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Financing the Future: Shaping Venture Capital Solutions for Technology Ventures—Value Creation in the Missing Middle

Hessel Glenn Mittelmeijer

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Het onderzoek of ontwerp dat in dit proefschrift wordt beschreven is uitgevoerd in overeenstemming met de TU/e Gedragscode Wetenschapsbeoefening.

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The cover design draws inspiration from the author's passion for hiking and symbolizes the "missing middle" faced by technology ventures. The two mountain walls represent the formidable challenges that separate technological innovation from commercial success. The canyon between them reflects the funding and commercialization gap that many technology ventures struggle to cross. At its center shines a guiding light, symbolizing the promise of sustainable value creation and societal impact. Rather than portraying the missing middle as a dead end, the cover depicts it as a challenge that can be overcome through vision, perseverance, and coordinated support.

Financing the Future:

Shaping Venture Capital Solutions for Technology Ventures—Value Creation in the Missing Middle

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door

Hessel Glenn Mittelmeijer
geboren te Nuenen, Gerwen en Nederwetten

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	Prof. dr. J.H.J. Bell

"If thou hast knowledge,
let others light their candle at thine."

—Thomas Fuller,
Introductio ad prudentiam;
or directions, counsel and cautions,
tending to prudent management of affairs in common life.
1731

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Chapter 1

Introduction

1.1 RESEARCH MOTIVATION AND PROBLEM STATEMENT

Technology ventures are key drivers of innovation, industry formation, and economic growth. They play a vital role in strengthening regional and national competitiveness (Parrish et al., 2019; Zhang et al., 2024). Increasingly, these ventures contribute to addressing urgent societal and environmental challenges in areas such as energy storage, defense and security, advanced manufacturing, and food production (e.g., Cumming et al., 2024; Mansouri & Momtaz, 2022). These technology ventures, often originating from universities and research institutes, face significant hurdles in their long, resource-intensive development processes before reaching the market (Parrish et al., 2019; Zhang et al., 2024). However, researching technology ventures remains complex, as ventures often follow non-linear and dynamic trajectories, especially in the early stages (Colombo et al., 2022; Gulati & Higgins, 2003; Liu et al., 2024).

A particularly critical and high-risk stage in this process is the resource-intensive transition from applied research and development to successful commercialization. Arora et al. (2024) refer to this stage as the *missing middle* of financing deep-tech entrepreneurship, also known as the valley of death. This "financing gap between development of science and development of commercial products" (Barr et al., 2009, p. 371) leaves many opportunities for creating or scaling technology ventures undeveloped or unexploited. The missing middle is characterized by substantial risks related to technological complexity (Tassey, 2014), the availability of financial resources (Barr et al., 2009), and the uncertain development of a sufficiently large market (Fisher et al., 2016). This stage is also marked by prolonged negative cash flow and high failure rates (Jääskeläinen et al., 2007; Wright et al., 2006). Scholars remain highly interested in the missing middle because solving it would enable more innovations to reach the market and generate societal benefits (Arora et al., 2024).

Although venture capital is typically considered critical for financing technology ventures in the missing middle, venture capital funds (VCs) remain negatively biased against the earliest investment stages. This reluctance is partially explained by investor behavior, which is influenced by high invisible fixed costs (e.g., intensive screening, due diligence, and monitoring), very high risk and uncertainty, and a general lack of expertise in early-stage

complex technology investments (Dimov et al., 2007; Lockett et al., 2002; Patzelt et al., 2009). As a result, the demand for early-stage funding remains significantly higher than supply (Wilson & Silva, 2013).

The scarcity of early-stage financing reflects two underlying issues. First, fund sizes have grown considerably, making small seed-stage investments disproportionately expensive relative to their transaction and monitoring costs (Dimov et al., 2007). Second, prevailing organizational and contractual techniques in the venture capital industry, designed to mitigate information asymmetry, uncertainty, and agency costs, are less suited to technology ventures at very early stages (Gilson, 2003). Although the European venture capital market has grown substantially. Several industry reports show that early-stage VC activity in Europe is still behind North America and Asia (Invest Europe, 2019; 2020; 2021; 2022; 2023).

Despite the importance of technology ventures for society, research on the missing middle remains fragmented across two largely disconnected literatures: entrepreneurial finance and technology entrepreneurship. The *entrepreneurial finance* literature focuses on investors and emphasizes funding dynamics, investment processes, and financial returns (e.g., Claes & Vissa, 2020; Wu et al., 2016). The *technology entrepreneurship* literature typically adopts the venture's perspective, highlighting resource orchestration, strategic decision-making, and value creation from emerging technologies (e.g., Carayannis et al., 2016; Fuller & Rothaermel, 2012). Although both perspectives are valuable and complementary, they rarely intersect, thereby limiting the development of a cohesive theoretical foundation that could help practitioners reduce the impact of the missing middle (Kalvapalle et al., 2024).

Moreover, scholars have been slow to address this pressing challenge by translating research insights into tools and knowledge that can be implemented by practitioners. Here, design science (DS) can enable scholars to combine theoretical contributions with actionable insights for entrepreneurship policy and practice (e.g., Berglund, 2021; Dimov et al., 2023; Van Burg et al., 2008). This highlights a clear need for more empirical examples demonstrating how DS methods and design propositions can be rigorously developed, validated, and valorized in complex, context-rich domains such as venture capital and technology entrepreneurship.

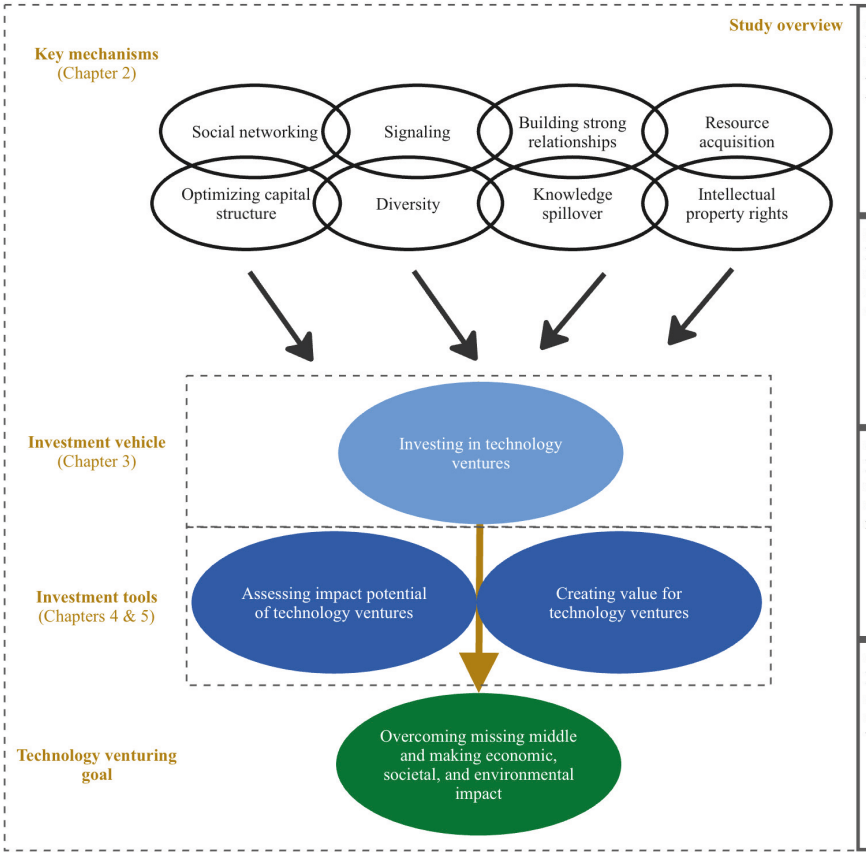
Technology ventures (the domain of *technology entrep*reneurship) and venture capital (the domain of *entrepreneurial finance*) are thus deeply intertwined, much like entrepreneurship and finance more generally. Both fields would benefit greatly from bridging these perspectives, to enable academic progress and enhance the economic, societal, and environmental impact of technology ventures and VC business ecosystems in Europe. These observations provide the rationale for this dissertation. Against this background, the overall research question guiding this dissertation is:

How can venture capitalists help technology ventures overcome the missing middle in the funding landscape?

1.2 EMPIRICAL CONTEXT AND OVERVIEW OF THE DISSERTATION

The studies in this dissertation investigate how venture capital solutions can support technology ventures in overcoming the missing middle and thereby contribute meaningful economic, societal, and environmental value. The research question formulated in Section 1.1 is addressed by designing venture capital mechanisms and frameworks that operate within the context of technology ventures and investors. The central premise is that venture capital plays an essential role in financing, guiding, and monitoring technology ventures, particularly deep-tech ventures, to increase their likelihood of success.

The dissertation consists of four interconnected studies that share an interdisciplinary, qualitative approach aimed at bridging theory and practice. Each chapter addresses a contextualized sub-question (SQ) that contributes to addressing the overarching research question. Figure 1.1 provides a visualization of the interrelations of the four studies in addressing the missing middle. The remainder of this section summarizes each chapter.



Chapter 2 Exploring mechanisms of technology venturing within the valley of death	**SQ1:** How can a mechanism-based synthesis of entrepreneurial finance and technology entrepreneurship literatures enhance our understanding of technology venturing in the missing middle?
Chapter 3 Design and implementation of a deep-tech venture capital fund	**SQ2:** How can a venture capital fund exclusively focused on seed-stage deep-tech ventures be designed, tested, and codified?
Chapter 4 Design and implementation of a sustainability impact & risk investment process	**SQ3:** How can venture capitalist funds assess the sustainability impact of early-stage technology ventures within the context of their investment process?
Chapter 5 Exploring and developing a value creation framework for venture capitalists	**SQ4:** How can venture capital funds provide value-added support to technology ventures within the European context?

Figure 1.1 Overview of the studies in this dissertation

1.2.1 Chapter 2: Technology ventures in the missing middle: A mechanism-based review of the entrepreneurial finance and technology entrepreneurship literatures

Technology ventures are central engines of innovation and economic growth, yet they face substantial challenges during the transition from early-stage development to commercialization, a period known as the *missing middle*. This stage is characterized by high uncertainty, extended negative cash flow, and a structural financing gap. Although important, existing research on this problem is fragmented across the entrepreneurial finance and technology entrepreneurship literatures. The lack of integration, or synthesis, between these perspectives limits theoretical progress and the development of practical solutions to reduce venture failure rates. Furthermore, prior studies often rely on linear representations of venture development, whereas technology ventures in the missing middle typically follow non-linear and dynamic trajectories (Colombo et al., 2022; Gulati & Higgins, 2003; Liu et al., 2024). No prior studies have examined how mechanisms interact across a venture's life cycle (Barbosa et al., 2024; Shepherd et al., 2021). This study therefore asks:

How can a mechanism-based synthesis of entrepreneurial finance and technology entrepreneurship literature enhance our understanding of technology ventures in the missing middle?

Chapter 2 presents a mechanism-based literature review of 201 peer-reviewed articles, identifying the key agencies, mechanisms, and outcomes shaping venture trajectories. By adopting a temporal lens, the study differentiates between the applied R&D and commercialization phases and synthesizes insights into a causal loop diagram (CLD) containing multiple feedback loops. The resulting framework establishes a unified theoretical foundation for technology ventures in the missing middle and serves as the theoretical baseline for the remaining studies in this dissertation. Chapter 2 partially addresses the main research question by developing an integrated, mechanism-based understanding of how technology ventures evolve in the missing middle, thereby clarifying the dynamic conditions and processes that shape venture trajectories across critical development phases.

1.2.2 Chapter 3: The missing middle: Designing and implementing a venture capital fund for seed-stage deep-tech ventures

Building the mechanisms identified in Chapter 2, it became evident that deep-tech ventures in Europe face disproportionate barriers in securing early-stage funding. These ventures, often rooted in photonics, quantum technologies, mechatronics, and advanced materials, require substantial capital well before commercialization. Their funding gap is particularly acute at the seed stage, in which technological complexity, long development cycles, and innovation ecosystem dependencies converge. Despite their transformative potential, deep-tech ventures remain underserved by traditional VCs, who typically prioritize later-stage, lower-risk opportunities. Existing academic research offers limited guidance on how to design VC structures that effectively address this early-stage funding gap in the European context. This study therefore asks:

How can a venture capital fund exclusively focused on seed-stage deep-tech ventures be designed, tested, and codified?

Using a design science (DS) approach, Chapter 3 develops and implements a VC tailored to seed-stage deep-tech ventures. The resulting fund, called DeepTechXL (today known as DeepTech Capital Partners), was launched based on design propositions derived from entrepreneurial finance and technology entrepreneurship literature and further refined through interaction with investors and practitioners. The fund's architecture incorporates staged financing, syndication strategies, debt leveraging, and innovation ecosystem support. DeepTechXL also operates as the empirical context for Chapters 4 and 5, serving as both as a research setting and as a real-world solution that directly increases the capital available to deep-tech ventures in the missing middle. Chapter 3 partially addresses the main research question by designing, implementing, and validating a specialized VC fund model that demonstrates how tailored VC structures can directly support seed-stage deep-tech ventures in overcoming the missing middle.

1.2.3 Chapter 4: Investing in the future: Evaluating technology ventures on sustainability impact in venture capital

Increasingly, technology ventures are not only considered the hallmark of innovation and economic growth, but also as a transformative force

towards sustainable futures. As expectations for sustainability-oriented investing grow, VCs are increasingly required to integrate sustainability considerations into their investment processes. Yet assessing sustainability impact for early-stage ventures is highly challenging due to limited data, high uncertainty, and sectoral diversity. Despite regulatory pressures such as the European Union (EU) Sustainable Finance Disclosure Regulation (SFDR), academic literature provides little guidance for systematically evaluating sustainability impact in VC decision-making. This study therefore asks:

How can venture capital funds assess the sustainability impact of early-stage technology ventures within the context of their investment process?

Chapter 4 adopts a DS approach to develop the *VC Green Scheme*; a sustainability impact assessment framework tailored to VC practice. Drawing on a systematic literature review and empirical insights from thirteen European VCs, the study formulates eight design propositions that shape the framework's development. The resulting tool integrates sustainability impact and risk assessment throughout the VC investment process, from initial screening to post-investment monitoring. The framework was implemented and evaluated at DeepTechXL, demonstrating both practical relevance and regulatory compliance. This study contributes to a validated methodological illustration and a practical tool for embedding sustainability into VC decision-making. Chapter 4 partially addresses the main research question by developing and validating a sustainability impact assessment framework that enables VCs to systematically evaluate and integrate sustainability considerations into investment decisions for early-stage technology ventures in the missing middle.

1.2.4 Chapter 5: Beyond capital: A framework for how venture capitalists create value in technology ventures

Venture capital has long been recognized as a key instrument for financing technology ventures (Drover et al., 2017; Svetek, 2022; Wuebker et al., 2015). Research shows that VC-backed ventures systematically outperform non-VC-backed firms and can offer extraordinary gains from a modest investment(Gompers et al., 2010; Harris et al., 2014; Lahr, 2023). This suggests that VCs contribute value not only through investment selection but also through their post-investment involvement. This chapter defines VC

value creation as the set of deliberate activities through which VCs reduce uncertainty, strengthen organizational and technological capabilities, and improve commercial and financial trajectories.

Structural and institutional fragmentation complicates venture scaling particularly in Europe (Croce et al., 2013; Pantea & Tkacik, 2025; European Investment Council, 2026). However, existing studies primarily list value-adding activities without providing a more holistic perspective regarding contextual factors, results of value creation, and the types of involvement of a VC (Gompers et al., 2020; Proksch et al., 2017; Siefkes et al., 2025). Moreover, technological value-adding activities (Arqué-Castells, 2012; Lahr & Mina, 2016) and signaling-based network effects (Milosevic et al., 2020) remain underrepresented in existing scholarly work and typologies of value creation. To address this gap, Chapter 5 asks:

How can venture capital funds provide value-added support to technology ventures within the European context?

Drawing on a comparative case study design (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) that integrates insights from a systematic literature review and twelve European VC cases, this study develops the VC value creation framework. The framework conceptualizes VC involvement across three dimensions, namely strategic, operational, and technological, and two modes of involvement, called direct and indirect, yielding six focus areas through which VCs create value. The study also identifies contextual venture- and VC-side factors shaping decisions of focus areas. Moreover, this study shows how value-adding activities lead to value inflection points relevant for subsequent financing and long-term outcomes.

Overall, Chapter 5 advances a more holistic and empirically grounded understanding of VC value creation, emphasizing that technological support is a fundamental, rather than peripheral, dimension of post-investment involvement. This clarifies how VCs can directly and indirectly support technology ventures in advancing through their critical, early stages of development. Chapter 5 partially addresses the main research question by developing a holistic, empirically grounded framework that explains how venture capitalists create value beyond capital, thereby supporting technology ventures in progressing through the missing middle.

1.2.5 Overview of studies

Table 1.1 provides a detailed overview of the four studies presented in Chapters 2 through 5. Each chapter addresses a specific sub-question (SQ) related to the overarching question and contributes to a distinct yet interconnected layer of insight. Together, the studies form a coherent research program that integrates theoretical contributions, empirical findings, and design knowledge. Table 1.1 not only summarizes the focus, method(ology), and contributions of each chapter but also highlights their empirical settings, periods of data collection, target stakeholders, valorization activities, and publication status. Together, these studies demonstrate the dissertation's integral approach: combining mechanism-based theorizing, design science, and qualitative inquiry to advance both scholarly understanding and practical solutions for technology ventures navigating the missing middle.

Table 1.1 Overview of the four studies

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Title	Technology ventures in the missing middle: A mechanism-based review of the entrepreneurial finance and technology entrepreneurship literatures	The missing middle: Designing and implementing a VC fund for seed-stage deep-tech ventures	Investing in the future: Evaluating technology ventures on sustainability impact in VC	Beyond capital: A framework for venture capital value creation in technology ventures
Research question	How can a mechanism-based synthesis of entrepreneurial finance and technology entrepreneurship literature enhance our understanding of technology ventures in the missing middle?	How can a venture capital fund exclusively focused on seed-stage deep-tech ventures be designed, tested, and codified?	How can VCs assess the sustainability impact of early-stage technology ventures within the context of their investment process?	How can venture capital funds provide value-added support to technology ventures within the European context?
Research Method (ology)	Literature review	Design science	Design science	Comparative case study

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Period of data collection	From the start of each journal selected until December 2025	2021 – 2024	February 2023 – December 2024	February 2025 – September 2025
Theoretical contribution toward	Technology entrepreneurship	Entrepreneurial finance	Entrepreneurial finance	Entrepreneurial finance
Practical contributions for	- Technology ventures - Venture Capitalists - Business ecosystem parties	- Venture capitalists - Institutional investors - Policy makers and innovation agencies - Technology ventures	- Venture capitalists - Technology ventures - Policy makers and regulators - Impact investors and limited partners	- Venture capitalists - Technology ventures - Policy makers and regulators - Limited partners
Valorization	Within company contributions. Both informative and reflective activities are related to key concepts on day-to-day activities.	The company was created and currently has >15 FTE, has invested in 10 companies, and raised a subsequent pre-seed fund with the leading universities in the Netherlands, TNO, and the Dutch government.	Within company contributions. A VC fund is currently using the framework within their due diligence activities, and several other funds have requested information on how the company is doing this.	Within company contributions. A VC fund is currently using the framework within their value creation activities, and several other funds have requested information on the framework for implementation.
Publication	Under review at *SAGE Open*	Published in: *Journal of Business Venturing Design*	Published in: *Technovation*	Under review at *Journal of Business Venturing Insights*

1.3 CONTRIBUTIONS OF THE AUTHOR, SUPERVISORS AND OTHERS

This doctoral candidate (Hessel Mittelmeijer) designed, conducted, and developed this doctoral dissertation. The research was carried out under the supervision of Georges Romme and Sharon Dolmans, whose guidance and feedback informed the conceptual, methodological, and analytical components of the project. Across the four studies, several additional academic and industry collaborators contributed to specific chapters in ways that strengthen the relevance, rigor, and practical impact of the work. For Chapter 3, the author's team also includes Guus Frericks and John Bell, two experienced practitioners in venture capital and technology ventures. John Bell additionally serves as a part-time professor at Tilburg University. Their expertise enhanced the study's design science (DS) work on creating and evaluating a venture capital fund for deep-tech ventures. For Chapter 4, the author team includes Duygu Keskin, whose contributions supported the development and theoretical grounding of the sustainability assessment framework. This chapter also draws partly on the work of Charlot Felderhof, a former TU/e master's student whose contributions are described in Table 1.2. For Chapter 5, the author team includes entrepreneurship scholar Annelies Bobelyn, who contributed to the development and refinement of the VC value creation framework. This chapter also draws partly on the TU/e master's thesis of Joos Kat, whose contributions are described in Table 1.2. Table 1.2 provides a detailed overview of the specific contributions made by the doctoral candidate, supervisors, and other collaborators across the seven major research activities: research design, literature review, data collection, data analysis, interpretation of results, writing of the main text, and revisions and feedback.

Table 1.2 Contributions of the authors

		Research design	Literature review	Data collection	Data analysis	Interpretation of results	Writing main text	Revisions and feedback
Chapter 1 – Introduction	Hessel Mittelmeijer	X	X				X	X
	Georges Romme							X
	Sharon Dolmans							X
Chapter 2	Hessel Mittelmeijer	X	X	X	X	X	X	X
	Georges Romme					X		X
	Sharon Dolmans					X		X
Chapter 3	Hessel Mittelmeijer	X	X	X	X	X	X	X
	Georges Romme					X		X
	John Bell				X	X		X
	Gustaaf Frericks				X	X		X
Chapter 4	Hessel Mittelmeijer	X	X	X	X	X	X	X
	Charlot Felderhof	X	X	X	X	X		
	Duygu Keskin					X		X
	Sharon Dolmans					X		X
Chapter 5	Hessel Mittelmeijer	X	X	X	X	X	X	X
	Joos Kat	X	X	X	X	X		X
	Sharon Dolmans					X		X
	Annelies Bobelyn					X		X
	Georges Romme					X		X
Chapter 6 - Conclusion	Hessel Mittelmeijer	X				X	X	X
	Georges Romme							X
	Sharon Dolmans							X

1.4 STRUCTURE OF THE DISSERTATION

The remainder of this dissertation is organized as follows. Chapters 2 to 5 constitute the core of this dissertation, focusing on answering a part of the overall research question. Throughout the dissertation, each chapter was written to function as a stand-alone article. This means that research design, definitions, and argumentation occasionally overlap across chapters, reflecting the academic conventions of article-based dissertations. The contributions outlined above collectively ensured that each chapter was methodologically sound, theoretically informed, and practically relevant, while maintaining coherence across the dissertation. Chapter 6 concludes the dissertation by summarizing the four studies, synthesizing their collective theoretical contributions, and presenting an integrated conceptual framework of the venture capital–technology venture dyad in the missing middle. The last chapter also discusses the practical implications, outlines limitations, and proposes avenues for future research.

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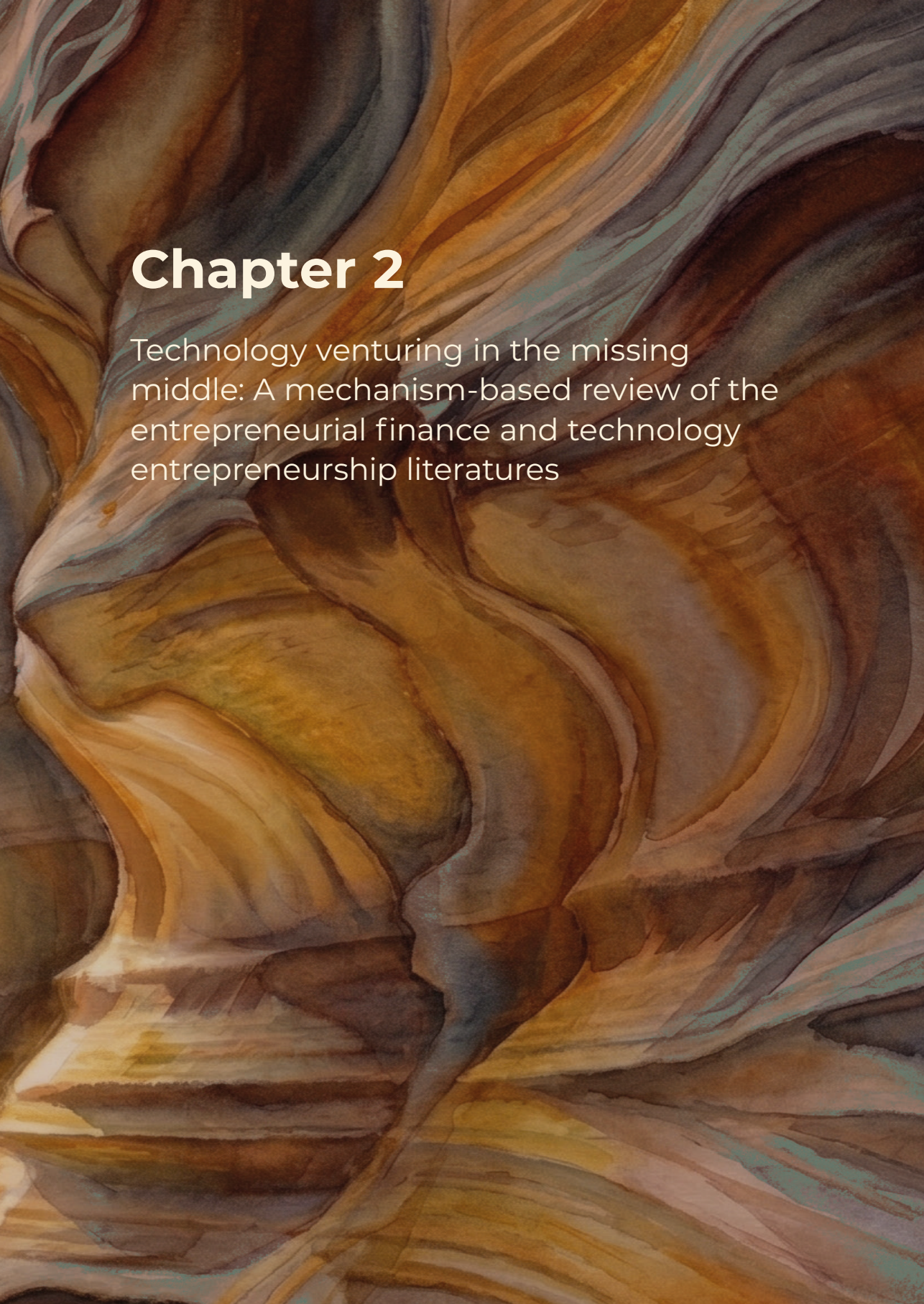
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Chapter 2

Technology venturing in the missing middle: A mechanism-based review of the entrepreneurial finance and technology entrepreneurship literatures

ABSTRACT

Technology ventures are critical to societal progress, yet they often do not survive a period known as the *valley of death*, a structural financing gap between the proof of concept phase and the commercialization phase. Studies of this phenomenon are distributed across the disconnected literatures on entrepreneurial finance and technology entrepreneurship. Our literature review addresses this disconnect by identifying and categorizing the key mechanisms, agencies, and outcomes of venture trajectories in the valley of death. The findings are synthesized in a causal loop diagram showing that the valley of death extends beyond a static financing gap: it involves a dynamic tipping point between two dominant loops, which determine whether a venture attracts sufficient capital to progress through the valley of death or fails to do so.

Keywords: technology entrepreneurship, entrepreneurial finance, technology ventures, venture capital, valley of death

A version of this chapter is under review at SAGE OPEN.

2.1 INTRODUCTION

Technology ventures (TVs) are key drivers of innovation, industry formation, and economic growth. They play a vital role in enhancing regional and national competitiveness (Parrish et al., 2019; Zhang et al., 2024). These ventures also increasingly contribute to addressing urgent societal and environmental challenges (e.g., Cumming et al., 2024; Mansouri & Momtaz, 2022). Many TVs, often originating from universities and research institutions, face significant hurdles in technology development, industrialization, and business model innovation before reaching the market (Parrish et al., 2019; Zhang et al., 2024).

A particularly critical and high-risk stage in this process is the transition from early-stage development to successful commercialization. This so-called 'valley of death' (Barr et al., 2009), also known as the 'missing middle' (Arora et al., 2024), is characterized by a prolonged negative cash flow and a structural financing gap between scientific discovery and market-ready products (Wright et al., 2006). The technology entrepreneurship literature defines the valley of death based on nine technology readiness levels (TRL), with the valley of death starting when the proof of concept is available (TRL-4) and ending with the commercially proven solution (TRL-9). The entrepreneurial finance literature labels the time-to-market and maturity level of a company in terms of the seed-stage (cf., TRL 4 to 7), early-stage (cf., TRL 7 to 9) and later-stage (cf., beyond TRL 9). Because TVs become more cash intensive from TRL-4 onwards and thereby face a steeper valley of death, it is important to develop a dynamic understanding of the key mechanisms at play.

Despite its importance, research on the valley of death remains fragmented across the largely disconnected literatures on entrepreneurial finance and technology entrepreneurship. The entrepreneurial finance literature focuses on the investor's perspective, emphasizing funding dynamics, investment processes, and financial returns (e.g., Claes & Vissa, 2020; Wu et al., 2016). By contrast, the technology entrepreneurship literature adopts the venture's perspective, highlighting resource orchestration, strategic decision-making, and value creation from emerging technologies (e.g., Carayannis et al., 2016; Fuller & Rothaermel, 2012). Although these two perspectives are complementary, they are rarely integrated, limiting the development of a systemic theoretical understanding (Kalvapalle et al.,

2024) and constraining the field's ability to build a cumulative body of knowledge. Such a body of knowledge may help reduce persistently high failure rates of TVs (Arora et al., 2024; Vaznyte & Andries, 2019).

Several previous literature reviews are relevant here. Bailetti (2012) provided a foundational definition of technology entrepreneurship and its distinctive aspects. Giones and Brem (2017) and Steininger (2019) expanded this definition by emphasizing digital artifacts and platform dynamics. Soto Simeone et al. (2020) focused predominantly on technology venture survival across the entrepreneurship, management, and sociology literatures. Other reviews addressed specific topics such as international entrepreneurship (Terjesen et al., 2016), dependent variables (Shepherd et al., 2019), entrepreneurial process stages (Shepherd et al., 2021), digital marketing (Barbosa et al., 2024), and pitching (McSweeney et al., 2025). However, none of these reviews explicitly examined TVs through a temporal lens, in order to develop a systemic framework connecting technology entrepreneurship and entrepreneurial finance. In this paper, we address this gap. We do so by formulating the following research question: how can a mechanism-based synthesis of the entrepreneurial finance and technology entrepreneurship literature inform a systemic understanding of the development of technology ventures in the valley of death? To answer this question, we conduct a mechanism-based systematic literature review that integrates insights from the entrepreneurial finance and technology entrepreneurship literatures.

To develop a systemic perspective on TVs, as a first step toward a cumulative body of knowledge in this area, we conduct a mechanism-based review and synthesis of both literatures to create a unified framework for understanding technology venturing in the valley of death. The mechanism-based synthesis approach (Denyer et al., 2008; Gross, 2009) serves to identify and connect the agents, mechanisms, and outcomes described in 201 peer-reviewed articles. Mechanisms are defined here as causal processes activated by specific agents that generate outcomes within a given context (Ogink et al., 2023; Van Burg & Romme, 2014). This approach is particularly well suited to integrating studies that draw on epistemologically diverse perspectives (Van Burg & Romme, 2014).

This study makes a theoretical contribution to the literature by integrating two largely disconnected literatures into a systemic framework of how TVs

succeed or fail to survive the valley of death. Using causal loop diagramming, we develop a framework that reconceptualizes the valley of death in terms of a tipping point governed by loop dominance.

The remainder of this paper is structured as follows. Section 2.2 outlines the methodology. Section 2.3 presents the main findings. Subsequently, we describe the dynamic causal loop framework in section 2.4. Finally, section 2.5 serves to discuss the contributions, limitations, and future research avenues arising from our study.

2.2 METHOD

We conducted a mechanism-based systematic review of the literature to synthesize insights from the entrepreneurial finance and technology entrepreneurship literature, focusing on the valley of death. Our review followed established guidelines for evidence-based literature review and synthesis (Denyer et al., 2008; Van Burg & Romme, 2014), emphasizing the identification of causal mechanisms as well as the agents and actions (together forming the 'agencies') that activate them, and the outcomes produced. Figure 2.1 outlines the steps taken. Each step is described in more detail in the remainder of this section.

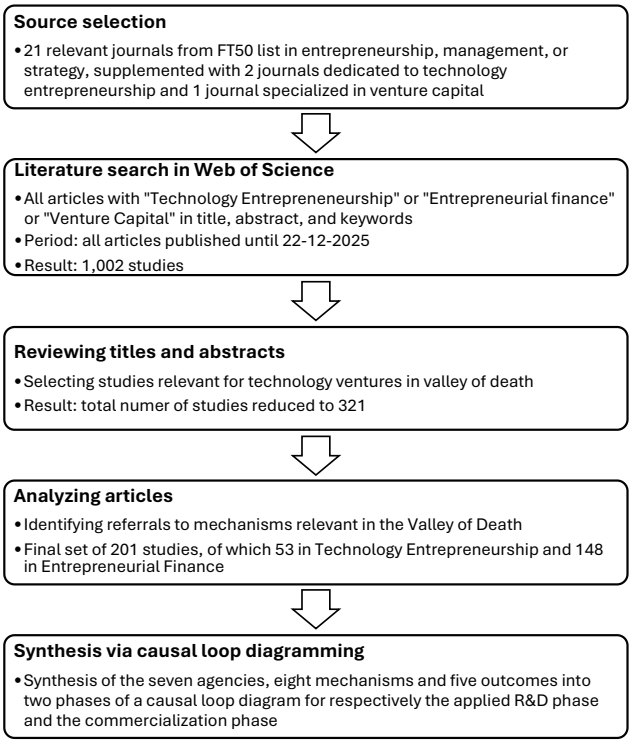


Figure 2.1 Steps taken in the review and synthesis of the literature

2.2.1 Search query development

We developed a data set from rigorous and credible sources to strengthen the validity of the results of our synthesis. We thus used Web of Science as the database, as it only includes peer-reviewed articles in journals with an accredited double-blind review protocol. The search query contained three operators, namely publication date, journal, and topic.

First, we decided to incorporate all published articles from each journal's inception until December 2025. This helped to identify foundational studies, understand how ideas evolved over time, limit potential temporal bias, and identify future research directions.

Second, we aimed to include journals that are globally recognized for their peer-reviewed, high-impact research to reinforce the rigor and credibility of the dataset. Consequently, we decided to select journals based on the FT50 list as a widely accepted benchmark for top-tier journals. From the FT50 list, we selected journals that are focused on the topics of entrepre-

neurship, strategy, finance, and management. As such, 21 journals from this list were included. We supplemented this initial set with three additional journals that publish large amounts of work on technology ventures and/or venture capital: Journal of Technology Transfer, Technovation, and Venture Capital. This selection ensured a broad coverage across both literatures.

Third, we formulated the search query in terms of three topics, namely "technology entrepreneurship", "entrepreneurial finance", or "venture capital". The topic operator in Web of Science ensured that all articles mentioning any of these topics in the title, abstract, or keywords are included. Combining the three topics in an OR format ensured that both venture and investor logics were covered in the set of studies selected. Table 2.1 provides an overview of the search query and Appendix A describes the full query.

Table 2.1 Search query

Publication date	Topic ("TS")	Journal ("SO")
1901-01-01 to 2025-12-22	Technology Entrepreneurship OR Venture Capital OR Entrepreneurial Finance	Academy of Management Journal OR Academy of Management Review OR Administrative Science Quarterly OR Entrepreneurship Theory and Practice OR Harvard Business Review OR Journal of Applied Psychology OR Journal of Business Venturing OR Journal of Finance OR Journal of Financial and Quantitative Analysis OR Journal of Financial Economics OR Journal of Management OR Journal of Management Studies OR MIT Sloan Management Review OR Organization Science OR Organization Studies OR Organizational Behavior and Human Decision Processes OR Research Policy OR Review of Finance OR Review of Financial Studies OR Strategic Entrepreneurship Journal OR Strategic Management Journal OR Technovation OR Journal of Technology Transfer OR Venture Capital

2.2.2 Article selection

The search query formulated previously resulted in 1,002 articles (see Table 2.2). Articles from this initial set were selected by means of a two-stage approach. First, we evaluated the titles and abstracts to assess their relevance to technology venturing in the valley of death. For example, work that exclusively focuses on investor–investor dynamics (e.g., Limited Partners–General Partners relationships) was excluded. This step reduced the sample to 321 articles.

Second, we reviewed the full text of the remaining articles to identify those that explicitly describe or explain any mechanisms, defined as causal processes activated by specific agents to produce outcomes in a given context (Gross, 2009; Van Burg & Romme, 2014). This resulted in a final sample of 201 articles: 148 studies in the entrepreneurial finance literature and 53 in the technology entrepreneurship literature. Table 2.2 provides an overview of the final sample of studies per journal. The final sample of articles is published in 14 of the 24 journals selected earlier.

Table 2.2 Overview of studies selected

Publication	Initial selection	Final selection
Journal of Business Venturing	195	42
Research Policy	83	27
Venture Capital	114	22
Journal of Financial Economics	73	18
Entrepreneurship Theory and Practice	80	17
Strategic Entrepreneurship Journal	55	15
Strategic Management Journal	42	14
Organization Science	26	10
Journal of Technology Transfer	57	9
Administrative Science Quarterly	17	6
Technovation	46	6
Journal of Management	14	3
Journal of Management Studies	24	3
Review of Financial Studies	31	3
Journal of Finance	30	3
Organization Studies	2	1
Review of Finance	20	1
Academy of Management Review	2	1
Harvard Business Review	32	0
MIT Sloan Management Review	3	0
Academy of Management Journal	31	0
Journal of Financial and Quantitative Analysis	24	0
Organizational Behavior and Human Decision Processes	1	0
Total	**1,002**	**201**

2.2.3 Mechanism-based review

To analyze the final set of studies, we applied the Context–Agency–Mechanism–Outcome (CAMO) framework (Denyer et al., 2008; Van Burg & Romme, 2014), which focuses on explaining how and why outcomes occur, rather than simply cataloging variables. In our review, the valley of death served as the overarching context. Each article was coded for mechanisms, the agents and actions activating them (e.g., entrepreneurs, investors), and the outcomes they produced (e.g., venture development, funding success). The CAMO framework is particularly well suited to integrating epistemologically diverse (e.g., positivist, critical realist, and constructivist) literatures (Gross, 2009; Van Burg & Romme, 2014). It also enables the identification of recurring patterns and feedback loops.

To capture the temporal dynamics of TVs, we distinguished between two phases of the valley of death: the applied R&D phase and the commercialization phase (Barr et al., 2009; Zhang et al., 2024). We excluded studies focused solely on the technology creation phase, which typically precedes the valley of death and involves fundamentally different actors and dynamics.

2.2.4 Causal loop diagram

Finally, we synthesized our findings into a dynamic and integrative framework using causal loop diagramming, a method developed in system dynamics (Sterman, 2000; Walrave et al., 2011). A causal loop diagram (CLD) is a visual tool that maps cause–effect relationships and highlights feedback loops, which are either reinforcing (amplifying) or balancing (stabilizing) in nature. In our study, the CLD approach serves to model how mechanisms interact over time across the two phases of the valley of death. Each loop represents a sequence of actions and reactions between ventures and investors. For example, signaling may influence fundraising, which then affects team expansion and venture development. By visualizing these loops, we identified tipping points, bottlenecks, and virtuous or vicious cycles that shape venture trajectories. This method is particularly valuable for understanding complex, non-linear dynamics unfolding over time, as dynamic patterns that static frameworks fail to capture. The resulting CLD offers a systemic view of how agency-mechanism-outcome relations evolve across the valley of death.

