance of digital technologies; therefore, we adopted an approach focused on identifying specific keywords, which is explained in the sections to follow. We used a keyword approach to identify ASOs that use, create, or commercialize digital technologies as part of their structural capital. Scopus was selected as the search engine (Passavanti et al., 2023). Its use permitted broad search coverage, minimizing the likelihood of overlooking relevant studies while encompassing a wide array of digital and technology-related research fields.

Table 1
Independent variables used to operationalize IC in ASOs.

IC dimension	Independent variable	Data type	Justification
Human capital	Age	Scalar	Reflects accumulated knowledge and experience over time, aiding ASOs in developing market-aligned capabilities (Cho & Sohn, 2017).
	Female prevalence	Binary (1 = majority female founders; 0 = otherwise)	Represents team diversity, strengthening resilience and adaptability in a competitive and dynamic market (Prencipe et al., 2023).
Relational capital	External participation	Binary (1 = external shareholders; 0 = none)	Involves external stakeholders, adding resources but with potential strategic complexities requiring alignment with ASO goals (Fini et al., 2011).
	University participation	Binary (1 = university shareholder; 0 = none)	Shows parent university support, increasing ASO credibility and facilitating access to strategic resources (Ortín-Ángel & Vendrell-Herrero, 2014).
	University ranking	Scalar	Represents the university's reputation, increasing an ASO's attractiveness to investors and strategic partners (Mustar et al., 2006).
Structural capital	Digital technologies	Binary (1 = above-average digital technology keywords; 0 = otherwise)	Measures digital integration, a driver of operational efficiency and market expansion (Rippa & Secundo, 2019).
	Patent	Binary (1 = revenue from intellectual property rights; 0 = otherwise)	Provides legal protection for innovations, increasing an ASO's market value and attractiveness to investors (Algieri et al., 2013).

Boolean operators were used to create a search string with variations of the words *technology* and *digital* to capture a wide range of relevant studies. The initial search yielded over 5.7 million results, which were narrowed down using criteria such as language and relevance to business, management and accounting and computer science, resulting in 39,829 articles. These articles' keywords were analyzed using VOSviewer software to extract and organize terms central to digital technology and innovation, forming a robust initial keyword database.

VOSviewer generated a list of 121,467 keywords, initially including all occurrences. To improve usability, only keywords with a threshold occurrence of 50 or more were included in the final list, reducing ambiguity and focusing on high-relevance terms. To ensure accuracy, keywords potentially unrelated to ASO core activities, such as *mobile phone*, were filtered out because they did not align with the digital business activities despite appearing in some company information.

Taking into account the bilingual nature of ASO descriptions—using English and Italian—the analysis also took linguistic variations into account, considering all common forms of the keywords (e.g., *block-chain, block-chain*, and *block chain*). The final keyword list shows a cohesive thematic structure, as illustrated by the interconnected keyword map in Fig. 1.

The final stage in identifying digital ASOs was to filter the ASO database using the digital keyword list. To achieve this, a Python script was created to match keywords in the ASO activity descriptions. The script cross-referenced entries from the keyword list with each ASO's activity field in the data set. If a match was detected, the corresponding ASO was marked as digital. This process identified 173 ASOs with digital technologies central to their core business and an additional 122 ASOs that use digital technologies but do not consider them a core driver of their business model.

This methodology reflects a comprehensive approach to defining digital ASOs, combining automated keyword matching with manual verification to ensure accurate classification. The resulting data allow a detailed examination of how adopting digital technology affects the economic and operational performance of Italian ASOs, distinguishing between those that see it as a core element to their business and those that consider it a mere addition.

The model

In this paper, we use GEE to analyze the economic performance of Italian ASOs. The GEE method extends generalized linear models (GLM) to accommodate qualitative dependent variables in the presence of correlated observations, such as repeated measures or clustered data. GEE was chosen for this study due to its ability to handle longitudinal data without relying on strict assumptions about multivariate normality or model specification.

This approach is particularly suitable for longitudinal studies of economic performance, providing robust regression coefficient estimates in samples with high correlation among repeated measures.

