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Open innovation in digital healthcare start-ups: how partner and complementary assets configurations affect their performance

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Abstract

Purpose – Digital health start-ups often depend on external assets to access business opportunities and achieve scalability. Open innovation facilitates collaboration and asset exchange within and across organisational boundaries. However, the configuration of partners and complementary assets that can boost the financial performance of digital healthcare start-ups remains insufficiently examined. This study aims to address this gap by exploring how different configurations of the start-up partners and complementary assets enhance the financial performance of digital healthcare start-ups.

Design/methodology/approach – A multiple-case study was conducted involving 12 digital healthcare start-ups in Lithuania. Data were collected through in-depth interviews and secondary sources such as PitchBook databases and start-up websites. A qualitative content analysis, supported by MAXQDA software, was used to identify configurations of partners and complementary asset exchanges in relation to financial performance outcomes.

Findings – A unique differentiating pattern in open innovation behaviour was identified across the 12 digital healthcare start-up cases. The configuration of partners and complementary assets differs according to ownership structure, which shapes how start-ups combine these elements.

Originality/value – This study shows how ownership structure is associated with digital healthcare start-ups' engagement in open innovation while operating in a highly regulated environment. Our findings suggest that start-up performance is linked to how firms combine and integrate complementary assets with selected partners, rather than relying on a single dominant partnering approach. We also observe that more than one combination of partners and complementary assets can be associated with similar financial performance outcomes among digital healthcare start-ups.

Keywords Digital healthcare start-up, Open innovation, Healthcare start-up performance

Paper type Research article

1. Introduction

Digital healthcare start-ups face regulatory, institutional, and appropriability challenges, which make access to external partners and complementary assets particularly important (Gawer, 2021; Kraus *et al.*, 2021).

Within the complex context of digital healthcare, open innovation provides a pathway for start-ups to overcome resource limitations by accessing external expertise, co-developing solutions with partners, leveraging user insights, and navigating regulatory and technological challenges (Chesbrough, 2003, 2011; Majchrzak *et al.*, 2023). Open innovation refers to purposive inflows and outflows of knowledge to accelerate internal innovation and expand markets for the external use of innovation (Chesbrough, 2003, 2006). In the development of digital healthcare start-ups, open innovation may involve accessing external expertise, co-developing solutions with partners, leveraging user insights, or forming collaborations to

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navigate regulatory and technological challenges. Thus, open innovation through collaboration can attract complementary assets that compensate for internal resource limitations (Baldwin and Von Hippel, 2011; Chesbrough, 2003; Majchrzak *et al.*, 2023; West *et al.*, 2014). Firms can generate rents by leveraging the complementary assets of alliance partners (Dahlander and Wallin, 2006). Teece (2018a, b) argued that in industries with weak appropriability regimes, such as digital health, ownership of complementary assets determines profit. Complementary assets are assets needed alongside an invention to ensure that value can be appropriated from it. When intellectual property protection is weak and the risk of knowledge spillovers to competitors is high, these assets become crucial for securing the benefits of innovation (Teece, 1986).

Yet, in the case of digital healthcare start-ups, there is a lack of clarity regarding *which configurations of partners and complementary assets enhance their financial performance*. Our study *aims to explore the configurations of partners and complementary assets that can enhance the financial performance of digital healthcare start-ups.* Drawing on a multiple-case analysis of twelve platform-based digital health start-ups operating in Lithuania, the study uses qualitative content analysis to examine configurations of partners – such as hospitals, universities, public and private sector actors, and end-users – and complementary assets, including technical knowledge, investments, and talent.

This study examines how digital healthcare start-ups with different ownership structures engage in open innovation by forming distinct configurations of collaboration partners and complementary assets in a highly regulated environment. Drawing on a qualitative multiple-case analysis, the paper shows that corporate-backed and independent start-ups rely on different combinations of external partners and complementary assets when pursuing financial performance. The study further shows that different partner and complementary asset configurations can be associated with similar financial performance outcomes. In doing so, the paper contributes to ongoing discussions in the open innovation and profiting-from-innovation literature by highlighting ownership structure as a differentiating factor.

2. Theoretical framework

2.1 Digital healthcare start-up performance

Digital healthcare start-ups face high failure rates due to limited resources, unproven products, and uncertain, highly regulated environments, where many ventures never reach the market (Kraus *et al.*, 2021). Performance in this context depends on start-ups' ability to access and integrate internal and external complementary assets through collaboration (Chesbrough and Bogers, 2014; Teece, 2018a, b). Measurable performance indicators such as revenue growth, profits, customer acquisition, capital raised, and innovation performance – such as patents or new product releases – are frequently used to evaluate start-up performance (Mann and Sager, 2007). However, such metrics are often insufficient to evaluate the performance of healthcare start-ups in the highly regulated, institutionally embedded health sector. Prior research emphasises that managing regulatory alignment and institutional complexity is critical to start-up success in the health ecosystem (Cozzolino *et al.*, 2018). Performance for Software as a Medical Device start-ups in the European Union (EU) depends on matching business models with certification procedures, such as CE marking [2], and integrating into clinical workflows (Martjan *et al.*, 2025). Both adoption and speed to market are influenced by these factors. Consequently, understanding performance in digital healthcare start-ups requires attention not only to outcomes but also to the mechanisms through which start-ups access internal and external complementary assets and coordinate partnerships within complex healthcare environments.