2.3 FINDINGS

This section presents the main findings of our literature review and synthesis. We first provide an overview of prior literature reviews in the area of technology entrepreneurship. Then, we introduce a general framework that captures the key mechanisms, agencies, and outcomes of TVs in the context of the valley of death. Each mechanism, agency, and outcome is briefly explained to clarify its role in venture progression. Appendix B provides a more detailed analysis. Finally, we synthesize these insights into a single causal loop diagram, which models the dynamic interplay across the applied R&D and commercialization phase, each representing a critical stage in the valley of death.

Table 2.3 provides a structured overview of prior reviews in terms of their focus, contributions, and limitations. This overview demonstrates how earlier review studies are distributed across specific domains, with a primary focus on typologies, stages, or isolated mechanisms. An integrative explanation of how various mechanisms in the entrepreneurial finance and technology entrepreneurship literatures interact over time is thus missing.

Table 2.3 Overview of prior literature reviews

Study	Topic	Key contribution	Focus
Bailetti (2012)	Definition, scope, and thematic structure of technology entrepreneurship	Formal definition of technology entrepreneurship as investment in projects combining specialized individuals and assets; identifies dominant themes in the literature	Primarily conceptual and static in orientation; limited attention to dynamic interactions and the role of financial mechanisms
Giones & Brem (2017)	Impact of digitization on entrepreneurship and conceptual differentiation of technology vs digital entrepreneurship	Extends technology entrepreneurship by incorporating digital technologies; introduces distinctions (technology entrepreneurship, digital technology entrepreneurship, digital entrepreneurship) and proposes a research agenda	Focuses on conceptual delineation by identifying and describing characterizations of technology entrepreneurship, digital technology entrepreneurship, and digital entrepreneurship. Limited integration with entrepreneurial finance literature

Study	Topic	Key contribution	Focus
Steininger (2019)	Systematic review of IT roles in entrepreneurship and classification of venture types	Identifies four roles of IT (facilitator, mediator, outcome, ubiquity) and links them to different venture types and value creation logics	Classification-oriented contribution related to IT and entrepreneurship; limited integration with broader entrepreneurial finance literature and of dynamic interactions across phases
Soto-Simeone et al. (2020)	Systematic review of antecedents of new venture survival	Provides a synthesis of survival factors across 54 years; categorizes determinants into environmental, firm-level, and individual factors; proposes survival as a key performance outcome	Focuses on categorization of antecedents; focuses on conditions characterizing the environment of a new venture, attributes and strategies of the new venture itself, and individual characteristics of the founding team. Limited attention to dynamic interactions.
Terjesen et al. (2016)	Systematic review examining comparative international entrepreneurship	Synthesizes 259 studies; highlights cross-country heterogeneity; introduces multi-level framework linking characteristics, antecedents, and outcomes	Highlights the heterogeneous nature of entrepreneurial activity across countries and its importance, especially in terms of outcomes at firm and country levels. Also identifies country-level antecedents to entrepreneurial activity; focuses on a specific subject within technology entrepreneurship.
Shepherd et al. (2019)	Systematic review of dependent variables in entrepreneurship research	Develops a meta-framework organizing entrepreneurship into initiation, engagement, and performance stages; offers comprehensive mapping of outcomes studied in the field	Focuses on categorizing outcomes; limited integration of financial dynamics or interactions across stages
Shepherd et al. (2021)	Systematic review of new venture creation processes and subtopics	Integrative framework of venture creation organized into three stages (co-creating, organizing, performing) and ten subtopics; provides a research agenda and highlights links between stages	Focuses on categorizing stages and subtopics; less attention to modeling of dynamic feedback mechanisms and integration of financing processes as interacting system dynamics

Study	Topic	Key contribution	Focus
Barbosa et al. (2024)	Systematic review of digital marketing strategies across the customer journey	Identifies 13 digital marketing techniques and links them to five stages of the customer journey (awareness, engagement, conversion, loyalty, advocacy); connects marketing actions to technology adoption	Emphasizes classification of techniques across stages; little integration with entrepreneurial finance and of interaction between mechanisms over time. Focuses on a specific subject within technology entrepreneurship.
McSweeney et al. (2025)	Systematic review of entrepreneurial pitching and resource acquisition processes	Process model of entrepreneurial pitching across four stages (pre-pitch, pitching, post-pitch, evaluation); identifies 15 topics and provides an integrative definition of pitching	Focused specifically on pitching as one mechanism; focuses on a specific subject within technology entrepreneurship.

Based on our own review and synthesis of the literature, Table 2.4 provides an overview of the mechanisms, agencies, and outcomes, including concise definitions and the number of referrals from either the technology entrepreneurship literature or the entrepreneurial finance literature. Each referral corresponds to a single article. Appendix B provides more details about the underlying sources.

Table 2.4 Definitions of key mechanisms, agencies and outcomes of technology ventures

	Mechanism, Agency or Outcome (# of referrals)	Definition
Mechanisms	Signaling (49)	The better-informed party can send an information signal to the less informed party to reduce information asymmetries and help form opinions (Hoenig & Henkel, 2015)
	Resource acquisition (34)	The acquisition of different resources and capabilities required to develop and obtain sustainable returns over time (Fernandez-Alles et al., 2015)
	Social networking (20)	Social networking describes what social ties a person has and how this network influence how key decisions are made (Echols & Tsai, 2005)
	Diversity (19)	diversity reduces the risk of social conformity and group thinking, which may eventually lead to inefficient decision-making (Butticè et al., 2023)
	Knowledge spillovers (37)	An exchange of ideas among actors, typically in the form of coaching, sharing best practices, or imprinting (Paik & Woo, 2017)
	Building strong relationships (16)	Building strong relationships is the activity of economic actors, i.e., individuals, groups, and organizations that are embedded and nurtured in networks and webs of social relationships (Batjargal & Liu, 2004)
	Optimizing capital structure (7)	optimizing capital structure is the act to optimize the cost of a company's funds (Winton & Yerramilli, 2008)
	Intellectual property rights (19)	Brand assets, trademarks, copyrights, intellectual property, and patents that aide a venture to defend or attack its competitive position (Forti et al., 2020)
Agencies	R&D strategies (10)	The research and development of patents, trademarks, and copyrights to subsequently develop a product or service that can be commercialized (Mann & Sager, 2007)
	Commercialization strategies (16)	Commercialize new technologies to create significant value for stakeholders and gain legitimacy to increase access to resources and accelerate organizational growth (Petkova et al., 2013)
	Expanding team (19)	Acquire human capital to enable a timely execution to take advantage of early mover advantages (Davila et al., 2003)

	Mechanism, Agency or Outcome (# of referrals)	Definition
	Syndicating (20)	Augmenting the available financial resources: investors pool their means (e.g., resources, experience, and complementary skills) in order to increase deal financing, boost their performance and that of their portfolio firms, and foster the exchange of information between investors to reduce risk exposure (Milosevic et al., 2020)
	Requesting support (18)	Advance new innovative technologies toward a commercializable product or service (Park & Tzabbar, 2016)
	Fundraising & investing (102)	Attracting external capital or investing capital to commercialize unproven technologies (Hochberg et al., 2018)
	Alliance creation (16)	An alliance refers to an enduring relationship between ventures that share resources and coordinate value chain activities (Dushnitsky & Lavi, 2010)
Outcomes	Exit performance (17)	The company has been acquired or has been listed through an Initial Public Offering (Bottazzi et al., 2008)
	Funds (not) raised (74)	(Un)successful raising of funds for the ongoing operations of the enterprise (Hsu, 2007)
	Venture development (83)	The growth of a company in terms of number of employees or sales (Colombo & Grilli, 2010)
	Venture innovation (17)	The expansion of innovative capabilities and the generation of intellectual property rights thereof (Park & Steensma, 2013)
	Venture productivity (10)	The efficiency in the use of inputs (e.g., capital and labor) toward a certain output (Croce et al., 2013)

Figure 2.2 presents an integrated view of the eight core mechanisms identified in the literature, along with the associated agencies and outcomes. The CAMO lens, introduced earlier, suggests that actors navigating the valley of death (primarily entrepreneurs and investors) activate specific mechanisms through deliberate actions (Van Burg & Romme, 2014). These configurations give rise to distinct, often intermediate, outcomes that either advance or hinder the TV's progress.

At the center of Figure 2.2 are the eight mechanisms, each triggered by key agents and their actions. Entrepreneurs typically engage in R&D strategies, commercialization strategies, and team expansion (e.g., Davila et al.,

2003; Mann & Sager, 2007; Petkova et al., 2013). Investors more often initiate syndication and provide strategic support (e.g., Milosevic et al., 2020; Park & Tzabbar, 2016). Some actions, such as fundraising, investing, and alliance creation, are jointly undertaken by both parties (e.g., Dushnitsky & Lavie, 2010; Hochberg et al., 2018).

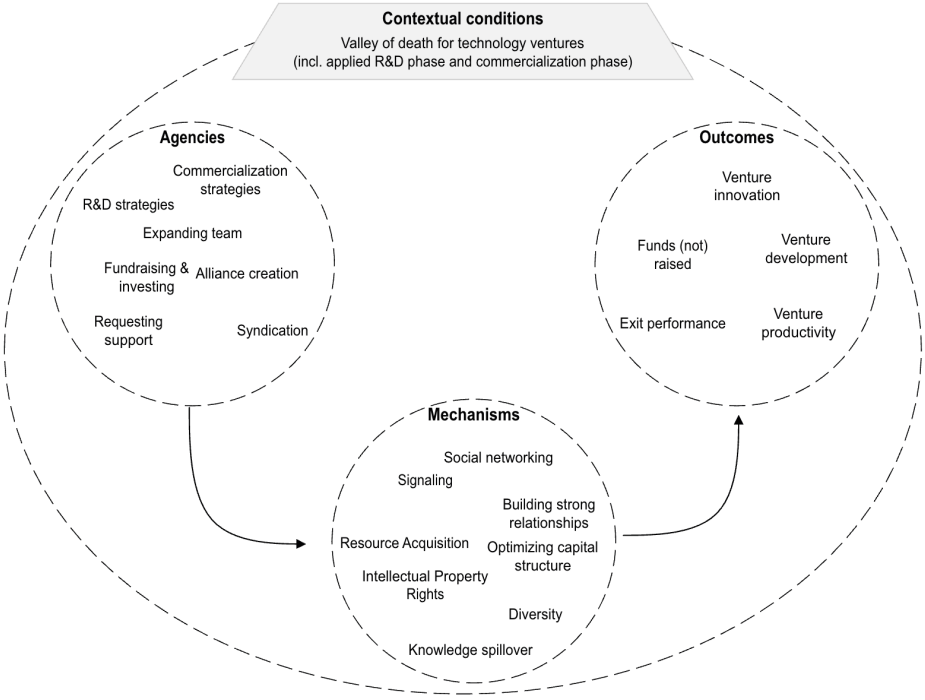


Figure 2.2 Conceptual framework of technology ventures in the valley of death

Notably, we decided not to include uncertainty (reduction) as a key mechanism, despite its central role in the literature (e.g., Makarevich & Kim, 2019; Matusik & Fitza, 2012). In this respect, uncertainty and uncertainty reduction are best conceived as pervasive systemic aspects of entrepreneurship, which cut across the various feedback loops mapped later in this section.

We also deliberately did not include industrialization (e.g., Zhang et al., 2024) as a core mechanism, because it is only relevant to a specific subset of TVs, especially deep-tech ventures exploiting breakthroughs in new materials and other hardware technologies (Arora et al., 2024). The industrialization mechanism does not fundamentally change the dynamics of the

synthesized framework presented later; it merely makes it more complex by adding another feedback loop.

The outcomes linked to the eight mechanisms vary by phase and disciplinary focus. For example, venture innovation is primarily observed during the applied R&D phase and in the technology entrepreneurship literature (e.g., Park & Steensma, 2013). In contrast, venture productivity and exit performance are more commonly associated with the commercialization phase and the entrepreneurial finance literature (e.g., Bottazzi et al., 2008; Croce et al., 2013). Some outcomes, such as venture development and funds (not) raised, span both phases and are addressed in both literatures (e.g., Colombo & Grilli, 2010; Hsu, 2007).

2.3.1 Mechanisms of technology venturing

Our review served to identify eight core mechanisms (see Table 2.4) that shape the trajectory of TVs as they navigate the valley of death. These mechanisms operate differently across the two phases, as the venture's priorities and challenges evolve over time.

Signaling. In the applied R&D phase, signaling helps a TV to reduce information asymmetries by communicating technological quality and legitimacy to external stakeholders. Common signals include patent filings, team composition, and early alliances (Block et al., 2014; Hoenig & Henkel, 2015) which are critical for attracting early-stage funding and partnerships (Guerini & Quas, 2016). In the commercialization phase, signaling shifts toward performance-based indicators such as revenue growth, customer acquisition, and VC backing (Petkova et al., 2013; Seigner et al., 2023). These signals affect follow-on funding, alliance formation, and exit readiness (Mohammadi & Khashabi, 2021).

Resource Acquisition. In the applied R&D phase, ventures rely on external sources, such as grants and resources from corporate partners, to access capital, infrastructure, and technical expertise (Dushnitsky & Lavie, 2010; Kolympiris et al., 2011). These resources are essential for building a viable product and organizational foundation. In the commercialization phase, the focus shifts to acquiring human capital and scaling capabilities, with VCs playing a key role in facilitating access to talent and supporting organizational development (Ouimet & Zarutskie, 2014; Haeussler et al., 2019).

Social Networking. In the R&D phase, social ties help ventures overcome the liability of newness and gain access to investors and partners (Wuebker et al., 2015; Colombo et al., 2022). Proximity to innovation clusters and prior affiliations further enhance funding prospects (Ferretti et al., 2022). In the commercialization phase, social networking becomes more investor-driven, supporting syndication and follow-on funding (Dimov et al., 2007; Zhang & Guler, 2020). Network centrality and prior collaboration history are key to forming effective investment coalitions (Dimov et al., 2007; Ozmel et al., 2013).

Diversity. In the applied R&D phase, diversity in founding teams, across gender, ethnicity, and experience, tend to enhance creativity and reduce groupthink, though it may also introduce bias in funding decisions (Franke et al., 2006; Butticè et al., 2023). In the commercialization phase, diversity within investor syndicates and leadership teams influences decision-making quality and exit performance (Gompers et al., 2016; Liu et al., 2023).

Knowledge Spillovers. Few studies address knowledge spillovers in the applied R&D phase, in which ventures benefit from alliances and incubators providing technological knowledge and regulatory expertise (Mathews, 2006; Wonglimpiyarat, 2016). In the commercialization phase, knowledge spillovers arise from VCs and corporate partners, which contribute strategic advice, operational support, and access to networks (Croce et al., 2013; Chemmanur et al., 2016). The venture's absorptive capacity moderates the effectiveness of this mechanism (Zahra & Hayton, 2008).

Building Strong Relationships. This mechanism spans both phases. In the R&D phase, trust-based ties with investors and partners influence funding decisions and alliance formation (Batjargal & Liu, 2004). In the commercialization phase, strong relationships enhance post-investment collaboration and knowledge transfer (De Clercq & Sapienza, 2006; Park & Tzabbar, 2016).

Optimizing Capital Structure. This mechanism emerges predominantly in the commercialization phase. As ventures begin generating revenue, they can reduce their reliance on equity-like capital and optimize financing costs by balancing equity, debt, and internal funds (Conti, 2018; Walthoff-Borm et al., 2018). Trade-offs are made by ventures in terms of value-added services from investors, ownership dilution, and availability and cost of cap-

ital (Deloof et al., 2019; Wu et al., 2016). These decisions affect governance, control, and strategic flexibility (Winton & Yerramilli, 2008).

2.3.2 Agencies in technology venturing

Agency here refers to both the actor (i.e., entrepreneur or investor) and its deliberate actions that activate mechanisms that (fail to) help overcome the valley of death. These actions differ across the applied R&D and commercialization phases.

R&D Strategies. R&D strategies are central in applied R&D, with the venture team being the key agent. Technology entrepreneurs develop intellectual property, such as patents and trademarks, to protect innovations and signal technological quality (Block et al., 2014; Mann & Sager, 2007). This outcome serves as a signaling function and a foundation for knowledge spillovers (Lahr & Mina, 2016; Veer et al., 2022). R&D strategies serve as signaling function for raising funds through showcasing sustainable differentiation and offering protection (Colombo & Shafi, 2016; Tumasjan et al., 2021). Thus, R&D strategies are especially relevant in the first phase.

Commercialization Strategies. Evidently, a commercialization strategy especially becomes important in the second phase, although preparations need to be made already in the first phase. The venture team predominantly engages in this action. Ventures engage in business planning, branding, and customer acquisition to gain legitimacy and accelerate growth (Petkova et al., 2013; Pontikes, 2012). These actions activate the signaling and social networking mechanisms and are critical for market entry and scaling (Kirsch et al., 2009; Makarevich & Kim, 2019).

Expanding the Team. Team expansion is relevant in both phases but shifts in focus, and is activated by the venture. In the R&D phase, it involves assembling a capable founding team with technical and entrepreneurial skills (Colombo & Grilli, 2010). As ventures mature, they must grow their teams to acquire new skills and scale operations. Thus, during commercialization, the emphasis moves to hiring experienced professionals and adapting organizational structures to support growth (Gerasymenko et al., 2006; Wasserman, 2003). Key mechanisms related to team expansion are resource acquisition, diversity, and signaling (Banerjee & Cole, 2012; Block et al., 2022; Butticè et al., 2023).

Fundraising & Investing. Fundraising and investing span both phases and represent the agency dimension that is most frequently observed (see Table 2.4). Both the venture and the investor are the agents here. Ventures seek capital to fund development and scaling, while investors deploy capital strategically to maximize returns and shape the venture's direction (Ayoub et al., 2017; Hochberg et al., 2018). This agency activates nearly all mechanisms, including signaling, resource acquisition, and optimizing capital structures (Aernoudt & De San Jose, 2020; Arqué-Castells, 2012; Conti, 2018).

Requesting Support. Requesting support involves venture teams proactively engaging investors, incubators or other partners for strategic, technical, or operational assistance. As investors also request support from their network, both the venture and investors can request support. This type of action is especially relevant when internal capabilities are limited. It especially activates the mechanisms of knowledge spillovers, resource acquisition, and building strong relationships (Croce et al., 2013; Fernandez Alles et al., 2015; Park & Tzabbar, 2016).

Alliance Creation. Alliance creation enables ventures to access complementary resources and coordinate value chain activities. Investors also create alliances through syndicates. Thus, venture teams as well as investors engage in alliance creation. Alliances are instrumental in acquiring resources, accessing knowledge, and building relational capital. They activate mechanisms such as resource acquisition, knowledge spillovers, social networking, and building strong relationships (Balachandran & Eklund, 2023; Dushnitsky & Lavie, 2010; Ferretti et al., 2022).

Syndicating. Syndicating is predominantly investor-driven. It facilitates co-investment, risk sharing, and knowledge exchange. Moreover, syndication enhances the diversity of expertise and facilitates knowledge exchange among investors. Syndication activates mechanisms such as signaling, diversity, and social networking, especially during the commercialization phase (Chahine et al., 2019; Makarevich, 2018; Wuebker et al., 2015). Syndicates with reputable lead investors are also associated with higher IPO probabilities (Kim & Park, 2021).

2.3.3 Outcomes of technology venturing

Outcomes are the tangible results of agency–mechanism interactions, but are also affected by the venture's exposure to capital market dynamics and competitive forces. In addition, these outcomes reflect different stages of venture progress and success.

Funds (Not) Raised. This is a critical intermediate outcome in both phases. It reflects the venture's ability to secure external financing, which is essential for survival and growth (Hsu, 2007). In the R&D phase, the signaling mechanism, via, for instance, patents, alliances and team experience, is key (Hoenig & Henkel, 2015). In commercialization, signals such as revenue traction and investor backing become more important (Wuebker et al., 2015). Gender, ethnicity, and cultural background have a potentially negative signaling impact on these outcomes (Brush et al., 2018; Zhang et al., 2016).

Venture Development. Venture development refers to organizational growth in size, structure, and capabilities. Venture development is primarily driven by resource acquisition and knowledge spillovers (Colombo & Grilli, 2010; Samila & Sorenson, 2010) as the main mechanisms. Ventures benefit from external knowledge through alliances, investor support, and peer learning (Fernhaber et al., 2009; Vanacker et al., 2013). Access to financial and non-financial resources, such as human capital, infrastructure, and networks, enables ventures to scale operations and professionalize their structures (Samila & Sorenson, 2010). Signaling also serves to enhance the venture's visibility and attractiveness to stakeholders (Cumming et al., 2024).

Venture Innovation. Venture innovation captures the ability to generate novel products, services, or processes, often reflected in the creation of intellectual property or the introduction of breakthrough technologies (Park & Steensma, 2013). This outcome is closely linked to knowledge spillovers and resource acquisition. Strategic alliances with corporates, corporate VC investments and VC coaching all contribute to enhancing a venture's innovative capacity (Dutta & Folta, 2016; Paik & Woo, 2017). Building strong relationships also plays a role, as relational trust facilitates the exchange of tacit knowledge and encourages experimentation (Park & Tzabbar, 2016). Additionally, a venture can optimize its capital structure, for instance by leveraging informal debt, to provide flexible financing that supports product innovation activity (Wu et al., 2016).

Venture Productivity. Venture productivity refers to the efficiency with which a venture transforms inputs, such as capital, labor, and knowledge, into outputs like revenue, products, or intellectual property (Croce et al., 2013). Knowledge spillovers and resource acquisition predominantly influence this outcome. Team expansion and alliance creation also contribute by enhancing operational capabilities and enabling more effective resource utilization (Kim, 2018; Mathews, 2006). Productivity gains are not only important for internal performance but also serve as signals to external stakeholders, reinforcing the venture's credibility and attractiveness.

Exit Performance. Exit performance, typically through acquisition or IPO, is the ultimate outcome for many ventures and investors (Bottazzi et al., 2008). This outcome is shaped by a combination of mechanisms, most notably signaling, resource acquisition, building strong relationships, and diversity (Gulati & Higgins, 2003; Useche, 2014). Diversity within the venture team and its (syndicate of) investors can also enhance exit outcomes (Matusik & Fitza, 2012; Liu et al., 2023).

2.3.4 Causal loop diagram of two phases in technology venturing

We now turn to describing and synthesizing the dynamic patterns of TVs moving through the valley of death. We draw on the CLD approach (Sterman, 2000) to synthesize key findings from the literature. Figure 2.3 visualizes the resulting CLD that provides a high-level overview of how a TV moves through the valley of death; that is, we deliberately chose to not develop an extremely complex representation of TV dynamics, but instead create a relatively straightforward CLD that captures the most salient variables and forces. In the remainder of this section, the various arrows and loops in this CLD are explained in a general sense, but we also provide more thick descriptions referring to more detailed causal effects and examples thereof.

The + and – signs connected to each cause-effect arrow in Figure 2.3 refer to positive versus negative effects from one variable to another. Most of these cause-effect relationships are non-linear in kind (e.g., so-called S-curves). The exception is the effect of Revenue & Profit on Fundraising Activities: this is an inverted U-curve, in which a growing revenue stream initially increases fundraising (due to signaling effects), until the targeted

level of revenue and profit is reached, after which fundraising activities decrease.

Notably, most cause-effect relationships in Figure 2.3 are stochastic rather than deterministic in nature; for example, a growing investment is likely to enhance the team quality (because the venture can more easily attract diverse talents), but not necessarily so. Stochastic relationships that refer to a relatively low to moderate level of probability are therefore depicted with a +/- in Figure 2.3. Moreover, various cause-effect relationships involve major time delays (indicated by double lines crossing the arrow in Figure 2.3), implying that the effect from A to B takes a significant time delay (i.e. at least half a year) to materialize. Stochastic cause-effect relations and time delays are intrinsic dimensions of the success and failure of TVs.

The various cause-effect relationships are combined in so-called feedback loops in Figure 2.3. Each feedback loop is either reinforcing or balancing in nature. For example, the feedback loop from investment via team quality, venture development, resource demand (and back to investment) is reinforcing in nature, if a growing level of investment positively affects team quality. But if team quality does not increase (or even decreases), despite investment growing, this feedback loop has a balancing impact. In other words, the stochastic nature of several arrows in Figure 2.3 imply that their intended effect may not materialize, which may change a reinforcing loop into a vicious one. For example, if the venture's CEO decides to invest only in the alliance and IPR portfolios (at the expense of investing in team quality), this may turn the feedback loop at the heart of Figure 2.3 from a virtuous into a vicious loop – with team quality decreasing, which in turn undermines venture development and reduces resource demand, and so forth.

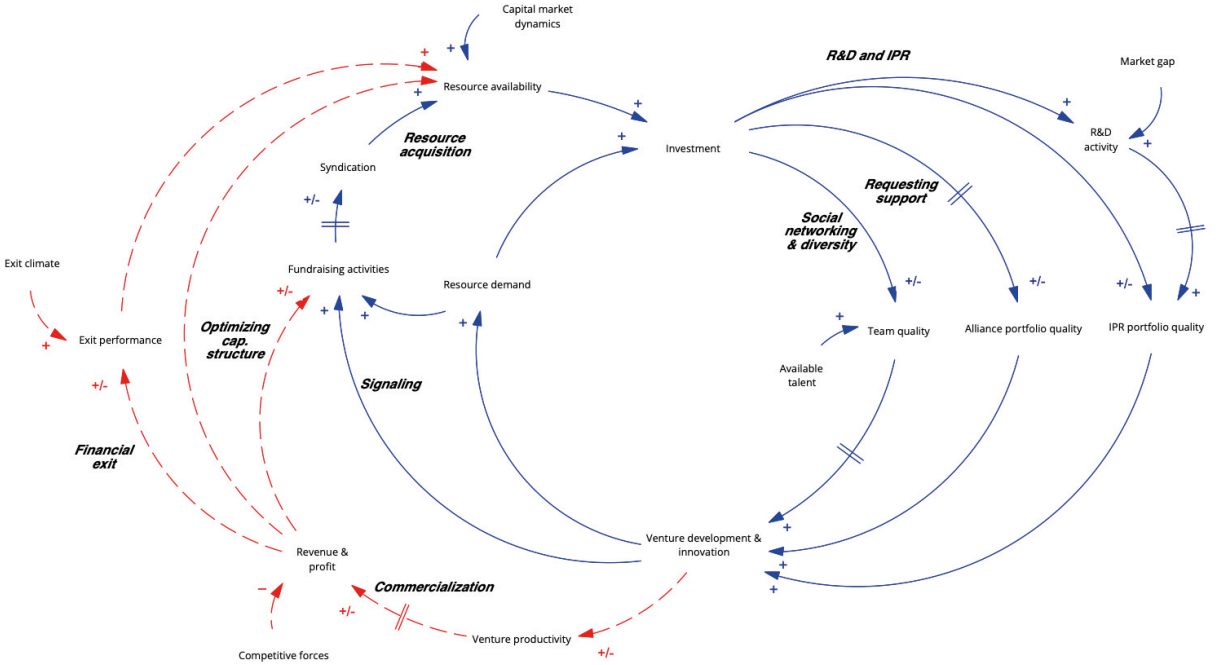


Figure 2.3 Causal loop diagram of technology ventures in valley of death (phase I operates on the solid/blue arrows; phase II involves the entire diagram, including the dashed/red arrows)

Subsection 2.3.5 covers the applied R&D phase (in the solid/blue arrows in Fig. 2.3), in which a TV predominantly focuses on venture innovation and progress by growing team quality, the portfolio of alliances, and the IPR portfolio. Subsequently, when the TV successfully progresses through this phase, it enters the commercialization phase in which the causal complexity of the TV grows – including the dashed/red arrows in Figure 2.3; we explore the commercialization phase in more detail in subsection 2.3.5. Accordingly, the second phase is characterized by the shifting focus toward commercialization, enabling optimization of the capital structure, and exit performance. The tipping point between the two phases is when the TV starts to sell a product, thereby entering the commercialization phase. This marks the shift in the TV's focus from innovation to productivity, revenue and profit. In subsection 2.3.6, we explore this tipping point in more detail.

2.3.5 Phase I: Applied R&D

The first phase of the valley of death is characterized by a set of feedback loops that center on the venture's internal development efforts. These include developing an IPR portfolio, building a high-quality team, and forming strategic alliances. As shown in the solid feedback loops of Figure 2.3, these mechanisms collectively drive venture innovation and (lack of) early-stage progress. The venture activates all three loops by means of investment.

At the heart of this phase is the TV's resource availability (created from fundraising activity and the syndicates arising from it), which enables the venture to invest in developing an *IPR portfolio*. A high-quality IPR portfolio does not arise from investments only, but also from relevant R&D activities. The venture can thus develop IPR in two ways (see Fig. 2.3): it can initiate R&D activities that, with a major time delay, serve to develop IPR, also in response to a perceived market gap (for the newly developed technology); but it can also buy or license IPR from others (De Rassenfosse & Fischer, 2016; Forti et al., 2020), as indicated by the direct arrow from investment to IPR portfolio in Figure 2.3. The resulting IPR portfolio operates both as a protective mechanism and a signal of technological quality to external stakeholders (e.g., Block et al., 2014; Hoenig & Henkel, 2015; Mann & Sager, 2007). The quality of the IPR portfolio enhances the venture's credibility and further development, thereby growing the strength of its signals in raising funds (e.g., Colombo et al., 2023; Zhou et al., 2016) and closing the IPR loop in Figure 2.3.

The second feedback loop is also driven by investment from available resources, but involves *building a portfolio of alliances* by the TV seeking support. That is, the TV forms partnerships to be able to access complementary resources and capabilities, which often compensate for internal limitations (e.g., Dushnitsky & Lavie, 2010; Mathews, 2006). These alliances with partners contribute to the TV's development and innovation, while also serving as signals to investors and partners (e.g., Gulati & Higgins, 2003; Hoehn-Weiss & Karim, 2014). The resulting increase in resource availability further fuels investment, which closes this loop in Figure 2.3.

Ventures also need to invest in team building, leveraging their *social networks and diversity* to improve their team quality (e.g., Butticè et al., 2023; Colombo & Grilli, 2010). This is the third feedback loop called social networking and diversity. A high-performing team contributes to venture development and innovation, which in turn strengthens the venture's signaling capacity, fundraising activity, and resource demand (see Fig. 2.3). This creates a reinforcing loop: stronger (weaker) teams tend to generate more (less) innovation that, in turn, attracts more (less) resources, which enables (inhibits) further team expansion (e.g., Davila et al., 2003; Haeussler et al., 2019).

The three feedback loops in phase I, IPR development, alliance formation, and social networking and diversity, all exploit the signaling mechanism toward external stakeholders. Signals such as patent filings (Block et al., 2014), team composition (Davila et al., 2003), and formalized alliances (Hoehn-Weiss & Karim, 2014) are pivotal in reducing information asymmetries and attracting funding (Guerini & Quas, 2016; Mohammadi & Khashabi, 2021). Successful signaling activates fundraising activities, which (if successful) replenish the stock of available resources, thus enabling further investment in the TV's development (depicting a stochastic relationship). Overall, entrepreneurs and investors interact to co-create specific deliverables in the fundraising and syndication activities in Figure 2.3, in a shared effort to increase the stock of available resources for their TV.

Any venture team will envision the dynamics of phase I to operate as a set of virtuous feedback loops: that is, a cycle in which internal progress enhances signaling, signaling attracts resources, and resources fuel further progress, thereby sustaining the venture's trajectory through the applied R&D phase. However, technology venturing is a highly selective

process (Arora et al., 2024; Vaznyte & Andries, 2019), in which ventures are exposed to capital market dynamics (see Fig. 2.3). Moreover, many cause-effect relationships in Figure 2.3 are stochastic in nature, implying that (despite all the efforts made) X may not produce Y. Accordingly, if a specific cause-effect relationship in one feedback loop fails to deliver the intended result, this transforms this loop into a vicious one, which in turn may also change the other loops into vicious cycles. For example, if the quality of the IPR portfolio is low and (despite substantial R&D activity) does not grow, this weakens the signals in the TV's fundraising activities, resulting in less funding (or no funding at all); consequently, less and less resources are available, in turn also causing difficulties in building the team and growing the alliance portfolio, which further reduce the quality of the signals to (potential) investors. This is a typical scenario of a TV getting stuck (i.e., failing) in the valley of death. Overall, the key challenge for any TV in phase I is to manage three reinforcing loops simultaneously in its efforts to increase (the signaling effects arising from) the quality of its IPR, alliances and human assets and thereby acquire sufficient external resources to fuel its growth.

Notably, some market engagement is already required in phase I to create attention from potential customers, validate (e.g., product-market fit) assumptions, and signal legitimacy (e.g., Petkova et al., 2013; Pontikes, 2012). However, commercialization is not yet the dominant logic in this early phase of the valley of death, because surviving it primarily depends on the ability to translate internal progress into credible signals that help to attract external resources.

2.3.6 Phase II: Commercialization

Once a TV transitions into the commercialization phase, the dynamics shift from internal development to market-exposure dynamics. In this phase, the venture must scale its operations, optimize its capital structure, and prepare for financial exit. Figure 2.3 visualizes these dynamics in an additional set of cause-effect relationships, indicated as dotted (red) arrows.

The process begins with market entry and initial scaling (Forti et al., 2020; Petkova et al., 2013), which increases venture productivity and generates an initial revenue stream. In the early stages of commercialization, when revenues are growing but profits do not yet materialize, the TV continues to rely heavily on external capital to sustain momentum. Here, progress in

commercialization operates as a signaling mechanism: revenue traction, customer acquisition, and operational scaling provide signals about the TV's progress and growth potential to investors (Petkova et al., 2013; Pontikes, 2012; Seigner et al., 2023); these signals reduce information asymmetries and support fundraising activities, which in turn enhance resource availability and enable further scaling of the venture. This signaling effect is stochastic in nature, because not all signals are picked up and embraced by the receiving parties or properly shaped by the sending party.

The signaling mechanism is especially critical during the pre-profit phase (the "Revenue & Profit" variable in Fig. 2.3, at this stage, thus primarily refers to revenue), in which external capital is required to bridge the gap between early market success and financial sustainability (Vaznyte & Andries, 2019; Wu et al., 2016). Figure 2.3 also emphasizes that competitive forces mediate the impact of the TV's development and innovation efforts and productivity improvements on its initial revenue stream; for instance, if competitors move faster in developing the technology and/or showcase a similar product of higher quality, (at least some) lead customers will buy products from these competing ventures, which will reduce (or even eliminate) the TV's revenues.

If the TV does not suffer from the latter problem but instead experiences a strong growth in its revenues (from a growing customer base), it at some point also starts boosting its profitability. This activates the arrow from revenue & profit to resource availability (see Fig. 2.3), because the TV can now also add its own profit to the resources available, which fuels investment, and so forth. At the same time, this reduces the TV's dependence on external capital, that is, it activates the "–" (minus) sign of the arrow from revenue & profit to fundraising activities. As explained earlier, the impact of revenue & profit on fundraising involves an inverted U-curve, in which a growing revenue (due to signaling effects) initially increases fundraising efforts until a substantial level of both revenue and profitability is reached, after which fundraising activities tend to decrease (cf., Conti, 2018; Walthoff-Borm et al., 2018). Together, these two cause-effect relationships drive the mechanism of *optimizing the capital structure* of the TV in Figure 2.3.

With a more balanced capital structure (i.e., profits as well as external capital), the TV continues to invest in the various assets at the right side of the

framework in Figure 2.3. For example, team quality remains a critical driver of venture success in phase II, but the focus shifts toward organizational design and leadership capabilities, that is, the TV expands its staff with skilled professionals capable of executing growth strategies (Ouimet & Zarutskie, 2014; Kim, 2018). VCs play a key role in shaping the venture team and other employees, often facilitating leadership transitions to align with commercialization goals (Gerasymenko et al., 2006; Wasserman, 2003). Moreover, the venture's evolving organizational structure and lifecycle maturity affect how effectively it scales and innovates and thereby reinforces investor signaling (Boeker & Wiltbank, 2005; Haeussler et al., 2019).

Similarly, the venture continues to invest in its portfolio of alliances, providing access to complementary resources and capabilities (Dushnitsky & Lavie, 2010; Paik & Woo, 2017), which support supply chain integration, customer acquisition, and so forth. If the TV seeks international expansion, the existing syndicate of investors may have to be extended to other (e.g., foreign) investors to create knowledge spillovers, comply with local regulations, and improve signaling credibility (Chemmanur et al., 2016; Christopoulos et al., 2022). The quality of the alliance portfolio (incl. syndication among investors) directly influences the TV's development and indirectly affects fundraising success and exit potential (Colombo et al., 2024; Gulati & Higgins, 2003).

The final set of relationships involves the VC investors' *financial exit* from the venture, typically by means of an IPO or an acquisition (see the arrows from revenue & profit to exit performance and from exit performance to resource availability in Fig. 2.3). The TV's signaling strength, resource base, and relational capital shape exit performance (Bottazzi et al., 2008; Useche, 2014). Potential buyers assess a venture's exit readiness based on indicators such as revenue growth, team maturity, and strategic alliances (Chahine et al., 2019; Gompers, 1996). The venture's team diversity can also influence exit outcomes, with more inclusive teams often achieving better performance (Liu et al., 2023; Matusik & Fitza, 2012). The exit loop is constrained by the prevailing exit climate (see Fig. 2.3); for example, the COVID pandemic negatively affected the exit climate, with VCs becoming more skeptical about investing in new ventures as well as potential buyers becoming more hesitant toward purchasing VC-backed ventures (Müller & Wöhler, 2023). Ultimately, only a few companies each year are sold as a

high-performance financial exit, showcasing the strong stochastic element in the exit loop.

In any case, TVs undergoing an exit are subsequently exposed to fundamentally different capital market dynamics (of the stock exchange in case of an IPO) or organizational logics (of the new mother company in case of an acquisition), implying that the CLD in Figure 2.3 no longer applies. In sum, phase II covers the entire CLD in Figure 2.3, with the venture's focus shifting from developing various assets to commercialization and financial performance. Many TVs do not survive the challenges outlined in Figure 2.3, with only a minority of cases successfully entering an IPO or being acquired.

2.3.7 Loop dominance

The CLD presented in Figure 2.3 consists of two overlapping but distinct phases: phase I (applied R&D) and phase II (commercialization). Each phase is governed by a distinct set of feedback loops, which differ in their impact over time. In phase I, a TV is predominantly inward-looking, focusing on building its IPR portfolio, alliances, and team. The three overlapping loops in this phase are mutually reinforcing and thus accelerate (or undermine) venture development and innovation, with various signals serving as cues to external resource providers. As emphasized earlier, some TVs experience these reinforcing loops as virtuous in nature (accelerating the path toward the commercialization phase), whereas these loops are increasingly vicious for most TVs, implying they die before (fully) getting to the commercialization phase.

As a more successful TV moves into the second phase, commercialization becomes its dominant logic. The feedback loops in this phase become more complex (covering all loops in Fig.2. 3), with various balancing factors also coming into play. For example, the causal relationship between profitability and fundraising follows an inverted U-curve: fundraising intensity increases with early revenue growth, but declines once a major level of profitability is accomplished and internal cash flows gradually reduce the need for (additional) external capital. The tipping point occurs when the venture begins to generate substantial revenue (i.e., beyond the sales of pilot products), marking the shift from product development to commercialization (Sterman, 2000). This transition reflects a change in *loop*

dominance (Walrave, 2016): the dynamic patterns of phase I give way to dynamics around productivity, scaling, and exiting.