The decision to use GEE was further justified by the binary nature of our dependent variable, which does not satisfy the assumptions of linear regression. Employing logistic regression within the GEE framework enabled us to model the success or failure of ASOs over time while accounting for within-firm correlation. Logistic regression was selected because the dichotomous, qualitative nature of our dependent variable does not meet the assumptions required for linear regression: linearity, homoscedasticity, and the normal distribution of errors. For instance,

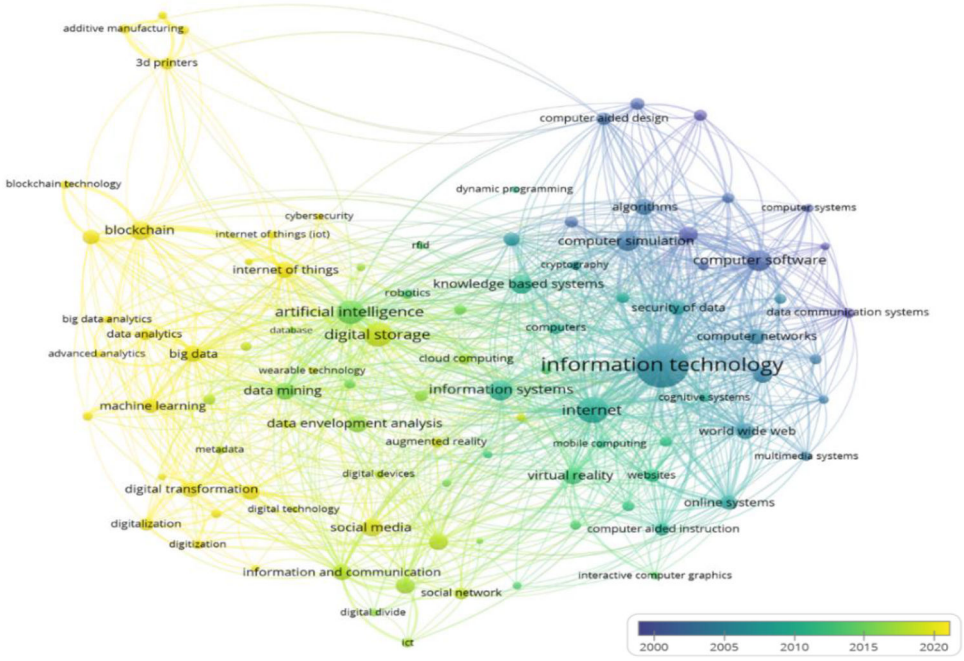

Fig. 1. Bibliographic coupling analysis.

although structural equation modeling (SEM) is a powerful tool for examining latent variables and complex path analysis, its application to longitudinal binary outcomes may be limited by stricter assumptions and sensitivity to sample size (Hardin & Hilbe, 2002).

The logistic model transforms the odds of the dependent event (e.g., the success of the spin-off) into a logistic function, maintaining the predicted probabilities between zero and one. This is achieved by applying a logit transformation to the odds ratio, resulting in a model where increases in the independent variable(s) translate to increases or decreases in the probability of the event occurring.

The model use in this research incorporates multiple independent variables to predict the binary outcome Y_{it}, representing the success or failure of the ASOs in year t for event i, as follows:

$$Y_{it} = a + \sum_{j=1}^{J} b_j X_{itj} + \varepsilon_{it}$$

Here, Y is the outcome, i indicates the event, t denotes time, a is the intercept, j represents the number of predictors, b_j is the slope of predictor j, X_{itj} is the predictor, and ε_{it} is the error term.

The variables used in this study are then explicitly included in the model, which can be expressed as:

$$Y = \ln\left(\frac{P(UN_i > 0)}{1 - P(UN_i > 0)}\right) = a + b_1 Age_{it1} + b_2 Fem\_Prev_{it2} + b_3 Ext\_Part_{it3} + b_4 Uni\_Part_{it4} + b_5 Uni\_Rank_{it5} + b_6 Digital\_Tech_{it6} + b_7 Patent_{it7} + \varepsilon_{it}$$

where t refers to the reference year (2013, …, 2022). This formulation allows for the examination of how various factors, including digital technology adoption, external partnerships, university competition, female participation, intellectual property, university ranking, and years of activity, influence the likelihood of spin-off success.