Despite the complexity of start-up performance indicators, financial indicators such as revenues and profits play a critical role in start-ups' early growth phases, as they serve not only as measures of economic viability but also as signals of legitimacy to external stakeholders. In the absence of long performance histories, early revenue generation and progress towards

profitability help reduce information asymmetries faced by investors, partners, and creditors, thereby facilitating access to critical resources (Colombo and Grilli, 2010; Davila *et al.*, 2003). Empirical evidence shows that revenue growth is strongly associated with survival probabilities and scaling potential in young firms, particularly in knowledge-intensive and technology-based start-ups (Coad *et al.*, 2016; Delmar *et al.*, 2013). From an open innovation perspective, financial performance is also essential for sustaining inbound and outbound knowledge flows, as firms require financial slack to absorb external knowledge and to commercialise innovations effectively (Chesbrough, 2006; Chesbrough and Bogers, 2014). While non-financial indicators such as user adoption or technological milestones are undoubtedly important in early stages, financial outcomes remain indispensable for validating business models and enabling start-ups to transition from experimentation to sustainable growth (Bogers *et al.*, 2019; Teece, 2010).

2.2 Open innovation

The open innovation paradigm challenges the traditional view that innovation must be developed and brought to market only within the firm. Instead, it suggests that companies can benefit by combining internal and external ideas and using both internal and external routes to market to strengthen their innovation efforts (Chesbrough, 2003, 2006). Open innovation knowledge flows are typically organised into outside-in, inside-out, and the more recent extensions known as inside-in and outside-out.

An outside-in open innovation strategy entails the acquisition and integration of external knowledge into the firm's innovation processes (Chesbrough, 2003; Martjan *et al.*, 2025; Pundziene *et al.*, 2023a, b). This strategy aims to reduce firms' costs, effort, and time required for innovation (Kumari *et al.*, 2024). It involves collaboration with a diverse array of stakeholders, including suppliers, competitors, academic institutions, policymakers, customers, and research bodies, to gain insights and market intelligence (Bogers *et al.*, 2018). Notably, outside-in approaches are especially prevalent in the healthcare sector, where service providers frequently outsource technological solutions due to limited internal capacities for technology development (Pundziene *et al.*, 2023a, b).

Inside-out refers to the dissemination of internal knowledge and technology to external actors, enabling them to incorporate it into their own business models (Chesbrough, 2006; Chesbrough and Bogers, 2014; Bogers *et al.*, 2019; Rua *et al.*, 2023; Wang and Xu, 2018). This approach is oriented toward value creation by facilitating the commercialisation of underutilised intellectual property and fostering creative collaborations (Wang *et al.*, 2023). Other open innovation types further emphasise that firms may manage knowledge flows in different ways across organisational boundaries, depending on their structure and strategic context (Gutmann *et al.*, 2023; Pundziene *et al.*, 2023a, b). Taken together, these perspectives indicate that open innovation is not a uniform practice but varies in scope and intensity depending on how firms organise and govern knowledge flows and collaboration.

Building on this logic of open innovation, digital healthcare start-ups do not innovate in isolation but operate within multi-actor ecosystems where businesses, universities, regulators, healthcare providers, patients, and civil society jointly shape access to complementary assets (Adner, 2017; Nambisan, 2017). Open innovation depends on relationships among actors who possess diverse complementary expertise, resources, legitimacy, or institutional power, which create opportunities for collaboration but also introduce challenges related to coordination and strategic alignment (Holgersson *et al.*, 2018).

In digital health, this perspective highlights that patients, healthcare professionals, advocacy groups, and broader societal actors shape not only technology validation and design choices but also the collaboration norms, rules, and expectations that entrepreneurs must navigate within complex innovation ecosystems (Nambisan, 2017; Pundziene *et al.*, 2023a, b). In this context, access to complementary assets is shaped by how start-ups engage with

partners that control resources, legitimacy, and adoption pathways (Adner, 2017; Aulkemeier *et al.*, 2019; Pundziene *et al.*, 2023a, b). However, operating within multi-actor ecosystems exposes digital healthcare start-ups to several structural and contextual barriers. The healthcare environment is heavily regulated, with legal, ethical, and safety requirements that are particularly pronounced in patient-facing services (Santarsiero *et al.*, 2023). Data privacy concerns, infrastructure costs, and brand image considerations also contribute to user inertia and slow adoption (Santarsiero *et al.*, 2023). In addition, information silos, rigid institutional processes, and limited in-house technical expertise hinder internal knowledge integration (Pundziene *et al.*, 2023a, b; Santarsiero *et al.*, 2023; Sermontyte-Baniule *et al.*, 2022). As a result, many healthcare organisations depend on external partners, using outside-in innovation strategies to access technologies, funding, and solutions that are difficult to develop internally (Kumari *et al.*, 2024).