Figure 2.4 illustrates this shift in loop dominance. The horizontal axis represents the time dimension and the vertical axis reflects the relative strength of the feedback loops of each phase. Phase I feedback loops (i.e. the solid arrows in Figure 2.3) initially prevail, but as commercialization progresses, phase II loops become more influential. As explained earlier, the dynamics of phase II also include the right half of Figure 2.3, so the shift in dominance primarily occurs from the signaling and resource acquisition forces to the commercialization and capital market optimization forces at the left side of this figure. This transition is non-linear and stochastic in nature; that is, ventures may oscillate between the two phases and/or experience setbacks on a single cause-effect relationship, which may turn most feedback loops into vicious patterns and outcomes. Overall, Figures 2.3 and 2.4 underscore the importance of timing, adaptability, and strategic reconfiguration in navigating the valley of death.

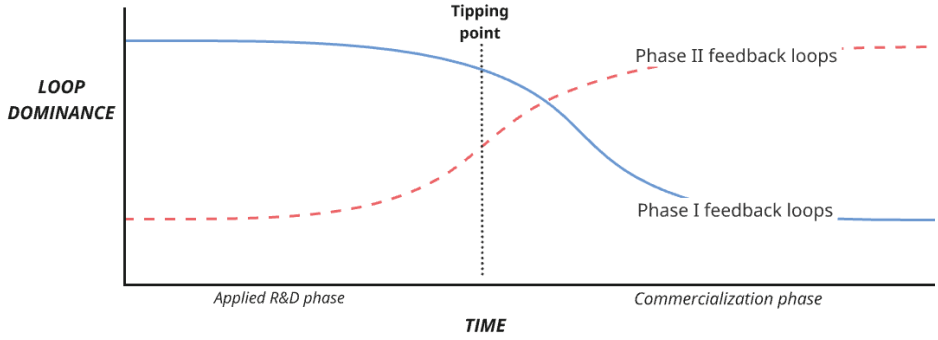


Figure 2.4 Loop dominance in the valley of death

2.4 DISCUSSION AND CONCLUSION

This study demonstrates that dynamic feedback loop interactions rather than isolated mechanisms drive TV success in the valley of death. This section serves to discuss the main contributions of this study. Moreover, we outline a research agenda informed by the main findings and insights arising from this paper.

2.4.1 Theoretical contribution

Our review and synthesis of two, largely disconnected, literatures generated a novel systemic framework that captures the dynamic interplay of TV mechanisms across two phases of the valley of death. By synthesizing 201 peer-reviewed studies into a single causal loop diagram (in Fig. 2.3), we move beyond more static representations of TV development toward a dynamic representation of the non-linear and path-dependent nature of TVs. This synthesis implies the valley of death is not merely a financing gap, but a dynamic tipping point governed by loop dominance; accordingly, reinforcing feedback loops in applied R&D must transition into balancing loops in the commercialization phase. The latter transition is not merely a temporal shift, but a co-evolutionary process in which ventures and investors jointly adapt their strategies, roles and expectations. Venture survival in the valley of death does therefore not so much depend on isolated mechanisms, but on the timing and orchestration of how mechanisms interact across phases. It also requires investors to move beyond transactional logic and engage in relational, capability-building behaviors. Importantly, our findings imply that investors must adopt a different logic in the applied R&D phase, one that prioritizes long-term capability building, relational mechanisms, absorptive capacity, and systemic signaling over short-term financial metrics. Our study thus reframes the valley of death as the transformation around a systemic tipping point, offering a new lens for understanding technology venture survival and failure.

This key contribution of our study also responds to Lu and Dimov's (2023) call for more dynamic theorizing and process-based explanations of entrepreneurial phenomena. In this respect, prior TV studies predominantly focused on single cause-effect relationships (Colombo et al., 2022; Gulati & Higgins, 2003; Liu et al., 2024) or a single context (Cerpentier et al., 2022; Crosetto & Regner, 2018; Shi et al., 2024), which limits opportunities to develop a deeper understanding of how mechanisms interact over time. For example, the distinction between the two phases in the valley of death helps explain why a life cycle perspective may be required (e.g., on venture teams) and why the organizational design of a venture has to evolve as it progresses from the applied R&D phase to the commercialization phase (Haeussler et al., 2019; Wasserman, 2003).

We synthesized the framework outlined in Figure 2.3 from two largely disconnected literatures (i.e., on technology entrepreneurship and entre-

preneurial finance) by mapping how venture teams and investors activate mechanisms to generate specific outcomes. The need for such an integrative perspective on entrepreneurship is increasingly recognized; for instance, recent reviews of the literature on entrepreneurial pitching demonstrate how the distinctive perspectives of the investor and the venture have shaped this literature (Kalvapalle et al., 2024; McSweeney et al., 2025). Our review and synthesis of the literature is broader in scope (i.e., the entire TV process across the valley of death) and systematically classifies causal relationships from both perspectives. The integration of these perspectives offers a more systemic understanding of how ventures and investors (fail to) co-create value across the valley of death.

Moreover, our study extends prior literature reviews (Cumming & Groh, 2018; Shepherd et al., 2019; Shepherd et al., 2021; Soto-Simeone et al., 2020) by systematically mapping the dynamic interplay of mechanisms across the TV's life cycle in the valley of death. This synthesis of the literature provides a systemic mechanism-based perspective on how ventures evolve, which also resonates well with the call by Patzelt et al. (2021) for more temporally grounded theorizing on the life cycles of entrepreneurial teams and ventures.

2.4.2 Practical contributions

Our findings offer several practical implications for entrepreneurs and investors navigating the valley of death. First, entrepreneurs can learn from our study that TV success depends not only on technology development, commercialization efforts, or securing funds, but also on orchestrating reinforcing feedback loops, particularly those related to signaling, team development, and alliance building. Early investments in intellectual property, team quality, and credible partnerships can strengthen signaling effects and improve access to capital in the applied R&D phase, which in turn helps the venture team to successfully cross the tipping point and thereby enter the commercialization phase.

Second, investors need to adapt their evaluation logic across phases. TVs in the applied R&D phase have to emphasize capability-building mechanisms rather than short-term financial metrics. Investors should therefore support these TVs by means of relational engagement, knowledge spillovers, and network access, which in turn reinforce the virtuous feedback loops

and thus increase the chance of successfully entering the commercialization phase.

Third, both entrepreneurs and investors should actively manage the transition between the applied R&D and commercialization phases. This transition represents a tipping point at which loop dominance shifts, requiring the venture to reconfigure toward scaling, revenue generation, and capital structure optimization. Misalignment of organizational capabilities at this stage can quickly turn the reinforcing dynamics in Figure 2.3 into vicious cycles. Both entrepreneurs and investors should understand it often also implies that venture teams need to be strengthened to ensure they manage these new dynamics effectively.

Overall, our framework suggests that successful navigation of the valley of death requires actions that strengthen positive feedback loops, while also mitigating the risks of adverse loop dynamics. Moreover, it implies that investors as well as entrepreneurs have to continually monitor the fit between the organizational skills of the TV team and the loop dominance at hand.

2.4.3 Limitations

Our review and synthesis of the TV literature has several limitations. First, our focus on peer-reviewed articles from a selected set of FT50 journals, supplemented with three domain-specific journals, may exclude relevant insights from the practitioner literature, policy reports, or other journals. Future reviews can broaden the scope to capture alternative perspectives, also from adjacent fields such as innovation policy or organizational behavior.

Second, the mechanism-based synthesis approach prioritizes causal explanation over statistical generalizability. While this approach enables integration across distinct research paradigms, it also limits the ability to quantify effect sizes or assess any publication bias. As such, complementary meta-analyses or configurational studies can help to validate and extend our findings.

Third, the conceptual framework outlined in Figure 2.3 is grounded in a review and synthesis of the literature, and thus is preliminary in nature. As a CLD, it can be further developed and tested in mathematical sim-

ulation models (Lu & Dimov, 2023; Walrave et al., 2011), which are also instrumental in developing a deeper understanding of the tipping point in Figure 2.4. Longitudinal empirical work may serve to empirically validate specific segments of these models. By developing elaborate mathematical simulation models, one can also assess in more depth how an additional feedback loop driven by the industrialization mechanism (e.g., Arora et al., 2024; Zhang et al., 2024) adds another level of complexity to the dynamics outlined in Figures 2.3 and 2.4.

Finally, the existing body of knowledge on TVs remains relatively young, fragmented, and skewed to a limited number of key variables. Many agency–mechanism–outcome relationships outlined in the previous section are underexplored or lack (substantial) empirical validation, and we can also readily assume that various relationships at the interface of finance and entrepreneurship are still unknown. This underlines the need for more extensive collaborative work between technology entrepreneurship and entrepreneurial finance scholars.

2.4.3 Moving forward: Future research avenues

Our synthesis of the extant literature on TVs in the valley of death points at critical gaps that warrant future work. We here outline four clusters of promising research avenues toward a more integrated and actionable body of knowledge on TVs. These avenues also resonate well with recent calls for dynamic theorizing (Lu & Dimov, 2023) and temporally grounded research (Patzelt et al., 2021). Appendix C outlines a more detailed list of future research questions for each mechanism.

First, the framework developed in this paper distinguishes between the applied R&D and commercialization phases, which helps to understand how various mechanisms shift in relevance and impact over time. Future research should empirically validate and develop new theory regarding this phase distinction, identify triggers, and explore how the timing of various mechanisms influences venture development. Moreover, future research can explore and test the non-linear dynamics and tipping points between maturity phases. Interesting questions in this area are, for example, how signaling strategies evolve from patent-based cues to performance-based indicators (Block et al., 2014; Petkova et al., 2013); and how the timing of team expansion or alliance formation affects venture outcomes (Haeussler et al., 2019; Wasserman, 2003). These research questions align well with

Patzelt et al.'s (2021) call for life cycle perspectives on entrepreneurial teams and organizational design.

Second, while prior work often isolates single cause–effect relationships and thereby overseeing systemic interplay (Colombo et al., 2022; Gulati & Higgins, 2003; Liu et al., 2024), the framework in Figure 3 highlights the importance of feedback loops and cross-mechanism interactions. Future research should therefore examine how various mechanisms reinforce or counteract each other. For instance, how do signaling and resource acquisition interact in early-stage fundraising (Guerini & Quas, 2016); and can knowledge spillovers amplify the effects of team diversity on innovation (Butticè et al., 2023)? Especially studies of how these mechanisms interact over time to enable TVs to move across the tipping point between phase I and II can strengthen our understanding of which strategies (do not) work. Scholars addressing these questions can draw on simulation models (Lu & Dimov, 2023) and configurational approaches to unpack these complex interdependencies.

Third, our synthesis of the literature suggests that investors and entrepreneurs jointly enact key mechanisms, yet their roles and influence vary across phases. Our synthesis shows that investors and entrepreneurs jointly shape venture development. Future research should explore how investor involvement shapes organizational design, team dynamics, and governance structures (Garg & Bingham, 2025; Gerasymenko et al., 2006). Co-evolutionary governance in TVs can be further investigated. Here, promising research questions are, for example, how VCs facilitate leadership transitions during commercialization (Wasserman, 2003) and how relational mechanisms such as trust and syndication affect venture development and exit performance (Christopoulos et al., 2022; Milosevic et al., 2020). These questions are central to understanding co-creation processes and outcomes in TV ecosystems.

Finally, methodological innovations may help to better map and understand various underexplored mechanisms, such as capital structure optimization (Hochberg et al., 2018), knowledge spillovers (Kang et al., 2021), and relationship building (Ferretti et al., 2022). Prior empirical work relies often on static hazard models and archival data. For instance, longitudinal data collection, mixed-methods, and mathematical simulation can be combined to capture the temporal and interactive nature of TV mecha-

nisms, agencies and outcomes. Moreover, future research should explore nascent mechanisms such as those in the area of governance (Krysta & Kanbach, 2022) and sustainability integration (Mansouri & Momtaz, 2022), which both are underrepresented in our literature review while being increasingly relevant in practice. In sum, the key mechanisms and synthesized framework developed in this paper offer a roadmap for future research, one that may also be instrumental in reducing the high failure rates of TVs.

2.4.4 Concluding remarks

In this paper, we reviewed and synthesized the extant literature on how mechanisms shape TVs outcomes across the valley of death. By synthesizing two separate literatures, we developed a mechanism-based framework in the form of a causal loop diagram that captures the dynamic interplay of agencies, mechanisms, and outcomes across two distinct phases. Our findings contribute to a more evidence-based and actionable understanding of TVs. The resulting framework may serve as a foundation for empirical and theoretical work in this area as well as more fine-grained mathematical models of how TVs succeed or fail. Beyond theoretical contributions, this study also generates actionable insights for entrepreneurs and investors regarding the importance of timing, coordination, and managing feedback loop dynamics in navigating the valley of death.

List of abbreviations Chapter 2

CAMO: Context-Agency–Mechanism–Outcome
CLD: Causal Loop Diagram
CVC: Corporate Venture Capital
IPR: Intellectual Property Rights
R&D: Research and Development
TV: Technology Venture
VC: Venture Capital (fund or firm)

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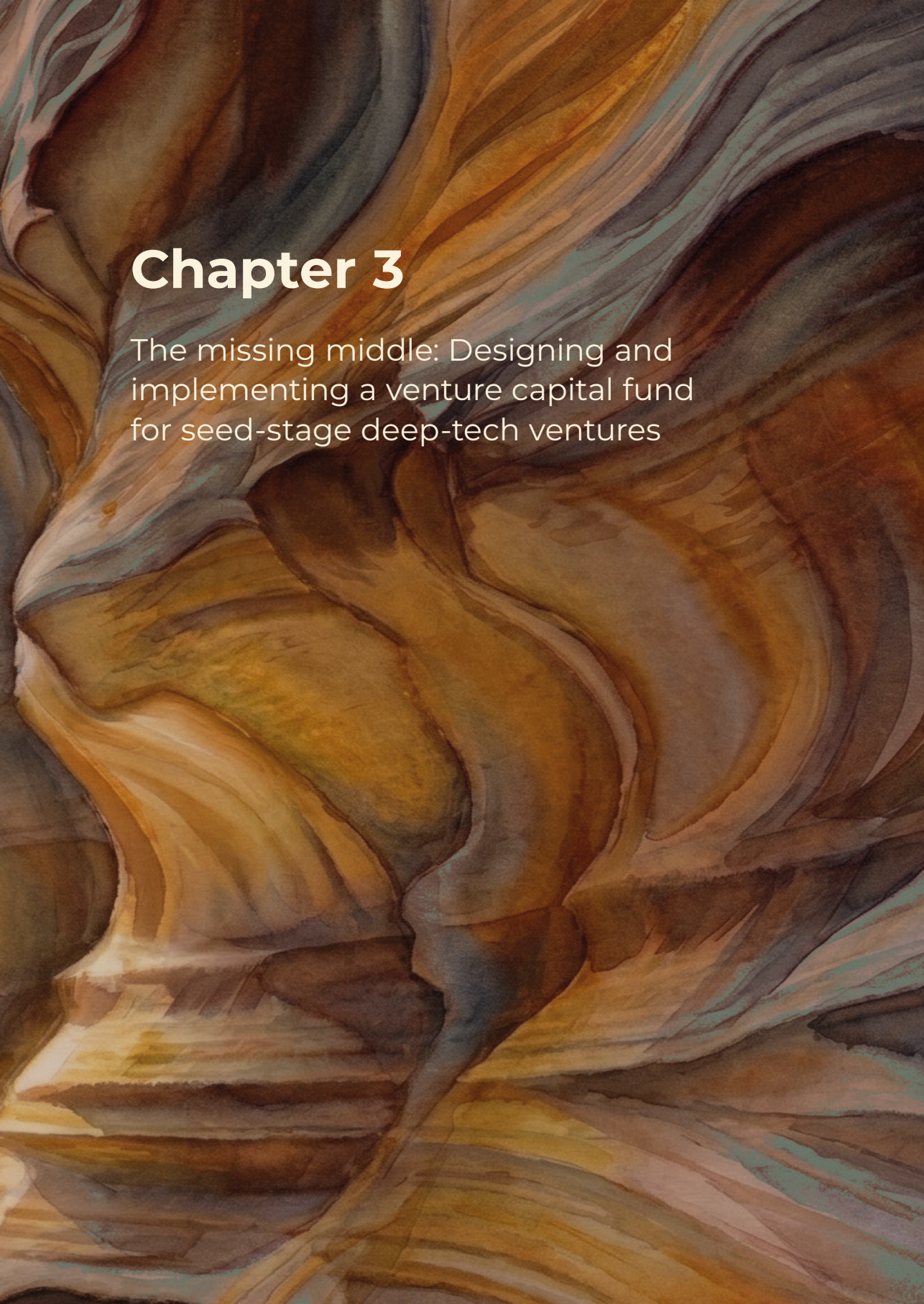
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Chapter 3

The missing middle: Designing and implementing a venture capital fund for seed-stage deep-tech ventures

ABSTRACT

Deep-tech ventures draw on technological breakthroughs in, for example, new materials, photonics, mechatronics, quantum computing, and nanotechnology. These ventures can help solve major societal challenges but, especially in Europe, they face significant barriers in raising capital and require significantly more time between funding rounds. These barriers arise from a capital supply-demand gap, also known as the 'missing middle' (or valley of death) of deep-tech entrepreneurship. Focusing on the supply side of this gap, we adopt a design science (DS) approach to craft a venture capital fund dedicated to deep-tech ventures in the seed-funding stage. The DS approach implies we iteratively move from problem analysis to creating and evaluating the solution, until a substantial number of investors have committed capital to this solution. The final solution is a venture capital (VC) fund that draws on an ecosystem-driven approach to provide seed-stage funding to deep-tech ventures. Subsequently, we theorize the main findings into two design propositions. Our study contributes to the extant literature by providing the detailed blueprint of a VC fund for investing in deep-tech ventures, one that can attract capital from investors and thereby fill the missing middle in the funding landscape. This chapter also has important practical implications such as the fund's economic life of 15 years and the power of a multi-disciplinary investment team.

Keywords: entrepreneurship; design; artifact; venture capital; deep-tech; impact investing.

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3.1 INTRODUCTION

Deep-tech ventures seek to commercialize novel technologies in, for instance, advanced materials, quantum computing, photonics, mechatronics, and precision electronics (Arora et al., 2024; Redmond, 2021). Examples include Bell Labs, RTX (formerly Raytheon Technologies), ASML and Tesla in their earliest stages. These ventures draw on breakthrough technological inventions that have a strong research base, face a long time to market, and often require heavy industrialization processes. Deep-tech ventures (DTVs) therefore face both technological and commercialization challenges and typically also need to build an extensive ecosystem of co-creating suppliers, complementors and/or distributors (Arora et al., 2024; De la Tour et al., 2017; Hello Tomorrow, 2021; Redmond, 2021). Consequently, their (pre-revenue) research and product development activities are extremely capital intensive and take significantly longer between funding rounds, compared to other technology-driven ventures (Bobier et al., 2023; De la Tour et al., 2017; Redmond, 2021).

Newly created DTVs thus face huge barriers in raising capital, despite their enormous potential for solving grand challenges in, for example, energy storage and food production. Arora et al. (2024) call this the *missing middle* of financing deep-tech entrepreneurship, also known as the valley of death, that is, "the financing gap between development of science and development of commercial products" (Barr et al., 2009, p. 371). This missing middle phenomenon results in many opportunities for (creating) DTVs remaining undeveloped and unexploited. It is characterized by major risks with regard to technological complexity (Tassey, 2014), access to financial resources (Barr et al., 2009), and developing a substantial market volume (Fisher et al., 2016) and therefore results in significant levels of negative cash flow and high failure rates, due to the large gap between demand and supply of capital (Jääskeläinen et al., 2007; Wilson & Silva, 2013; Wright et al., 2006).

In this respect, the few venture capital (VC) funds that are dedicated to deep-tech ventures tend to focus on series A and subsequent stages (Dealroom, 2023); consequently, the supply of seed-capital for DTVs is rather low. Moreover, compared to other (e.g., software-based) startups, the lifetime distribution of capital needs of DTVs is reversed, that is, they require substantially more capital in their earliest stages (Hello Tomorrow, 2021). Thus, the capital needs of DTVs peak in the pre-commercialization stage, which

is the least attractive stage for the supply-side (i.e., investors). This gap between capital demand and supply for young DTVs is especially evident in Europe (Atomico, 2023; Invest Europe, 2023).

The extant literature on the supply side of VC funding focuses on venture-funding dynamics, investment processes and financial returns (e.g., Wu et al., 2016) and governance structures, investment theses, and fundraising trajectories of VC funds (e.g., Nacke & Seckler, 2023; Sahlman 1990). VC funds use a standardized governance structure, and the investment thesis (also called investment strategy) therefore is the competitive edge for raising capital from investors (Nacke & Seckler, 2023). However, the literature provides hardly any instrumental knowledge about how VC funds should raise capital (Nacke & Seckler, 2023) and thereby help resolve the missing middle of seed-stage DTVs. This raises questions about how a VC fund dedicated to seed-stage DTVs can be effectively designed to attract large investment volumes; and whether one can codify such a solution and its underlying assumptions, to enable others to replicate and adapt it to other contexts. Here, the primary design challenge therefore is designing a fund structure that can successfully raise capital for investing in seed-stage DTVs, to address the missing middle problem outlined earlier. This chapter therefore explores *how a venture capital fund exclusively focused on seed-stage DTVs can be designed, implemented and codified*. We address this question in the European context, characterized by a low supply of capital for seed-stage DTVs.

We address this question by adopting a design science approach (Berglund, 2021; Dimov et al., 2023; Simon, 1996) to iteratively create and evaluate the design of a new VC fund and theorize the key findings into design propositions (Denyer et al., 2008; Romme & Dimov, 2021). Design science is a methodology at the interface of creative design and explanatory science (Holmström et al., 2009; March & Smith, 1995), which enables practitioners and scholars to team up in designing and evaluating solutions for major societal challenges.

This study contributes to the literature by developing and demonstrating the design of a VC fund for seed-stage DTVs, which helps to fill the missing middle in the deep-tech funding landscape (Arora et al., 2024; Nacke & Seckler, 2023). The design of this investment thesis and vehicle is instantiated in a €118M venture capital fund, called *DeepTechXL*. Theoretically,

DeepTechXL's design is codified in a set of design requirements and propositions, as a body of instrumental knowledge (Dimov et al., 2023; Romme & Reymen, 2018) for developing similar VC solutions elsewhere. Our study also has several practical implications in the area of, for instance, the fund horizon of 15 years and the power of an multi-disciplinary investment team.

The next section describes the design science methodology. The third section reports the main findings. The last section then serves to discuss these findings.

3.2 METHODOLOGY

In this section, we first describe the methodology adopted, then outline the empirical setting of this study, and finally describe how data was collected and analyzed.

3.2.1 Design science

This chapter draws on a design science approach (Dimov et al., 2023; Romme, 2003; Van Burg et al., 2008), a methodology that best fits the practical and normative thrust of our research question. Simon (1996) advocated design science (DS) by arguing that business research is about designing systems that do not yet exist or redesigning existing systems to improve their performance. Accordingly, DS is strongly oriented toward problem solving, that is, it serves to develop evidence-based solutions and instrumental knowledge (Denyer et al., 2008; Van Burg et al., 2008).

There are several ways to visualize and describe a DS cycle (e.g., Romme and Reymen, 2018; Tuunanen et al., 2024). In this study, we adapted the DS cycle proposed by Romme and Reymen (2018) and Dimov et al. (2023). The resulting cycle is outlined in Figure 3.1:

1. *analyzing* the problem and formulating *design requirements*;
2. *creating* and *evaluating* a solution design; and
3. *theorizing* the main findings in terms of *design propositions*.

As is evident from Figure 3.1, the first and middle parts of the cycle are highly iterative in nature, allowing the design team to go back and forth, also in view of new learnings and insights obtained (Romme & Reymen,

2018). The remainder of this section describes the three stages in Figure 3.1 in more detail.

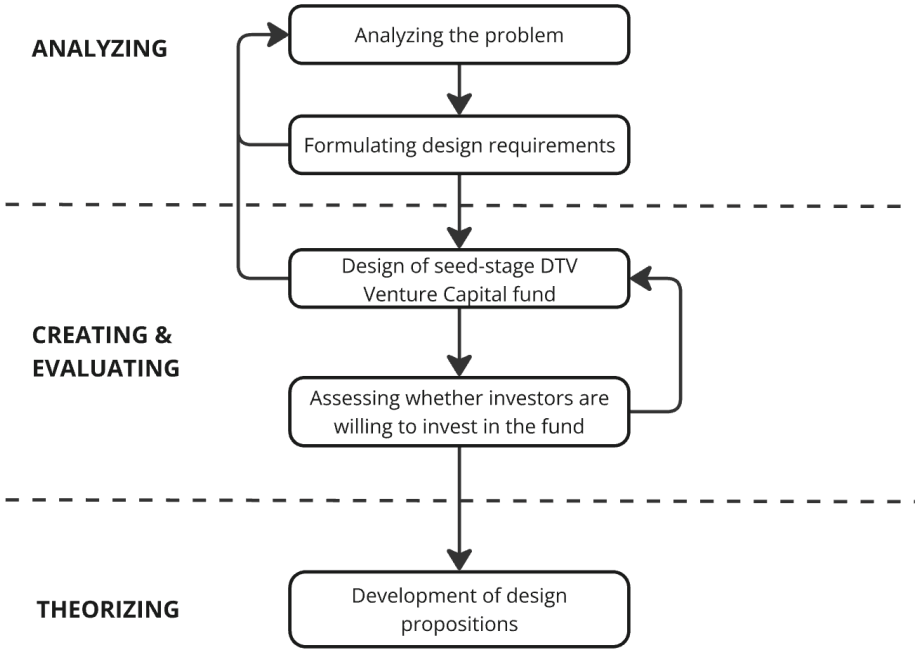


Figure 3.1 Design science cycle

Analyzing the problem. The creation phase started with analyzing the problem, that is, the gap between supply and demand of seed-stage capital for DTVs in Europe. The main findings of this problem analysis were subsequently synthesized in a set of design requirements, which informed the next phase.

Creating and evaluating. Based on the design requirements, we created an initial solution design. The (initial) solution design was iteratively evaluated with potential investors. The primary aim of the evaluation was to assess the solution design against criteria such as usefulness, feasibility, and viability (Romme & Reymen, 2018). As such, the evaluation of the solution is a central and critical part of any DS cycle (Tremblay et al., 2010; Venable et al., 2016). We followed an evaluation strategy with two 'levels of granularity' (Sun & Kantor, 2006; Venable et al., 2016) by evaluating (1) whether investors are interested to invest in a VC fund operating in the

missing middle for DTVs and (2) whether this leads to a successful closing of the fund. This evaluation strategy serves to establish whether the solution is relevant and viable for investors.

Theorizing. We subsequently theorized our insights and learnings in the form of a set of design propositions. Design propositions can synthesize the extant literature into guidelines for creating solutions for specific problems, but are also instrumental in codifying insights emerging from practice (Gauss et al., 2024; Romme & Endenburg, 2006). In this study, design propositions serve the latter purpose. These design propositions have to be as *complete* as possible, rather than merely novel (Romme & Dimov, 2021). More specifically, our design propositions draw on the so-called CAMO format: if in context C, agency A activates mechanism M, this is likely to generate outcome O (Dimov et al., 2023; Romme & Dimov, 2021). This type of proposition can also be formulated in a more actionable way: in context C, agency A should activate mechanism M to generate outcome O. A design proposition thus explains the outcome from a specific CAM combination, in which the Mechanism is the key causal driver, the Agency is the activator of this cause, and the Context delineates the boundary conditions (Romme & Dimov, 2021). Therefore, a design proposition is descriptive-explanatory as well as prescriptive-normative in nature, which allows others to test it elsewhere while also informing (future) practical design work.

3.2.2. Empirical setting and design team

This study was conducted in collaboration with a DTV builder in the Netherlands, which sources deep-tech inventions from CERN (European Organization for Nuclear Research), European Space Agency, University of Copenhagen, and other research institutes in Europe to create impactful DTVs (Romme et al., 2023). At the time, this DTV builder faced a substantial lack of financial resources for DTVs operating in the seed-stage.

The design team involved three 'insiders' in this DTV builder and an academic 'outsider.' Following Bartunek and Louis (1996), an insider-outsider team benefits from the insiders' closeness to the problem studied as well as the outsiders' efforts to keep the process transparent and evidence-based. In our case, the lead author of this chapter was fully engaged (as an insider) in all phases outlined in Figure 3.1. Two other coauthors, as insiders, made substantial contributions to the creation and evaluation

phase; and the academic outsider mostly contributed to the problem analysis as well as theorizing efforts.

3.2.3 Data collection and analysis

Data was collected via interviews, focus groups, and documents in a period of more than three years. The interviews and focus groups primarily served to create and discuss (subsequent versions of) the design solution and evaluate them with potential investors. In total, we interviewed 72 persons using a semi-structured interview protocol (see Appendix D), in line with previous work in this area (e.g., Nacke & Seckler, 2023). The majority of interviewees were institutional investors and informal investors (incl. family offices), also because they constitute the main investors in European VC funds. We also interviewed representatives from both large companies and institutional investors as well as various VC experts. In addition, we conducted two focus groups to enable intersubjective dialogues on the proposed solution. We selected the interviewees as well as participants in the focus groups on the basis of convenience sampling (Saumure & Given, 2008), using our direct and indirect personal networks to identify suitable candidates. Table 3.1 provides an overview of the interview and panel data. The focus groups were primarily used to feed the creation phase. The interviews were analyzed to feed both the creation and evaluation phase (see section 3.2.1).

Table 3.1 Overview of participants in interviews and focus groups

	Interviews	Focus group I	Focus group II
Institutional investors	28	8	1
Corporate investors	9	1	2
Informal investors and family offices	32		
Representatives of research institutes	3		1
Total # of participants	**72**	**9**	**4**

We also studied more than 70 documents, including annual reports and slide sets of (potential) investors as well as the minutes of meetings of relevant committees and boards, such as the advisory board of the new VC fund created.

3.3 FINDINGS

We report the main findings of each phase in Figure 3.1 in this section. Subsection 3.3.1 presents the problem analysis. Subsequently, the creation and evaluation of the solution design is described (in 3.3.2) and the main findings are theorized in design propositions (in 3.3.3).

3.3.1 Problem analysis and design requirements

In this section, we outline the extant literature about the missing middle for DTVs to formulate a set of design requirements. We start by defining the missing middle from the perspective of the demand side, then focus more extensively on its supply side, and combine these insights to define the missing middle in more detail. Finally, we formulate several design requirements for a VC fund dedicated to seed-stage DTVs.

3.3.1.1 Demand side of the missing middle

At the demand side, seed-stage DTVs face three major challenges. First, they face very high levels of technological complexity in developing their products and systems (Murphy & Edwards, 2003; Tassey, 2014). Second, DTVs have a long time-to-market of at least three to five years, but often much longer. During this period, these ventures require major investments in resources for product development and related activities, but without being able to provide any significant evidence of commercial traction (Barr et al., 2009; Branscomb et al., 2000; Savanevičienė et al., 2015). DTVs therefore also typically require a longer period—that is up to 40 percent longer—between funding rounds than other technology-driven ventures (Bobier et al., 2023). Third, a DTV typically needs to develop an extensive (often novel) innovation ecosystem around its value proposition; this ecosystem typically includes multiple suppliers (of essential components) and other partners that co-create key assets or necessary conditions for the value proposition to materialize (Walrave et al., 2018). This creates a major collaborative risk for the focal DTV, in the sense that if one key supplier or partner cannot deliver, the DTV is likely to fail (Walrave et al., 2018).

To address these three major challenges, seed-stage DTVs need large amounts of seed funding (Arora et al., 2024), which in fact reverses the lifetime distribution of their capital needs compared to other ventures (Hello Tomorrow, 2021), as already observed in the Introduction section. That is, the capital needs of DTVs peak in the pre-commercialization stage (Arora

et al., 2024). However, a DTV that attracts too much equity funding in the seed-stage can suffer from major valuation and dilution issues, which tend to reduce the commitment of venture team members that own equity as well as make the venture less attractive for other investors to join (Nacke & Seckler, 2023; Winton & Yerramili, 2008).

3.3.1.2 Supply side of the missing middle

The main resource providers in the missing middle for DTVs are informal investors and VC funds. *Informal investors* (also known as angel investors) are wealthy individuals (Baldock & Mason, 2015; Hellmann & Thiele, 2015) that only have small amounts of (their own) capital available; they also tend to have a lower impact on venture performance, compared to VC funds (Chemmanur & Chen, 2006; Dutta & Folta, 2016; Schwienbacher, 2007). Moreover, most informal investors lack experience in deep-tech engineering and are more risk averse due to the limited size of their portfolio (Lerner et al., 2018; Wright et al., 2006). Interestingly, the average amount invested per informal investor as well as the number of active informal investors per company has been declining (Shane & Nicolaou, 2018).

VC funds typically adhere to a standard structure and governance approach, which have remained unchanged for many decades (Sahlman, 1990). These include a standard legal structure (i.e., limited partner agreement), general partner contribution, takedown and distribution schedules, compensation, reporting requirements, decision-making committees, and a pre-set economic life of the fund. This standardization enables limited partners (investing in VC funds) to reduce the perceived risk arising from governance issues. VC funds can either be open-ended (i.e., no fixed term to invest and divest) or closed-end (i.e., fixed term to invest and divest) (Nacke & Seckler, 2023).

VC funds are widely recognized as a key source of equity financing for startup companies, especially those using intellectual property assets (Drover et al., 2017; Gompers et al., 2020; Hsu, 2007; Samila & Sorenson, 2010). Contrary to most other equity-shareholders or debtholders, they operate as active investors that provide their portfolio companies with value-added activities (Block et al., 2019). That is, a typical VC fund not only provides support in terms of recruitment, strategizing, and (access to) networks, but a VC investment also constitutes a powerful signal regarding the venture's growth potential because VC funds only select around 1% of

all investment proposals (Ragozzino & Blevins, 2016). However, these funds typically avoid the seed-stage as well as complex technologies (Block et al., 2019; Invest Europe, 2023) and thus predominantly focus on ventures that are software-driven and/or produce consumer products (Lerner & Nanda, 2020).

VC funds need a specific investment thesis to create a competitive edge in the eyes of (potential) fund investors. This investment thesis typically depicts how the fund sources investments, makes deals, and how it supports its investments better than other VCs (Nacke & Seckler, 2023). Moreover, most investors only become interested in a VC fund when it is likely to generate a competitive financial return (>20% annual return) and satisfies ESG criteria; corporate investors especially also look at a VC fund as a medium to spot innovation trends (Nacke & Seckler, 2023).

Although the VC industry has significantly grown, it still is negatively biased toward the earliest stages of technology-driven (incl. deep-tech) ventures (Arora et al., 2024; Lockett et al., 2002). This general sense of unattractiveness of seed-stage ventures arises from very high risk and uncertainty levels and the lack of expertise on seed-stage investments in many VCs; another factor that makes seed-stage ventures unattractive are the invisible fixed costs in effectively screening and selecting ventures and monitoring each investment (Dimov et al., 2007; Lockett et al., 2002; Patzelt et al., 2009; Schwienbacher, 2007). In addition to these more general conditions, the incentives to invest in highly innovative seed-stage DTVs are rather weak, due to the dynamics of extremely high cash demands as well as significant technological, commercial, and collaborative risks (see section 3.3.1.1).

The scarcity of funds for seed-stage DTVs is also driven by the increasing size of most VC funds, with an investment in a seed-stage venture requiring disproportionally high deal-making and monitoring costs; the latter costs, in turn, arise from the organizational and contractual techniques used by the VC industry to address high levels of uncertainty and information asymmetry (Dimov et al., 2007; Gilson, 2003; Lockett et al., 2002; Metrick & Yasuda, 2011). As a result, Invest Europe (2019; 2020; 2021; 2022; 2023) observes that only 1% of all VC investments are in seed-stage ventures, with an average deal size of €700K. Moreover, while the global VC market has been strongly growing (Wagemans & Schram, 2020), Europe

invested less in (pre-)seed companies in 2019 than in 2010. Access to capital therefore remains a critical concern for European startups, including DTVs (Atomico, 2023), which the European Union recently acknowledged by appointing a commissioner dedicated to startups and scaleups.

3.3.1.3 The missing middle defined

The missing middle can now be defined in more detail, based on the exploration of its demand and supply side dimensions thus far. The extant literature defines it in two distinct but complementary ways. First, some authors define it at the *macro-level*, in terms of the funding gap between the development of scientific and technological inventions and their subsequent development into commercial products (Barr et al., 2009; Romme, 2022; Tassey, 2014). This macro-level notion serves to explain that many opportunities (e.g., arising from technologies developed at research institutes) for creating DTVs remain unexploited (Arora et al., 2024). But it also explains why DTVs tend to be severely resource-constrained and therefore often fail in their nascent stages (Barr et al., 2009).

A second way to define the missing middle is from the perspective of a *single venture*'s cash flow development over time (Mason, 2018; Savanevičienė et al., 2015). This notion is typically adopted in the VC literature (Invest Europe, 2016). For example, Mason (2018) defines the valley of death as a relatively long phase of negative cash flow resulting from investments in research, product development, and marketing before any revenue and profits are generated—also known as the J-curve (Mason, 2018; Savanevičienė et al., 2015). This perspective on the missing middle serves to understand how ventures, starting with some initial funding, can run into severe (cumulative) cash flow problems, which often motivate the investors to abandon them.

Figure 3.2 combines both perspectives on the missing middle for deep-tech inventions and ventures. The solid curve represents the macro-curve of available resources (connected to the vertical axis on the left) and the dotted curve represents a typical cash flow scenario at the level of a single DTV (i.e., the vertical axis on the right). This figure demonstrates that the two curves draw on different timelines in the x-axis. The macro-curve traces the development of a rough idea about new basic principles (e.g., developed in university labs) until these principles have been fully operationalized in a commercial product (Barr et al., 2009; Tassey, 2014).

The cash-flow curve, however, assumes that the proof of concept of the new technology is available (Mason, 2018). Figure 3.2 synthesizes these two horizontal axes via the Technology Readiness Level (TRL) scale (Mankins, 2009), a nine point-scale for determining the maturity of an invention and its readiness for market uptake and potential investments (Belz et al., 2025; EARTO, 2015; European Commission, 2014; Hensen et al., 2015). We adapted this scale to the DTV context (see Appendix E for the full scale used).

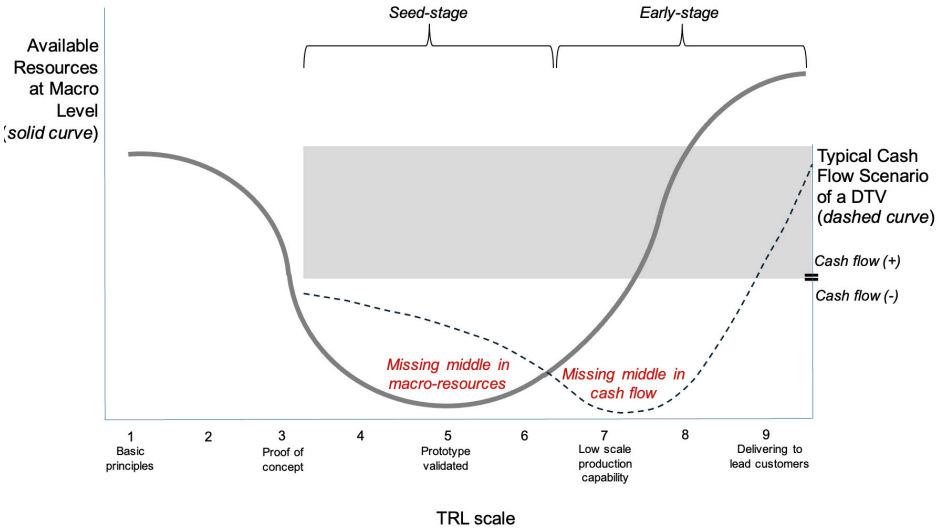


Figure 3.2 The missing middle from a macro-resource as well as a single venture perspective

The available data on the VC industry is somewhat limited and its reliability is questionable (Retterath & Braun, 2020). For example, Dealroom (2023) states that a total of $17.7B was invested in European DTVs in 2022, while Invest Europe (2023) writes that a total of €18.2B was invested in all European startups in 2022. Dealroom (2023) also reports there are 10 dedicated deep-tech VCs in Europe, which each have a fund size of more than €100M, but these VCs predominantly focus on series A and subsequent investment rounds, that is, starting from the early-stage (as defined above).