This involves examining how the ownership structure, including the identity and shareholding percentages of parent universities or external entities, influences the ASO's IC and, consequently, its performance. Given the longitudinal nature of our data set, which includes repeated measures over a 10-year period for each ASO, GEE was an optimal method for accounting for intra-cluster correlations and producing robust estimates of the effects of IC dimensions on spin-off success. This feature is particularly relevant to our study because it ensures the reliability of the results even when the panel is unbalanced or missing observations.

Results

As shown in Table 2, the average age of the ASOs in the sample is approximately nine years (SD = 5.60), with values ranging from two to 24 years. Female-majority founding teams comprised only 7.9 % of the sample, while 58.8 % of spin-offs used digital technologies as part of their core operations. Patent-holding ASOs made up 8.8 % of the sample and external shareholders were present in 54.4 % of cases, with universities holding equity stakes in 4.4 % of the ASOs. The average university ranking score was 84 (SD = 10.34), with values ranging from 47 to 94. Lastly, 4.4 % of the ASOs reported a positive net income.

To understand the interrelationships among the key variables used in this study, a bivariate correlation analysis was conducted using Pearson's correlation coefficient, as shown in Table 3.

ASO age correlates positively with patents ($r = 0.278, p < 0.001$) and external participation ($r = 0.092, p < 0.001$), suggesting that older ASOs tend to accumulate intellectual property and attract external investors, possibly as a result of increased market visibility and a more established reputation.

Female prevalence within the team shows several noteworthy associations. It is negatively correlated with digital technology adoption ($r =$

Table 2
Descriptive statistics.

Variable	Mean	%		Min	Max	SD
		0	1			
Age (years)	9.02			2	24	5.59
Female prevalence		92.1	7.9			
External participation		75.4	25.1			
University participation		95.6	4.4			
University ranking	84			47	94	10.34
Digital technologies		42.2	57.8			
Patent		91.2	8.8			
Net income		54.4	45.6			

Table 3
Correlation.

	1.	2.	3.	4.	5.	6.	7.
1. Age	1						
2. Female prevalence	−0.054	1					
3. External participation	.092**	−0.038	1				
4. University participation	−0.043	.121**	−0.078*	1			
5. University ranking	.047	−0.065*	.003	−0.409**	1		
6. Digital technology	.027	−0.117**	.046	−0.015	.027	1	
7. Patent	.278**	.015	.178**	−0.059	.014	.090**	1

Note: $p < 0.001$ for.
** and $p < 0.05$ for.
* significance levels.

−0.117, $p < 0.001$), suggesting that ASOs with a higher proportion of women founders are less likely to prioritize digital technologies. However, Female prevalence correlates positively with university participation ($r = 0.121$, $p < 0.001$), suggesting that female-led ASOs may receive more institutional support.

External participation and university participation also show noteworthy correlations. External participation positively correlates with patents ($r = 0.178$, $p < 0.001$), suggesting that intellectual property ownership attracts outside investors. Conversely, university participation has a negative correlation with university ranking ($r = -0.409$, $p < 0.001$), indicating that ASOs from higher-ranked universities tend to show lower levels of direct institutional involvement.

Lastly, digital technology adoption is positively correlated with patents ($r = 0.090$, $p < 0.001$), indicating that ASOs focusing on digital technologies also have intellectual property assets. However, its lack of a statistically significant relationship with university ranking indicates that digital adoption occurs across ASOs affiliated with both high- and low-ranked institutions.

The key variables in the logistic regression model were assessed using the β coefficients, standard errors, Wald statistics, p values, and Exp(β) values (odds ratios). The individual contribution of each independent variable is discussed below. Table 4 presents the regression coefficients, Wald statistics, significance levels, and odds ratios for each of the predictors.