2.3 The role of complementary assets in start-up performance

The significance of complementary assets is discussed in the Profiting from Innovation (PFI) framework, which highlights their role in innovation's value appropriation and firm performance. Initially introduced by Teece (1986), the framework seeks to explain why certain innovators achieve market success while others fail, often becoming easily imitated (Teece, 2018a, b). A central focus of this framework is that a firm's ability to profit from innovation depends on its access to and control over complementary assets (Park and Steensma, 2012; Holgersson *et al.*, 2018; Teece, 2018a, b). In environments where appropriability regimes are weak, access to complementary assets becomes critical for value capture (Teece, 2018a, b). Because access to and control over complementary assets are distributed across different actors, understanding who owns or governs these assets becomes essential for explaining performance differences among digital health start-ups (Jacobides *et al.*, 2018).

Ownership structure provides a lens for understanding how complementary assets shape digital health start-ups' innovation strategies and performance outcomes. According to the PFI framework, it is not the novelty of technology alone, but the ownership and control of complementary assets that determine who captures value from innovation (Pisano and Teece, 2007; Teece, 1986, 2006). Venture capital (VC) and corporate venture capital (CVC) investors affect these outcomes not only through capital provision but also by exercising strategic oversight and decision-making authority embedded in their ownership positions (Pisano, 2006). This logic aligns with research showing that, in digital ecosystems, the ownership of key complementary assets largely determines where value is captured and which actors hold a strategic advantage (Jacobides *et al.*, 2018; Teece, 1986). For corporate-backed ventures, such ownership arrangements embed the start-up within the parent firm's priorities and resource base, granting access to assets that would otherwise be costly or difficult to obtain (Pisano, 2006). Independent start-ups, in contrast, must secure access to these assets through alliances, partnerships, or equity-sharing arrangements. As a result, ownership structure shapes not only which complementary assets a start-up can access but also the terms under which value is created and appropriated in the digital healthcare ecosystem.

Complementary assets, therefore, are not merely support structures but act as strategic instruments that help firms overcome path dependency, pursue new trajectories, and enhance adaptive agility, ultimately enabling them to generate synergistic gains (Colombo *et al.*, 2006; Carmona-Lavado *et al.*, 2021). In this sense, the performance implications of open innovation depend on whether firms possess or can access the complementary assets required to mobilise internal and external knowledge effectively. Open innovation acknowledges complementary assets as a necessary foundation for transforming openness into improved performance outcomes. Prior research shows that complementary assets act as amplifiers of open innovation practices by enabling firms to orchestrate diverse partnerships and sustain knowledge flows across organisational boundaries (Greco *et al.*, 2016). Configurations that

combine openness with strong complementary assets tend to outperform those relying on openness alone (Carmona-Lavado *et al*., 2021).

3. Methodology

3.1 Research design

This study adopts a qualitative multiple-case study design (Yin, 2011). Using multiple cases strengthens the reliability and theoretical generalisability of the findings by enabling cross-case comparison (Baxter and Jack, 2008; Eisenhardt, 1989).

The empirical setting consists of twelve digital healthcare start-ups based in Lithuania. These ventures reflect different stages of development and operate across diverse segments of digital health, including remote monitoring, diagnostics, mental health services, and biotechnology.

3.2 Case selection

The primary data collection was based on a sample of digital healthcare start-ups in Lithuania. In the first step, a preliminary list of potential digital healthcare start-ups was identified using the PitchBook [1] database. This list was refined using additional information from the Bureau van Dijk Orbis database.

In the second step, specific criteria were used to narrow down the sample. These criteria included companies that had been formally established within the past seven years, which reflects the definition of a start-up. At this stage, an additional criterion was applied to identify start-ups operating as digital healthcare platforms, and only those ventures that met this requirement were retained. The sample also included an older company (Case H) that had launched a start-up initiative focused on digital healthcare platform innovation. Following this two-step procedure, the final sample consisted of twelve digital healthcare platform start-ups, representing the full set of Lithuanian platform-based digital health ventures identified in this process.

An overview of the final sample, including start-up descriptions, age, industry, employee count, average sales revenue (2020–2024), and aggregated profitability (2020–2024) is provided in Table 1.

Sales revenue represents the average annual revenue for each start-up over the period 2020–2024. This value was calculated by summing the reported annual revenues for the five years and dividing the total by five. The aggregation provided a more stable indicator suitable for cross-case comparison.

Profitability reflects the overall balance between revenues and expenses over the same period (2020–2024). A positive label indicates that the company reported a positive average balance over the five-year period. A negative label indicates a negative average performance over the five-year period. “No data” indicates that publicly accessible financial information was missing, incomplete, or not reported in business registries for one or more required years, making it impossible to determine profitability status.