The two curves in Figure 3.2 demonstrate that the missing middle from a macro-resource perspective especially runs from TRLs 3-4 to TRL 7, whereas it extends to TRLs 8-9 in terms of cash flow development of a single DTV. These two versions of the missing middle are complementary, in the sense that their combined visualization provides a deeper understanding

of the macro- and micro-dynamics of the missing middle. As indicated in Figure 3.2, the entrepreneurial finance literature (Block et al., 2019; Ritter, 2015) labels the time-to-market and maturity level of a company in terms of the *seed-stage* (cf., TRL 4-7 in Fig. 2), *early-stage* (cf., TRL 7-9) and *later-stage* (cf., beyond TRL 9).

The available data on the VC industry is somewhat limited and its reliability is questionable (Retterath & Braun, 2020). For example, Dealroom (2023) states that a total of $17.7B was invested in European DTVs in 2022, while Invest Europe (2023) writes that a total of €18.2B was invested in all European startups in 2022. Dealroom (2023) also reports there are 10 dedicated deep-tech VCs in Europe, which each have a fund size of more than €100M, but these VCs predominantly focus on series A and subsequent investment rounds, that is, starting from the early-stage (as defined above).

Moreover, investing in deep-tech is also rather challenging because it requires in-depth knowledge of various complex technologies (Dealroom, 2023). Specialized VCs therefore tend to perform better than their general counterparts (Gompers, 1995), because they do not have to make any trade-offs between DTV propositions with long holding periods and high risks and other propositions with relatively short holding periods and limited risks.

In sum, the financial challenges for DTVs in overcoming the missing middle are huge. That is, resources of informal investors cannot provide the capital volume required as of TRL 4, whereas VC funding—often combined with debt in the form of bank loans—especially becomes viable when the TRL is at least 7 (i.e., early-stage funding). Thus, a major funding gap for DTVs exists at the seed-stage, between TRL 4 and TRL 7.

3.3.1.4 Design requirements for a VC fund dedicated to seed-stage DTVs

Based on the problem analysis thus far, several design requirements (Tuunanen et al., 2024) for creating a deep-tech seed-stage VC fund can be formulated. The first two design requirements (DRs) arise from the demand-side of the missing middle (see section 3.3.1.1):

DR1. The VC fund should be able to make *initial investments of a sufficient size in the seed-stage of DTVs* (Barr et al., 2009; Nacke & Seckler, 2023); the

minimum viable size of the fund can be assumed to be €100M, as inferred from observations by Dealroom (2023).

DR2. The VC fund should mitigate potential valuation and dilution issues, arising from DTVs attracting too much equity funding in the seed-stage, by *attracting non-dilutive funding* (such as grants and subsidies) for these DTVs on top of (dilutive) equity investments (Nacke & Seckler, 2023; Winton & Yerramili, 2008).

Several other requirements arise from the supply-side (see section 3.3.1.2) and focus on making the investment thesis as attractive as possible for fund investors:

DR3. The VC fund should *reserve a sufficient amount of capital to invest significant equity volumes across several investment stages of each portfolio company*, to help each DTV in its portfolio overcome the missing middle (Savanevičienė et al., 2015; Trigeorgis, 1993).

DR4. To ensure that the VC fund can source, assess, support, and exit DTVs better than others and achieve a competitive financial return of at least 20% annually (Nacke & Seckler, 2023), *a multi-disciplinary investment team* needs to be created (Block et al., 2019).

DR5. The investment thesis of the VC fund also has to be sufficiently differentiated from other VCs in terms of *its specificity for seed-stage DTVs*, including well-defined decision criteria regarding geographic location, scalability of the venture, type of technology, intellectual property protection, and sustainability (Dealroom, 2023; Nacke & Seckler, 2023).

DR6. The VC fund should offer a specific *support (i.e., value creation) framework* that further helps DTVs overcome the missing middle (Block et al., 2019).

These six design requirements translate the problem analysis into key conditions and guidelines for a solution design.

3.3.2 Creating and evaluating a VC fund for seed-stage DTVs

This section describes the creation and evaluation of a VC fund for seed-stage DTVs. We first describe the design of the new DeepTechXL fund in terms of its investment thesis and its structure and governance, followed by an outline of the fundraising process for the new fund. Finally, we describe how potential investors evaluated the new fund.

3.3.2.1 Investment thesis

The investment thesis of a VC fund is the "raison d'être" and outlines how the fund will approach the market. For the new DeepTechXL fund, we developed an investment thesis focusing on seed-stage DTVs that can make significant contributions to solving various grand challenges (see Appendix F). This investment thesis extends the extant literature on VC fund design in two key aspects: its impact focus via deep-tech and its capital allocation strategy. First, DeepTechXL's focus on deep-tech is different because the extant literature on sustainable finance and sustainable entrepreneurship centers around social enterprises (Barber et al., 2021; Block et al., 2021).

Second, VC funds typically allocate their capital in a more balanced way between initial investments and follow-on investments (Gilson, 2003; Sahlman, 1990; Trigeorgis, 1993), whereas DeepTechXL's investment thesis entails a focus on building syndicates in the seed-stage, while also being able to invest in series A, B and C for the same ventures. Following the real options perspective (Trigeorgis, 1993), this staged approach to investments enables the VC fund to optimize its capital allocation across several stages of multiple portfolio companies; it also enables the fund to reallocate capital when specific portfolio companies fail to reach the next stage. DeepTechXL therefore needed to reserve 70 to 80 percent of its capital for follow-on rounds, as detailed in DR3. As implied by DR1, the initial investment in any specific portfolio company would have to provide sufficient funding to successfully move it through the seed-stage, with various critical aspects being de-risked to motivate other (e.g., more generalist) VCs to join as investors in follow-on rounds.

The investment thesis also included the goal to develop a portfolio of 15 to 20 seed-investments and a knowledge transfer engine that supports cross-fertilization of knowledge to further strengthen the deep-tech ecosystem around the VC fund. Moreover, DeepTechXL would need to active-

ly seek debt facilities on top of its equity investments in all investment rounds, while actively monitoring progress, to optimize the founders' dilution (as proposed in DR2). The first part of Appendix F outlines DeepTechXL's investment thesis.

3.3.2.2 Structure and governance

DeepTechXL adopted the standard structure and governance approach of VC funds (Nacke & Seckler, 2023; Sahlman, 1990). A major extension of this standard approach was DeepTechXL's economic life, which is a maximum 15 years instead of the 10 years that other VC funds use (Sahlman, 1990); this substantially longer economic life accommodates the longer time-to-market as well as time-to-exit of seed-stage DTVs (De la Tour et al., 2017) and therefore accommodates the investment thesis outlined earlier. Other structural and governance arrangements complied with the common standards expected by institutional and other investors. The new fund was formed as a closed-end fund (Nacke & Seckler, 2023), that is, with a fixed term to invest and divest its capital.

As implied by DR4, we deliberately created a multi-disciplinary investment team for DeepTechXL, one that understands the deep-tech content and interdependencies between technological, commercial, and financial issues and can provide tailor-made (value creation) support to DTVs. Our assumption was that this multi-disciplinary investment team would enhance DeepTechXL's credibility for institutional investors (cf., Nacke & Seckler, 2023). The second part of Appendix F outlines the structure and governance of DeepTechXL.

3.3.2.3 Fundraising process

The fundraising process involved a highly iterative process. First, based on the design requirements (in 3.1.4), the investment thesis (in 3.2.1) and compliance aspects (in 3.2.2), we created a set of acquisition documents (i.e., presentation, pitch deck, and private placement memorandum) and a data room to prepare for the start of fundraising efforts for the new DeepTechXL fund—in early 2021.

Subsequently, we approached a substantial number of pension funds, corporate investors and family offices. In these exploratory interviews, many interviewees found DeepTechXL's investment thesis very interesting but also expressed it does not fit their portfolios and investment strategy.

For example, we interviewed several representatives of a Dutch pension fund and one of them observed that DeepTechXL's "structure needs to be a standard one with a proper governance" before they would reconsider the proposition. Moreover, the same representative signaled that the commitment of at least one other pension fund would help as well: "If pension fund X approves and joins DeepTechXL, then this would give us a very strong signal". This type of feedback was quite common in the early interviews, which especially motivated us to improve the compliance aspects of the envisioned fund.

A critical turning point was the first meeting with PME Pensioenfonds, a large Dutch pension fund, in the second half of 2021. At the time, there was a growing societal pressure in the Netherlands on pension funds, urging them to invest more in innovative Dutch companies, and especially those with substantial ambitions in the area of sustainability (VNO-NCW, 2022). These societal expectations positively influenced PME's decision to join DeepTechXL. Moreover, we obtained early signals from ASML, Philips and TNO that they were willing to make an investment in the new fund, which also helped to convince PME, and vice versa.

Additionally, the Dutch government opened a tender for a seed-stage loan, specifically for deep-tech VCs, in September 2021. With this new opportunity and the initial consortium of PME, ASML, Philips and others in-the-making, we decided to apply for this tender and also won it. As such, ASML, Philips, BOM, and TNO signed an initial closing for DeepTechXL in February 2022 with the Dutch Government, for an investment of €20M by the latter. This further enhanced the signaling effect of the new fund to potential fund investors. Moreover, the newly created fund continued to hire key staff members during the fundraising process, further underpinning the quality of the team (reinforcing the signaling effect). This led to a first close in May 2022 of €75M, which enabled DeepTechXL to start operating and investing. In February 2024, a final close was done at €111M.

In December 2024, a group of Dutch knowledge institutes in the deep-tech domain—including Eindhoven University of Technology, Delft University of Technology, University of Twente, Wageningen University, and TNO—invited DeepTechXL to lead the process of forming a consortium that would apply for another deep-tech pre-seed fund of the Dutch government. This request illustrated that the DeepTechXL team had developed into a pivotal

Dutch actor in (seed-stage) DTV funding, one that was trusted by Dutch knowledge institutes. These shared efforts led to a successful closure of an additional deep-tech pre-seed fund of €7M, increasing the committed capital to a total of €118M by October 2025.

3.3.2.4 Evaluating the solution

As described in section 3.2, we evaluated the outcomes of DeepTechXL's fundraising efforts in two ways: first, whether investors have an initial interest in investing in DeepTechXL; and second, whether this initial interest can lead to a successful closing of the fund. The fundraising process and outcomes, outlined previously, suggest there was a sufficient level of initial interest as well as commitment to actually invest. Here, we focus on the main reasons for actually investing in the new fund. For example, the PME pension fund explained its commitment as an institutional investor in a press release:

> *"PME takes care of pensions in the (Dutch) metal and technology industry. With our investments, we work on a good pension and at the same time on a positive social impact. Because you want to enjoy a good pension in a livable world. Deep-tech can help with this, with solutions for societal challenges. This new investment also fits seamlessly into our program to stimulate the Dutch technology and innovation sector. We provide the assets to create good pensions, a thriving tech sector and a better world."*

PME's investment decision was also based on the framework of standards in its investment portfolio, which underlines that a new VC fund must fit in a specific asset class in the portfolio strategy of institutional investors.

Various corporate investors also joined DeepTechXL. A critical step here was ASML's decision to invest in DeepTechXL, which created positive signals that motivated several other companies (e.g., Philips) to join. ASML showcased DeepTechXL in its 2022 annual report as follows:

> *"Together with the other investing industry partners (Philips, Brabantse Ontwikkelings Maatschappij, research institute TNO, PME Pension Fund, Invest-NL and some family offices), the fund provides deep-tech startups and scaleups with access to knowledge, network, technology, licenses and business*

development support, and it intends to finance these tech ventures particularly in their early stage of growth, where investments risks are still at the highest. The fund aims to introduce launching customers, find partners in the supply chain and to assist in entering new markets and scaling up manufacturing."

In addition, once DeepTechXL had obtained commitments from institutional investors like PME and corporate investors like ASML and Philips, ten family offices (which we repeatedly interviewed) also decided to commit capital to the new fund. A family office is a privately held company that manages investments for a wealthy family that owns a family business.

As reported earlier, the commitments of a pension fund, several corporations, the Dutch government, and ten family offices resulted in a total capital of €118M. Thus, the design of DeepTechXL, as a new VC fund dedicated to seed-stage DTVs, appears to effectively address the supply-side dimension of the missing middle.

3.3.3 Theorizing in terms of design propositions

We theorized the findings from the creation and evaluation phase of the DS cycle into two key design propositions (see Fig. 1). The shared context of both design propositions is the missing middle, in terms of the scarcity of financial resources for seed-stage DTVs in Europe.

3.3.3.1 Investment thesis: First design proposition

The first design proposition (DP1) arises from the investment thesis of DeepTechXL as a specialized VC fund. Theoretically, this proposition draws on the mechanisms of staging, power law, and syndication to make the investment thesis of the fund as compelling as possible for investors to deploy their capital (Nacke & Seckler, 2023). Table 3.2 provides an overview of DP1.

The first agency-mechanism relationship within DP1 is about sustainability and impact. In raising capital for the new fund, we noticed that European (and especially Dutch) investors were more interested in VC funds that provide both financial returns and sustainability impact. This impact-focused vision is also evident in recent EU rules, such as the Sustainable Finance Disclosure Regulation, which requires funds to determine and report their

level of sustainability-related disclosures (European Commission, 2022). DTVs are excellent inputs for such disclosures, as they foster innovation, create new industries (incl. employment), and yields solutions to various grand challenges (Redmond, 2021; Romme et al., 2023; Xiao & Su, 2022). When a VC fund has the deliberate intention to generate substantial social and environmental impact, alongside a financial return, it has a significant impact on the Corporate Social Responsibility records of its ventures, compared to ventures in which VCs do not have a responsible investment orientation (Alakent et al., 2020; Barber et al., 2021). The first agency-mechanism relationship in DP1 synthesizes the literature and the findings on DeepTechXL by showing how a specialized VC fund for seed-stage DTVs can adopt an impact-focus to differentiate itself from other VCs.

The second agency-mechanism component of DP1 involves the power law principle and syndication theory. Power law explains why a larger (number of investments in a) portfolio of seed-stage ventures increases the chance of investing in those specific ventures that will generate significant returns (Kerr et al., 2014; Lahr, 2023). Syndication implies that a VC fund shares the unique risk of a single company with other investors, meaning that at least two VC funds invest in the same venture in the same round. In turn, this also means each investor in these VC funds allocates its resources to a greater number of companies, ultimately reducing the overall portfolio risk for this investor (Dimov & Milanov, 2010; Lockett & Wright, 2001; Statman, 1987). Thus, this agency-mechanism relationship in DP1 combines the power law principle and syndication theory to point out how the sharing of unique risks enables a VC fund to increase the number of portfolio companies, thereby increasing the chances of having winners in this portfolio (Dimov & Milanov, 2010; Lahr, 2023).

Table 3.2 Design proposition 1: Investment thesis

Context (C)	Agency (A)		Mechanism (M)	Outcome (O)
In financially supporting seed-stage DTVs in Europe	*the VC fund should*	*have an impact-focused investment thesis*	*to differentiate itself from other VCs and provide additional benefits on top of a financial return*	*which creates a competitive edge of this specialized VC fund toward investors*
		adopt a syndication strategy for each investment	*to spread the available capital across a larger number of ventures and thereby share each venture's unique risk and reduce the overall portfolio risk of the fund (and therefore the investors in this fund)*	

3.3.3.3 Structure and governance: Second design proposition

The second design proposition (DP2) addresses the structure and governance of the specialized VC fund. Table 3.3 provides the complete proposition. First, a key learning from section 3.3.2.3 is that the fund needs to comply with what especially institutional investors require. As such, the design of the new fund should draw on common standards for structuring and governing its operations (Gilson, 2003; Sahlman, 1990). By doing so, the fund complies with, and fits in, the portfolio strategy of institutional investors. This part of DP2 thus makes the extant theory in this area (Gilson, 2003; Sahlman, 1990) actionable.

Second, as observed in section 3.3.2.2, the economic life of 15 years is the only element of DeepTechXL's structure that is not common in the VC landscape. This long economic life follows directly from the investment thesis of DeepTechXL, and especially its focus on DTVs that require a substantially longer holding period than other ventures (see 3.2.1). Investors expect a high level of consistency between the fund's structure and investment thesis; any inconsistency in this area tends to motivate them to not invest. Thus, this agency-mechanism relationship in DP2 challenges the common assumption that a VC fund has an economic life of maximum 10 years (Gilson, 2003; Sahlman, 1990), by arguing that a VC fund dedicated to seed-stage DTVs needs a substantially longer life.

The third agency-mechanism relationship in DP2 is about developing an ecosystem of committed partners (Fisher et al., 2016; Shepherd et al., 2021), based on key learnings from the DeepTechXL case reported earlier. This proposition draws on signaling theory (Kleinert et al., 2022; Lanahan & Armanios, 2018), especially credibility signals that reduce information asymmetry (Davila et al., 2003; Block et al., 2014; Nahata, 2008). If multiple prominent actors in the ecosystem support and endorse the new VC fund (Walrave et al., 2018), this sends signals about its credibility to other potential investors. In sum, this agency-mechanism relationship applies signaling theory to how important ecosystem partners can accelerate the establishment of a new VC fund (Gulati & Higgins, 2003; Nahata, 2008).

The final agency-mechanism element in DP2 involves the composition of the investment team. The experience and expertise embedded in this team is important for both the initial fundraising efforts and the long-term success potential of the fund. Interestingly, Franke et al. (2008) collected data on the background and experience of the managers of more than 50 VCs, which showed that 76 percent had a business or economics background instead of an engineering background. This resonates with studies of VC investment criteria, which are mainly focused on the venture's commercial, financial, and managerial characteristics (Block et al., 2019; Cosh et al., 2009; Gompers et al., 2020; Shafi, 2021). The so-called similarity bias explains the latter focus (Franke et al., 2006). Consequently, it is rather challenging for a typical VC fund to assess the potential of complex deep-tech inventions long before there is any commercial traction. Fund managers with an engineering background as well as entrepreneurial experience are more likely to invest in seed-stage ventures (Patzelt et al., 2009); and first-time fund managers with science/engineering backgrounds, financial experience, or executive experience in early-stage ventures tend to be more successful than their counterparts with more general (e.g., MBA) backgrounds (Zarutskie, 2010).

Moreover, DTV entrepreneurs looking for seed-funding often have little to no experience in setting up a business, acquiring human and financial resources, handling legal affairs, and developing network ties (Fernández-Alles et al., 2015; Knockaert et al., 2010). In sum, a well-crafted investment team provides additional credibility signals to investors. This part of DP2 extends the literature on entrepreneurial finance (Franke et al., 2008;

Gompers et al., 2020) by depicting how the multi-disciplinary composition of a VC team enhances its credibility for potential investors.

Table 3.3 Design proposition 2: Structure and governance

Context (C)	Agency (A)		Mechanism (M)	Outcome (O)
In financially supporting seed-stage DTVs in Europe	*the VC fund should*	*adopt a standardized VC format*	*that complies with and fits in the portfolio strategy of institutional investors*	*which ensures the fund is compliant with what investors expect*
		adapt its economic life to the relatively long holding period of the DTVs in its portfolio	*to enhance the consistency of the fund's structure and investment thesis*	
		facilitate fund investments from a strong ecosystem of committed partners	*to enhance credibility signals to (other potential) investors*	
		be managed by a multi-disciplinary team that includes deep-tech, entrepreneurial, industrial and financial experts		

3.4. DISCUSSION AND CONCLUSION

The key question in this study is what a VC investment vehicle and thesis for supporting seed-stage DTVs might look like. Using a design science approach, we analyzed the problem space and formulated design requirements to inform the creation and evaluation of a solution design. Subsequently, we theorized this solution into a set of design propositions. The remainder of this section first discusses the theoretical and practical contributions of our study and then explores its main limitations and implications for future work.

This study explored what a VC investment thesis and vehicle for supporting seed-stage DTVs might look like. Using a design science approach, we analyzed the problem space and formulated design requirements to inform the creation and evaluation of a solution design. Subsequently, we

theorized this solution into a set of design propositions. The remainder of this section first discusses the theoretical and practical contributions of our study and then explores its main limitations and implications for future work.

3.4.1 Theoretical and practical contributions

Previous studies focused on demand-side issues of the missing middle (Dimov et al., 2007; Lockett et al., 2002; Patzelt et al., 2009). Other work mapped the ideas and assumptions underlying the extant structures and governance approaches of VC funds (Nacke & Seckler, 2023; Sahlman 1990). More specifically, Nacke and Seckler (2023) assessed the solution design of a VC fund for food-tech ventures, but did not implement it. Our study contributes to this literature by designing a VC fund dedicated to seed-stage DTVs as well as demonstrating how capital was raised for this new fund. The newly created VC fund successfully raised €118M, which underlines its potential for solving the supply-side challenges of the missing middle in Europe. This contribution to the literature can be further spelled out with help of Seckler et al.'s (2021) design knowledge contribution matrix.

For one, the blueprint of a seed-stage deep-tech VC fund constitutes a situated artifact, representing a so-called *theoretical design object* contribution (Seckler et al., 2021) that complements and extends the extant literature on VC fund design (outlined in section 3.3.1). This theoretical artifact is codified in two design propositions, inferred from the literature as well as the DeepTechXL case. These propositions codify the various mechanisms, actions and outcomes involved. Together with the design requirements formulated in section 3.3.1, the two DPs specify how a new fund can be designed and implemented to help DTVs overcome the missing middle in the investment landscape (Arora et al., 2024), especially in Europe.

As argued in section 3.2, any set of DPs must be complete rather than merely novel. Our study resulted in two key DPs, one about the investment thesis and the other about structuring and governing the fund. For example, DP1 outlines how a competitive edge can be created for a specialized VC fund through sustainability impact and syndication (e.g., Barber et al., 2021; Hochberg et al., 2018). The pivotal function of the entire set of DPs is to theorize the (learnings from the) project, in which theory and practice interacted to create and implement solutions for financing seed-stage DTVs. From a theoretical point of view, each (part of the) proposition can

act as a stand-alone causal statement, to be further scrutinized and tested in future work. From a design perspective, however, the two DPs contain a coherent set of complementary guidelines (Romme & Endenburg, 2006) for creating and implementing a new VC fund.

In addition, the implementation of the design requirements and propositions in DeepTechXL involves an *empirical design object* contribution (Seckler et al., 2021), as it transforms the conceptual blueprint into a real-world VC fund. Moreover, by demonstrating that the latter VC fund works in practice, our study also makes an *empirical design evaluation* contribution (Seckler et al., 2021). More specifically, a VC fund dedicated to seed-stage investments in DTVs appears to be a significant addition to existing VC offerings in the deep-tech domain, in which investors need a rather long time horizon before their investments start generating returns; this is especially evident from DeepTechXL's economic life of 15 years.

Other key learnings from the DeepTechXL case are the signaling effect of early investors and the power of an multi-disciplinary investment team (Bafera & Kleinert, 2023; Baumann et al., 2018). Another key implication of DeepTechXL's design for other funds is that an exclusive focus on DTVs is critical for the internal consistency between the fund's investment thesis and operations. Overall, DeepTechXL's design can inspire and inform the creation of similar VC funds, to substantially increase the supply of capital to seed-stage DTVs.

3.4.2 Limitations and future research

This study has several limitations. First, a deep-tech VC fund is a novel phenomenon in the venture funding landscape (Drover et al., 2017; Samila & Sorenson, 2010), one that focuses on seed-stage investments in DTVs operating at TRLs 4 to 7. Our study suggests that several conditions have to be in place to ensure the viability of such a specialized VC fund. The VC fund should offer an investment thesis that can generate attractive financial returns due to its capabilities in deal selection and value creation. Thus, the VC team must not only have financial and investment expertise but also strong technological expertise, provide venture-building support, adopt a relatively long holding period for most investments, and be able to participate in several subsequent investment rounds (for any specific venture), while also offering attractive conditions for institutional investors to join. Future research in this area has to provide a deeper understanding

of these conditions and their effects on the return potential of VC funds (Drover et al., 2017). For example, studies of how similarity bias and gender gap affect investors and fund managers (Franke et al., 2008; Guzman & Kacperczyk, 2019; Murnieks et al., 2011) can be extended toward the DTV setting.

Second, we focused on the supply-side of the missing middle and therefore did not evaluate whether improving the supply of seed-capital also actually helps DTVs to overcome the missing middle. We designed and implemented a novel solution for the supply side, which was implemented in a new VC fund that attracted a capital volume of €118M. These resources are currently being allocated to various seed-stage DTVs. Consequently, the ultimate impact on the performance of these DTVs, in overcoming the supply-demand gap, cannot be assessed yet. A substantially longer data period is needed to systematically assess the efficacy of the new VC fund for the various ventures involved.

Finally, this study is based on qualitative data only. Future work may adopt a quantitative approach to more systematically understand how the missing middle for DTVs, as a supply-demand gap, can and should be mitigated. Here, studies drawing on survey, panel and other quantitative data will also be instrumental in further validating our design propositions, which over time may lead to an evidence-based body of actionable knowledge in this area.

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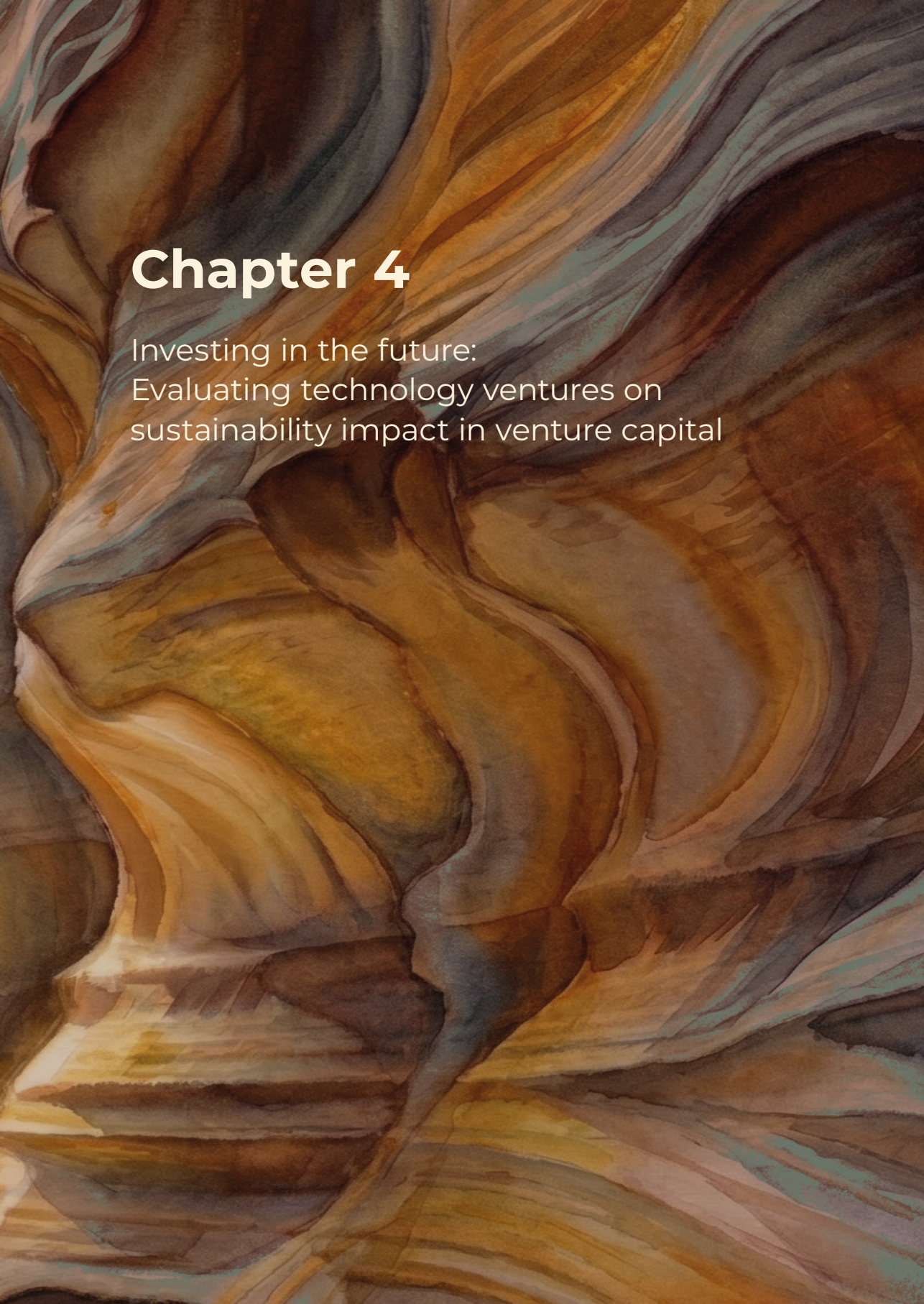
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Chapter 4

Investing in the future:
Evaluating technology ventures on sustainability impact in venture capital

ABSTRACT

Venture capital firms (VCs) play a unique role in fostering the transition to a sustainable society by financing and supporting technology ventures that contribute to long-term societal and environmental goals. However, the sustainability promise of technology ventures is typically not clear at the early stages of development, requiring critical evaluation and continuous monitoring. VCs thus require an approach for sustainability impact assessment to assess and monitor the sustainability impact of technology ventures and guide sustainable investment decisions – even more so in light of emerging regulatory requirements, such as the European Sustainable Finance Disclosure Regulation. Despite this need, limited research exists on sustainability impact assessment in the venture capital context. This study addresses this gap by investigating how VCs can assess the sustainability impact of technology ventures. Employing a design science research approach, we develop and evaluate a novel sustainability impact assessment framework tailored to the unique characteristics of VC investment. The framework adopts a Design Science (DS) approach, combining insights from a systematic literature review with findings from an in-depth qualitative study with VCs. Our contribution is twofold. First, we propose a set of design principles that enable VCs to conceptualize, assess, and monitor the sustainability impact and risks of their portfolio ventures. Second, we develop a framework for developing and validating design principles in highly contextual and emergent domains such as sustainable venture capital. The resulting design principles and framework integrate perspectives from entrepreneurial finance and technology entrepreneurship, aiming to inform both academic discourse and venture capital practice by positioning sustainability impact assessment as a central criterion in investment decision-making and venture support.

Keywords: Venture Capital, Technology Ventures, Sustainability Impact, Sustainable Entrepreneurship, Design Science, Entrepreneurial Finance, Impact Investing

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4.1 INTRODUCTION

Venture capital firms (VCs) play a central role in advancing sustainable development by financing technology ventures with the potential for significant societal and environmental impact. Through funding and strategic support, VCs help such ventures grow and scale. These technology ventures—often grounded in scientific and technical innovation—can contribute to sustainable development by commercializing innovations that address urgent environmental and societal challenges (Bailetti, 2012; Shepherd et al., 2021; Skala, 2019).

Technology ventures, therefore, have considerable potential to tackle pressing sustainability problems (Xiao & Su, 2022). For example, they can offer transformative solutions in areas such as renewable energy, health care, and circular technologies, helping to reduce dependence on virgin materials and foster social welfare (Grübler, 1998). At the same time, the development and deployment of new technologies can entail substantial environmental costs related to resource use, energy consumption, pollution, and waste generation (Fleischer & Grunwald, 2008; Grübler, 1998).

Given this duality, the sustainability contribution of technology ventures cannot be assumed. Instead, it requires critical assessment from the earliest stages of development. Early evaluations not only guide sustainable venture development but also support continuous improvement of sustainability impact over time (Matthews et al., 2019).

In this context, sustainability impact assessments are gaining visibility in both research and practice. Such assessments provide systematic approaches to identify and evaluate the sustainability outcomes of a venture's past, current, and planned activities (Trautwein, 2021). As a result, impact assessment has developed rapidly (Ness et al., 2007) and is increasingly recognized within sustainable entrepreneurship research (see Appendix G). A well-known example is the Social Return on Investment (SROI) framework, which compares the financial costs of an investment with its social benefits (Lingane & Olsen, 2004). Yet despite its growing relevance, sustainability impact assessment remains largely absent from the venture capital literature (Alakent et al., 2020; Barber et al., 2021; Roundy et al., 2017).

Similarly, in practice, sustainability considerations are rarely integrated into standard VC investment assessment criteria. Traditional assessments prioritize technological innovation, market potential, competitive positioning, team capability, intellectual property, and financial projections (e.g., Fisher et al., 2015; Gompers et al., 2020; Wessendorf et al., 2019), with a primary focus on revenue growth (Block et al., 2019).

Although impact-oriented VCs often report lower annualized internal rates of return than traditional VCs (Barber et al., 2021), interest in sustainability-focused investing is rising—particularly in Europe (Combs, 2014; Roundy et al., 2017; Trelstad, 2016). This shift is driven in part by regulatory developments such as the EU Taxonomy (European Commission, 2023a) and the Sustainable Finance Disclosure Regulation (SFDR) (European Commission, 2023b). These regulations oblige European VCs to assess, monitor, and report on both the sustainability impact and sustainability risks of their portfolio ventures.

Consequently, there is a growing need for evidence-based frameworks that enable VCs to integrate sustainability impact assessment into investment decision-making, monitoring, and post-investment support (Botsari & Lang, 2020; Popescu et al., 2021; Trelstad, 2016). In this chapter, we address the following research question: *How can VCs assess the sustainability impact of early-stage technology ventures within the context of their investment process?*

To answer this question, we adopt a Design Science (DS) approach (Dimov et al., 2023; Simon, 1996) and develop a set of design principles (DPs) (Denyer et al., 2008; Romme & Dimov, 2021) to guide the creation of a sustainability impact assessment framework. DS provides a collaborative methodology in which practitioners and scholars jointly design and evaluate solutions to complex societal challenges. Rooted at the intersection of creative design and explanatory science, DS has been widely applied in fields such as information systems (March & Smith, 1995) and operations management (Holmström et al., 2009), inspired by Simon's (1996) *The Sciences of the Artificial*.

Our study integrates theoretical and empirical insights. The theoretical analysis draws from the literature on sustainability impact assessment, venture capital, and technology entrepreneurship, resulting in research-based

design principles (RB-DPs). The empirical study analyzes the investment and sustainability assessment processes of thirteen European VCs, producing practice-based design principles (PB-DPs). We synthesize the RB-DPs and PB-DPs into a final set of design principles. The resulting method design—a sustainability impact assessment framework—builds on eight DPs that articulate how sustainability assessments can be conducted across the key phases of the VC investment process (March & Smith, 1995).

This study offers two contributions. First, although sustainability considerations are gaining traction across entrepreneurship and finance, academic research has not yet established how VCs can conceptualize and systematically assess the sustainability impact and risks of the ventures they fund, representing a significant gap in entrepreneurial finance. Our study addresses this by synthesizing insights across domains into a novel assessment framework developed through a systematic DS cycle (Gompers et al., 2020; Granz et al., 2021). Second, while DS is increasingly used in management and entrepreneurship research, few studies provide richly contextualized examples of how to develop and validate design principles in emergent and uncertain domains (Romme & Holmström, 2023). We illustrate how established DS approaches can be operationalized in the context of sustainable venture capital (Lee et al., 2011; Cronholm et al., 2023; Gregor et al., 2020).

4.2 METHODS

This study employs a Design Science (DS) approach (Dimov et al., 2023; Romme, 2003; Van Burg et al., 2008), integrating theoretical and empirical insights to develop a sustainability impact assessment framework for VCs. The rationale for adopting DS is threefold. First, DS is well-suited to the growing need for evidence-based sustainability impact assessment tools, given its emphasis on creating practical solutions grounded in both theory and real-world relevance. This aligns directly with our objective to develop actionable guidance that supports decision-making, monitoring, and post-investment activities. Second, DS thrives in collaborative settings that involve both practitioners and scholars (Van Burg et al., 2008), making it particularly appropriate for addressing the sustainability-related needs of VCs, whose expertise is essential for designing a viable assessment approach. Third, DS enhances the practical applicability of academic research

by emphasizing utility, thereby ensuring that outcomes are immediately implementable and directly relevant to VC practice (Denyer et al., 2008; Van Burg et al., 2008). Through this approach, our study contributes new insights to the literature at the intersection of sustainability assessment and venture capital.

4.2.1 Empirical setting

The study was conducted in collaboration with DeepTechXL, an early-stage deep-tech impact VC fund in Europe. DeepTechXL launched its first fund in 2022 with a capital base of €118 million sourced from corporate, pension fund, research institute, family office, and government investors. The fund exclusively invests in early-stage, purpose-driven companies aligned with the UN Sustainable Development Goals (SDGs) and leveraging key enabling technologies (deep-tech) to advance environmental or social sustainability objectives. Its investment scope includes health and care, energy transition and sustainability, security, and agriculture, water, and food. As a result, DeepTechXL is classified under Article 9 of the Sustainable Finance Disclosure Regulation (SFDR).

At the start of this research, DeepTechXL did not yet have a systematic methodology for assessing sustainability impact and risks. Its processes were largely ad hoc, as the fund was still exploring and experimenting with potential methods and tools to meet its SFDR Article 9 obligations. The collaboration thus provided an opportunity both to design a structured framework and to evaluate it in practice.

4.2.2 Research Design

Our research design follows the DS approaches outlined by Dimov et al. (2023) and Romme and Reymen (2018), consisting of four iterative steps: theorize, create, evaluate, and justify. Figure 4.1 illustrates the sequence and iterative nature of these steps.

1. *Theorize*: Define the problem and develop research-based design principles (RB-DPs) using theoretical analysis, and practice-based design principles (PB-DPs) using empirical analysis.
2. *Create*: Develop an initial assessment framework informed by these design principles.
3. *Evaluate*: Assess the pragmatic validity and relevance of the framework in a naturalistic environment.

4. *Justify*: Reflect on and refine the design principles to enhance their generalizability and theoretical grounding.

The DS cycle was highly iterative, with frequent movement between steps as new insights emerged. The following sections detail each step.