The logistic regression model used in this study is expressed as follows:

$$\ln\left(\frac{P_{Y=1}}{P_{Y=0}}\right) = -0.775 + 0.109\ Age + 0.054\ Fem\_Prev - 0.618\ Ext\_Part + 0.013\ Uni\_Par + 0.008\ Uni\_Rank + 0.319\ Digital\_Tech - 0.591\ Patent$$

The parameter estimate table reveals which covariates are significant for the model. The constant in the model was negative and not statistically significant ($\beta = -0.775$, $p = 0.139$), suggesting that when all independent variables are zero, the likelihood of achieving a positive net income is low; however, the result is not statistically significant enough to draw definitive conclusions.

Table 4
Results of logistic regression.

	β	S.E.	Wald	gl	Sign.	Exp(β)
Constant	−0.775	.524	2.191	1	.139	.461
Human capital						
Age	.109	.012	89.498	1	<0.001	1.115
Female prevalence	.054	.204	.071	1	.790	1.056
Relational capital						
External participation	−0.618	.122	25.587	1	<0.001	.539
University participation	.013	.301	.002	1	.966	1.013
University ranking	.008	.006	1.800	1	.180	1.008
Structural capital						
Digital technologies	.319	.113	8.010	1	.005	1.376
Patent	−0.591	.173	11.652	1	<0.001	.554

The age of the ASO was a highly significant predictor of positive net income ($\beta = 0.109$, $p < 0.001$). The odds ratio (Exp(β) = 1.115) suggests that for each additional year of the spin-off's age, the odds of achieving a positive net income increase by 11.5 %. This finding supports the hypothesis that ASOs may benefit from more developed business models, greater market experience, and an established customer base, all of which enhance profitability. This is consistent with previous research suggesting that ASOs require prolonged market engagement to refine their business models, secure steady revenue streams, and transition from research-driven to commercially viable entities (Shane, 2004; Vohora et al., 2004).

Contrary to expectations, the prevalence of women in the founding team was not a significant predictor of the outcome ($\beta = 0.054$; $p = 0.790$). The odds ratio (Exp(β) = 1.056) indicates a slight increase in the likelihood of a positive net income as the proportion of women increases, but this effect is not statistically significant. While previous studies have highlighted the role of gender diversity in promoting innovation and problem-solving (Alsos et al., 2017; Prencipe et al., 2023), our findings indicate that gender composition alone does not directly translate into economic benefits for ASOs. This may be due to the predominant influence of other factors, such as industry type, technological domain, or access to funding networks.

A key finding of this study is that the use of digital technologies positively influences the likelihood of generating positive net income ($\beta = 0.319$; $p = 0.005$). The odds ratio (Exp(β) = 1.376) indicates that ASOs employing digital technologies are 37.6 % more likely to report a positive net income than those that do not. This finding supports the evolving role of structural capital in value creation, as digital transformation contributes to operational efficiency, market adaptability, and knowledge dissemination (Broccardo et al., 2024; Rippa & Secundo, 2019). Given the growing reliance on AI-driven knowledge management systems and automation, this result highlights the need to embed digital strategies within the IC framework.

Surprisingly, external equity participation exhibited a negative relationship with net income ($\beta = -0.618$, $p < 0.001$). The odds ratio (Exp(β) = 0.539) indicates that ASOs with external equity participation are 46.1 % less likely to report a positive net income. Although external investors often provide essential financial resources and strategic guidance, they may also exert pressures that diverge from the long-term development trajectories of ASOs (Colombo & Piva, 2012; Ortín-Ángel & Vendrell-Herrero, 2014). This finding suggests that ASOs may encounter difficulties in reconciling investor expectations with their innovation-driven business models, potentially leading to suboptimal financial performance.

University participation in ASOs had little effect on the likelihood of a positive net income ($\beta = 0.013$, $p = 0.966$). The odds ratio (Exp(β) = 1.013) points to a negligible effect. This suggests that, although university affiliation may confer credibility and facilitate access to knowledge networks, it does not directly translate into financial success. Previous studies indicate that university-backed ASOs often operate within rigid governance structures and have slower decision-making processes, offsetting the potential benefits of academic support

(Wright et al., 2007; Rasmussen, 2011). Accordingly, university involvement may play a more indirect role, chiefly by facilitating access to resources rather than by directly influencing economic performance.