3.3 Sample overview

The start-ups vary in terms of technological domain, organisational age, team size, and financial profile (see Table 1). Some ventures focus on connected monitoring equipment for chronic disease management or cardiac monitoring (e.g. Case A, Case F, Case K), while others develop AI-driven diagnostic tools (e.g. Case G), software platforms for outpatient services (Case C), or enterprise systems for medical institutions (Case H). Mental health and psychological well-being are represented through ventures offering therapeutic and organisational support tools (Case E, Case J). One company operates in the biotechnology domain, developing genomics-based data solutions (Case L).

Table 1. Overview of digital health start-ups

Case no.	Start-up description	Start-up age	Corporate backed/ New venture	Primary industry	Employees	Average annual sales revenue (2020–2024) in EUR	Profitability (2020–2024; negative, no data, positive)
Case A	The company focused on connected medical devices for home-based symptom tracking in chronic disease management	5	New venture	Monitoring equipment	10	0	Negative
Case B	A company providing digital platform-based services in the area of physical activity and training	3	New venture	Training services	1	0	No data
Case C	Company providing private outpatient care supported by digital service components	5	New venture	Clinics, outpatient services	67	7111094.6	Negative
Case D	A company providing medical services with integrated digital support features	4	Corporate-backed	Medical services	9	5412.6	No data
Case E	A company providing technology-based solutions related to psychological well-being and organisational health	5	New venture	Psychological health services	1	331516.2	Negative
Case F	A company providing digital tools for individual health data monitoring	7	New venture	Monitoring equipment	2	39205.6	No data

(*continued*)

Table 1. Continued

Case no.	Start-up description	Start-up age	Corporate backed/ New venture	Primary industry	Employees	Average annual sales revenue (2020–2024) in EUR	Profitability (2020–2024; negative, no data, positive)
Case G	A company providing software-driven solutions for diagnostic imaging and clinical assessments	7	New venture	Diagnostic equipment	13	0	Negative
Case H	A company providing enterprise-level information systems for healthcare and pharmaceutical sectors	26	Corporate-backed	Software development	49	2852909.2	Positive
Case I	A company providing digital applications for data-informed support of health-related interventions	6	New venture	Software development	10	331283.2	Positive
Case J	A company providing physiological support and monitoring tools	1	New venture	Monitoring equipment	3	0	No data
Case K	A company providing integrated medical monitoring hardware and software for use in care environments	5	Corporate-backed	Monitoring equipment	9	3554112.6	Negative
Case L	A company providing biotechnology services focused on advanced data handling and storage techniques	5	New venture	Biotechnology	11	165880.4	Positive

Most ventures were established within the past five to seven years, aligning with the start-up definition criteria. Although one company (Case H) is older, it owns a digital healthcare platform business line whose age is compatible with the other cases.

Team sizes differ substantially. Some companies operate with very small teams of 1–3 employees (Cases B, E, F, and J), while others employ larger teams exceeding 10 to 60 staff members (e.g. Case C with 67 employees, Case H with 49).

Average annual sales revenue (2020–2024) ranges from zero (Case A, B, G, and J) to over 7 million euros (Case C).

3.4 Data collection

Primary data were collected through semi-structured interviews with key decision-makers in each company. The interviews focused on understanding how these ventures engaged in open innovation practices, the types of partnerships they formed, and the incentives guiding their open innovation efforts with external stakeholders.

The duration of the interviews ranged from 20 to 46 min, with an average of approximately 33 min. Interview data, including interviewee role and interview duration, are presented in Table 2.

The questions addressed the types of external partners involved, the structure and content of collaboration, and their perceived impact on company development and performance.

In addition to interviews, secondary data were collected from other public sources, including official company websites, competitive funding portals, and national business registries (e.g. financial data). These sources provided supporting information on company age, industry classification, team size, and sales performance.

3.5 Data analysis

This study adopted a qualitative content analysis approach (Gizzi and Rädiker, 2021; Hsieh and Shannon, 2005; Lindgren *et al.*, 2020). The analysis aimed to explore the configuration of digital healthcare start-up partners and complementary assets that can enhance financial performance. The coding process was structured around two main analytical categories, into which the identified codes were grouped based on thematic relevance:

Table 2. Primary and secondary data description

Case no.	Interviewee position	Interview time	Secondary data	Purpose of the secondary data
Case A	CEO	31:09	EU investments website, PitchBook website, Dealroom website, company website	Interview data triangulation
Case B	CEO	29:15	PitchBook website	
Case C	CEO	24:10	Dealroom website, company website	
Case D	CEO	27:30	Dealroom website, vz.lt	
Case E	CEO	40:10	Pitchbook website, Dealroom website, vz.lt	
Case F	CEO	34:30	Pitchbook website, Dealroom website, Tracxn website, vz.lt	
Case G	COO	20:30	PitchBook website, Dealroom website, Tracxn website, company website	
Case H	Manager	46:22	Company website	
Case I	CEO	37:32	EU investments website, PitchBook website, Dealroom website, Tracxn website, company website	
Case J	CEO	31:29	Company website	
Case K	CEO	34:10	Company website	
Case L	CEO	37:00	Dealroom website, company website	

(1) Partners (e.g. partnerships with universities, public or private healthcare organisations)

(2) Complementary assets (e.g. product development, access to expertise, regulatory alignment)

A within-case review helped to map partner and complementary asset configurations for each start-up, followed by cross-case comparison to identify differences among the twelve start-ups. An example of the data structure and coding linking illustrative quotes with first-, second-, and aggregated-level codes is provided in Table 3.