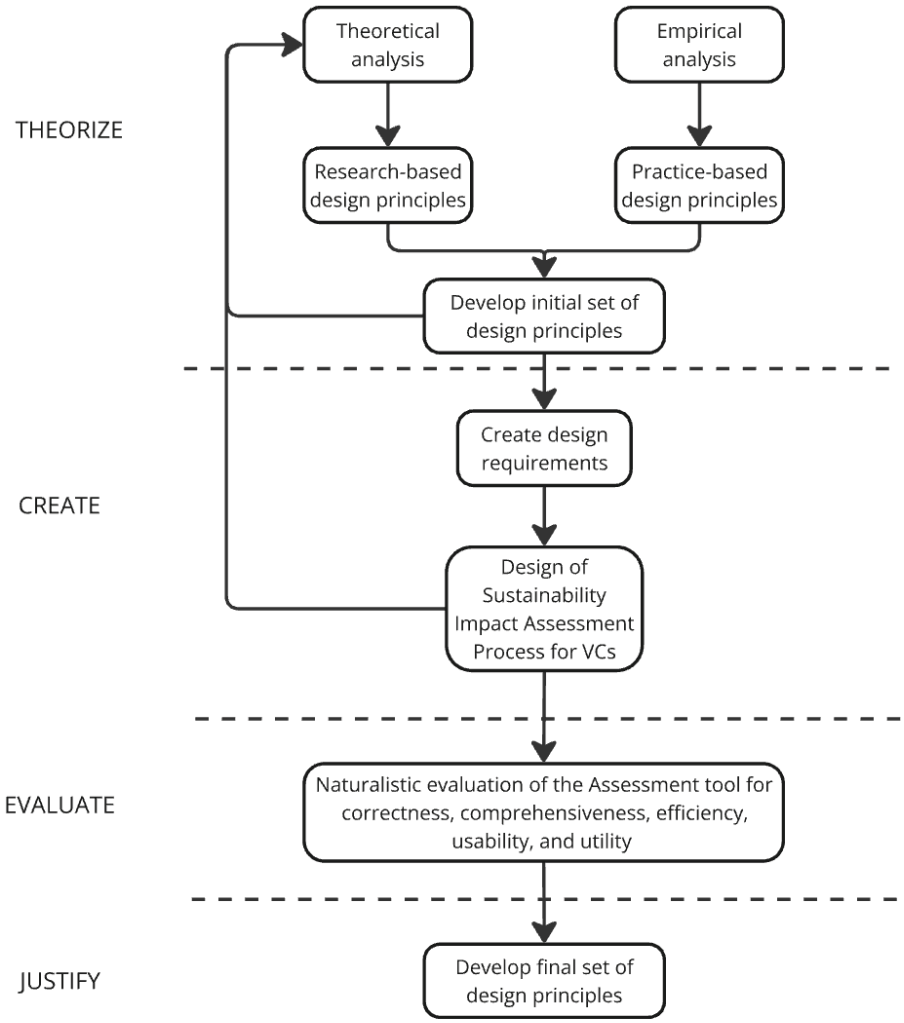


Figure 4.1 Design science cycle (adapted from: Romme and Reymen, 2018)

4.2.3 Theorize

The theorize phase seeks to integrate theoretical and empirical insights to develop an initial set of design principles (DPs).

4.2.3.1 Design principles

Design principles serve as a bridge between scientific knowledge and practical design, functioning as both the input and outcome of DS research. They capture generalizable knowledge that researchers and practitioners can apply when addressing similar problems (Keskin & Romme, 2020). Following the CAMO logic (Context, Agency, Mechanism, Outcome), we formulated each DP to specify: the *context* in which the assessment is used; the *agency*—the actions or design features involved; the *mechanisms* through which these actions operate; and the intended *outcomes* (Denyer et al., 2008).

All DPs share the same context: "VCs assessing the sustainability impacts and risks of technology ventures". This ensures a coherent problem domain. Variation across principles arises through differences in actions, mechanisms, and outcomes.

4.2.3.2 Theoretical analysis

The theoretical analysis reviewed literature on sustainability impact assessment relevant to technology ventures and VC (Dresch et al., 2016). A structured keyword search was conducted across Scopus and ProQuest—two widely recommended databases for entrepreneurship research (Denyer & Tranfield, 2009; Kraus et al., 2020)—covering studies published between January 2003 and March 2023. ProQuest was included to capture grey literature, reflecting the emerging nature of sustainable investing (Centobelli et al., 2020; Koenigsmarck & Geissdoerfer, 2023). Table 4.1 presents the search terms.

Table 4.1 Keywords operationalized for the search strings

Search Cloud			
Sustainability impact assessment	**Technology venture**	**Venture capital**	**Method**
"sustainab* impact assessment"; "sustainab* assessment"; "impact assessment"; "sustainab* measurement"; "ESG assessment; "ESG measurement"; "Sustainab* Return on Investment"	"early-stage technology venture"; startup; start-up; venture; "early-stage venture"; "early stage venture"; entrepreneur*; "early-stage technolog*"; "early stage technolog*"; "immature technolog*"; "pre-mature technolog*"; "emerging technolog*"; "disruptive technolog*"; "key enabling technolog*"; deeptech; "deep technolog*"	"Venture capital"; "sustainable invest*"; "sustainable financ*"; "impact invest*"; "impact financ*"	framework; approach; process; plan; tool; design
Title, abstract, keywords	*Title, abstract, keywords*	*Title, abstract, keywords*	*Abstract*

The review followed the principles of design-oriented research synthesis (Denyer et al., 2008), emphasizing transparency in search, selection, extraction, and synthesis. After screening titles, abstracts, and subsequently introductions and conclusions, 39 studies were retained. Backward snowballing (Wohlin, 2014) yielded an additional 13 relevant publications, resulting in 52 total sources.

Each publication was analyzed using a CAMO structure (Keskin & Romme, 2020). Iterative cross-study comparisons were conducted to identify recurring patterns, refine provisional CAMO linkages, and synthesize them into higher-order categories. This process resulted in eight RB-DPs.

4.2.3.3 Empirical analysis

To design a method tailored to VC sustainability assessment, we employed purposeful sampling to select information-rich cases (Eisenhardt, 1989; Reymen et al., 2015). Selection criteria included:

1. Headquarters in the European Union, ensuring exposure to SFDR or comparable regulatory frameworks.

2. Evidence of sustainability-oriented investment practices, based on publicly available documentation.
3. Interviewees with sustainability-related responsibilities, ensuring detailed insights into assessment practices.

This resulted in a sample of thirteen cases from six European countries, as depicted in Table 4.2 (Belgium, Finland, Germany, the Netherlands, Norway, Sweden). Out of the thirteen cases, three cases report under Article 8, promoting environmental or social characteristics but do not have a sustainable investment objective (allowing for more flexibility in its strategy), five cases report under EU SFDR Article 9 (highest sustainability-related reporting requirements), that must have sustainable investment as their core objective, meeting stricter criteria, and providing more rigorous reporting and evidence of impact, three cases were government-backed VCs, and two cases do not fall under this regulation.

Table 4.2 Overview of research cases

Cases	Country	SFDR Article #[1]	Job title of informant	VC age
VCa	Netherlands	Government-backed	Fund Manager	10 – 15 years
VCb	Belgium	8	Portfolio Manager	5 – 10 years
VCc	Netherlands	9	ESG and Impact Officer	5 – 10 years
VCd	Sweden, Finland	n.a.	Investment Manager	1 – 5 years
VCe	Netherlands	9	Investment Analyst	10 – 15 years
VCf	Netherlands	Government-backed	Impact Engineer	1 – 5 years
VCg	Netherlands	Government-backed	Impact Officer	>15 years
VCh	Sweden	n.a.	Managing Director	10 – 15 years
VCi	Belgium	9	Impact Associate	5 – 10 years
VCj	Norway	8	Investment Manager	1 – 5 years
VCk	Netherlands	9	Investment Manager	>15 years
VCl	Netherlands	9	Investment Manager	1 – 5 years
VCm	Germany	8	ESG Manager	>15 years

[1] Research participants with *"n.a."* or "government-backed" listed in this column do not operate under the SFDR.

Data collection relied primarily on semi-structured interviews, supported by archival documents. All interviews followed a standardized protocol and were conducted by a single researcher to ensure consistency. Interview topics included assessment frameworks, data collection practices, stakeholder involvement, and decision-making processes. Interviews were recorded, transcribed, and member-checked with participants.

Using the Gioia methodology (Gioia et al., 2013), we coded transcripts, documents, and archival sources to identify first-order concepts, second-order themes, and aggregate dimensions. Data triangulation (Yin, 2018) increased validity. The resulting data structure is presented in Figure 4.2. The themes were later synthesized using the CAMO logic to derive practice-based design principles (PB-DPs), detailed in Table 4.4.

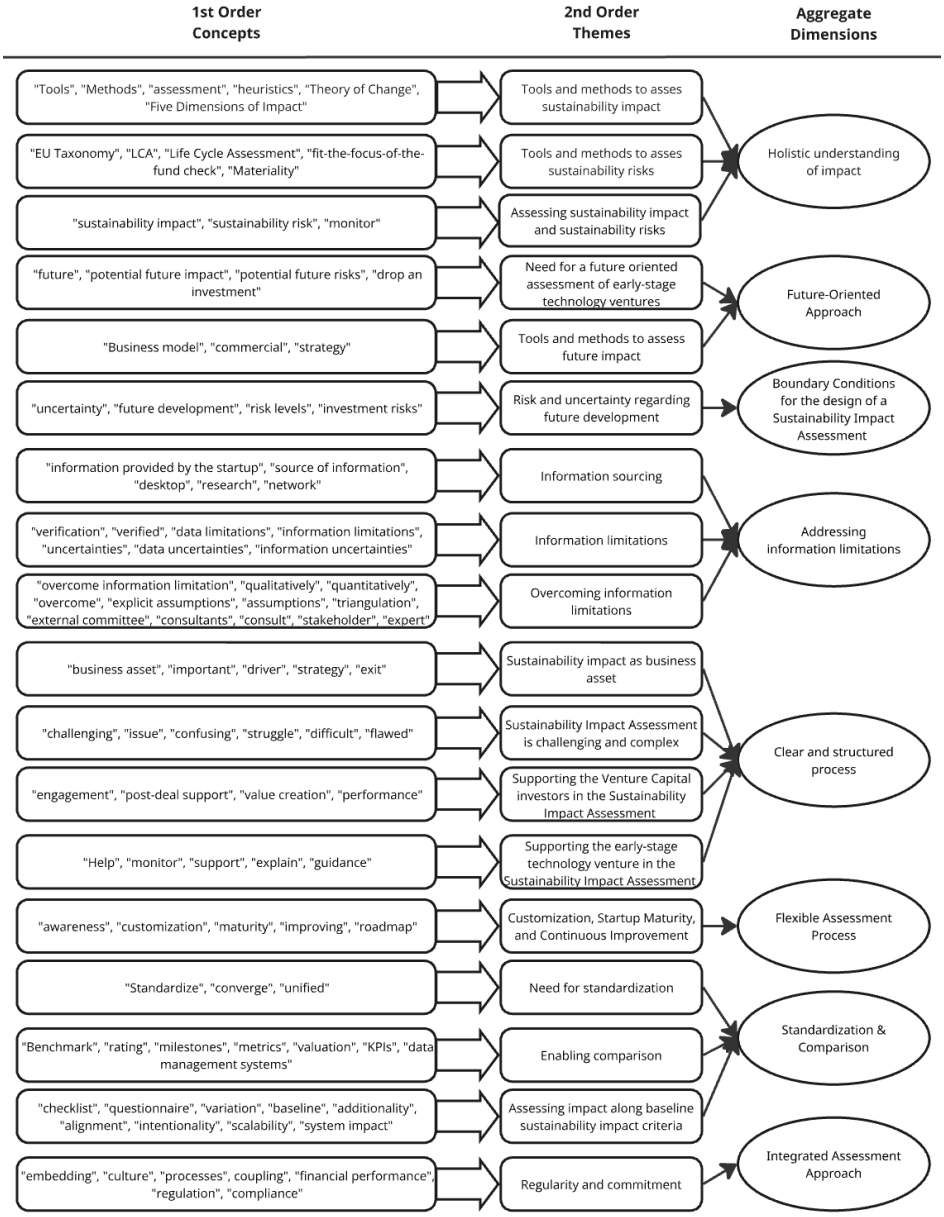


Figure 4.2 Gioia data structure

4.2.4 Create

The creation phase began by establishing design requirements (Romme & Endenburg, 2006; Van Aken & Berends, 2018), categorized as functional requirements, user requirements, and boundary conditions. These requirements, together with the DPs, informed the development of the initial sustainability impact assessment framework.

The framework was developed using principles of disciplined imagination and idealized design, resulting in a method comprising a set of structured steps (March & Smith, 1995). When conceptual gaps emerged, we returned to the theorize phase, iterating until a coherent framework suitable for evaluation in the DeepTechXL context was achieved.

4.2.5 Evaluation

The evaluation phase aimed to establish the pragmatic validity of the designed artifact (Dimov et al., 2023). Following the framework for DS evaluation proposed by Venable et al. (2016), we adopted a human risk and effectiveness evaluation strategy, emphasizing naturalistic settings. We conducted three main evaluation activities, of which the first two were conducted between February 2023 and December 2024, and the third was conducted in June 2024:

1. *Formative Evaluation 1*: Initial implementation at DeepTechXL and review with its Impact Committee, focusing on usability and comprehensiveness.
2. *Formative Evaluation 2*: Further review emphasizing correctness and refinement needs.
3. *Summative Evaluation*: Assessment of utility, focusing on compliance, reporting quality, and perceived value for VC decision-making.

Evaluation criteria included correctness, comprehensiveness, usability, and utility (Venable et al., 2016). Assessments also considered alignment with design requirements. Results indicated high relevance and viability.

4.2.6 Justify

Finally, the justify phase involved revisiting the initial DPs in light of evaluation findings to assess their continued relevance, refine their scope, and enhance generalizability (Dimov et al., 2023; Romme & Reymen, 2018). This reflection produced a final set of DPs, presented in Section 5. Due to space constraints, only these finalized principles are included in the main text.

4.3 THEORETICAL ANALYSIS

This section reviews and integrates existing literature on sustainability impact assessment, technology entrepreneurship, and venture capital to support the development of the research-based design principles (RB-DPs) presented in Table 4.3. The review examines key dimensions of sustainability assessment, including the primary actors involved (e.g., technology ventures and VCs), contextual conditions shaping sustainability considerations, and the rationale for and challenges associated with conducting sustainability impact assessments. These insights form the basis for deriving the RB-DPs.

4.3.1 The role of venture capital in funding and scaling technology ventures

VCs are widely recognized as critical providers of equity financing for technology ventures (Drover et al., 2017; Gompers et al., 2020; Hsu, 2007). VCs raise capital from limited partners (LPs), including institutional investors, wealthy individuals, and pension funds (Invest Europe, 2023). They identify and select potential investments by evaluating ventures on their growth potential, market opportunities, founding teams, technological capabilities, and competitive advantages (Gompers et al., 2020; Granz et al., 2021). Once an investment is made, VCs assume an active role by providing capital and value-added services such as coaching, strategic advice, network access, and recruitment support (Block et al., 2019; Paik & Woo, 2017; Vanacker et al., 2013; Zhang et al., 2024).

VC investments follow a high-risk, high-return profile: approximately fifty-five percent of investments result in write-offs, while only around six percent generate more than fifty percent of a fund's gross returns (Kerr et al., 2014; Lahr, 2023; Shepherd et al., 2000). Technology ventures typically progress through multiple stages—*pre-seed, seed, early-stage, expansion, growth, and exit*—with evolving capital needs (Roberts, 1991; Invest Europe, 2023). VCs often stage their investments to manage risk, balancing agency and monitoring costs (Sahlman, 1990; Gompers, 1995; Tennert et al., 2018). Accordingly, RB-DP1 emphasizes the need for sustainability assessments to accommodate venture maturity.

Investment evaluation typically includes *screening, preliminary due diligence, due diligence, closing, and post-investment activities*—forming a

funnel in which only about 1% of initial contacts lead to an eventual investment (Bronzini et al., 2020; Ragozzino & Blevins, 2016). Standard VC evaluations focus on technology, market, competition, team characteristics, intellectual property, and financials (Fisher et al., 2015; Houterman et al., 2014; Wessendorf et al., 2019). This process generally excludes sustainability considerations. RB-DP2, therefore, highlights the value of incorporating reference calls and verification mechanisms analogous to those used in financial due diligence. Eventually, VCs maximize their financial returns using an *exit* strategy (Cumming, 2007; Hellmann, 2006; Mohammadi & Khashabi, 2021

RB-DP3 stresses the importance of integrating sustainability assessment into existing VC processes. Figure 4.3 depicts a typical VC assessment process, which must accommodate sustainability-related analyses without disrupting established workflows.

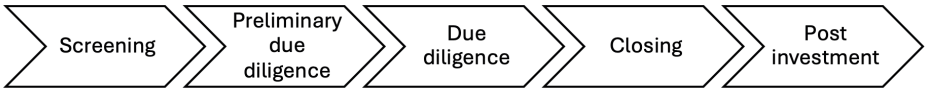


Figure 4.3 VC Assessment Process (adapted from Bronzini et al., 2020)

4.3.2 Sustainability impact assessment

Sustainability assessment is a relatively new but rapidly evolving field. Broadly, it refers to any process designed to guide decision-making toward sustainability (Bond et al., 2012). Sustainability assessments contribute to understanding sustainability issues, supporting decision-makers, and encouraging sustainable development (Waas et al., 2014). A variety of tools exist, including life cycle assessments (LCAs)—which require quantitative data that early-stage ventures often lack (e.g., Cooper & Gutowski, 2020; Van der Hulst et al., 2020; Van Schoubroeck et al., 2021)—as well as qualitative tools such as cognitive maps (Nakagawa et al., 2010), systems-level impact mapping (Hervieux & Voltan, 2019), and sustainability quick-check models (Halberstadt & Matthew, 2014). Other frameworks attempt to translate sustainability outcomes into monetized values, such as Social Return on Investment (SROI) (Arvidson et al., 2013; Corvo et al., 2021; Lingane & Olsen, 2004) or the CISL Impact Framework (CISL, 2019). While promising, these methods are often incompatible with the early-stage context due

to data constraints. Accordingly, RB-DP4 underscores the need for simple, easy-to-use assessment approaches.

Impact assessments, a related set of practices, aim to identify potential future effects—both positive and negative—of current or proposed activities. The International Association for Impact Assessment (2012) defines impacts broadly as effects on the environment, society, human health, well-being, and sustainability objectives. Sustainability impact assessments help clarify a startup's sustainability objectives and increase the visibility, tangibility, and accountability of its intended impact (Fichter et al., 2023; Strömmer & Ormiston, 2022; Trautwein, 2021). Because sustainability outcomes include long-term environmental, social, and economic impacts (Brundtland, 1987; Cohen et al., 2008; Schaltegger & Wagner, 2011), RB-DP3 emphasizes the importance of forward-looking, anticipatory assessment approaches.

Within financial markets, sustainability has frequently been framed through *Environmental, Social, and Governance* (ESG) factors, introduced by the UN Global Compact (2004). *ESG* frameworks provide lenses for evaluating sustainability performance and identifying sustainability-related risks. The concept of "*double materiality*" recognizes the bidirectional relationship between corporate activities and sustainability outcomes: sustainability factors can affect firm performance, and firms can impact environmental and social systems. The EU's SFDR expands regulatory expectations by requiring financial actors to consider sustainability risks and define sustainable investments in terms of environmental or social contributions, "do-no-significant-harm" criteria, and good governance (European Commission, 2019; 2022). RB-DP4, therefore, stresses simplicity and usability while maintaining alignment with regulatory expectations.

4.3.3 Sustainability impact within the VC assessment process

Despite its growing importance, conducting sustainability impact assessments in the venture capital context poses several methodological and ethical challenges. One of the most significant challenges derives from the inherent *heterogeneity of sustainability dimensions*. Environmental, social, and economic aspects of sustainability represent fundamentally different value domains and types of impact, making them difficult—if not impossible—to directly compare or weigh against one another (Fleischer

& Grunwald, 2008; Sauve et al., 2023). Attempting to prioritize or trade off such dimensions raises important ethical concerns, particularly when investors implicitly or explicitly decide that progress on one sustainability dimension should outweigh negative effects on another (Van Schoubroeck et al., 2022). These challenges are further amplified when assessments attempt to consolidate diverse sustainability outcomes into a single, aggregated "master sustainability indicator," which can obscure underlying complexities or produce misleading conclusions (Fleischer & Grunwald, 2008; Haase et al., 2022). As a result, sustainability impact assessments based on varying indicators and methodological frameworks may yield inconsistent or even contradictory findings, complicating efforts to benchmark or compare sustainability performance across technology ventures (Fleischer & Grunwald, 2008).

A second challenge emerges from the *heterogeneous nature* of technology ventures themselves. Technology ventures differ substantially across industries, applications, target markets, and maturity levels. This diversity requires tailored, context-specific methods for assessing sustainability impact (Varga, 2018). Furthermore, a technology deemed sustainable in one sector may be viewed as unsustainable in another, depending on its use case, supply chain context, or systemic implications (Fleischer & Grunwald, 2008; Grübler, 1998). Consequently, any attempt to standardize a sustainability assessment across diverse technology categories risks oversimplifying or mischaracterizing the true impact potential of a venture. RB-DP5, therefore, posits that assessment frameworks must be adaptable not only to sectoral and technological variation but also to venture maturity and evolving business models.

A third challenge relates to the *immaturity* of early-stage technology ventures, which complicates the development of robust sustainability assessment processes. Early-stage ventures typically lack historical data, comprehensive documentation, or validated performance metrics (e.g., Fichter et al., 2023; Haase et al., 2022; Sauve et al., 2023; Trautwein, 2021). When data does exist, it is often incomplete, anecdotal, context-specific, or non-representative, making quantitative assessment methods difficult to apply reliably (Clarke-Sather et al., 2011; Haase et al., 2022; Judl et al., 2015). Such ventures also face resource constraints—limited financial capital, time, and personnel—reducing their ability to conduct or participate in complex sustainability assessments (Trautwein, 2021). These limitations underscore

the need for frameworks that incorporate life cycle perspectives (RB-DP6) to identify upstream and downstream impacts, uncover hidden effects, promote systems thinking, and support comparative evaluation over time.

A fourth challenge arises from the diversity of VC investment strategies, which influences how sustainability impact assessments can be applied in practice. Some VCs follow a *diversification strategy*, investing in a variety of technologies, sectors, and business models to increase returns and reduce risk (Norton & Tenenbaum, 1993; Matusik & Fitza, 2012). While diversification spreads risk, it complicates sustainability assessment because each investment may require different metrics, tools, or analytical approaches. Conversely, VCs that pursue *specialization strategies* benefit from deeper knowledge and industry-specific expertise, but this specialization makes it harder to develop a universally applicable assessment method that holds across different domains. In both cases, heterogeneity within and across VC portfolios reinforces the need for adaptable, flexible assessment processes (as emphasized in RB-DP7).

Taken together, these challenges suggest that sustainability impact assessment is a complex, context-dependent undertaking for VCs. Heterogeneity in sustainability dimensions, technology characteristics, venture maturity, and VC investment strategies complicates the development of standardized, cross-venture assessments. Although current research provides useful insights and tools, detailed, actionable guidance on how VCs should assess sustainability impact within early-stage technology ventures remains lacking. This gap underscores the importance of developing design principles that explicitly address the complexity and contextual variability inherent in sustainable venture capital assessment.

4.3.4 Concluding theoretical analysis with research-based design principles

The theoretical analysis synthesized insights from sustainability assessment, venture capital, and technology entrepreneurship using a CAMO-based framework. Iterative refinement resulted in eight RB-DPs, presented in Table 4.3. All principles share a common context—VCs assessing early-stage technology ventures—while varying in their agency, mechanisms, and intended outcomes. These RB-DPs inform the development of the final set of design principles presented later in the manuscript.

Table 4.3 Research-based design principles

Context (C)	Agency (A)	Mechanism (M)	Outcome (O)	RB-DP
When VCs assess early-stage technology ventures on their sustainability impact and risks,	they must tailor the design of the assessment to the maturity level of a technological product,	thereby ensuring adaptability,	to create an assessment focused on control in lower maturity levels and predictability in higher maturity levels.	RB-DP1
	they should adopt prospective, ex-ante, and anticipatory assessment approaches (such as scenario analysis, formulating hypotheses, and business model assessments),	thereby forecasting the future development of these technology startups,	to identify multiple possible trajectories for their evolution and, consequently, i) detect unintended consequences or side-effects of the technology startup; and ii) shape technology startups in the most favorable outcome regarding sustainable development.	RB-DP2
	they should involve relevant stakeholders throughout the assessment process,	thereby increasing engagement and trust, and enhancing the collaboration among stakeholders,	to ensure that their perspectives and needs are considered, and the assessment is relevant to the stakeholders.	RB-DP3
	they should involve multiple relevant stakeholders early on and throughout the assessment process,	thereby facilitating the establishment of shared visions for desirable futures among stakeholders and coordinates the actions towards achieving these futures,	to reduce uncertainties.	RB-DP4
	they should choose a simple assessment approach and offer the early-stage technology startups expert knowledge and support,	thereby minimizing the resource need,	to ensure that performing the assessment becomes workable and attainable to early-stage technology startups.	RB-DP5

Context (C)	Agency (A)	Mechanism (M)	Outcome (O)	RB-DP
	standardized measurements should be adopted,	thereby ensuring transparency and uniformity among assessments,	to enhance comparability and reliability.	RB-DP6
	the assessment should be adaptable to the sector, technology, startup maturity, and should remain adaptable to refinement	thereby enabling customization,	to fit the characteristics of a specific technology startup.	RB-DP7
	they should adopt a life cycle perspective,	thereby creating a holistic understanding of sustainability impact of the startup's technology over its lifetime,	to i) uncover hidden impact; ii) encourage system thinking; iii) identify trade-offs; and iv) allow for a comparative assessment.	RB-DP8
	they should integrate the assessment into existing organizational activities and processes, as well as culture and decision-making of the technology startup,	thereby ensuring regularity and commitment,	to save time and resources and drive strategic impact decision-making.	RB-DP9

4.4 EMPIRICAL ANALYSIS

This section presents the empirical analysis and the resulting practice-based design principles (PB-DPs), followed by a comparison of the research-based design principles (RB-DPs) and PB-DPs. Together, these analyses inform the development of the final design principles.

4.4.1 Empirical analysis and practice-based design principles

We analyzed the semi-structured interview transcripts following the Gioia methodology (Gioia et al., 2013), which involves an iterative approach to developing a structured hierarchy of concepts that reflect informants' lived experiences while enabling rigorous theoretical abstraction. We began by identifying first-order concepts expressed in the informants' own terms, focusing closely on descriptions of their sustainability impact and risk assessment practices. These first-order concepts were subsequently clustered into second-order themes that capture broader patterns across cases. Finally, these themes were distilled into eight aggregate dimensions, representing the higher-order constructs underpinning assessment practices across the VCs in our dataset. Supplementary Material B contains illustrative quotes for each second-order theme.

Drawing on these aggregate dimensions and the underlying interview evidence, we derived twelve practice-based design principles (PB-DPs), which are summarized in Table 4.4. These PB-DPs capture empirically grounded insights into how VCs currently approach sustainability impact and risk assessment in early-stage technology ventures. Together, they provide an important foundation for synthesizing theory and practice in the development of the final design principles.

Table 4.4 Practice-based design principles

Context (C)	Agency (A)	Mechanism (M)	Outcome (O)	PB-DP
When VCs assess early-stage technology ventures on their sustainability impact and risks,	they should assess both positive sustainability impact as well as ESG risks,	thereby creating a holistic understanding of the sustainability impact of the startup and its technology,	to enable a comparison of economic, environmental, social, and governance impact and identify synergies and trade-offs.	PB-DP1
	they should adopt future-oriented approaches, such as analyzing the business model of these early-stage technology startups formulating an impact narrative,	thereby forecasting the development of technology startups,	to identify if the technology startups will potentially create a significant sustainability impact and discover potential ESG risks that may be caused by or can create harm for the technology startups.	PB-DP2
	they should rely on qualitative assessments rather than quantitative analyses and make informed assumptions throughout the assessment,	thereby mitigating information limitations,	to closely reflect the actual situation whenever (quantitative) information is not available.	PB-DP3
	they should explicitly document and communicate their assumptions, actively engage with the early-stage technology startup, and employ a triangulation approach throughout the assessment process,	thereby mitigating information limitations,	to improve the reliability of the assessment process and outcome.	PB-DP4
	the assessment process should be clear and structured,	thereby minimizing the resource need,	such that performing the assessment is workable and attainable to VC investors.	PB-DP5

Context (C)	Agency (A)	Mechanism (M)	Outcome (O)	PB-DP
	they should offer early-stage technology startups knowledge and support,	thereby minimizing the resource need,	such that performing the assessment is workable and attainable to early-stage technology startups.	PB-DP6
	the assessment should remain adaptable in how the activities are executed,	thereby enabling customization,	to ensure the assessment fits the focus of the VC fund and the characteristics of a specific investment case.	PB-DP7
	they should assess the maturity of these technology startups,	thereby considering the differing abilities and needs of technology startups,	to tailor their assessment and support to the technology start-up's advancement level.	PB-DP8
	the assessment should remain adaptable to refinement, compliance with (new) regulations, and stay aligned with sustainable developments,	thereby ensuring continuous improvement,	to improve the quality and efficiency of the assessment process while meeting regulations and remaining applicable to the current status quo of sustainability.	PB-DP9
	they should adopt a standardized process,	thereby ensuring transparency and uniformity among assessments,	to enhance comparability and reduce the resource burden for investors and technology startups.	PB-DP10
	they should quantify the impact in monetary terms,	thereby ensuring uniformity among assessment outcomes,	to enhance the comparability of technology startups.	PB-DP11
	they should integrate the assessment into the investment process of the VC, as well as in the organizational processes of the technology startup,	thereby ensuring regularity and commitment,	to drive strategic decision-making in favor of sustainability impact.	PB-DP12

4.4.2 Comparison of the research-based design principles and practice-based design principles

We compared the two initial sets of design principles to synthesize the theoretical and empirical insights. This comparison informed the final design principles (DPs) presented in Table 4.5 and highlights how the practice-based design principles (PB-DPs) relate to the research-based design principles (RB-DPs). Through this comparison, we identified areas where theory and practice converge, as well as domains where empirical insights offer additional nuance or highlight gaps in the theoretical literature. The resulting synthesis forms the foundation for the final set of DPs, which are further explained in the next section.

Table 4.5 Comparison of RB-DPs and PB-DPs

	RB-DP1	RB-DP2	RB-DP3	RB-DP4	RB-DP5	RB-DP6	RB-DP7	RB-DP8	RB-DP9
PB-DP1								X	
PB-DP2		X							
PB-DP3									
PB-DP4			X	X	X				
PB-DP5									X
PB-DP6									
PB-DP7							X		
PB-DP8	X								
PB-DP9									
PB-DP10						X			
PB-DP11									
PB-DP12									X

4.5 THEORIZING AND JUSTIFYING FINAL DESIGN PRINCIPLES

Since the justify step aimed to refine the initial principles into a more generalizable final set, this section describes the finalized design principles resulting from the theorizing and justifying phases.

4.5.1 Create a life cycle understanding

The first design principle (DP1) is grounded in the idea that a sustainability impact assessment framework must incorporate a life cycle understanding of the technology, as articulated in RB-DP8. Evaluating environmental impact across each stage of technology development—from raw material extraction to manufacturing, distribution, use, and end-of-life—provides a comprehensive perspective on impacts throughout the technology's life cycle (Popescu et al., 2021). This perspective helps uncover hidden upstream or downstream impacts that may not be immediately apparent. As an impact officer from VCc notes (supporting PB-DP1):

> *"We almost always assess impact potential. At the time of our investment, there is rarely impact because companies usually don't have a product on the market yet. There's no revenue yet."*

A life cycle perspective prevents VCs from focusing too narrowly on one part of the value chain and ensures that impacts across all stages are considered (UNEP, 2004; Judl et al., 2015; Popescu et al., 2021). Such an approach supports the identification of synergies and trade-offs over time.

> **DP1:** *When VCs assess technology ventures on their sustainability impact and risks (**C**), they should assess both positive sustainability impact as well as the sustainability risks over time (**A**), thereby creating a life cycle understanding of the technology (**M**), to i) enable a comparison of economic, environmental, social, and governance impact; ii) identify synergies and trade-offs over time; and iii) uncover hidden impacts (**O**).*

4.5.2 Forecasting sustainability developments over time

The second design principle (DP2) is based on the value of future-oriented assessment approaches, as emphasized in RB-DP2. VCs acknowledge that early-stage ventures—often described as "three people in a lab" (VCm)—rarely have commercialized products or demonstrable impact. Because sustainability impact typically materializes only after commercialization, assessing only current impact would provide an incomplete view. VCs thus rely on assumptions and projections to evaluate a venture's potential future sustainability impact and risks. A portfolio manager of VCb highlights this logic (aligned with PB-DP2):

"We have to look at the impact that will be generated later on. We have to look at what could be an ESG issue once they actually go to production and how can we mitigate that? So, we definitely take a future outlook."

The literature similarly emphasizes prospective assessments that explore multiple possible future trajectories (Fichter et al., 2023; Matthews et al., 2019; Strömmer & Ormiston, 2022; Trautwein, 2021). Industry tools such as theories of change, impact hypotheses, scenario analysis, and the Five Dimensions of Impact also rely on forward-looking reasoning (Impact Frontiers, n.d.; McLoughlin et al., 2009; Shields & Shelleman, 2017; Sopact & Sheth, 2020). An investment manager of VCk states (underpinning PB-DP2):

"We use the Theory of Change to define what the organization does, for whom and why. A Theory of Change is a visual description of the activities that an organization undertakes, and how they lead to certain effects (outcomes) and social objectives (impact) in the short or long term."

Together, these insights result in the following design principle:

DP2*: When VCs assess technology ventures on their sustainability impact and risks (***C***), they should adopt future-oriented approaches such as impact hypothesis and sustainability risk analysis (***A***), thereby forecasting the development of technology ventures and its potential future impact (***M***), to shape technology ventures in the most favorable outcome regarding sustainable development (***O***).*

4.5.3 Mitigating information limitations by qualitative assessments

Although sustainability impact assessment requires relevant data, early-stage technology ventures often lack sufficient or reliable information. An ESG manager from VCm notes (supporting PB-DP3):

"In the early seed phase, the data required for this task is often available only to an insufficient extent and in inferior quality."

This is consistent with scholarly findings that early-stage ventures face data scarcity, uncertainty, and context-specific information limitations (Fichter et al., 2023; Haase et al., 2022; Sauve et al., 2023; Trautwein, 2021). Quantitative methods are often not feasible, as ventures may revise their processes or lack stable benchmarks (Clarke-Sather et al., 2011). Still, the future remains uncertain (Barberio et al., 2014). As an analyst from VCe explains (supporting PB-DP3):

> *"You are doing a forecast for a company that barely exists; there are just so many things we don't know and won't know because these ventures might still revise their process."*

In response, VCs often rely on qualitative assessments, using informed assumptions, expert opinions, and discussions with venture teams. As one impact officer from VCc put it:

> *"Because we invest in early-stage companies, data is often not available. But we try to fill in as much data points as we can. Often qualitative, sometimes quantitative."*

Moreover, when quantitative data is unattainable, VCs draw on experience with similar ventures to approximate realistic values (Clarke-Sather et al., 2011; Judl et al., 2015). An investment manager from VCj stated (supporting PB-DP3):

> *"Estimations will be used in situations where it is not possible or unduly burdensome to obtain observable data. Such estimations will be based on experience with similar companies and will aim to reflect the actual situation as closely as possible."*

Thus, qualitative assessments, paired with informed assumptions, help mitigate information limitations common in early-stage technology ventures.

> **DP3***: When VCs assess technology ventures on their sustainability impact and risks (***C***), they rely on qualitative assessments rather than quantitative analyses and make informed assumptions throughout the assessment (***A***), thereby mitigating information*

*limitations (**M**), to closely reflect the actual situation whenever (quantitative) information is not available (**O**).*

4.5.4 Mitigating information limitations by stakeholder involvement

The fourth design principle draws on RB-DP3, RB-DP4, and RB-DP5, as well as PB-DP4, emphasizing that stakeholder involvement is essential for mitigating information limitations in sustainability impact assessments. Involving multiple stakeholders and experts helps address gaps, validate assumptions, and increase the reliability of the assessment. Examples of relevant stakeholders include the technology venture itself, the VC, customers, and supply chain partners (Lingane & Olsen, 2004; Matthews et al., 2019; McLoughlin et al., 2009; Strömmer & Ormiston, 2022).

First, involving stakeholders ensures that the assessment remains meaningful and aligned with their needs (Coffay et al., 2022). Incorporating their perspectives enhances relevance, strengthens cooperation, facilitates discussion, stimulates scenario building, and enables collective learning—ultimately fostering trust (Hervieux & Voltan, 2019; Sam-Aggrey, 2020; Strömmer & Ormiston, 2022).

Second, stakeholder involvement supports the development of future scenarios. By integrating diverse perspectives, VCs can reduce uncertainties surrounding the development of the technology venture and its potential impact, thereby increasing the assessment's legitimacy (Strömmer & Ormiston, 2022; Matthews et al., 2019). An investment manager from VCd described how they triangulate multiple types of information (supporting PB-DP4):

"We use various research papers, databases, interviews, opinions, and combine those with our owns."

VCs frequently verify information provided by ventures through reference calls, triangulating different types of information sources. Triangulation also extends to the people involved in the assessment. For example, at VCc, results produced by deal teams or investment managers are reviewed by ESG officers, and vice versa (supporting PB-DP4):

"To ensure quality and consistency, assessments that the deal team or investment manager performs are reviewed by the ESG officer, and vice versa"

Third, active engagement during the assessment process helps reduce the risk of ventures producing inaccurate or fabricated answers. A portfolio manager from VCb explained their reasoning for conducting interviews rather than sending questionnaires (again supporting PB-DP4):

"Why we do it as an interview and not just as a list that we ask them to send back, for example, is because I think we would have a larger risk if we just send them a list of questions. We would have a larger risk that they will maybe make up an answer. For us it's better to say: hey, it's OK to not provide an answer rather than have an answer that is not based on anything."

In sum, involving stakeholders throughout the assessment process—through interviews, consultations, reference calls, and internal cross-checks—helps triangulate information, reduce uncertainty, and increase the reliability of sustainability impact and risk assessments.

DP4*: When VCs assess technology ventures on their sustainability impact and risks (***C***), they should involve multiple relevant stakeholders throughout the assessment process to facilitate diversity in perspectives, expertise, and learning dimensions (***A***), thereby ensuring data triangulation (***M***), to reduce uncertainties and improve the reliability of the assessment process and outcome (***O***).*

4.5.5 Manage resources throughout the process

There is a clear need for simple assessment approaches, as articulated in RB-DP5. Although both VCs and technology ventures recognize the importance of managing sustainability impacts and risks, many describe the sustainability assessment process as challenging and complex. Practitioners noted that sustainability considerations are relatively new in the VC context, and the introduction of regulations such as the SFDR has added further complexity. A portfolio manager of VCb emphasized these difficulties (supporting PB-DP5):

"For our team, this assessment is quite confusing. They have to do all these assessments and checks that they never did before, and they don't all know the regulations."

VCs also face uncertainty in interpreting regulatory expectations. As an investment manager from VCl explained (underpinning PB-DP5):

"We are in the initial phase of a potentially significant theme in the investment industry. Complex laws and regulations are being interpreted differently, leading to a lack of consensus, despite the strict guidance provided. As a result, there is divergence in the actions of different entities."

Technology ventures similarly experience sustainability assessment as complicated and time-consuming. Many lack the expertise, experience, or resources—time, knowledge, personnel—to complete complex sustainability evaluations (Shields & Shelleman, 2017; Trautwein, 2021). VCs in our sample outlined several strategies to address these challenges. One strategy is to integrate sustainability assessments directly into existing VC investment processes, rather than treating them as separate tasks. An investment manager from VCj explained (supporting PB-DP12):

"Impact considerations are ingrained throughout the investment process. Impact assessments are ingrained throughout the investment process – from screening through the ownership period and exit."

To make the assessment easier to implement, VCs emphasized the importance of using a clear and well-structured process. VCc provided an example of this (supporting PB-DP5 and PB-DP12):

"For our team, this assessment is quite confusing. They have to do all these assessments and checks they never did before, and they don't all know the regulations. It created confusion, so we created a checklist to help them."

A clear, structured approach reduces the resource burden for both VCs and ventures (Trautwein, 2021; Varga, 2018). Literature and practitioners alike argue that sustainability assessments must be practical, feasible, and

supported through guidance to ensure that limited resources—especially at early-stage ventures—are used effectively (Clarke-Sather et al., 2011; Fichter et al., 2023; Judl et al., 2015).