Patent ownership had a statistically significant negative impact on the likelihood of achieving a positive net income ($\beta = -0.591$, $p < 0.001$). The odds ratio ($\text{Exp}(\beta) = 0.554$) indicates that ASOs holding patents are 44.6 % less likely to report a positive net income. This challenges the conventional assumption that intellectual property enhances competitive advantage and firm valuation (Algieri et al., 2013; Goldenberg & Linton, 2012). A plausible explanation is that patenting involves high costs and administrative complexity for ASOs, diverting resources away from market-driven activities and delaying market entry (Shane, 2004; Zhou & Baines, 2024). This finding calls for a reassessment of how ASOs incorporate intellectual property in their strategic decision-making.

Lastly, the ranking of the university associated with the ASO was not a significant predictor of economic success ($\beta = 0.008$, $p = 0.180$). The odds ratio ($\text{Exp}(\beta) = 1.008$) indicates that university ranking has only a marginal effect on the likelihood of achieving a positive net income. This result suggests that, although the reputation of the parent university may confer some intangible benefits, such as credibility or networking opportunities, it does not directly influence an ASO's economic outcomes (Martínez-Martínez & Ventura, 2020).

Discussion

The results indicate that economically successful ASOs tend to exhibit specific characteristics. In particular, ASO age and the adoption of digital technologies emerged as significant predictors of positive net income. At the same time, external equity participation and patent ownership had a negative effect on the likelihood of achieving a positive result. Interestingly, university participation in ASO equity and the prevalence of women in the founding team were not significant predictors, suggesting that some of the expected influences do not necessarily translate directly into financial success.

As ASOs mature, they develop stronger internal processes, refine their business models, and strengthen their market orientation (Cho & Sohn, 2017). The results highlight the need for long-term strategic planning and ongoing support mechanisms to help ASOs develop their entrepreneurial competencies.

The findings also reveal that certain factors have a considerable influence on the economic performance of ASOs, while others may lead to unintended negative consequences. This highlights the need for ASO entrepreneurs and managers to carefully assess key drivers of success and the potential risks.

First, the age of the ASO emerged as a significant predictor of positive net income. This finding is consistent with previous research suggesting that as they mature, ASOs strengthen their ability to meet market challenges, improve internal efficiency, and optimize their commercialization strategies (Cho & Sohn, 2017). Older ASOs benefit from accumulated experience, expanded networks, and a deeper understanding of industry dynamics, which contribute to their ability to achieve financial sustainability. Moreover, their prolonged exposure to entrepreneurial challenges allows them to refine strategic decision-making processes and establish more robust business models over time (Visintin & Pittino, 2014).

The study also shows that external equity participation has a negative impact on net income, suggesting potential misalignments between ASOs and external investors. Previous research has highlighted that industry partners and financial investors often prioritize short-term returns, whereas ASOs require longer time frames to develop and commercialize their innovations fully (Fini et al., 2011). This divergence may result in tensions over governance, strategic priorities, and the allocation of resources, ultimately constraining financial performance. In addition, conflicts between academic values and commercial priorities may undermine decision-making processes and weaken operational effectiveness (Abbate & Cesaroni, 2017).

Another unexpected finding is the negative effect of patent ownership on economic performance. Although patents are commonly viewed as valuable assets for protecting intellectual property and attracting investors, the so-called patent paradox (Goldenberg & Linton, 2012) suggests that they do not necessarily lead to financial success, particularly for resource-constrained ASOs. The costs and administrative demands associated with maintaining patents, combined with the inherent uncertainty of successful commercialization, may divert essential resources from other strategic priorities, such as market engagement and business development (Levitas & McFadyen, 2009; Li et al., 2022). Moreover, in certain academic contexts, patents may be pursued primarily as a means of career advancement rather than for commercial purposes, leading to a misalignment between intellectual property strategy and business viability (Fini et al., 2010).