To evaluate performance, secondary financial data covering the years 2020–2024 were collected from publicly available registries and databases (e.g. EU Investments site, Cordis EU site, Research Council of Lithuania site, PitchBook, and Dealroom databases). Three performance indicators were coded per case using binary logic (1 = present and positive; 0 = absent or negative):

(1) Sales revenue

(2) Profit before tax

(3) External funding received

Each case's values were summed into a total score, with aggregated grand totals across cases used for comparative performance trends (see Table 6). By integrating the analysis of complementary asset types, open innovation incentives, and performance indicators, the study examined how specific configurations of assets and incentives correspond to performance outcomes in digital health start-ups (see Figure 1).

4. Results

4.1 Configuration of the digital healthcare start-up partners

The analysis of partners across the twelve digital healthcare start-ups revealed diverse collaboration patterns. A total of eleven partner types were identified (see Table 4).

Table 3. Example of coding

Illustrative quote	First order code	Second order code	Aggregated dimension
"Hire existing experts in the field . . . some of them are associated with academic institutions."	Reliance on academic institutions	Academic institutions (UNI)	Partner
"Some of them are associated with academic institutions . . . some of them are in other places."	Collaboration with diverse partners	Field experts (FldExp)	
"We did it in Vilnius, at the independent research centre . . . with Lithuanian doctors."	Use of private healthcare providers for clinical testing	Healthcare providers (private) (HCPvPR)	
"We don't have many people in the company itself, but the number of experts involved is over forty."	External expertise compensating limited internal resources	Outsourcing services and expertise (SERV)	Complementary asset
"We collect from healthy volunteers . . . simply data collection."	Access to external data resources	Data acquisition and collection (DATA)	
"We have also received a public grant . . . very important for us."	Research and innovation grants as financial resource	Research and innovation grants (GRANTS)	

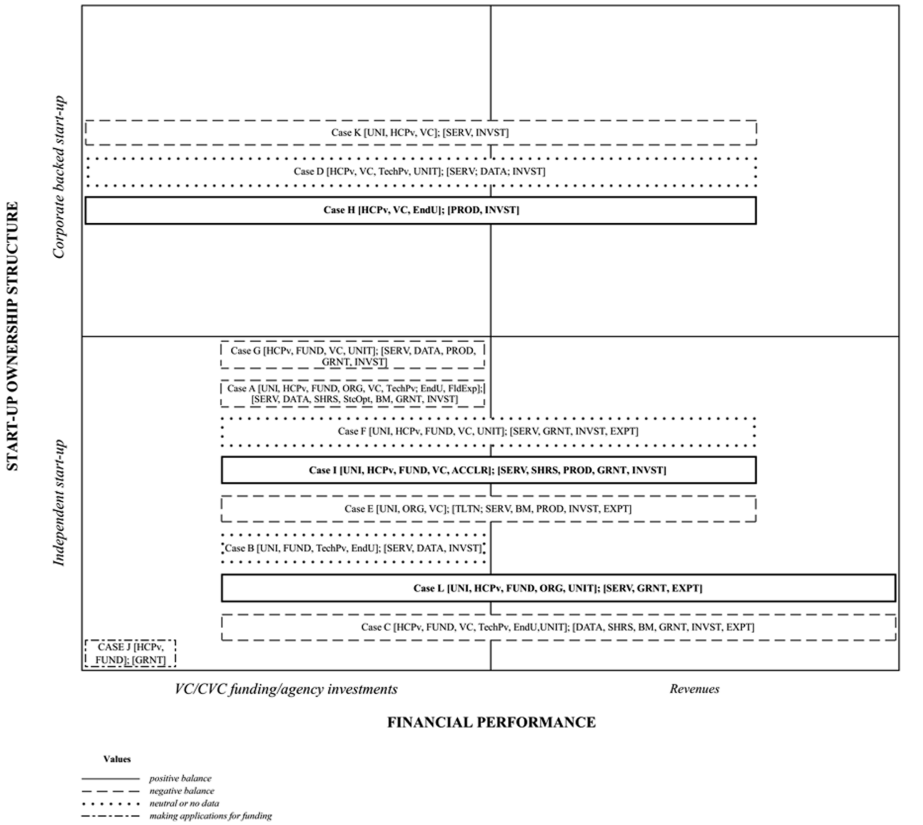

Figure 1. Ownership structure, partnership configurations, complementary assets and financial performance of start-ups

Among these, the most frequently engaged partners were VC investors, including corporate investors, reported in nine cases. Public healthcare providers and research and innovation funding institutions followed, each present in eight cases. Academic institutions appeared in seven cases, while private healthcare providers, technology providers, and end-users were each identified in four cases. B2B partners were engaged in three cases, start-up internal units in five cases, and only single cases reported accelerators, technology parks, or field experts.