> **DP5***: When VCs assess technology ventures on their sustainability impact and risks (***C***), the assessment should be a clear and well-structured process (***A***), thereby minimizing the resource need (***M***), such that performing the assessment is practical and achievable to both VCs and ventures (***O***).*

4.5.6 Create uniformity in the process

The sixth design principle is grounded in RB-DP6 and PB-DP10, addressing the widespread lack of standardization in sustainability impact assessments across the venture capital industry. Currently, VCs use highly heterogeneous methods, making cross-venture or cross-portfolio comparisons extremely difficult. This inconsistency undermines reliability, reduces transparency, and increases the resource burden for both VCs and ventures (Popescu et al., 2021).

Although several frameworks attempt to standardize measurement—such as Social Return on Investment (SROI) (Arvidson et al., 2013; Corvo et al., 2022; Lingane & Olsen, 2004), IRIS+, the GRI Standards, or the CISL Investment Impact Framework—these are often challenging to apply directly to early-stage technology ventures. Monetizing impact (i.e., SROI) is especially difficult because early-stage data is insufficient for producing meaningful or comparable results. VC practitioners in our sample emphasized the need for greater uniformity in assessment. As an impact associate from VCi stated (supporting PB-DP10):

> *"There is a growing need for a unified approach that enables investors to compare strategies and understand how well capital has been deployed and what impact has been created."*

Standardizing assessment processes and outcomes ensures greater transparency, reduces the cognitive and administrative load associated with evaluating ventures, and improves comparability—both within and across VC portfolios.

DP6: *When VCs assess technology ventures on their sustainability impact and risks (**C**), they should adopt a standardized impact assessment process (**A**). This ensures consistency and reliability in assessments and their outcomes (**M**), ultimately enhancing the comparability of technology ventures (**O**).*

4.5.7 Enable customization in sustainability impact assessments

While standardization is important, sustainability impact assessments must also allow for customization, as emphasized in RB-DP7 and PB-DP7. The empirical evidence shows that assessments must be adaptable because technology ventures differ substantially in terms of their sector, technology, geographic location, maturity level, and business model (McLoughlin et al., 2009; Varga, 2018). A portfolio manager from VCb explained (supporting PB-DP7):

> *"Some things are also depending on where they are located, for example, the stage of the company."*

Both practitioners and researchers note that trying to impose a rigid, "one-size-fits-all" assessment method risks misrepresenting venture characteristics and missing important information. Ventures operate in highly heterogeneous contexts, and sustainability risks and opportunities vary accordingly. As an investment analyst from VCe stressed (supporting PB-DP7):

> *"Yes. I would say eighty percent of this is tailor made. That was the key takeaway for me I think that will also be a key takeaway for you, any kind of analysis on startups and VC begins and ends with "it depends."*

Thus, the challenge is to balance standardization (DP6) with the flexibility required to account for sector-, technology-, and maturity-specific factors. The literature similarly recommends combining generalizable frameworks with methods that support venture-specific tailoring (Bhatt, 2018; Varga, 2018; Puttick & Ludlow, 2012).

DP7: *When designing an assessment for VCs to assess technology ventures on their sustainability impact and risks (**C**), the*

*assessment should remain adaptable in how the assessment steps are executed (**A**),this adaptability enables a balance between standardization and customization (**M**), ensuring reliability while aligning with the unique characteristics of each investment case (**O**).*

4.5.8 Consider the technology ventures' stages in a sustainability impact assessment

The final design principle builds on RB-DP1 and PB-DP8 and concerns the need to account for the maturity level of a technology venture. A venture's stage of development—technologically and organizationally—shapes the type of information available, the predictability of future sustainability impacts, and the venture's ability to take corrective action.

In early-stage ventures, a process known as *shaping* is possible: VCs and founders can steer technological development toward more sustainable trajectories and avoid or mitigate negative consequences (Fleischer & Grunwald, 2008; Sauve et al., 2023; Van der Hulst et al., 2020). Early-stage data may be limited and uncertain, but the potential to influence outcomes is high (Matthews et al., 2019).

Later-stage ventures, by contrast, typically have more predictable business models, clearer technology-market fit, and more robust data. However, their ability to change fundamental technological or organizational choices is lower. The maturity level also determines what types of governance or data-collection structures are feasible. As an impact officer from VCc explained (supporting PB-DP8):

"We regularly assess the level of maturity of a company's ESG management capacity on the basis of a broad range of aspects, from level of responsiveness amongst the Management Team to implementation of mitigating measures."

VCs also adjust their post-investment support based on maturity. Early-stage ventures may need help developing governance frameworks and impact measurement systems, whereas later-stage ventures may need support in scaling existing sustainability practices.

DP8*: When VCs assess technology ventures on their sustainability impact and risks (***C***), they should assess both the maturity of the technology and the venture team (***A***). This approach accounts for the varying abilities and needs of technology ventures (***M***), to: (i) to emphasize control at lower maturity levels and predictability at higher maturity levels; and (ii) tailor both the assessment and post-investment support to the level of maturity of the technology and the venture team (***O***). This approach accounts for the varying abilities and needs of technology ventures various stages (***M***), to: (i) to emphasize control at lower maturity levels and predictability at higher maturity levels; and (ii) tailor both the assessment and post-investment support to the level of maturity of the technology and the venture team (***O***).*

In sum, see Table 4.6 for the full overview of the final set of design principles.

Table 4.6 Final set of design principles

DP#	Context (C)	Agency (A)	Mechanism (M)	Outcome (O)	Underpinning
DP1	When VCs assess early-stage technology ventures on their sustainability impact and risks,	they should assess both positive sustainability impact and risks,	thereby creating a life cycle understanding of the sustainability impact of the startup and its technology,	to i) enable a comparison of economic, environmental, social, and governance impact; ii) identify synergies and trade-offs; and iii) uncover hidden impacts.	RB-DP8 & PB-DP1
DP2		they should adopt future-oriented approaches, such as analyzing the business model and formulating impact hypotheses,	thereby forecasting the development of technology ventures,	to i) identify if the technology ventures will potentially create significant sustainability impact; ii) discover potential sustainability risks that may be caused by or can create harm for the technology ventures; and iii) shape technology ventures in the most favorable outcome regarding sustainable development.	RB-DP2 & PB-DP2
DP3		they should rely on qualitative assessments rather than quantitative analyses and make informed assumptions throughout the assessment,	thereby mitigating information limitations,	to closely reflect the actual situation whenever (quantitative) information is not available.	PB-DP3

DP4	they should involve multiple relevant stakeholders throughout the assessment process who facilitate the establishment of shared visions for desirable futures,	thereby mitigating information limitations,	to reduce uncertainties and improve the reliability of the assessment process and outcome.	RB-DP3 & RB-DP4 & RB-DP5 & PB-DP4
DP5	the assessment should fit the organizational processes and be clear and well-structured, and help must be offered to technology ventures,	thereby minimizing the resource need,	such that performing the assessment is workable and attainable to both VCs and ventures.	RB-DP9 & PB-DP5 & PB-DP12
DP6	they should adopt a standardized process and measurement,	thereby ensuring uniformity among assessments and assessment outcomes,	to enhance comparability of technology ventures.	RB-DP6 & PB-DP10
DP7	the assessment should remain adaptable in how the activities are executed,	thereby enabling customization,	to ensure the assessment fits the focus of the VC fund and the characteristics of a specific investment case.	RB-DP7 & PB-DP7
DP8	they should assess the maturity of the technology as well as the startup team,	thereby considering the differing abilities and needs of technology ventures,	to i) to create an assessment focused on control in lower maturity levels and predictability in higher maturity levels; and ii) tailor the assessment and post-investment support to the level of advancement of the startup team.	RB-DP1 & PB-DP8

4.6 CREATING AND EVALUATING THE VC GREEN SCHEME

The eight design principles outlined above formed the foundation for developing a generic design solution for VCs. In addition to the DPs, a set of design requirements was formulated to support the creation of the framework (Section 4.6.1). The solution is detailed in Section 4.6.2, followed by the evaluation of the framework in Section 4.6.3.

4.6.1 Design requirements

The design requirements were derived from the empirical analysis. Table 4.7 lists the requirements that informed the creation of the framework.

Table 4.7 Design requirements

Functional requirements	User requirements	Pre- or boundary conditions
1. provide guidance for an informed and objective investment decision regarding sustainability impact and sustainability risks.	1. be well-structured, easy to use, and easy to interpret.	1. adhere to EU regulations and fulfill the SFDR Article 9 requirements.
2. provide the ability to compare early-stage technology ventures within the fund.	2. significantly reduce the time spent by investment managers on sustainability impact and sustainability risk assessment	2. be compatible with the investment process of a VC.
3. be a standardized approach.	3. be easy to implement and easy to update.	3. be focused on early-stage technology ventures.
4. be financially affordable for early-stage technology ventures.		

The requirements include functional requirements (e.g., providing guidance for informed and objective investment decisions, enabling comparability between ventures, and ensuring affordability for early-stage startups); user requirements (e.g., ease of use, clarity, reduced time demands); and pre- or boundary conditions (e.g., compliance with EU regulations such as SFDR Article 9, compatibility with VC investment processes, and a focus on early-stage technology ventures).

These requirements collectively guided the development of a framework that is both practical for VCs and feasible for early-stage ventures to adopt.

4.6.2 The framework: VC Green Scheme

The VC Green Scheme is a sustainability impact assessment framework designed to integrate seamlessly into the four phases of a typical VC investment process: screening, due diligence, closing, and post-investment. The framework consists of five key steps: (1) Scan for exclusion criteria, (2) Sustainability impact analysis, (3) Sustainability risk analysis, (4) Impact game plan, and (5) Reporting. Figure 4.4 outlines the framework, its integration with standard VC investment phases, and its relationship to the design principles.

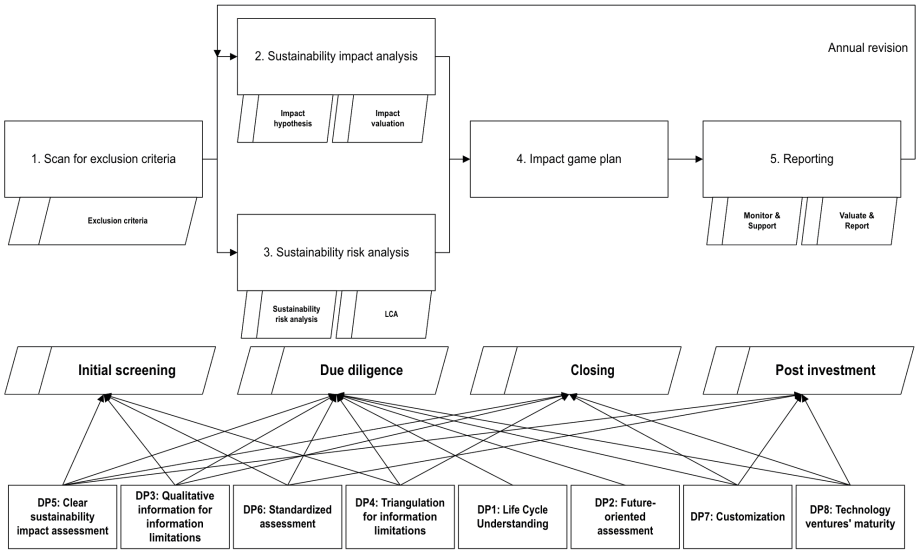


Figure 4.4 Solution Design "The VC Green Scheme": Sustainability impact assessment framework

1. *Scan for exclusion criteria.* At the start of a new fund, sustainability-oriented VCs typically create a list of sectors and technologies they will not invest in, aligned with the expectations of their fund investors (linked to DP5). These exclusion lists usually cover sectors deemed inherently unsustainable (e.g., tobacco, gambling, fossil fuel extraction) or activities considered socially or environmentally harmful.

During the screening phase, a checklist is used to assess whether new investment opportunities fall within the fund's sustainability scope (DP6).

Here, VCs begin collecting qualitative data and triangulating sources (DP3, DP4). Data is verified through reference calls, desk research, internal assessments, and, when possible, external perspectives.

2. *Sustainability impact analysis*. The sustainability impact analysis takes place during the due diligence phase and evaluates the potential scale and nature of a venture's positive contributions to environmental and social objectives. According to SFDR, a sustainable investment must contribute to such objectives, avoid significant harm to other environmental or social objectives, and follow good governance practices (European Commission, 2019).

To assess the sustainability impact, VCs may draw on tools such as the theory of change, dimensions of impact, or similar qualitative frameworks (DP1, DP3, DP5, DP6, DP7). These tools enable VCs to apply a future-oriented perspective (DP2), particularly important because early-stage ventures have yet to commercialize their products or generate measurable impact. Appendix G provides a further overview of potential assessment methods for steps 2 and 3.

VCs may also attempt to quantify impact using methods such as CO_2 reduction estimates or impact monetization (DP4). However, because early-stage ventures rarely have robust data, valuation exercises often rely on qualitative information and assumptions. The maturity of the venture influences the depth and specificity of the impact analysis (DP8).

3. The *sustainability risk analysis* identifies, classifies, and assesses risks related to environmental, social, and governance factors. This includes tools such as double materiality assessments, ESG questionnaires, dual-use assessments, and SFDR-mandated analyses such as Principal Adverse Impacts (PAIs) and Do-No-Significant-Harm (DNSH) criteria (DP1, DP2, DP7).

Depending on the venture's maturity, sustainability risk metrics may or may not be readily available (DP6). When metrics cannot yet be reported by ventures, VCs estimate or approximate values (DP3). The framework also recommends incorporating a validation plan in Step 4, enabling ventures to test or refine assumptions over time.

4. The fourth step of the VC Green Scheme is the creation of an *impact game plan*. As part of the closing and post-investment phases, VCs

collaborate with ventures to develop an impact game plan—a structured set of steps the venture will take in the period following investment to measure, monitor, and improve sustainability impact and risks (DP5, DP7). This includes activities such as: (1) establishing data collection processes, (2) setting impact-related milestones, (3) identifying governance improvements, and (4) validating key assumptions made in earlier assessments (DP8). Early-stage ventures focus on validating assumptions and triangulating data; later-stage ventures may focus on scaling or formalizing sustainability practices (DP3, DP4).

5. During the post-investment phase, the emphasis shifts to monitoring and *reporting*. This includes ongoing support and formal follow-up, such as: (1) regular updates between VCs and ventures, (2) integration into board meeting agendas, (3) annual sustainability and risk reports, and (4) reassessments of impact and risk as new data emerges.

VCs are expected to revisit the sustainability impact and risk assessments annually, customizing the impact game plan as needed (DP5, DP7, DP8). These updates also allow internal and external comparability within the VC portfolio (DP6).

To support implementation, a customized Excel-based tool was developed at DeepTechXL. This tool operationalized the VC Green Scheme as a step-based workflow and helped integrate the assessment into the broader investment team's routines.

4.6.3 Evaluating VC Green Scheme

The VC Green Scheme was evaluated from February 2023 to December 2024. Over this period, DeepTechXL assessed 10 ventures using the framework. The evaluation followed a three-stage human risk and effectiveness strategy (Venable et al., 2016), focusing on *correctness*, *comprehensiveness*, *usability*, and *utility*. The adherence of the framework to the design requirements was also evaluated and can be found in Appendix H.

4.6.3.1 Formative evaluation one

The first version of the assessment framework was implemented in February 2023. A formative evaluation took place in May 2023 with the DeepTechXL Impact Committee, followed by a feedback session with employees. The evaluation focused on *usability* and *comprehensiveness*. Impact Committee feedback indicated that the structure was clear and the framework sufficiently complete. One member commented:

"Found it very complete. Links to SDGs is good. Risks are well articulated."

DeepTechXL employees considered the framework to be compatible with existing investment processes and effective in supporting sustainability assessments for early-stage ventures. Based on feedback, two adjustments were made. First, the team removed impact monetization from the initial due diligence because it required excessive assumptions and produced limited comparability. Second, sustainability risk analysis was shifted primarily to the final due diligence, with only a preliminary risk scan conducted earlier, to ensure efficient resource allocation. In sum, the first formative evaluation validated the *usability* and *comprehensiveness* of the framework while providing additional feedback to improve.

4.6.3.2 Formative evaluation two

A second formative evaluation in June 2024 further assessed the framework's *correctness*. The Impact Committee reported that the expanded structure for impact and risk analysis improved completeness. They also highlighted that the framework offered multiple strategies to mitigate information limitations, such as qualitative assessments, assumption-based forecasting, triangulation, and the inclusion of the committee's external perspective before decisions. One investment manager noted that the framework was easier and less time-consuming than expected, and a Partner stated "it is a great step forward, let's implement the framework". A key recommendation was that the Impact Committee's input should become a formalized component of the investment decision process. As a result, the deal teams began presenting sustainability assessments to the committee at both the initial and final due diligence stages prior to the respective investment committees. In conclusion, the solution is *correct*.

4.6.3.3 Summative evaluation

The summative evaluation centered on the *utility* of the framework. This was assessed from two perspectives: Compliance and monitoring, and long-term effects on venture success.

DeepTechXL's results were included in its annual SFDR Article 9 reports and Impact Reports for 2022, 2023, and 2024. These reports were successfully audited in both 2023 and 2024. Regarding the 2023 Impact Report, the Impact Committee commented:

"The document shows enthusiasm and dedication to impact investing."

These findings indicate that the framework supports regulatory compliance and systematic monitoring. Evaluating longer-term effects (e.g., follow-on funding, exit success) will require future longitudinal research. Overall, the framework was deemed relevant, viable, and effective, addressing a real-world problem and demonstrating practical value for VCs and stakeholders (Dimov et al., 2023; Tremblay et al., 2010; Venable et al., 2016), concluding the positive *utility* of the solution.

4.7 DISCUSSION AND CONCLUSION

Although recent regulatory developments in Europe require VCs to assess, monitor, and report on sustainability-related issues—including the EU Taxonomy and the SFDR—there remains limited guidance on how VCs can meaningfully evaluate the sustainability impact of early-stage technology ventures (European Commission, 2022). This gap represents a significant omission in both theory and practice. Existing literature seldom incorporates sustainability as a central criterion in VC assessments or in the value-adding support VCs provide to portfolio companies (De Bettignies & Brander, 2007; Croce et al., 2013; Dutta & Folta, 2016). Similarly, in practice, VCs lack a standardized and systematic approach for assessing, monitoring, and reporting sustainability impacts.

To address this gap, we developed a sustainability impact assessment framework tailored to VC needs. Our findings demonstrate that it is possible to design a structured and adaptable framework that allows VCs to customize assessment steps to different contexts. The resulting VC Green Scheme provides a comprehensive blueprint for sustainability assessment and is intended both as a theoretical contribution and a practical tool.

4.7.1 Theoretical contributions

This study makes two primary contributions to theory. First, we designed and evaluated a novel sustainability impact assessment framework that enables VCs to assess technology ventures from a socio-environmental perspective. The framework emerged from a systematic DS cycle, grounded in design principles derived from both theoretical foundations and em-

pirical insights. While sustainability considerations are becoming more prominent in entrepreneurship and finance research, scholars have yet to clearly define how VCs can conceptualize and systematically assess sustainability impact and risks—a significant blind spot in entrepreneurial finance. Our study addresses this gap by integrating insights from entrepreneurship, sustainable entrepreneurship, and entrepreneurial finance into a new theoretical foundation for sustainability-oriented VC assessment (Gompers et al., 2020; Granz et al., 2021). This contribution opens new avenues for research on how sustainability considerations influence VC decision-making, innovation pathways, and impact creation in early-stage ventures.

Additionally, we show that VCs are increasingly engaging in sustainability-related value-added support. Through DPs 5 to 8, we offer theoretically grounded explanations of how VCs assess and support sustainability in early-stage ventures. These principles extend existing entrepreneurial finance theory by providing actionable and generalizable insights into how sustainability can be integrated into VC assessment processes. The VC Green Scheme thus functions both as a practical artifact and a conceptual contribution, illustrating the potential of DS to generate targeted solutions for under-explored but pressing challenges.

Second, our study contributes to the DS research methodology by demonstrating how DPs can be developed and validated in highly contextual and emergent domains. While DS is increasingly used in management and entrepreneurship research, more examples are needed to show how DS can be rigorously applied in real-world, uncertain contexts such as sustainable venture capital. Our study offers such an illustration. We provide a transparent, context-specific approach to deriving DPs through the integration of qualitative data and practitioner engagement, consistent with abductive reasoning approaches (Lee et al., 2011; Cronholm et al., 2023). Abduction enabled us to iteratively interpret patterns in empirical data alongside theoretical perspectives, ultimately translating them into normative, prescriptive design knowledge.

In line with Gregor et al. (2020), our DPs move from descriptive insights to prescriptive guidance, offering context-sensitive yet theoretically informed design knowledge. These principles—such as integrating life cycle perspectives (DP1), adopting future-oriented assessments (DP2), and balanc-

ing standardization with adaptability (DP6, DP7)—serve as design heuristics that are more actionable than grand theories yet more generalizable than simple case-specific recommendations.

Finally, following Gierlich-Joas et al. (2024), we explicitly articulate the contextual conditions for which the DPs are intended, namely, when VCs assess early-stage technology ventures on sustainability impact and risks. By clarifying the design context, we enhance the analytical generalizability of the principles. More broadly, the study demonstrates how DS can support the co-creation of actionable, practitioner-oriented knowledge in ill-structured, real-world problem spaces. In doing so, we respond to recent calls for a more instrumental approach in research on technological innovation (Romme & Holmström, 2023), illustrating how scholars can move beyond analysis toward designing solutions that shape practice.

4.7.2 Managerial implications

This study offers several important implications for VCs and technology ventures. First, it raises awareness among VCs about the growing strategic importance of sustainability impact as a core investment criterion. Our findings support the view that sustainability considerations align not only with long-term societal goals but also with the long-term financial performance of VC portfolios. By integrating sustainability into their assessment processes, VCs can evolve from a primarily economic focus toward a more balanced approach that captures economic, social, and environmental value.

Second, the DPs provide practical guidance for structuring and formalizing sustainability impact assessments across the VC investment cycle. They offer actionable insight into how VCs can design clear, usable, and context-sensitive assessment processes while also customizing practices to reflect their investment strategy and portfolio composition. Tools such as life cycle assessments, theories of change, and impact hypotheses can be integrated into these processes, depending on venture maturity, data availability, and industry context.

The VC Green Scheme operationalizes these insights into a step-by-step model that VCs can adopt or adapt. By visualizing and structuring the assessment process, VCs gain a more coherent approach to evaluating sustainability potential and risks. The framework improves decision-making,

enhances the consistency of evaluation across ventures, and strengthens post-investment value creation by identifying sustainability-related areas for support.

These insights also hold implications for technology ventures. Understanding how VCs assess sustainability—and which factors they consider important—can help ventures prepare more effectively for fundraising. Ventures that can articulate their sustainability impact potential, risk management strategies, and readiness for data collection are likely to be more attractive to sustainability-oriented VCs.

4.7.3 Limitations

This study contributes to research on sustainability impact assessment for early-stage technology ventures, yet several limitations should be acknowledged.

First, while our systematic literature review identified relevant sustainability impact assessment approaches, the available academic literature on this topic remains limited. As a result, the review was expanded to include adjacent research streams, such as literature on sustainability assessment, venture capital, and early-stage technologies. Consequently, not all sources are fully tailored to the VC context. To mitigate this constraint, we focused on themes and insights supported by multiple sources, ensuring that only robust and relevant findings informed the DPs.

Second, the inclusion of grey literature was necessary due to the emerging nature of sustainability-oriented investing. While this increased the breadth of insights, it also introduced heterogeneity in the scientific quality of the review sources. Furthermore, our database search was limited to Scopus and ProQuest. Although both are widely used in entrepreneurship research, relevant literature indexed elsewhere may have been missed. To minimize this risk, we conducted a backward snowballing procedure to broaden the literature base.

Third, the sustainability impact assessment framework was designed in accordance with the EU's SFDR regulations, particularly the requirements of Article 9 funds. This regulatory alignment may limit the applicability of the framework outside the EU or in contexts with different sustainability reporting expectations. Nevertheless, many of the principles—such as

life cycle thinking, future-oriented assessments, and stakeholder involvement—are broadly generalizable to VCs in other regions.

4.7.4 Future research

This study opens several avenues for future research. First, further investigation is needed into the relationship between sustainability impact, ESG considerations, and financial performance—both at the VC fund level and the portfolio venture level. While practitioners in this study perceived positive effects from integrating sustainability impact assessments, quantitative research is required to examine the magnitude, mechanisms, and boundary conditions of these effects.

Second, both VC and sustainable entrepreneurship research would benefit from the development of LCA methodologies tailored to early-stage technology ventures. Traditional LCAs require substantial quantitative data and must be updated regularly—challenges that are particularly pronounced for resource-constrained startups. Future research could develop lighter, adaptive, and more scalable LCA approaches suitable for early-stage contexts.

Third, more research is needed on the post-investment value-added activities VCs provide in the realm of sustainability. Existing entrepreneurial finance literature emphasizes value creation in areas such as strategy, hiring, and networking, but sustainability-specific support remains understudied. Our findings suggest that many European VCs already engage in sustainability-related guidance, indicating a need to extend theoretical frameworks to incorporate sustainability as a distinct dimension of VC value-added contributions.

Finally, future research could investigate the specific conditions under which particular assessment tools (as listed in Appendix G) should be used and how these tools influence decision-making outcomes. While a detailed, prescriptive mapping of tools to contexts lies beyond the scope of this study, such research would support further refinement, testing, and enhancement of the VC Green Scheme and its underlying DPs.

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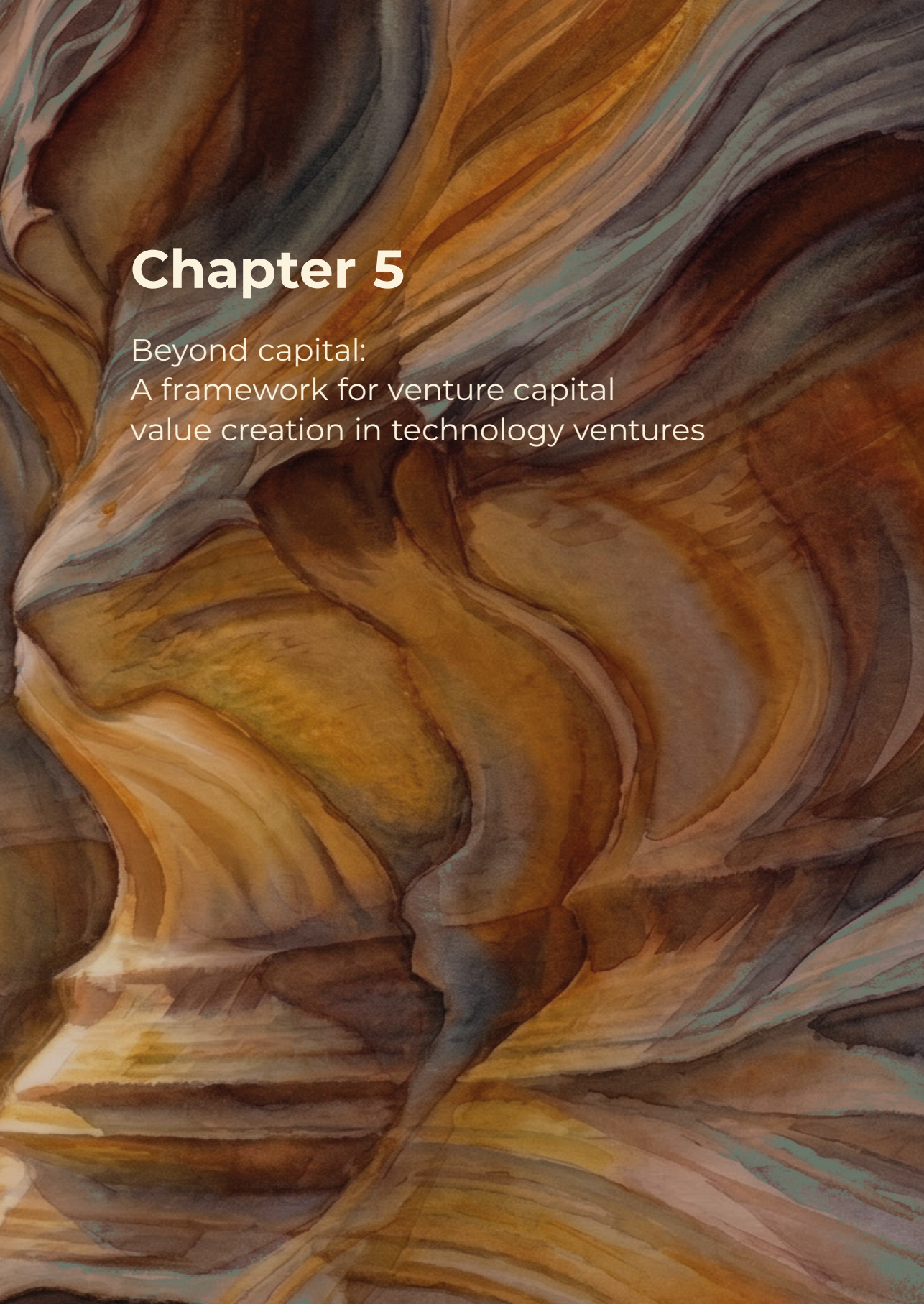
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Chapter 5

Beyond capital: A framework for venture capital value creation in technology ventures

ABSTRACT

Ventures funded by venture capitalists (VCs) systematically outperform their non-VC-backed counterparts. This comparative advantage may arise not only from venture capitalists' superior approach to investment selection, but also from the post-investment activities through which they generate value. Yet, prior research has primarily focused on investment decision-making by VC firms, rather than the complex and diverse activities through which they create value in the post-investment stage. Our study addresses this gap by adopting a comparative case study design that combines a literature review with an empirical analysis of twelve VC cases. Our findings are synthesized in the *VC Value Creation* framework. The framework involves six focus areas through which VC funds create value in their portfolio companies. It maps value-adding activities across three (i.e., strategic, operational, and technological) dimensions, two (i.e., direct and indirect) modes of VC involvement, along with venture-side and VC-side factors that shape VC value creation. By moving beyond one-dimensional lists of value-adding activities, our study provides a theoretically grounded and empirically informed framework of value-adding activities and modes of involvement of a VC. These findings have major implications for both scholars and practitioners in entrepreneurial finance.

Keywords: Venture capital; non-financial support; non-financial contributions; value creation; technology venture; technology entrepreneurship; entrepreneurial finance

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5.1 INTRODUCTION

Venture capital is a critical resource for financing technology ventures and has attracted substantial scholarly attention, since its rise in the late twentieth century (Gompers, 1995; Macmilllan et al., 1985, Svetek, 2022). A robust body of research demonstrates that ventures backed by venture capital (VC) funds systematically outperform their non-VC-backed counterparts (Gompers et al., 2010; Harris et al., 2014; Lahr, 2023). This body of evidence suggests that VC funds not only have superior capabilities in identifying and accessing high-potential investment opportunities, but also create value through their active involvement during the holding period (Kaplan & Schoar, 2005; Proksch et al., 2017). We define VC value creation here as the set of deliberate value-adding activities through which VC investors reduce uncertainty, enhance organizational and technological capabilities, and improve the commercial and financial trajectory of their portfolio companies.

More specifically for the European VC market, prior studies document positive effects of VC funds on firm growth, survival, and exit outcomes, although these effects vary substantially across countries, regions, and investor types in Europe (Croce et al., 2013; Pantea & Tkacic, 2025). The need to understand how VC funds create value has become even more pressing as the European Union (EU) seeks to strengthen and scale deep-tech and high-tech ventures by means of major initiatives such as the European Innovation Council and, more recently, the Scaleup Europe Fund (European Investment Council, 2026).

Whereas prior research mainly focused on the determinants of VC investment selection (Berliner et al., 2025; European Investment Council, 2026), our understanding of VC value-adding activities remains underdeveloped. Some studies examine the types of value-adding activities that VC funds undertake to support portfolio companies (Gompers et al., 2020; Proksch et al., 2017; Siefkes et al., 2025); though highly relevant, this work typically produces a list of activities which offers limited insight into the underlying mechanisms that drive and connect them. These lists have not yet sufficiently acknowledged the growing body of product-driven and technology-driven value-adding activities (Arqué-Castells, 2012; Lahr & Mina, 2016), nor have they accounted for contextual factors (Gompers et al., 2020; Siefkes et al., 2025). This study therefore reviews and maps the entire range

of post-investment value-adding activities employed by VCs, to develop a more holistic understanding of how activities jointly create value (Eisenhardt & Graebner, 2007). We adopt a comparative case study design (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) that integrates insights from a systematic literature review with evidence from twelve European VC cases to develop a conceptual framework of VC value creation.

This study contributes to the entrepreneurship literature by reconceptualizing VC value creation as a configurational and multi-modal process. In addition, our study contributes to entrepreneurship theory by showing that technological support constitutes a distinct and foundational dimension of VC value creation; it also introduces a conceptual distinction between the dimensions of value creation and modes of involvement. Finally, our study highlights that VC value creation is inherently adaptive and context-dependent, which extends existing typologies that omit these contextual factors (Gompers et al., 2020; Proksch et al., 2017).

5.2 METHOD

This section details the comparative case study approach, the role of the systematic literature review, and the data collection and analysis.

5.2.1 Research design

Our study draws on a literature review combined with a comparative case study design (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) that is well suited for examining VC value-adding practices within and across cases, particularly in view of our objective to build and extend theory from qualitative evidence. In line with other studies of entrepreneurial finance (Blume & Hsueh, 2024; Siefkes et al., 2025), we employed a case-based design supported by semi-structured interviews. This study therefore draws on the following four steps of the comparative case study approach (Eisenhardt, 1989), which is discussed in more detail in the remainder of this section: *(1) Literature review*: define the research question and conduct an a priori review; *(2) Data collection*: select cases, design the interview protocol, and gather data; *(3) Data analysis*: conduct within-case and cross-case analyses and compare emerging insights with the literature, and *(4) Theory building*: synthesize findings into a conceptual framework that provides a holistic perspective on organizing the value-adding activities of VCs.

5.2.2 Literature review

The principles of systematic review (Denyer & Tranfield, 2009) guided the literature review. More specifically, we used a conceptual integrative review approach (Okoli & Schabram, 2010), aimed at identifying and synthesizing the state of the art of the literature on categories of venture capital value-adding activities. This approach ensured a sufficient, a priori theoretical grounding of our empirical questions and emerging themes, enabling an effective comparison of empirical data with the literature to shape a robust novel conceptual framework (Eisenhardt, 1989). Figure 5.1 outlines the steps taken in the literature review process, which are described in more detail in the remainder of this subsection.

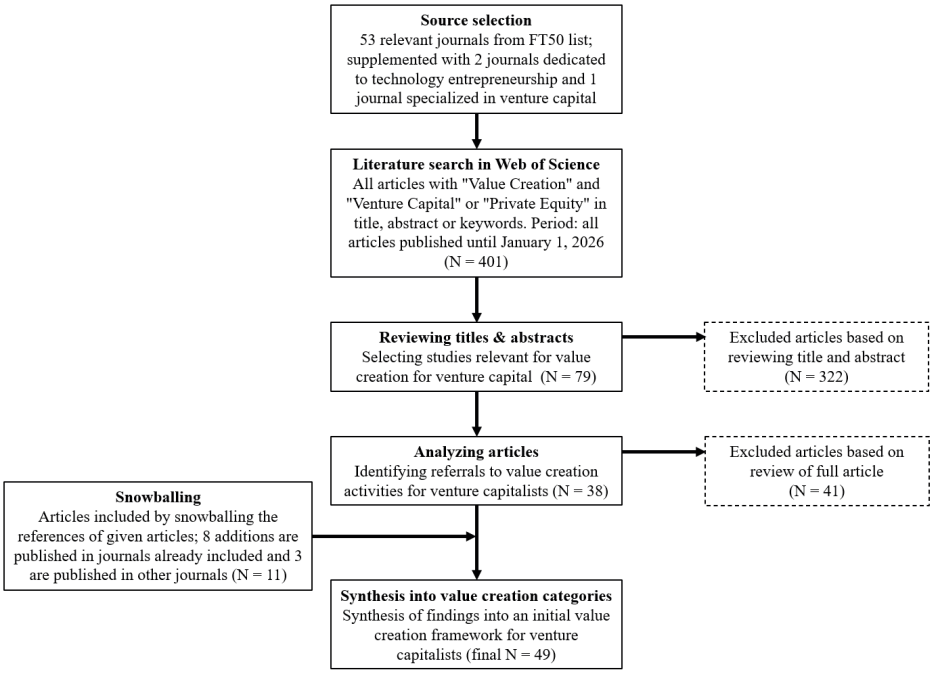


Figure 5.1 Steps taken in the review and synthesis of the literature

First, we constructed a dataset using Web of Science, which indexes peer-reviewed articles in journals operating an accredited double-blind review process. We included all articles published from each journal's inception through December 2025. The journal selection was based on the FT50 list, supplemented by Journal of Technology Transfer, Technovation, and Venture Capital, to ensure a broad coverage of technology venture-specific and VC-focused work. Finally, the topic operator com-

bined two keyword sets: “value creation” AND (“venture capital” OR “private equity”). Private equity was included as it serves as an umbrella term encompassing VC. Appendix I provides the complete search query.

Second, the initial query yielded 401 articles (see Appendix J). We reviewed titles and abstracts to assess the relevance to value creation in venture capital; papers focusing exclusively on private-equity fund performance were excluded. Then we did a full-text screening. Next, we applied backward snowballing by examining reference lists and endnotes in the retrieved articles (Krysta & Kanbach, 2022). The final selection included 49 articles. Appendix J provides an overview of both the initial selection and the final sample.Third, we synthesized the literature into value creation categories following an inductive approach toward conceptual clustering. We extracted all value-adding activities reported in the identified studies into a matrix. Following the principles of conceptual framework development (Jabareen, 2009), the clusters were iteratively refined into higher-order categories. The summary table of the literature review can be found in Appendix K.

5.2.3 Data collection

We identified twelve European VC funds as suitable cases for the comparative case study (Milosevic et al., 2020). The cases were selected using a combination of purposeful and convenience sampling, to ensure information-rich observations that would support theoretical inference (Brady, 2006; Palinkas et al., 2015; Reymen et al., 2015). We purposefully selected cases and their representative informants, based on three criteria. First, each VC fund’s headquarters needed to be in Europe to ensure a comparable institutional context. Second, each VC fund’s representative had a demonstrable track record in engaging in value creation for the fund’s technology ventures, ensuring the representative’s understanding of, an experience in, post-investment value-adding activities. Third, the representative’s VC fund was required to incorporate post-investment value creation into its core tasks and activities, enabling us to collect detailed information on the specific value-adding activities undertaken in the fund’s day-to-day operations. Within the scope of these criteria, we applied convenience sampling, which is often used for data collection in settings in which data is sensitive (Brady, 2006). Value creation, including value-adding activities, is often undisclosed, sensitive, and secretive within the context of VC, making personal connections critical to gaining access.

Value-adding activities in early-stage VC funds tend to be concentrated in small, expert-driven teams of senior investment professionals who personally execute or supervise all post-investment support activities. As such, we used our direct and indirect personal networks to identify suitable candidates within the criteria mentioned. All twelve interviews were conducted in 2025, recorded with the representatives' consent, transcribed verbatim, anonymized, and peer-debriefed within the research team to enhance reliability. Theoretical robustness was achieved after the tenth interview, suggesting that saturation was accomplished (Guest et al., 2006). Table 5.1 provides an overview of the final sample of cases and interviewees and the interview protocol can be found in Appendix L.