The results also highlight the important role of digital technology adoption in driving ASO success. Digitalization strengthens operational efficiency, scalability, and market reach, giving ASOs a competitive edge in knowledge-intensive sectors (Ferreira et al., 2019; Nambisan, 2017). Digital tools enable rapid prototyping, integration of customer feedback, and agile product development, all of which contribute to better market placement and financial performance (Rippa & Secundo, 2019). Additionally, digital platforms allow ASOs to engage in open innovation ecosystems, encouraging collaboration with external stakeholders and accelerating the commercialization process (Sciarelli et al., 2021).

By contrast, certain factors, such as the prevalence of women in founding teams, university rankings, and university equity participation, were found to have no great impact on economic performance. While diversity and institutional prestige may bring other entrepreneurial benefits, they do not influence ASOs' short-term financial success directly. This finding is consistent with previous research indicating that, although universities are central to knowledge creation and the creation of new spin-offs, their direct equity involvement does not necessarily improve financial performance (Murray & Stern, 2007).

To summarize, our findings indicate that intellectual capital theory provides a useful framework for understanding the economic performance of ASOs. In particular, while human capital—especially the experience accumulated over time—emerges as a key driver of financial success, not all elements of relational capital exert a positive influence. External equity participation and patent ownership—traditionally regarded as valuable assets—may, instead, introduce constraints that diminish profitability. This questions some conventional assumptions of intellectual capital theory and highlights the need for ASOs to manage their relational assets carefully, in order to avoid misalignments between academic and commercial objectives. The results also highlight the growing importance of structural capital, particularly the integration of digital technologies, as a key enabler of economic success. This study extends the intellectual capital theory framework by demonstrating that ASOs require a dynamic and context-specific approach to leveraging their intangible assets, rather than relying on traditional categorizations of IC components.

Conclusions

This study set out to answer two central research questions: Why do ASOs display divergent economic outcomes? To what extent do intangible assets account for these differences?

It contributes to the literature by clarifying the ways in which intangible assets, particularly human capital and digital technologies, shape the economic performance of ASOs. It extends intellectual capital theory by exploring the dynamic interplay between intangible resources and firm-level outcomes, specifically in knowledge-intensive ventures such as ASOs. Moreover, the study offers new insights into the underexplored role of patents and external equity participation in ASO performance, calling into question traditional assumptions regarding their positive impact. The study also highlights the hybrid nature of ASOs,

which originate in academic settings but must operate within complex commercial markets. This duality presents specific challenges and opportunities that received limited attention in the literature, thereby offering a fresh perspective on academic entrepreneurship.

From a theoretical standpoint, this study reinforces the central role of intangible assets—particularly human and relational capital—in shaping firm performance. It also questions conventional assumptions regarding patents and external equity, indicating that these factors may not always align with the long-term goals of ASOs. The findings fine-tune intellectual capital theory by incorporating dynamic and context-specific elements that contribute to the effectiveness of intangible assets in driving economic success.

From a managerial perspective, the findings suggest that ASO founders and managers should prioritize the development of human capital and the adoption of digital technologies to improve economic performance. Investing in skills development and the cultivation of an innovation-oriented culture is essential for bridging the gap between scientific research and commercial success. Furthermore, ASOs should critically assess the strategic value of patents, considering alternatives such as early market validation and sustained customer engagement as more effective pathways to business growth.

While this study provides valuable insights, it is subject to certain limitations. The cross-sectional nature of the data restricts the ability to draw causal inferences and the focus on a specific sample of ASOs may limit the broader applicability of the findings. Future research could explore longitudinal studies to examine the evolution of ASOs over time and examine how intangible assets interact with other organizational factors to reshape long-term success. Additionally, future studies could explore the role of specific digital tools and platforms in ASO performance, providing deeper insights into how technology influences the commercialization process.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT to correct grammatical errors and typos and to improve the clarity of the manuscript, while ensuring that the originality and intellectual contributions of the research remained unaffected. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Passavanti Carmine: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Investigation, Data curation, Conceptualization. **Simonetta Primario:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Rippa Pierluigi:** Writing – review & editing, Supervision, Investigation, Conceptualization.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article.

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