4.2 Configuration of the complementary assets

The analysis identified ten distinct complementary assets across the twelve digital healthcare start-ups (see Table 5). The most frequently reported complementary assets were outsourcing services and expertise and early-stage investment, each present in nine cases. Research and innovation grants were reported in eight cases. The respondents, for instance, noted the following:

> Partnership helped to develop the algorithm and the initial prototype. (Case K)

> They are developing modules and selling them with full certificates . . . what this means is that it speeds up the process . . . so we buy some of these models. (Case D)

Data acquisition and collection, and product development were each reported in five cases. These complementary assets were typically leveraged to generate real-world data, validate functionalities, and refine service offerings. The respondents, for instance, quoted the following:

Table 4. Distribution of partners across cases

Case no.	Academic institutions (UNI)	Healthcare providers (private) (HCPvPR)	Healthcare providers (public) (HCPvPB)	Research and innovation funding institutions (FUND)	B2B partners (ORG)	Venture capital, including corporate (VC)	Accelerators and technology parks (ACCLR)	Technology provider (TechPv)	End users (EndU)	Field experts (FldExp)	Start-up internal units (UNIT)	Total
Case A	•	•	•	•	•	•		•	•	•		9/11
Case B	•			•				•	•			4/11
Case C			•	•		•		•	•		•	6/11
Case D		•				•		•			•	4/11
Case E	•				•	•						3/11
Case F	•	•		•		•					•	5/11
Case G			•	•		•					•	4/11
Case H			•			•			•			3/11
Case I	•		•	•		•	•					5/11
Case J			•	•								2/11
Case K	•		•			•						3/11
Case L	•	•	•	•	•						•	6/11
Total	7/12	4/12	8/12	8/12	3/12	9/12	1/12	4/12	4/12	1/12	5/12	

Table 5. Distribution of complementary assets across cases

Case no.	Talent development and internship facilitation (TLTN)	Outsourcing services and expertise (SERV)	Data acquisition and collection (data)	Shared start-up shares (SHRS)	Start-up stock options (StcOpt)	Business model co-creation (BM)	Product development (PROD)	Research and innovation grants (GRNTS)	Early-stage investment (INST)	Expertise sharing and conceptualisation (EXPT)	Total
Case A		•	•	•	•	•		•	•		7/10
Case B		•	•				•	•			4/10
Case C			•	•		•		•	•	•	6/10
Case D		•	•						•		3/10
Case E	•	•				•	•		•	•	6/10
Case F		•						•	•	•	4/10
Case G		•	•				•	•	•		5/10
Case H							•		•		2/10
Case I		•		•			•	•	•		5/10
Case J								•			1/10
Case K		•							•		2/10
Case L		•						•		•	3/10
Total	1/12	9/12	5/12	3/12	1/12	3/12	5/12	8/12	9/12	4/12	

Table 6. Results of start-up performance

Case no.	Sales revenue 2020	2021	2022	2023	2024	Total	Profit before tax (€) 2020	2021	2022	2023	2024	Total	Funding received 2020	2021	2022	2023	2024	Total	Total
Case A						*0*						*0*			•	•	•	*3*	3/15
Case B						*0*						*0*	•	•				*2*	2/15
Case C		•	•	•	•	*4*			•	•		*2*	•	•				*2*	8/15
Case D			•	•		*2*						*0*	•	•	•			*3*	5/15
Case E	•	•	•	•	•	*5*	•					*1*		•				*1*	7/15
Case F	•			•	•	*3*						*0*		•		•		*2*	5/15
Case G						*0*						*0*	•			•		*2*	2/15
Case H	•	•	•	•	•	*5*	•	•	•	•	•	*5*					•	*1*	11/15
Case I	•	•	•	•	•	*5*	•	•	•	•	•	*5*			•	•	•	*3*	13/15
Case J						*0*						*0*						*0*	0/15
Case K	•	•	•	•	•	*5*						*0*				•	•	*2*	7/15
Case L	•	•	•	•	•	*5*		•	•	•	•	*4*				•		*1*	10/15
Total	6/12	6/12	7/12	8/12	7/12		3/12	3/12	4/12	4/12	3/12		4/12	5/12	3/12	6/12	4/12		

> We tested the product with 10,000 users; it was well received in Europe. (Case C)

> It is now very popular to sell data. There are start-ups that collect data from hospitals, analyse it, and sell it. Basically, we used to do this in the beginning. (Case G)

Expertise sharing and conceptualisation appeared in four cases, while business model co-creation and shared start-up shares were each observed in three cases. The respondents, for instance, quoted the following:

> They're [partners] very involved, they're interested; curiosity is something you either have, or you don't. And they help a lot; we talk about the whole conceptual part. I can say that you have to choose the right partner here – really, that's a hundred percent true. (Case C)

> We had signed a cooperation agreement with the university. (Case F)

Less frequently observed complementary assets were start-up stock options and talent development or internship facilitation, each reported in only one case. These assets reflect more specific forms of engagement. The respondents, for instance, quoted the following:

> If the technology was successful, there would be some additional financial incentives for reaching certain milestones. Stock options are foreseen for key people. (Case A)

> It happens that students want to do an internship with us; they find it through the European Commission, and we get an experienced designer from Paris for half a year. So maybe that's where the partnership would be – they are contributing more to the content development. (Case E)

4.3 Start-up performance

Start-up performance was assessed using three indicators: sales revenue, profit before tax, and external funding received over the period from 2020 to 2024 (see Table 6). Each indicator was coded as binary (1 = present and positive; 0 = absent or negative) per year and per case and then summed to generate a performance profile for each start-up.