5.2.4 Data analysis

Our data analysis and coding procedures involve an informed thematic analysis (Gioia et al., 2013), with the aid of NVivo coding software. Consistent with Eisenhardt's (Eisenhardt, 1989) recommendations, the analysis iterated between the emerging qualitative insights and the literature, using a cyclical inductive–deductive process (Braun & Clarke, 2006; Eisenhardt & Graebner, 2007; Fereday & Muir-Cochrane, 2006). Coding efforts were informed by the flexible logic described by Deterding and Waters (Deterding & Waters, 2018), allowing the structure to evolve through code consolidation and ongoing refinement. Figure 5.2 presents the resulting data structure: the left column shows representative first-order terms used by practitioners, the middle column consolidates these into second-order themes, and the right column outlines the five higher-order dimensions derived from these themes.

Table 5.1 Sample of cases and interviewees

ID	Role / Seniority	Preferred Stage	Sector Focus	Year founded	Investment geography
VC01	Investment Manager	Series A	Deep-tech, climate tech	2020	Europe
VC02	Managing Partner	Seed	Deep-tech	2022	The Netherlands
VC03	Principal	Pre-seed	High-tech (hardware and software)	2021	The Netherlands
VC04	Partner	Pre-seed	High-tech impact (hardware and software)	2020	Europe
VC05	Partner	Seed	Deep-tech, climate tech	2009	Europe & USA
VC06	Head of Value Creation	Seed-Series C	High-tech impact (hardware and software)	2011	Europe
VC07	Analyst	Seed	High-tech impact (hardware and software)	1983	The Netherlands
VC08	Senior Analyst	Series A	Deep-tech	2023	Europe
VC09	Investment Director	Seed	High-tech, agriculture and food	2017	Europe
VC10	Investment Manager	Series A	High-tech, life sciences, agriculture, food	2019	The Netherlands
VC11	Managing Partner	Series A	High-tech (hardware & software)	2022	Europe
VC12	Investment Manager	Series A	High-tech, life sciences	2019	Europe

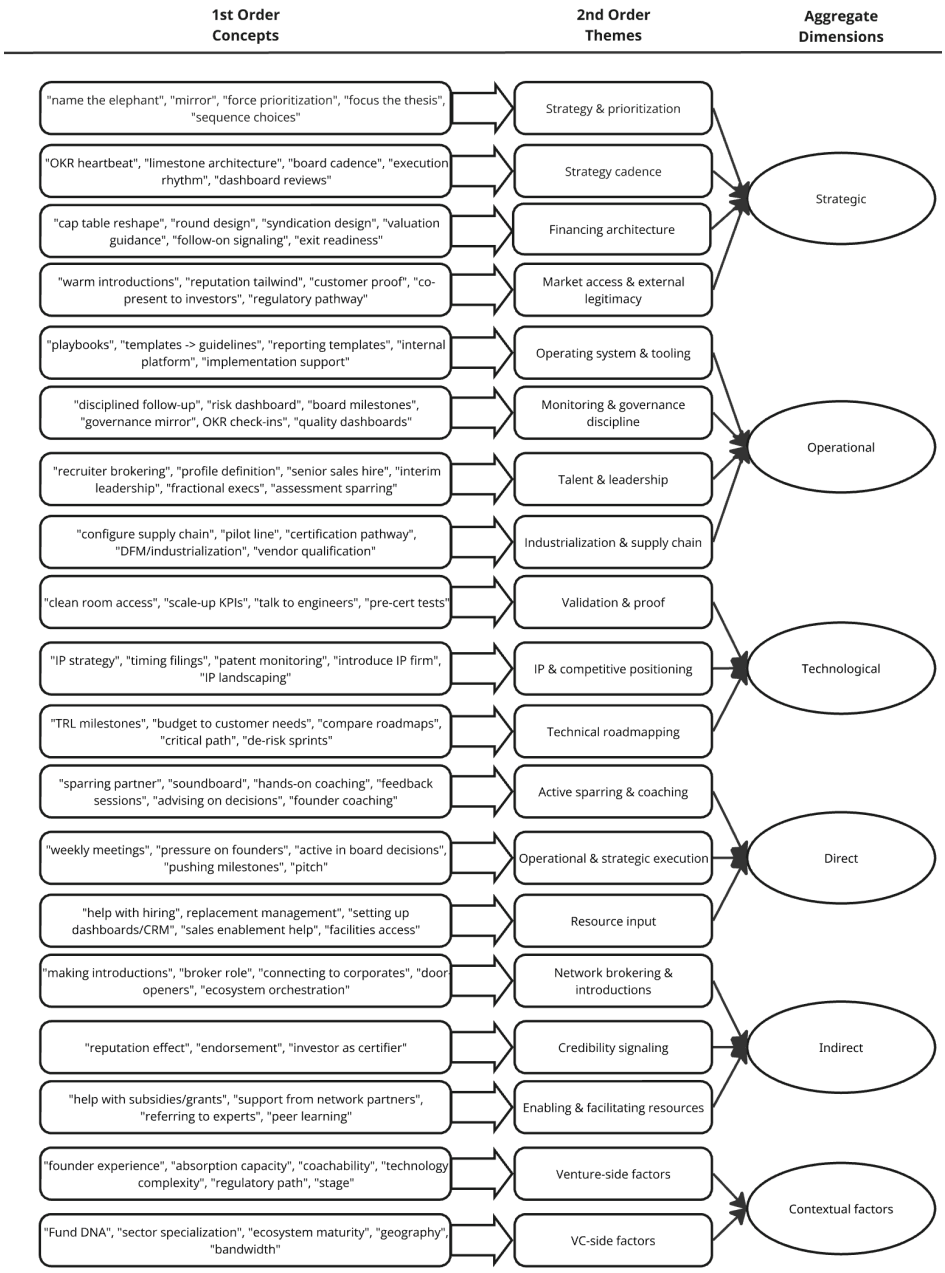


Figure 5.2 Data structure

5.3 FINDINGS

The three value-creation dimensions and the two involvement modes together suggest that VC funds draw on a multi-dimensional set of practices or activities as part of their post-investment engagement. Figure 5.3 captures these theoretical and empirical findings. This framework structures value-adding activities using two axes: (1) *Value creation* in the strategic, operational, and technological domain; (2) *Type of involvement* in terms of a direct or indirect mode of engagement. The framework yields six focus areas that structure how VC funds create value during the holding period.

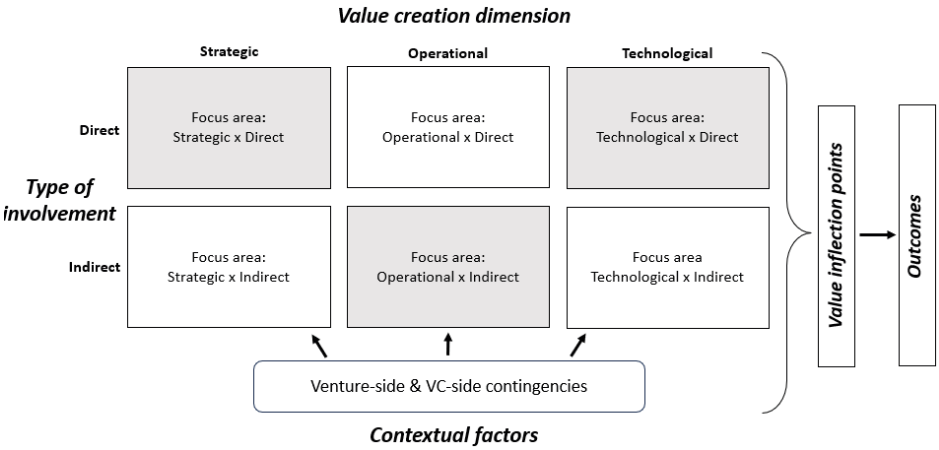


Figure 5.3 VC Value Creation framework

5.3.1 Strategic x direct

In the strategic-direct area, the VC fund contributes by directly shaping a company's long-term strategy and ensuring disciplined execution. Strategic activities include refining business strategies, sales strategies, market-entry plans, and defining internationalization paths. Direct strategic involvement may also include financial support, such as co-developing financial plans and preparing exit scenarios. This focus area also includes governance support, such as corporate governance structuring and board representation. Finally, this focus area includes human capital development, such as top management team coaching and incentive-plan structuring. Overall, this focus area captures hands-on, time-bounded collaboration aimed at instilling strategic focus and discipline as well as investor readiness.

5.3.2 Strategic x indirect

Indirect strategic involvement centers on leveraging networks and structuring syndicates. These include strategic activities, network activities, financial activities, and human capital activities. For example, the VC fund can introduce its portfolio companies to co-investors and potential customers, coordinate syndicates, engage consultants and advisors, and introduce independent directors. Indirect strategic involvement extends the strategic-direct support outward to the portfolio company's external ecosystem, also to enable signaling effects.

5.3.3 Operational x direct

Direct operational involvement occurs when VC funds get immersed in the companies' executional processes, especially during fragile transitions or periods of scaling. Key activities here include human capital and organizational support, such as recruiting key team members, supporting leadership transitions, and professionalizing human resource processes. Direct operational support also includes governance improvements, such as designing financial controls, improving internal workflows, and contracting structures. Direct operational involvement may also include support in professionalizing management skills, operational planning, cost-reduction initiatives, supplier selections, and sustainability policies. Thus, this focus area captures hands-on operational support aimed at improving the executional discipline of a portfolio company and its organizational development.

5.3.4 Operational x indirect

Indirect operational support focuses on enabling rather than executing. Here, the VC fund mobilizes networks, advisors, and governance routines to support professionalization of the portfolio company. For example, the VC fund provides playbooks, templates, and workshops for independent implementation. Indirect operational support also involves network-based support, such as brokering access to marketing agencies, legal specialists, and portfolio roundtables. In general, indirect operational involvement extends operational-direct forms of support by expanding the portfolio company's operational capacity by means of networking.

5.3.5 Technological x direct

Direct technological focus involves actively reducing technical uncertainty. Here, VC funds get involved by supporting the portfolio company in

technological due diligence, IP strategy development, design reviews, and technical milestone planning. Direct involvement may also include support in R&D budgeting and certification planning. Direct technical support may also be provided in technological road mapping and aligning R&D trajectories with commercial milestones. Overall, this focus area involves hands-on technological support aimed at reducing technological uncertainty and developing the product and technology.

5.3.6 Technological x indirect

Finally, the technological-indirect focus area reflects brokerage rather than execution. Network-related indirect technological support includes connecting portfolio companies to certification and regulation advisors, validation partners, university labs, domain experts, or scientific advisors. Such validation by external experts often strengthens the credibility of the technological proposition for investors and customers. Other types of support are patent filing and mobilizing access to lab and equipment setups. Thus, indirect technological involvement extends technological-direct forms of support by enabling networks and facilities of organizations to support the portfolio company in developing its product and technology.

5.3.7 Contextual factors

VC funds decide which focus areas are most relevant for the situation, by acknowledging and assessing several contextual factors. Our data imply that the effectiveness and necessity of specific value-adding activities depend on a combination of venture- and VC-side conditions.

On the *venture side*, three characteristics of technology ventures were highlighted as shaping both the type and intensity of VC involvement: the development stage, the managerial experience and absorptive capacity of the founding team, and the technological and regulatory complexity of the product or market. For example, the VC fund must adjust its focus area(s) based on the venture's stage of development.

On the *VC side*, interviewees highlighted factors such as geography and ecosystem maturity, fund identity or DNA, and organizational capacity and expertise. Because our study focused on European VC funds, the interviewees frequently emphasized ecosystem fragmentation, which limits the density and accessibility of specialized networks compared to more consolidated ecosystems. Other VC-side factors include the internal team

structure and specialist expertise, which shape the feasibility of hands-on engagement. The venture-side and VC-side contextual factors jointly influence not only which value-adding activities the VC fund deploys, but also how it engages in support activities across the six focus areas.

5.3.8 Value inflection points and outcomes

Our findings also point to the role of so-called 'value inflection points'. Several interviewees define a *value inflection point* as an observable milestone that justifies higher valuations in subsequent financing rounds. These milestones function as tangible evidence of progress achieved through the combined efforts of the portfolio company and the VC fund during the preceding period, such as efforts resulting in commercial pilots, certifications, key hires, and technical validation steps. According to most interviewees, these inflection points serve both internal and external functions: internally, they structure the development roadmap; externally, they act as signals to potential investors, partners, and customers.

In contrast, *outcomes* reflect more distal performance results that materialize over a longer time horizon. Interviewees described these outcomes as becoming visible only after the cumulative effects of value-adding activities (and associated value inflection points) have been accomplished. Exemplary outcomes include metrics such as annual (recurring) revenue, securing follow-on financing, valuation step-ups, and successful exits.

While we did not set out to systematically study inflection points and outcomes, our empirical data suggest that both play an important role in how VC funds conceptualize the (lack of) success of their value creation activities and justify their post-investment support strategies. Table 5.2 summarizes the value-adding activities identified in the empirical analysis.

Table 5.2 Value-adding activities per focus area

	Strategic dimension	Operational dimension	Technological dimension
Direct mode of involvement	*Hands-on support in strategic development* Example activities: Directly influence strategies, such as business, sales, and market-entry strategies, support in establishing business plans, performing competitive analyses, or internationalization paths, help in defining exit scenarios, becoming investor ready, and establishing governance structures	*Hands-on support in operational development* Example activities: Directly influence professionalization of the organization, supporting in establishing operational processes, such as operational planning, cost-reduction initiatives, and establishing quality routines, establishing performance measurement tools, or supporting in implementing sustainability-related policies	*Hands-on support in technological development* Example activities: Perform technical due diligence, support in improving IP strategies, perform design reviews, support in establishing or improving product-, technology- or industrialization roadmaps, implement risk assessments, support in developing regulatory- and certification pathways
Indirect mode of involvement	*Providing access to external strategic expertise & partners* Example activities: Introducing to co-investors and help coordinate syndicate developments, introduce to external expertise and partners for, for example, non-dilutive funding advisors, M&A consultants, sales consultants, strategy consultants, or independent board members	*Providing access to external operational expertise, partners and tools* Example activities: Provide playbooks, tools and templates through libraries, host portfolio workshops and facilitate knowledge-sharing, introduce to external expertise and partners for, for example, recruiters, fractional executives, legal advisors, tax advisors, HR advisors, introduce to customers	*Providing access to external technological expertise, partners and facilities* Example activities: Facilitate technology audits and certifications, provide lab- and equipment setups, support in patent filing, introduce to external expertise and partners for, for example, regulatory advisors, testbeds, external labs, OEMs, scientific advisors, or key opinion leaders

5.4 DISCUSSION AND CONCLUSION

5.4.1 Theoretical contribution

This study contributes to the entrepreneurship literature by reconceptualizing VC value creation as a configurational and multi-modal process. While

prior research has predominantly described value creation in terms of discrete value-adding activities, our findings challenge this view by demonstrating that value creation emerges from configurations of interrelated activities rather than separate activities. In doing so, we move beyond one-dimensional lists of value-adding activities focused on descriptive categorizations and provide a more integrative perspective on how VC funds create value in their portfolio companies (Gompers et al., 2020; Proksch et al., 2017; Siefkes et al., 2025). For example, existing typologies do not systematically incorporate technology support, signaling-based networking, or contextual factors, highlighting the fragmented nature of research on VC value creation (Gompers et al., 2020; Large & Muegge, 2008; Proksch et al., 2017).

Second, our study contributes to entrepreneurship theory by showing that technological support constitutes a distinct and foundational dimension of VC value creation, rather than a peripheral or context-specific activity. While prior studies of VC value-adding activities did not identify innovation and technology support as a distinct category (Busenitz et al., 2004; Gompers et al., 2020), our review shows that such support is consistently acknowledged in the literature (Arqué-Castells, 2012; Lahr & Mina, 2016; Sapienza et al., 1996). This pattern points to a conceptual blind spot, rather than an empirical absence.

Third, our study contributes to entrepreneurship theory by introducing a conceptual distinction between the dimensions of value creation (i.e., what VCs do) and modes of involvement (i.e., how they engage), demonstrating that similar activities can be leveraged via fundamentally different mechanisms. This separation advances existing categorizations, which often conflate activities and engagement modes. For example, prior studies list network-based support as just another category of value-adding activity (Proksch et al., 2017; Sapienza et al., 1996), but our findings suggest this should be conceptualized as a separate axis. This distinction is important because VC funds may generate value not only through direct engagement, but also through indirect forms of involvement, particularly by mobilizing their networks.

Fourth, our study highlights that VC value creation is inherently adaptive and context-dependent, while existing typologies omit these contextual factors (Croce et al., 2013; Gompers et al., 2020). VC funds combine different

configurations of activities across dimensions and modes of involvement, depending on venture-level and VC-level characteristics. In addition, our findings highlight the role of value inflection points, as anchors that structure the timing and sequencing of VC involvement, which prior studies have not explored (Busenitz et al., 2004; Proksch et al., 2017). This configurational perspective provides a more dynamic and integrative understanding of how VCs create value and creates new avenues for research into which configurations of value-adding activities are most effective under specific contextual conditions.

5.4.2 Practical implications

The proposed VC Value Creation framework offers guidance for multiple stakeholders in and around VC funds. For VC fund managers, the framework serves as a diagnostic tool at both the company and the fund level. By mapping activities across domains and modes, these managers can benchmark their current practices, identify gaps, and intentionally calibrate their involvement. Instead of offering ad hoc support, our framework promotes a more systemic and learning-based approach to post-investment engagement.

For ventures and portfolio companies, the VC Value Creation framework provides a shared vocabulary for understanding and negotiating investor involvement. It clarifies the spectrum of support activities as a portfolio company matures, fosters expectation alignment, and enables clear planning and coordination of responsibilities among investors and founders.

For limited partners in VCs and policymakers, the framework offers an alternative lens for evaluating VC performance, one that moves beyond financial return metrics. This perspective supports more sophisticated performance assessments and enables the design of policy instruments that complement, rather than duplicate, the role of investors. Collectively, these implications help transform heterogeneous VC practices into a coherent framework for reflection, coordination, and evaluation, by linking investment actions to venture-level and ecosystem-level outcomes without prescribing a single optimal mix of activities.

5.4.3 Limitations and future research

This study has several limitations and implications for future research. First, the empirical base consists of a relatively small sample of European

venture capital professionals. We used a combination of purposeful and convenience sampling, as VC value creation is often undisclosed, sensitive, and secretive in nature (Brady, 2006; Palinkas et al., 2015; Reymen et al., 2015). Although comparative case studies often rely on multiple data sources per case, we conducted only a single in-depth interview per VC fund (Eisenhardt, 1989). The resulting data sample offers rich (practice-based) insights, but does not capture any potential heterogeneity across geographies, investment stages, or fund types (e.g., corporate venture capital or late-stage growth funds). As such, our findings support analytical rather than statistical generalization (Yin, 2014). Future research should further validate the VC Value Creation framework by way of large-scale surveys and comparing patterns across ecosystems with different institutional characteristics.

Second, the VC Value Creation framework developed in this paper is grounded in a snapshot of contemporary VC practices, rather than constituting an exhaustive prescriptive model. It provides a holistic perspective organizing value-adding activities of VC funds. Future work on this framework may serve to develop it into a more complete prescriptive tool (Talmar et al., 2025).

Third, future work can explore configurational patterns of value-adding activities. These studies can address questions about, for example, whether or not certain combinations of focus areas yield superior results, whether VC funds have to specialize in particular dimensions, or whether the emphasis on specific domains varies by context (e.g., stage, sector, technological intensity). Thus, future work can turn our framework for organizing VC value-adding activities into a complete theory that explains when and why certain types of VC value-adding activities are most effective.

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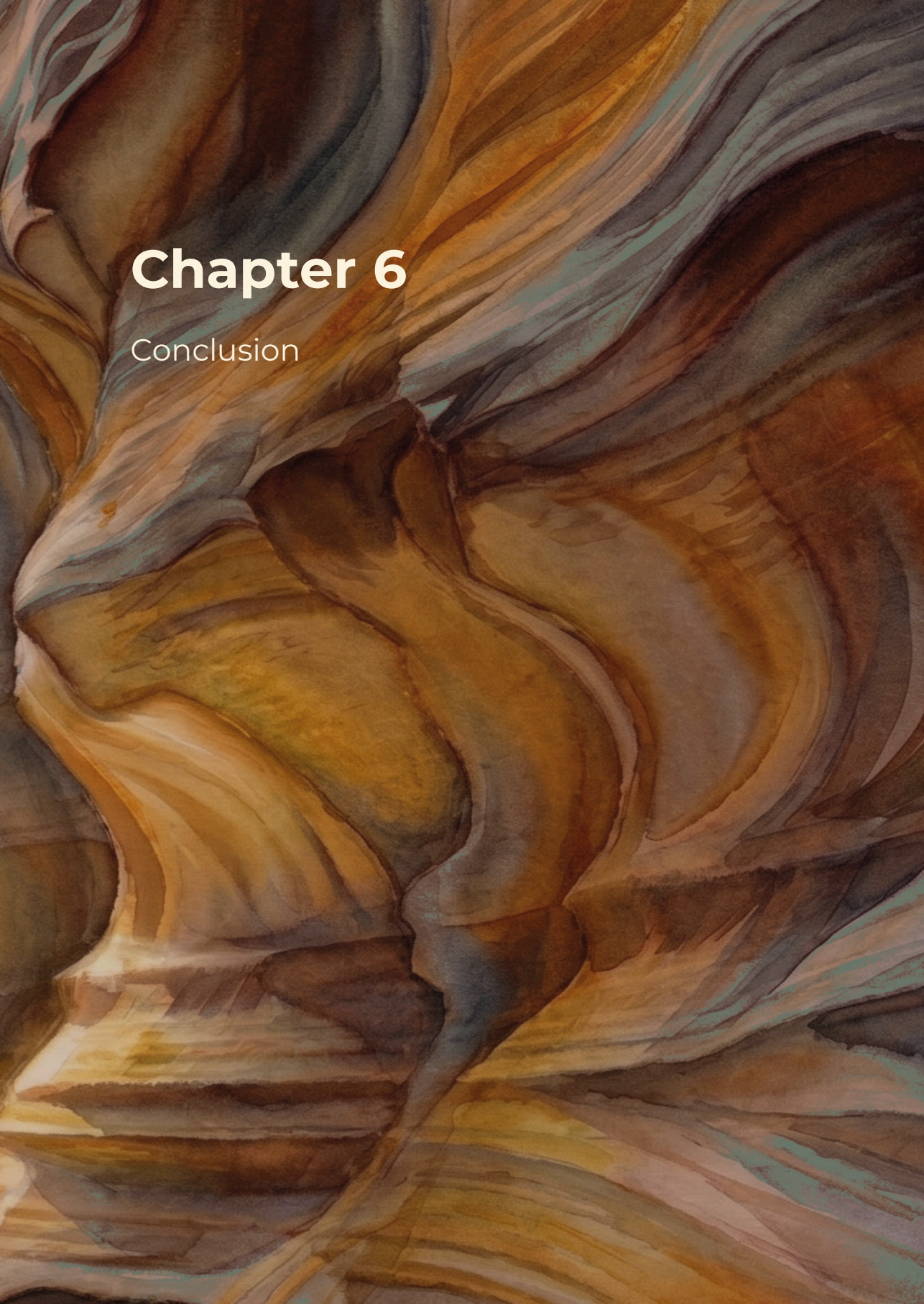
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Chapter 6

Conclusion

6.1 INTRODUCTION

Despite the importance of technology ventures for society, research on the missing middle remains fragmented across two largely disconnected discourses: the entrepreneurial finance literature and the technology entrepreneurship literature. Practitioners have not yet succeeded in resolving the challenges inherent to the missing middle, and scholars have likewise not generated sufficient knowledge or tools that practitioners can implement to address this gap. Consequently, there is a clear need across both practice and theory for actionable insights and robust frameworks that enable technology ventures and venture capital to mitigate the effects of the missing middle. Against this backdrop, the central research question in this dissertation is: *How can venture capitalists help technology ventures overcome the missing middle in the funding landscape*?

In addressing this question, several research approaches were adopted, including a literature review, a design science approach, and a qualitative research approach. This dissertation has explored various perspectives and solutions regarding venture capital and technology ventures across four studies. Together, these studies offer insights that clarify how venture capital solutions can help technology ventures overcome the missing middle in the funding landscape.

The findings of this dissertation yield three principal theoretical contributions. First, the dissertation contributes to bridging two historically disconnected literatures, technology entrepreneurship and entrepreneurial finance, by illustrating a pathway in which these perspectives can be meaningfully integrated. Second, the findings raise awareness amongst entrepreneurial finance scholars that sustainability impact has already become a core construct in venture capital decision-making, and that it should therefore no longer be overlooked or treated as peripheral. Third, the dissertation demonstrates that design science is a fruitful methodological approach for both analyzing the current state-of-the-art literature and addressing real-world problems in an evidence-based manner. The insights emerging from this work are subsequently aggregated into a conceptual framework for the venture capital–technology venture dyad, offering a structured means to help technology ventures overcome the missing middle with the support of VCs.

The remainder of this chapter first provides a synopsis of the four studies in this dissertation and answers the overall research question. Section 6.3 integrates the four studies and presents an overview of their theoretical contributions at the dissertation level. Section 6.4 synthesize the individual studies and outlines their practical contributions. Section 6.5 discusses the limitations of this dissertation and identifies directions for future research, and Section 6.6 concludes the chapter with closing remarks.

6.2 SYNOPSIS

This section discusses the key findings of the various studies in this dissertation and subsequently provides an answer to how venture capital solutions can help technology ventures overcome the missing middle in the funding landscape. Each of the four studies in this dissertation addresses a distinct facet of the central research question. A combination of research methods is employed to examine this question, resulting in several frameworks and theoretical contributions that advance the literature at the intersection of entrepreneurial finance and technology ventures. Table 6.1 provides a synthesis and reflection on the four studies. The elements of this table are further elaborated for each chapter below. This section concludes with an integrated answer to the central research question.

Table 6.1 Synthesis of and reflection on the four studies

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Title	Technology ventures in the missing middle: A mechanism-based review of the entrepreneurial finance and technology entrepreneurship literatures	The missing middle: Designing and implementing a VC fund for seed-stage deep-tech ventures	Investing in the future: Evaluating technology ventures on sustainability impact in VC	Beyond capital: A framework for venture capital value creation in technology ventures
Research question	How can a mechanism-based synthesis of entrepreneurial finance and technology entrepreneurship literatures enhance our understanding of technology ventures in the missing middle?	How can a VC fund exclusively focused on deep-tech ventures (DTVs) be designed, tested, and codified?	How can VCs assess the sustainability impact of early-stage technology ventures within the context of their investment process?	How can venture capital funds provide value-added support to technology ventures within the European context?
Research Method	Literature review	Design science	Design science	Comparative case study
Framework	Causal loop diagram for technology ventures in the two phases of the missing middle	Design principles and a blueprint for creating a specialist VC fund	Design principles and a framework for VCs assessing sustainability and impact of technology ventures	VC value creation framework for technology ventures

	Chapter 2	Chapter 3	Chapter 4	Chapter 5
Theoretical contribution	- Bridging technology entrepreneurship and entrepreneurial finance by mapping how ventures and investors jointly activate mechanisms - Reveals how reinforcing and balancing feedback loops shape venture trajectories - Offering a novel, mechanism-based synthesis extending beyond reviews on specific subdomains and across the venture life cycle	- Provides a detailed blueprint of a VC vehicle and demonstrates how it drove the fundraising process - Codifies a set of theoretically grounded design propositions that can inform the creation of similar funds in other contexts – Makes a methodological contribution as the first study to apply a complete DS cycle to the field of entrepreneurial finance	- Introduces a novel, actionable framework for sustainability impact assessment in VC - Offers a contextualized methodological illustration of how established DS approaches can be operationalized in VC	- Proposes a VC value creation framework organizing VC value creation

6.2.1 A mechanism-based review of technology ventures in the missing middle

The persistent challenge faced by early-stage ventures in transitioning from applied R&D to commercialization is addressed in the study presented in Chapter 2 (e.g., Arora et al., 2024; Vaznyte & Andries, 2019; Barr et al., 2009). Despite extensive scholar attention, this phenomenon remains insufficiently understood due to fragmentation across two largely disconnected literatures: the entrepreneurial finance literature (e.g., Claes & Vissa, 2020; Wu et al., 2016) and the technology entrepreneurship literature (e.g., Carayannis et al., 2016; Fuller & Rothaermel, 2012).

To bridge this gap, the study draws on a mechanism-based literature review of 201 peer-reviewed articles from leading journals. Using the CAMO (Context–Agency–Mechanism–Outcome) framework, the review identified eight core mechanisms (e.g., signaling, resource acquisition, knowledge spillovers), seven agency types (e.g., fundraising, alliance creation), and five venture outcomes (e.g., venture development, exit performance). These elements were synthesized into a dynamic, systems-level framework using

causal loop diagramming (CLD), which models how feedback loops evolve across two distinct phases of venture development: applied R&D and commercialization (Sterman, 2000; Walrave, 2016).

The study makes three key contributions. First, the CLD reveals how reinforcing and balancing feedback loops shape venture trajectories, offering a powerful tool for understanding the non-linear, path-dependent nature of technology venture development. This approach directly responds to recent calls for more dynamic theorizing and process-based explanations of entrepreneurial phenomena (Lu & Dimov, 2023). Second, the study contributes to bridging two historically disconnected literatures, technology entrepreneurship and entrepreneurial finance, by mapping how ventures and investors jointly activate mechanisms to generate outcomes (Kalvapalle et al., 2024). Third, the study offers a novel, mechanism-based synthesis that goes beyond reviews on specific subdomains and spans the entire venture life cycle (Cerpentier et al., 2022; Colombo et al., 2022).

Overall, this study lays the theoretical foundation for understanding how ventures and investors co-create value across the missing middle, offering a novel perspective on venture failure and innovation outcomes. In doing so, it establishes a common conceptual basis between two previously siloed literatures and thereby contributes to the central research question by clarifying the key constructs and their underlying context.

6.2.2 Designing a deep-tech venture capital fund to bridge the missing middle

The study in Chapter 3 addressed the funding gap faced by early-stage deep-tech ventures (DTVs), commonly referred to as the “missing middle” or the “valley of death”. DTVs aim to commercialize novel technologies in fields such as advanced materials, quantum computing, photonics, mechatronics, and precision electronics (Arora et al., 2024; Redmond, 2021). These ventures draw on breakthrough technological inventions with a strong research base, face long time-to-market cycles, and often require substantial industrialization efforts. As a result, DTVs encounter both upstream (technological) and downstream (commercialization) challenges and typically need to build extensive innovation ecosystems involving co-creating suppliers, complementors, and distributors (De la Tour et al., 2017; Granstrand & Holgersson, 2020; Hello Tomorrow, 2021). Consequently, their pre-revenue research and product development activities are ex-

tremely capital-intensive (De la Tour et al., 2017; Redmond, 2021). Moreover, compared to other types of startups (e.g., software-based ventures), the lifetime distribution of capital needs is inverted for DTVs, with substantially more capital required in the early stages (Hello Tomorrow, 2021). Thus, DTVs face a peak in capital need prior to commercialization, whereas this peak typically occurs during commercialization for other ventures. Traditional VC models often fail to support deep-tech startups at the seed stage, leaving many promising technologies underfunded and undeveloped.

To address this challenge, the study adopted a DS approach to develop and implement a novel VC model tailored to the needs of seed-stage DTVs. Drawing on a synthesis of the entrepreneurial finance and technology entrepreneurship literature, the study formulated two design propositions (DPs) that codify the mechanisms, actions, and contextual conditions required to effectively support deep-tech venturing (e.g., Berglund, 2021; Dimov et al., 2023; Van Burg et al., 2008). The first DP focused on the investment thesis and the second DP focused on the structure and governance (e.g., Kerr et al., 2014; Tennert et al., 2018).

The resulting fund, DeepTechXL, was implemented in 2022 in the Netherlands and raised €118 million from institutional, corporate, and governmental investors. Its ability to raise such an amount as a first-time team and first-time fund demonstrates the initial strength of its value proposition to institutional investors.

The study makes three key contributions. First, it offers a detailed blueprint of a VC investment vehicle, including the investment thesis, for investing in DTVs and demonstrates how this design informed and shaped the fundraising process (Nacke & Seckler, 2023; Sahlman, 1990). Second, it codifies a set of theoretically grounded design propositions that can inform the creation of similar funds in other contexts (Barber et al., 2021; Dimov et al., 2023). Third, it makes a methodological contribution by being the first study to apply a complete DS cycle to the field of entrepreneurial finance (Nacke & Seckler, 2023; Van Burg et al., 2008).

Thus, Chapter 3 contributes to both theory and practice by offering a replicable blueprint for addressing the structural funding challenges in deep-tech entrepreneurship and by demonstrating how the supply-side dimension of the missing middle can be effectively addressed.

6.2.3 Designing a sustainability impact assessment framework for venture capital

The third study, reported in Chapter 4, examined the growing need for VCs to assess, monitor, and report on the sustainability impact of their portfolio ventures, particularly in light of emerging regulatory frameworks such as the EU Sustainable Finance Disclosure Regulation (SFDR) (European Commission, 2023; Trautwein, 2021). Despite increasing attention to sustainability within the venture capital industry, the field still lacks a systematic, evidence-based approach for evaluating the sustainability impact of early-stage technology ventures and remains notably underexplored in the academic literature (Alakent et al., 2020; Barber et al., 2021; Roundy et al., 2017).

To address this gap, the study adopted a DS methodology to develop and validate a tailored sustainability impact assessment framework for VCs (Denyer et al., 2008; Romme et al., 2021). First, a systematic literature review was conducted to derive research-based design principles, followed by the collection and analysis of qualitative data from thirteen European VCs, which yielded practice-based design principles. These two sets of principles were subsequently synthesized into a final set of eight design principles that guide the assessment of sustainability impact and risk across the VC investment process, addressing key challenges such as data limitations, venture maturity, stakeholder involvement, lifecycle understanding, and the need to balance standardization with customization.

The resulting framework, the “VC Green Scheme”, integrates sustainability assessment into the four phases of the VC investment process: screening, due diligence, closing, and post-investment (Bronzini et al., 2020). It incorporates tools for lifecycle impact analysis, future-oriented forecasting, stakeholder triangulation, and impact game planning (Barberio et al., 2014; Matthews et al., 2019). The framework was implemented and evaluated at DeepTechXL, a Dutch deep-tech VC, and was found to be usable, comprehensive, and effective in supporting SFDR compliance and impact reporting.

The study makes two main contributions. Firstly, it introduces a novel, actionable framework for sustainability impact assessment in venture capital, grounded in both theory and practice (Gompers et al., 2020; Granz et al., 2021). Second, it provides a contextualized methodological illustration of

how established DS approaches can be operationalized in a highly emergent and uncertain domain, namely, sustainable venture capital (Cronholm et al., 2023; Gregor et al., 2020; Lee et al., 2011).

In conclusion, this study contributes to the emerging literature on sustainable entrepreneurship and entrepreneurial finance by offering a structured, replicable approach to integrating sustainability into VC decision-making and venture support. It aids in answering the central research question by demonstrating how VC solutions can be developed to help investors better understand, evaluate, and support impactful technology ventures.

6.2.4 Beyond capital: A framework for how venture capitalists create value in technology ventures

Finally, the fourth study, described in Chapter 5, examines how VCs create value for technology ventures and addresses the fragmented understanding of VC involvement beyond initial investment. Although VC-backed ventures generally outperform non-VC-backed firms and can offer extraordinary gains from a modest investment (Gompers et al., 2010; Harris et al., 2014; Lahr, 2023), prior research has focused mainly on selection and investment decisions rather than the post-investment activities through which VCs help ventures progress (Kaplan & Schoar, 2005; Proksch et al., 2017). Existing studies typically provide descriptive lists of value-adding activities (e.g., Gompers et al., 2020; Proksch et al., 2017; Siefkes et al., 2025), but they do not offer a holistic perspective to organize the value-adding activities of VCs.

Therefore, this study adopted a comparative case study design (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) and a systematic literature review of 59 articles to propose a VC value creation framework. This framework organizes VC involvement across three dimensions, namely strategic, operational, and technological, and two modes of engagement, namely direct and indirect, resulting in six focus areas that organize how VCs intervene during the holding period.

The study reported in Chapter 5 makes one primary contribution. This study moves beyond one-dimensional lists of value-adding activities and proposes a conceptual framework that offers a more holistic perspective of VCs value creation (e.g., Gompers et al., 2020; Proksch et al., 2017; Siefkes et al., 2025). Prior typologies do not systematically incorporate technology

support, signaling-based network, or contextual factors, underscoring the fragmented nature of existing VC value-creation research (e.g., Gompers et al., 2020; Proksch et al., 2017).

Overall, Chapter 5 advances entrepreneurial finance research by providing a holistic, empirically grounded, and multidimensional framework. This framework organizes the value creation dimensions and modes of involvement of VC value creation, the contextual factors, and the resulting value inflection points and long-term outcomes. It integrates overlooked technological and signaling-based activities, structures disparate findings from prior literature, and contributes to a practical lens for understanding how VCs support technology ventures in navigating the missing middle. Thus, it aids in answering the main research question by proposing a VC value-creation framework that supports technology ventures in overcoming the missing middle.

6.2.5 Answering the central research question

The studies in this dissertation collectively highlight different aspects of how venture capital solutions can help technology ventures overcome the missing middle in the funding landscape. These challenges stem from the inherently high-risk stage of transitioning from applied research and development to successful commercialization (Arora et al., 2024). As such, venture capital remains the critical means of financing this phase for technology ventures, even though the industry continues to exhibit a negative bias toward early-stage investments (Lockett et al., 2002) and faces deeper structural constraints in addressing this challenge (Gilson, 2003).

First, Chapter 2 contributes to answering the central research question by reviewing the state-of-the-art literature and identifying key mechanisms, agency types, and outcomes, which are synthesized into a dynamic, systems-level framework using Causal Loop Diagramming. This synthesis enhances practitioners' and scholars' understanding of where venture capital solutions should be targeted to increase the likelihood of overcoming the missing middle.

Chapter 3 builds on this foundation by directly addressing the supply-side gap faced by deep-tech ventures. Using a DS approach, it demonstrates how a VC fund can be designed to successfully raise capital from institutional investors, large companies, and governmental agencies for invest-

ment in the high-risk phase of the missing middle. This study provides a concrete example of a VC solution aimed at bridging this gap.

Chapter 4 further supports the central research question by using a DS approach to design a sustainability impact assessment framework for venture capital. This framework equips VCs with a structured toolbox to articulate, classify, and evaluate sustainability as a core component of their decision-making processes.

Finally, Chapter 5 presents a VC solution by organizing VC value creation for technology ventures and thereby increases their likelihood of success. Taken together, the studies reported in this dissertation demonstrate that an in-depth understanding of the mechanisms underlying the missing middle enables the development of VC solutions that support technology ventures in overcoming this critical phase.

Rather than functioning solely as a provider of capital, this dissertation implies that VC involves a multi-dimensional intervention that combines capital provision, venture assessment, and post-investment value creation. Chapter 2 explains the mechanisms through which ventures progress through the missing middle; Chapter 3 demonstrates how venture capital structures can be designed to fund this process; Chapter 4 shows how sustainability considerations can inform investment decisions, and Chapter 5 clarifies how investors can actively support venture development in the post-investment phase. Collectively, these studies suggest that the effectiveness of VC depends on the alignment of these activities across the venture life cycle rather than on any single intervention alone.