Six cases (C, E, H, I, K, and L) generated sales revenue consistently across at least four of the five years, whereas four cases (A, B, G, and J) did not report revenue throughout the period. Overall revenue activity increased from six cases in 2020 to a peak of eight cases in 2023. Profitability was far less common. Only Cases H and I reported profit before tax in all five years, while most start-ups showed either no annual profit or only occasional positive years.

External funding was recorded in most cases. Eight cases (A, B, C, D, F, G, I, and K) each secured two or more funding events, indicating more active engagement with external resource acquisition.

Across all indicators, Cases H and I demonstrate the strongest overall financial performance. Case H shows consistent revenue generation, sustained annual profitability, and one funding event, resulting in a combined score of 11/15. Case I displays the most robust financial profile, with continuous revenue, continuous profitability, and three funding events, yielding the highest score in the sample (13/15). Case L also performs strongly (10/15), driven by stable revenue and recurring profit for four years. In contrast, Cases A, B, G, and J exhibit the weakest financial activity, with no revenue, no profit, and limited or no access to external funding.

4.4 Ownership structure, partnership configurations, complementary assets, and financial performance of start-ups

The sample comprised three corporate-backed ventures (Cases K, D, and H) and nine independent start-ups. To examine how ownership structure relates to differences in partnership configurations and complementary assets, we compared the number of partners and complementary assets across the two groups.

Independent start-ups engaged with a broader set of partners than corporate-backed ventures, with an average of 4.88 partners compared with three in the corporate-backed group. A similar

pattern was observed for complementary assets. Independent start-ups leveraged a wider range of complementary assets (mean = 4.55) than their corporate-backed counterparts (mean = 2.33).

To contextualise these structural differences, we also examined how ownership structure, partnership configurations, and complementary assets align with the financial outcomes reported in Section 4.3. Figure 1 presents an integrated overview of all cases by mapping ownership structure on the vertical axis and financial performance on the horizontal axis.

The vertical axis distinguishes independent start-ups from incumbent-backed ventures. The horizontal axis plots financial outcomes, from reliance on early-stage investment (VC, CVC, and agency investment) on the left, to revenues on the right. The line styles further indicate whether ventures sustain positive, neutral, or negative balances (see Figure 1).

Each case is annotated with two bracketed indicators. The first lists the partner categories associated with the start-up (using abbreviated labels), and the second lists the complementary assets identified for that case (also shown in abbreviated form). The figure also highlights that none of the incumbent-backed ventures in the sample applied for external funding (FUND) sources other than VC. The placement of cases illustrates how different configurations, such as Cases I and L (independent) and Case I (corporate-backed), can achieve strong financial results.

5. Discussion and contribution

With this paper, we aimed to answer the question of how and which configurations of start-up partners and complementary assets enhance financial performance. The findings reveal that digital healthcare start-ups in Lithuania, as in many other countries, engage in open innovation as a necessary response to ecosystem complexity and resource scarcity (Bogers *et al.*, 2019; Martjan *et al.*, 2025). Instead of relying exclusively on internal capabilities, these start-ups proactively engage with external partners to access complementary assets that support product and service development (Bogers *et al.*, 2019; Teece, 2018a, b). This is particularly important in a healthcare context where strong regulations apply.

5.1 Ownership structure. Open innovation practices within corporate-backed and new venture start-ups

Systematic differences between corporate-backed and independent start-ups were identified. Corporate-backed ventures configure partnerships and complementary assets around CVC, while new venture start-ups pursue diversified funding sources by applying for public funds and VC investments; yet in both groups, early-stage investment is the decisive complementary asset for financial outcomes. This is consistent with research showing that CVC provides both capital and market or technical validation, improving access to complementary technologies and commercialisation routes, especially salient when navigating clinical procurement and regulatory evidence (Park and Steensma, 2012; Santamaria and Breschi, 2025).

On the other hand, CVC has tighter control over partner and complementary assets configurations (Jacobides *et al.*, 2018; Pisano, 2006). While corporate-backed start-ups pursue "efficient openness", new venture start-ups engage with more diverse partners and complementary assets in pursuing their goals. Consequently, new venture start-ups engage in less selective open innovation than corporate-backed start-ups.

5.2 Configuration of partners and complementary assets leading to sustainable financial performance

The results suggest that it is the configuration and integration of complementary assets, rather than the diversity of partners, that best explain financial performance in digital health start-ups. This aligns with Teece's (2018a, b) profiting-from-innovation logic: returns accrue to ventures that can access and orchestrate non-generic complementary assets (e.g. finance, data capabilities) around the core innovation, rather than those that merely broaden their external ties.

Among complementary assets, data capabilities and outsourced services or technologies emerged as particularly consequential. This pattern is compatible with boundary-of-the-firm research (e.g. Gawer, 2021).

Furthermore, prior research links openness (breadth and depth) to performance but also warns of coordination costs and an "optimal" level of search (Carmona-Lavado *et al.*, 2021). Our study supports the argument that the value of open innovation depends on a firm's ability to access and integrate the right complementary assets (Park and Steensma, 2012; Teece, 2018a, b), not merely on the number of collaborations.

5.3 Theoretical contribution

The study offers three empirically grounded observations that inform existing discussions in the open innovation and profiting-from-innovation literature. First, ownership structure is a differentiating variable in digital health start-ups' open innovation behaviour patterns. We show that corporate-backed and independent start-ups assemble different partner and complementary asset bundles (e.g. fewer partners and complementary assets among corporate-backed start-ups than independent start-ups), yet diverse configurations can lead to strong performance. Corporate-backed start-up configurations tend to exhibit limited openness, resulting in more efficient performance and faster revenue generation. These findings add empirical evidence to prior research by illustrating how ownership structure is associated with different open innovation practices and distinct performance trajectories in digital healthcare start-ups (e.g. Bigliardi *et al.*, 2020a; Han and Jiang, 2025).

Second, the study shows that there is no single way in which digital healthcare start-ups combine partners and complementary assets when striving for financial performance (e.g. Bigliardi *et al.*, 2020b). Instead, the findings indicate that different combinations of partners and complementary assets can be associated with similar performance outcomes. These differences reflect start-ups' ownership structure, funding situation, and regulatory setting, which shape strategic priorities and constraints when selecting partners and assets (Bigliardi *et al.*, 2020b).

Third, the findings indicate that financial performance in digital healthcare start-ups is associated with how selected partners are combined with complementary assets, rather than with the partnership breadth alone. In the empirical cases, access to specific complementary assets (e.g. early-stage funding sources, data capabilities, and product development expertise) appears particularly important in highly regulated healthcare settings. This observation is consistent with the profiting-from-innovation arguments emphasising the role of complementary assets in value capture (Pisano and Teece, 2007), and illustrates how these mechanisms operate in digital healthcare start-ups (Bigliardi *et al.*, 2020a; Chesbrough, 2003; Han and Jiang, 2025; Teece, 2018a, b). Taken together, these observations provide context-specific insight into how ownership structure and partner and complementary asset combinations relate to financial performance in digital healthcare start-ups.

5.4 Practical contribution

The study offers several implications for entrepreneurs, investors, and policymakers in digital healthcare. The findings suggest that financial performance is associated less with the breadth of partnerships and more with how start-ups combine selected partners with key complementary assets, such as early-stage funding, data capabilities, and regulatory expertise.

Healthcare providers, especially public institutions, emerge as pivotal partners, as they act as adoption and procurement channels that translate openness into revenue and profit.

Ownership structure further appears to shape practical choices around partnerships. Corporate-backed ventures can leverage CVC for both funding and accelerated commercialisation through parent networks, while independent start-ups benefit from building networks of investors, agencies, and providers to compensate for limited internal resources.

Finally, the findings suggest that multiple partner and complementary asset combinations may be associated with performance, provided that partnerships and complementary assets are aligned with the start-up's specific context and stage of development.

6. Limitations and future research

This study has several limitations that also open avenues for future research. First, the analysis is limited to twelve digital healthcare start-ups in Lithuania, a relatively small sample. While this provides valuable contextual insights, the findings may not be directly generalisable to larger or more mature digital health markets.

Second, performance measurement presents several constraints. Financial information was not uniformly reported across companies, and in some cases, the data were incomplete or unavailable in public registries. To address this, financial indicators were aggregated for the period 2020–2024 to provide an overall view of financial balance. While this approach enabled comparability across cases, it required the use of simplified binary indicators, which reduced the granularity of performance assessment and may obscure short-term fluctuations or year-specific developments. In addition, the use of a scoring system across three indicators (revenue, profit, and external funding) is appropriate for comparative purposes but does not capture the magnitude or timing of performance differences, nor does it reflect non-financial dimensions such as clinical impact or user outcomes.

Third, external funding was included as an indicator of external validation and access to complementary assets rather than as a direct measure of performance. However, funding may function both as an enabler and, in some cases, as an outcome of venture development processes. Finally, the study focused on partners and complementary assets but did not explore founders' backgrounds, organisational capabilities, or investor influence, all of which may shape strategic decisions around openness. Future research could investigate how these internal and external factors interact to influence open innovation strategies in digital health start-ups.

Note

1. PitchBook. (2024). PitchBook Data, Inc. Retrieved from https://pitchbook.com
2. CE marking, short for Conformité Européenne (European Conformity), indicates that a product meets all applicable EU directives and regulations at the time it is placed on the market.

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