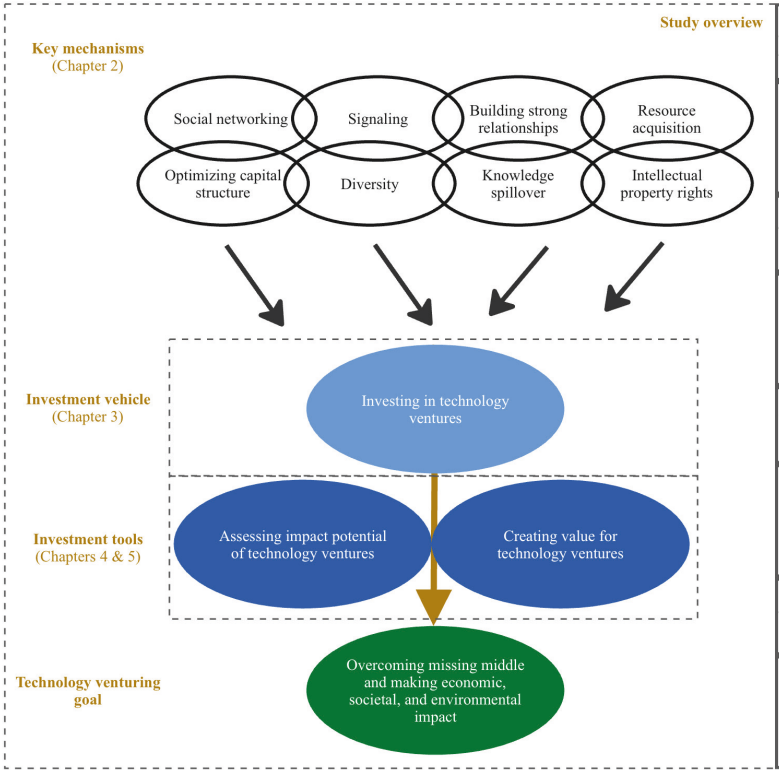
Thus, an overarching insight emerging from this dissertation is that the missing middle is not merely a financing problem but a coordination problem. Technology ventures require different forms of support as they progress from applied R&D toward commercialization. Consequently, successful navigation of the missing middle depends on the ability of VCs to continually combine financial resources with expertise, networks, legitimacy, sustainability considerations, and value-adding activities. This shifts the focus from VC as a transactional funding mechanism to understanding it as a system of interconnected activities that collectively shape venture development.

The insights emerging from the studies presented in Chapters 2 to 5 are therefore synthesized into a conceptual framework for the venture capital–technology venture dyad (in section 6.3). This framework reflects how VC can influence venture development through three complementary functions: providing access to financial resources, evaluating investment opportunities, and actively supporting venture development after investment. By integrating these functions into a single perspective, the framework offers a structured means to understand how VCs can help technology ventures overcome the missing middle. This conceptual framework is presented in section 6.3.

The remainder of this chapter further elaborates on the theoretical contributions, practical contributions, and limitations and future research avenues associated with this answer to the central research question.

6.3 THEORETICAL SYNTHESIS AND CONTRIBUTION

This section first describes the key theoretical contributions of this dissertation across the various studies (see Figure 6.1 for an overview). It then synthesizes these contributions into a conceptual framework (visualized in Figure 6.2).



Chapter 2: How can a mechanism-based synthesis of entrepreneurial finance and technology entrepreneurship literatures enhance our understanding of technology venturing in the missing middle?	
Mechanisms of technology venturing within the valley of death	- Developed a mechanism-based synthesis - Concluded with a causal loop diagram that captures the dynamic interplay of agencies, mechanisms, and outcomes across two distinct phases of the valley of death
Chapter 3: How can a venture capital fund exclusively focused on seed-stage deep-tech ventures be designed, tested, and codified?	
Blueprint for an early-stage deep-tech VC fund	- Evidence-based designed, inferring design propositions from the literature and iteratively creating a solution - VC fund created that focuses on deep-tech ventures - Made capital available for ventures operating in the missing middle
Chapter 4: How can venture capital funds assess the sustainability impact of early-stage technology ventures within the context of their investment process?	
Blueprint for a sustainability risk/ impact assessment framework	- Designed a structured and adaptable framework that allows customization of assessment steps to suit different contexts. - The VC Green Scheme a comprehensive blueprint for sustainability impact assessment within venture capital.
Chapter 5: How can venture capital funds provide value-added support to technology ventures within the European context?	
Framework for VC value creation	- Conducted a literature review on value creation and a comparative case study to propose a VC value creation framework - A VC value creation framework created consisting of three dimensions and two modes of involvement

Figure 6.1 Overview of the dynamics and mechanisms between technology ventures and venture capital to overcome the missing middle

6.3.1 Bridging the literatures of technology entrepreneurship and entrepreneurial finance

The first contribution relates to bridging two historically disconnected literatures: technology entrepreneurship and entrepreneurial finance.

Chapter 2 goes beyond existing literature reviews by offering a novel, mechanism-based synthesis of technology ventures and investors in the missing middle. While prior reviews focused on specific subdomains such as international entrepreneurship (Terjesen et al., 2016), dependent variables in entrepreneurship (Shepherd et al., 2019), or stages of the entrepreneurial process (Shepherd et al., 2021), none have systematically mapped the dynamic interplay of ventures and investors and their influence on mechanisms across the venture life cycle. In the entrepreneurial finance literature, Cumming and Groh (2018) synthesized unifying themes but did not address the temporal dynamics of venture development. Accordingly, the study presented in Chapter 2 contributes to a dynamic, temporally structured framework that distinguishes between the applied R&D and commercialization phases and provides a mechanism-based perspective on the relationship of technology ventures and investors. Chapter 3 shows how an early-stage deep-tech VC must develop a deep understanding of its unit of investment, technology ventures. Chapter 5 illustrates how VCs can enhance their value creation when they better understand the realities and dynamics of technology ventures. Together, these chapters demonstrate that the two literatures should be more closely integrated to establish a shared body of knowledge. This integrated perspective provides the theoretical foundation for the subsequent contributions of this dissertation. In particular, it enables a more comprehensive understanding of how sustainability considerations (section 6.3.2) and design-oriented VC interventions (section 6.3.3) influence venture development within the missing middle.

In doing so, this dissertation reveals important blind spots in the literature. The literature on entrepreneurial finance is extensive, but tends to overlook critical venture-side dimensions, such as team expansion and commercialization strategies. Conversely, the technology entrepreneurship literature focuses on how ventures develop technologies, capabilities, teams, and commercialization strategies, but tends to overlook financial performance outcomes. By integrating the two perspectives, this dissertation offers a more holistic understanding of how ventures and investors

co-create value across the missing middle. Thus, the integration of these literatures reveals that venture development and venture capital are not independent processes but mutually reinforcing activities. That is, venture outcomes emerge from the continuous interaction between venture-side development activities and VC-side interventions. As a result, the missing middle can be understood as a co-evolutionary process in which ventures and investors jointly shape the trajectory of venture development.

This investor–venture duality has important implications for future research and practice. Rather than studying technology ventures and investors as separate units of analysis, the findings arising from this dissertation suggest that greater attention should be paid to the interactions between them. The mechanisms identified in Chapter 2, such as signaling, resource acquisition, knowledge spillovers, and relationship building, are inherently relational and depend on the actions of both ventures and investors. Consequently, future research may benefit from placing the venture capital–technology venture dyad, rather than either actor individually, at the center of analysis. Such a dyadic perspective provides a richer explanation of venture success and failure.

6.3.2 Sustainability impact as core construct in VC decision-making

The second theoretical contribution builds on the growing interest among practitioners in sustainability impact and addresses an underdeveloped area in the technology entrepreneurship and entrepreneurial finance literatures. The literature review in Chapter 2 revealed that only a limited number of sources have examined sustainability specifically within the specific context of venture capital (e.g., Alakent et al., 2020; Croce et al., 2021; Siefkes et al., 2025). However, the studies in Chapters 3, 4, and 5 show that practitioners are already integrating sustainability as a core construct in decision-making and value creation.

Chapter 4 addresses this gap by integrating and synthesizing insights from the entrepreneurship, sustainable entrepreneurship, and entrepreneurial finance domains, thereby generating novel theoretical contributions at their intersection (Gompers et al., 2020; Granz et al., 2021). This opens promising avenues for future research on the role of sustainability, and in particular sustainability impact assessments, in VC decision-making and its implications for innovation and impact for early-stage ventures.

The resulting assessment framework (developed in Chapter 4) serves as a concrete design artifact, illustrating how DS research can produce targeted solutions to underexplored yet pressing challenges in entrepreneurial finance. Moreover, this dissertation shows that VCs are increasingly offering value-added activities related to sustainability (see Chapters 4 and 5), thereby shaping the impact orientation of portfolio ventures over time. In this respect, sustainability does not operate as a standalone assessment criterion but as an additional dimension of VC decision-making and value creation. Consequently, the sustainability perspective complements the mechanism-based understanding developed in section 6.3.1 and expands the scope of VC interventions discussed in section 6.3.3.

6.3.3 Design science as a methodological lens in technology entrepreneurship and entrepreneurial finance

The third contribution concerns the use of DS as a methodological lens within the technology entrepreneurship and entrepreneurial finance literatures. Design science scholars have argued that researchers can effectively combine theoretical contributions with contributions to entrepreneurship policy and practice (Berglund, 2021; Dimov et al., 2023; Van Burg et al., 2008). Building on this position, this dissertation applies DS in the domain of entrepreneurial finance.

The design propositions developed in Chapters 3 and 4 codify the underlying mechanisms, actions, and outcomes of the studies. Together, they constitute the principal contributions of these chapters. The dual function of design propositions is fundamental to DS-informed research. They ground causal relationships theoretically while simultaneously informing design activity. By leveraging both functions, this dissertation engages in what Dimov et al. (2023) refer to as world-to-theory alignment; that is, aligning theory with the world and enabling purposeful action to shape practice in line with theoretical intentions. For example, the design propositions presented in Chapter 3 provide actionable insights concerning the development of a VC investment thesis and the structure and governance of a VC fund. Consistent with Gregor et al. (2020) and Gierlich-Joas et al. (2024), this dissertation provides an example within the entrepreneurial finance domain by demonstrating a shift from retrospective insights toward prospective, actionable design propositions that define design-relevant contextual variables. These design propositions can assist VCs and technology ventures in bridging the missing middle. The resulting design propositions

translate the theoretical insights generated in sections 6.3.1 and 6.3.2 into actionable intervention mechanisms. Design science therefore operates as a bridge between theorizing about the missing middle and developing practical solutions that enable ventures to overcome it.

In doing so, this dissertation demonstrates how entrepreneurship scholars can move beyond observation and analysis existing phenomena to actively shaping practice, offering contributions that are both theoretically meaningful and practically impactful in advancing the technology entrepreneurship and entrepreneurial finance literatures.

6.3.4 Conceptual framework for the venture capital - technology venture dyad

The studies reported in this doctoral dissertation collectively suggest that overcoming the missing middle requires the alignment of venture capital structures, investment decisions, and post-investment support activities throughout the venture life cycle. In this subsection, the results of the individual studies are synthesized into a conceptual framework that may offer insights for VCs and technology ventures. Figure 6.2 presents the conceptual framework synthesized from the findings outlined in section 6.1. At its core, the model illustrates how VCs can support technology ventures in overcoming the missing middle, a critical phase often bypassed by VCs due to its high risk, capital intensity, and long time-to-market. The framework represents the synthesis of the four studies presented in this dissertation. More specifically, it integrates the dynamic mechanisms underlying venture development (Chapter 2), the organizational design of specialized venture capital funds (Chapter 3), sustainability-oriented investment assessment (Chapter 4), and post-investment value creation activities (Chapter 5) into a single explanatory perspective on the venture capital–technology venture dyad.

At the heart of the framework is a specialized VC (see the dotted box at the top of Figure 6.2) equipped with targeted investment tools (see the dotted box in the center of Figure 6.2). These tools include a tailored investment process to identify and select high-potential, impact-driven ventures (middle-left dotted box; Chapter 4) and a value-added support toolbox to actively guide ventures through the missing middle (middle-right dotted box; Chapter 5).

Technology ventures (see the dotted box in the bottom half of Figure 6.2) play a central role in this dynamic. They must first signal their potential to investors and seek funding (bottom-left upward arrow). The VC then applies its investment tools to determine whether to invest (bottom-left downward arrow). Once funded, the venture progresses along key business dimensions, such as commercial traction, technology validation, industrialization, and team expansion, with support from the VC (bottom-right downward arrow).

This cycle repeats across successive funding rounds and strategic support, ultimately enabling ventures to enter commercialization and exit the missing middle (bottom-center downward arrow), thereby generating meaningful economic, societal, and environmental impact for stakeholders. This progression is depicted in the lower part of the figure: ventures in the fundamental research phase are represented by light orange dots, typically financed through research grants and informal investors; ventures in the applied R&D phase appear as orange dots, encountering the most severe funding constraints; ventures in the commercialization phase appear as dark orange dots, experiencing increasing availability of resources as they gain market traction and validation. Only after a venture establishes a sustainable financial baseline and has achieved relevant value inflection points, it can ventures begin to generate meaningful societal or environmental outcomes, as depicted via the accolade on the right-hand side.

The core mechanisms identified in Chapter 2, such as signaling, resource acquisition, and building strong relationships, serve as the connective tissue between VCs and technology ventures, shaping the trajectory and success chance of their collaboration. The aim of the venture capital-technology venture dyad is to increase the success chance of ventures to overcome the missing middle. This framework provides entrepreneurial finance scholars with deeper insight into how investor behavior is influenced by venture-side dynamics, while offering technology entrepreneurship scholars a clearer understanding of how ventures operate within a broader financial business ecosystem (Moore, 1993).

In sum, the conceptual framework provides a structured lens for understanding the venture capital–technology venture dyad. It explicates the key mechanisms that shape interactions between investors and ventures. Taken together, the findings suggest that overcoming the missing middle

ultimately depends on the alignment of VC structures, investment decisions, and post-investment support activities throughout the venture life cycle.

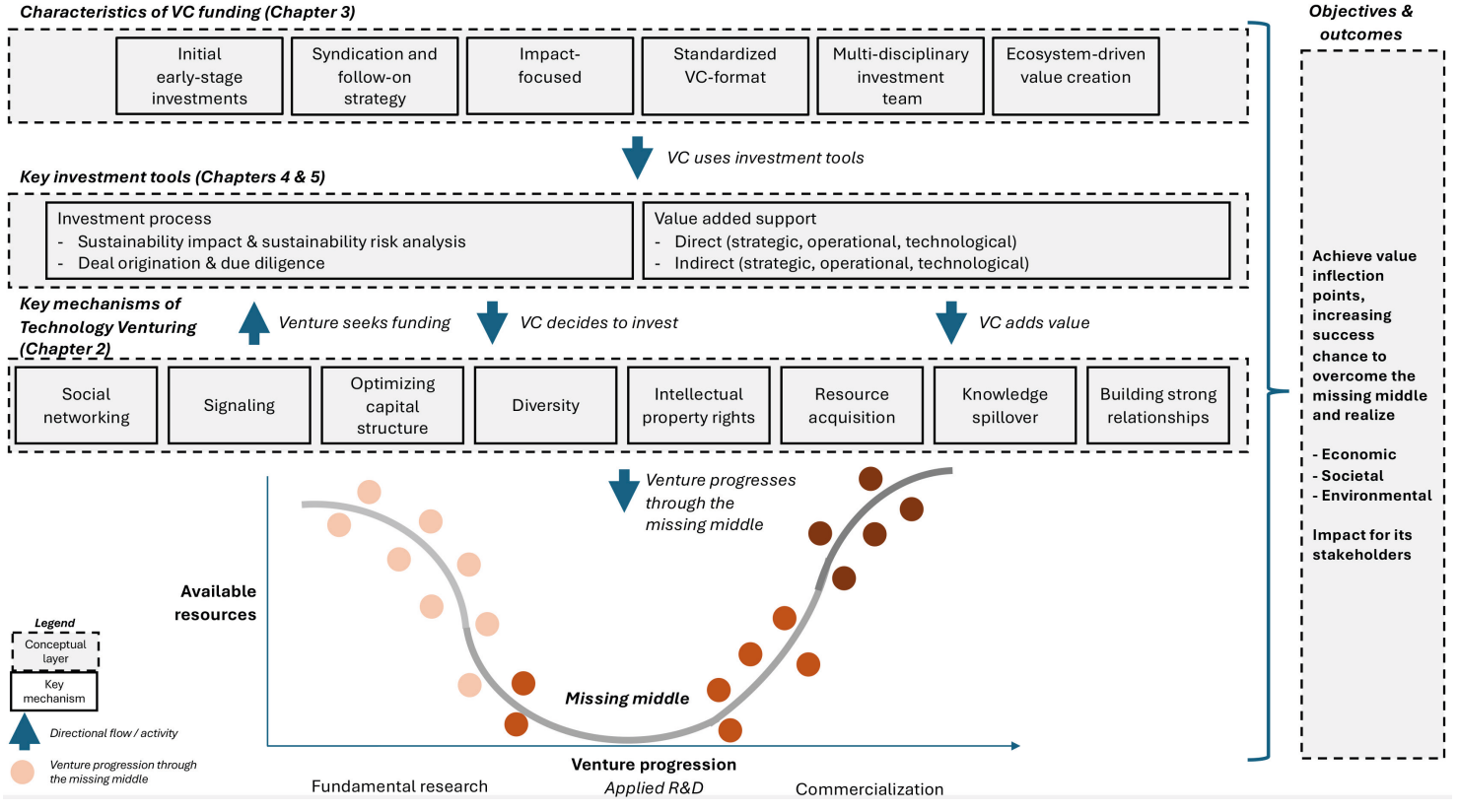


Figure 6.2 Conceptual framework of the venture capital-technology venture dyad in the missing middle

6.4 PRACTICAL IMPLICATIONS

This section describes the key practical contributions of this dissertation arising from (a) the four individual studies, (b) the overview presented in Figure 6.1, and (c) the conceptual framework outlined in Figure 6.2. The combination of technology ventures and venture capital plays a critical role in the innovation ecosystem, which will continue to evolve in pursuit of the development and commercialization of impactful technologies. Understanding the various dynamics, mechanisms, and tools is therefore essential for advancing knowledge of this dyad as well as enabling more effective collaboration between technology ventures and VCs. From a practical perspective, the findings of this dissertation suggest that overcoming the missing middle is not solely a financing challenge but a coordination challenge. Technology ventures require different forms of financial, strategic, technological, and sustainability-oriented support as they progress toward commercialization. Consequently, effective venture capital solutions require the alignment of venture capital structures, investment decision-making processes, and post-investment value creation activities throughout the venture life cycle.

6.4.1 Enabling industry–university collaboration through design science to address real-world challenges and drive innovation leadership

This dissertation demonstrates how DS can serve as a powerful methodology for fostering collaboration between academia and industry to address complex, real-world challenges. Specifically, it shows how academic insights can be translated into practical implementations within VC practice. Scholars have long argued that theoretical insights can be effectively combined with entrepreneurship policy and practice (Berglund, 2021; Dimov et al., 2023; Van Burg et al., 2008). Through the development of design propositions, DS enables the creation of actionable insights that narrow the translation gap between theory and practice. Compared to traditional academic–industry collaborations, DS is more iterative, co-creative, and solution-oriented, making it particularly well suited for innovation in dynamic and uncertain environments.

This dissertation is among the first to apply DS within the context of venture capital and deep-tech entrepreneurship in Europe. Its practical impli-

cations are especially relevant for VCs and institutional investors seeking to enhance their strategic capabilities and innovation leadership.

Several Tier-1 VC firms already share insights on technology ventures publicly, often in collaboration with academic institutions. For example, Index Ventures, Andreessen Horowitz, and Bessemer Venture Partners publish books, articles, and podcasts aimed at supporting technology ventures (Andreessen Horowitz, n.d.; Bessemer Venture Partners, n.d.; Jacquesson, 2024). Bessemer and Atomico go further by releasing academic-level benchmarks, such as the State of Deep Tech and the State of European Tech (Atomico, 2026; Wan et al., 2024). In early 2020s, Andreessen Horowitz launched a multi-disciplinary crypto research lab led by professors from Stanford and Columbia to deepen their understanding of the crypto industry (Andreessen Horowitz, 2022). Although these initiatives reflect a growing interest in bridging theory and practice, successful examples of DS-based collaboration with VCs remain limited.

This dissertation contributes to this emerging practice by applying DS to advance venture capital solutions for technology ventures, particularly in Studies 2, 3, and 4. Chapter 3 offers practical implications for VCs and institutional investors by designing a specialized VC for seed-stage deep-tech ventures, grounded in the entrepreneurial finance literature. This fund, DeepTechXL, has demonstrated its practical relevance by raising €111 million in its first fund and an additional €7 million for a pre-seed fund collaboration with leading Dutch universities in 2025, underscoring their confidence in DeepTechXL.

Chapter 4 introduces an actionable framework for assessing the sustainability impact and risks of technology ventures. DeepTechXL has adopted this framework, which has attracted interest from other impact-focused VCs and institutional investors. Both the studies reflected in Chapters 3 and 4 provide practical implications through their design propositions, which serve as transferable, evidence-based guidelines.

Chapter 5 illustrates how VCs can create value for technology ventures and via which focus areas. It provides institutional investors with a tool to evaluate how “hands-on” a VC is, while offering VCs a roadmap to enhance their value-added support. This framework is currently in use at DeepTechXL and has already been requested by several other VCs.

Together, the creation of DeepTechXL, the VC Green Scheme, and the value-added support framework position DeepTechXL as a prototype for DS-enabled collaboration in the venture capital industry. This dissertation shows that VCs can benefit from building internal capabilities around DS and academic partnerships, and from adopting DS-based collaboration models in their pursuit of innovation leadership. DeepTechXL provides the organizational infrastructure through which capital is deployed, the VC Green Scheme improves the quality of investment selection, and the value-added support framework enhances post-investment venture development. Together, these artifacts illustrate how design science can support the full venture capital process, from fund design and investment decision-making to venture scaling and impact creation.

6.4.2 Enhancing investor–venture collaboration through mechanism-based understanding across the venture lifecycle

This dissertation contributes to improving investor–venture collaboration by offering a mechanism-based framework that clarifies how ventures and investors interact across the venture lifecycle. By identifying the key mechanisms that influence venture success, such as signaling, resource acquisition, and venture-building support, it provides actionable insights that help both parties navigate the missing middle more effectively.

Chapter 2 provides a systems-level understanding of how technology ventures evolve through the missing middle, highlighting the mechanisms that shape venture trajectories and outcomes. Chapter 3 identifies the mechanisms required to design a successful early-stage VC, including the need for venture-building support and innovation ecosystem orchestration. Chapter 4 introduces mechanisms for assessing sustainability impact and risk, such as lifecycle understanding and approaches for mitigating data limitations, helping VCs align their investment decisions with long-term societal objectives. Rather than representing independent mechanisms, these elements operate as an interconnected system throughout the venture life cycle. For example, signaling influence investment decisions, sustainability assessments influence venture selection, and strategic, operational or technological support contributes to the achievement of critical value inflection points. Consequently, successful venture capital-technology venture collaboration depends on understanding how these mechanisms interact and reinforce one another over time.

Together, these studies demonstrate how a mechanism-based understanding can improve investor decision-making, strengthen venture support strategies, and foster better alignment between investors and entrepreneurs. Although investors and ventures may not always share identical goals, both benefit from increasing the likelihood of venture success. This framework helps to clarify interdependencies, enhance communication, and guide strategic collaboration throughout the venture lifecycle.

6.4.3 Equipping venture capitalists with tools to improve support for technology ventures and maximize economic, societal, and environmental impact

This dissertation provides venture capital practitioners with a suite of science-based tools designed to enhance their effectiveness in supporting technology ventures and maximizing economic, societal, and environmental impact. These tools were developed through industry–university collaboration using DS and offer actionable frameworks that can be directly implemented in VC practice.

Chapter 3 introduces a blueprint for operating a specialized VC focused on seed-stage deep-tech ventures. The instantiation of DeepTechXL, which raised €111 million in its first fund and an additional €7 million for a pre-seed fund collaboration with leading Dutch universities, demonstrates the practical viability of this model.

Chapter 4 presents a framework for assessing the sustainability impact and risks of technology ventures and integrates these considerations into the VC investment process. This framework has been adopted by DeepTechXL and has generated interest from other impact-focused VCs and institutional investors.

Chapter 5 offers a roadmap for enhancing value-added support, helping VCs define, communicate, and strengthen their strategic involvement in portfolio ventures. The framework is currently in use at DeepTechXL and has been requested by several other VCs seeking to differentiate themselves and improve their support capabilities.

Together, these tools form an integrated venture capital toolkit for supporting technology ventures throughout the missing middle. The DeepTechXL model addresses the provision of financial resources, the VC Green

Scheme strengthens venture assessment and portfolio monitoring, and the value-added support framework guides post-investment involvement. Used in combination, these tools enable VCs to align investment structures, decision-making processes, and venture support activities around the evolving needs of technology ventures. This integrated approach increases the likelihood that ventures successfully reach the commercialization phase, while maximizing their economic, societal, and environmental impact.

6.5 LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This section outlines overarching limitations that transcend the individual studies and offers directions for future research. The four studies in this doctoral dissertation share an exploratory, qualitative approach aimed at deepening the understanding of how venture capital solutions can support technology ventures in overcoming the missing middle. While this approach has yielded rich insights and actionable frameworks, it also introduces several limitations.

6.5.1 Limited longitudinal evidence of venture outcomes

Although this dissertation presents two design-based solutions (e.g., the early-stage deep-tech VC model and the VC Green Scheme) and a framework for VC value creation, their long-term performance and impact, particularly with respect to overcoming the missing middle, venture success, scalability, exit outcomes, and broader economic, societal, and environmental effects, cannot yet be fully assessed. These tools have only recently been implemented, and the ventures supported by them have not yet completed their full lifecycle. A substantially longer data period is therefore needed to systematically evaluate the viability and efficacy of these VC tools.

Future research should conduct longitudinal studies to track venture survival, growth trajectories, and impact metrics across multiple funding rounds and exit events. Such research would help validate and refine the design propositions and tools introduced in this dissertation.

6.5.2 Context-specificity of design propositions and tooling

A second limitation concerns the context-specific nature of the design propositions and tools developed in Chapters 3, 4, and 5. These frameworks are grounded in the European venture capital business ecosystem, with a particular focus on the Dutch deep-tech context. The Netherlands was selected due to its strong tradition of industry–university collaboration (Eindhoven University of Technology, 2021), its robust base of large deep-tech companies, leading universities in key technological domains, and its emerging deep-tech venture capital landscape.

While data was gathered from a variety of European VCs, including non-deep-tech firms, the implementation of the tools occurred within a Dutch deep-tech VC. Additionally, the European regulatory environment, most notably the EU's SFDR, differs significantly from those in other regions. Nevertheless, many elements of the tools developed here, such as lifecycle thinking, staged financing, sustainability risk analysis, and value-added support, are likely to be relevant across geographies and sectors.

Future research should therefore explore the transferability and adaptation of these tools in other contexts, including North America, Asia, and emerging markets, as well as across different venture types (e.g., software, biotech, prop-tech). Comparative studies could help generalize the findings and identify context-sensitive modifications.

6.5.3 Reliance on qualitative data

A third limitation relates to the reliance on qualitative data across the studies. While this approach enabled deep contextual understanding and supported the development of nuanced design propositions, it inherently limits the generalizability and scalability of the findings. Sample sizes are relatively small, and the insights are highly context-specific, which may constrain broader empirical validation.

To strengthen the empirical foundation and broaden the applicability of the tools and propositions developed in this dissertation, future research should incorporate quantitative methods. Possible approaches include survey-based studies, panel data analysis, and longitudinal tracking of venture performance. Such methods can statistically validate the mechanisms identified, assess causal relationships across larger and more diverse

samples, and contribute to a more robust evidence base of generalizable and actionable knowledge. Mixed-methods approaches, in particular, will offer a valuable bridge between depth and generalizability in future work in this area.

6.5.4 Emphasis on framework development rather than theory building

Fourth, the primary objective of this dissertation was to synthesize fragmented knowledge and develop actionable frameworks that can be used by VC practitioners and technology ventures to address the missing middle. Consequently, Chapters 3 and 5 focus on developing design propositions and conceptual frameworks that organize and structure existing insights, rather than on developing fundamentally new theoretical constructs or causal explanations. While this approach improves conceptual clarity and practical applicability, it provides less insight into the underlying generative mechanisms that may explain why particular VC interventions are more effective than others under specific conditions. Thus, the resulting frameworks should be viewed as foundations for further theory development, rather than as fully developed explanatory theories. Future research can build on these initial frameworks by means of longitudinal, comparative, and theory-building studies aimed at uncovering new causal relationships and boundary conditions.

6.5.5 Empirical scope and research context

The fifth limitation is related to the empirical scope and research context. The empirical studies in this dissertation were conducted within a relatively focused research context, primarily involving European VCs and technology ventures, with several studies centered on the DeepTechXL initiative. This focus enabled an in-depth examination of the missing middle phenomenon, while potentially limiting the transferability of findings to other geographical, institutional, or investment contexts.

The qualitative research designs adopted throughout the dissertation were particularly suitable for exploring an emerging and complex phenomenon, generating rich insights into VC practices, fund design, sustainability assessment, and value creation activities. However, these insights would benefit from further validation through complementary quantitative and mixed-methods approaches. For example, the data collection in Chapters 4 and 5 primarily relied on interviews with highly knowledgeable respon-

dents. While these informants were selected because of their expertise and strategic overview, incorporating multiple respondents per organization would potentially have provided additional perspectives on the phenomena under investigation. Moreover, the active involvement of (Hessel Mittelmeijer as) the lead researcher in the development and implementation of the frameworks developed in Chapters 3, 4, and 5 facilitated unique access to stakeholders, decision-making processes, and insights which would otherwise have been difficult to obtain. At the same time, this embedded position may also introduce the risk of researcher bias. Close involvement in the design and implementation of the studied interventions potentially increases the likelihood of selective interpretation, confirmation bias, or the overemphasis of positive outcomes. Several measures were therefore taken throughout the research process to enhance rigor and reduce potential bias. These included the use of multiple data sources, iterative feedback from practitioners and academic supervisors, transparent documentation of design decisions, and the systematic application of (design science, data analysis, and other) methods. Nevertheless, the lead researcher's proximity to the empirical setting may have influenced the data analysis and the evaluation of the proposed frameworks.

Thus, future research may seek to extend the empirical scope of this dissertation by conducting comparative studies of different VC funds, technology ventures, and geographical regions, as well as by testing the proposed frameworks and design propositions using large quantitative datasets.

6.5.6 Theoretical scope and disciplinary boundaries

The sixth limitation concerns the theoretical scope of this dissertation. The studies within this dissertation predominantly draw on the technology entrepreneurship and entrepreneurial finance literatures to examine how venture capital solutions can help technology ventures overcome the missing middle. This focus was appropriate given the central research question and enabled the development of a coherent body of knowledge across the four studies.

In addition, Chapters 2 and 5 deliberately focused on high-quality peer-reviewed journal articles, primarily from FT50 journals. While this approach enhanced the rigor and consistency of the literature reviews, it may also have excluded relevant insights from adjacent disciplines, specialized jour-

nals, and emerging research streams that address similar phenomena from alternative theoretical perspectives.

The decision to focus primarily on technology entrepreneurship and entrepreneurial finance was made to maintain analytical focus and theoretical consistency. However, this choice may have limited opportunities to connect the findings to broader theoretical debates and alternative explanations emerging from these adjacent literatures.

Future research could strengthen and extend the theoretical foundations of this dissertation by examining the proposed frameworks and mechanisms through alternative theoretical lenses, thereby incorporating a broader range of academic sources and exploring how insights from adjacent disciplines complement, enrich, or challenge the conclusions presented here.

6.6 CLOSING REMARKS

This dissertation set out to explore how venture capital solutions can help technology ventures overcome the missing middle, a phase marked by high uncertainty, capital intensity, and strategic complexity. Through four interrelated studies, it offers theoretical insights, practical tools, and methodological innovations that contribute to bridging the worlds of entrepreneurial finance and technology entrepreneurship.

By adopting a DS approach, this dissertation has not only analyzed existing challenges but also co-created solutions with practitioners. The instantiation of DeepTechXL, the development of the VC Green Scheme, and the value-added support framework exemplify how theory-informed design can yield meaningful impact in practice. These contributions demonstrate that VC providers can evolve from passive financiers into active lifecycle partners capable of shaping venture trajectories and enabling broader economic, societal, and environmental outcomes.

At the same time, the dissertation highlights the importance of collaboration between investors and entrepreneurs, between academia and industry, and across disciplinary boundaries. It shows that overcoming the missing middle is not merely a matter of capital allocation, but one

of strategic alignment, innovation ecosystem orchestration, and shared understanding.

While the findings are promising, they also invite further inquiry. Taken together, these future research opportunities suggest a shift from studying isolated VC activities toward understanding how fund design, investment decision-making, sustainability considerations, and value creation activities interact throughout the venture life cycle. Longitudinal validation, cross-contextual adaptation, and quantitative generalization will be essential for building a robust evidence base around the tools and frameworks introduced. In doing so, future research can continue to refine and extend the contributions made here, helping to shape a more resilient and impact-oriented venture capital landscape. The collaboration between Eindhoven University of Technology and DeepTechXL provides a strong foundation for continued solution-oriented research that advances both theory and practice and further closes this gap.

Ultimately, I hope this dissertation inspires scholars and practitioners alike to engage in deeper collaboration, embrace design-driven thinking, and pursue innovation not only for financial return but for the broader benefit of society.

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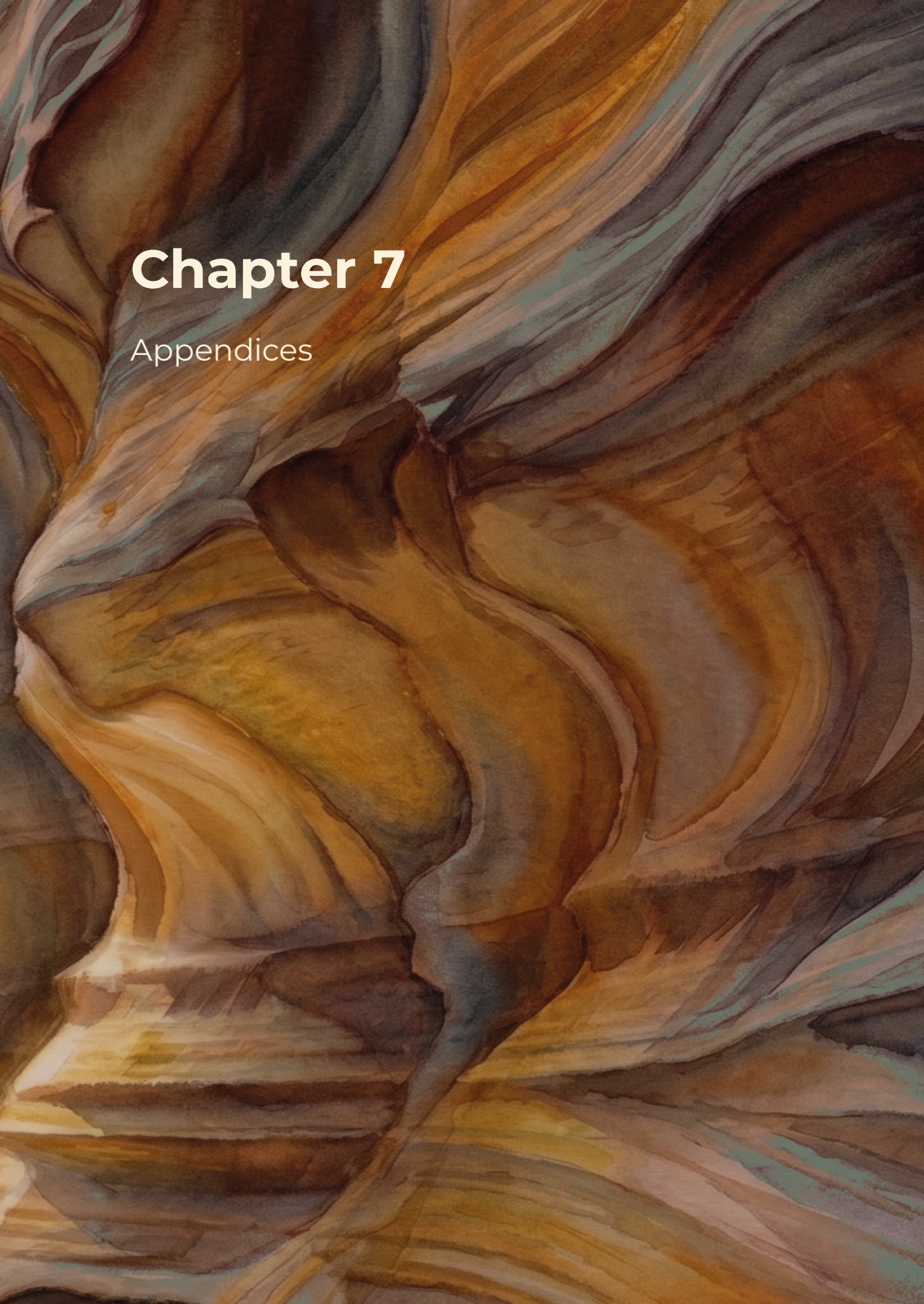
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Chapter 7

Appendices

APPENDIX A: SEARCH QUERY (CHAPTER 2)

The complete query used in section 2 is as follows:

TS=(Technology Entrepreneurship OR Venture Capital OR "Entrepreneurial Finance") AND SO=(Academy of Management Journal OR Academy of Management Review OR Administrative Science Quarterly OR Entrepreneurship Theory and Practice OR Harvard Business Review OR Journal of Applied Psychology OR Journal of Business Venturing OR Journal of Finance OR Journal of Financial and Quantitative Analysis OR Journal of Financial Economics OR Journal of Management OR Journal of Management Studies OR MIT Sloan Management Review OR Organization Science OR Organization Studies OR Organizational Behavior and Human Decision Processes OR Research Policy OR Review of Finance OR Review of Financial Studies OR Strategic Entrepreneurship Journal OR Strategic Management Journal OR TECHNOVATION OR Journal of Technology Transfer OR Venture Capital) AND Publication date (1980-01-01 – 2025-12-22)

APPENDIX B: DETAILED LITERATURE ANALYSIS (CHAPTER 2)

This appendix reports the detailed analysis of the literature (of which the main findings are outlined in section 2.3).

Mechanisms of technology venturing

Table B.1 provides an overview of the evidence base of each of the eight mechanisms, also categorized in the applied R&D and commercialization phases.

Table B.1 key mechanisms of technology venturing

Mechanism	Phase (# referrals)	Perspective (# referrals)	References
Signaling	Applied R&D (17)	Tech. Entr. (6) Entr. Fin. (11)	Ayoub, Gottschalk and Müller, 2017; Block, Fisch and Diegel, 2022; Chan, Park and Patel, 2018; Colombo, D'Adda and Pirelli, 2016b; Fuller and Rothaermel, 2012; Guerini and Quas, 2016; Honjo and Kurihara, 2023; Islam, Fremet and Marcus, 2018; Kirsch, Goldfarb and Gera, 2009; Latifi, Grilli and Herrmann, 2024; Paik, 2014; Pan et al., 2020; Roma, Vasi and Kolympiris, 2021; Svetek, 2022; Vanacker and Forbes, 2016; Wright et al., 2006; Zhang, 2019
	Commercialization (32)	Tech. Entr. (6) Entr. Fin. (26)	Blevins and Ragozzino, 2018; Brinster, Hopp and Tykvova, 2020; Butticè, Di Pietro and Tenca, 2022; Chahine, Saade and Goergen, 2019; Chang, 2004; Crosetto and Regner, 2018; Cumming et al., 2024; Gerasymenko and Arthurs, 2014; Gompers, 1996; Gu and Xiaohui, 2014; Gulati and Higgins, 2003; Hochberg, Serrano and Ziedonis, 2018; Hong, Guerini and Park, 2025; Huang and Pearce, 2015; Kleinert et al., 2022; Kleinert and Hildebrand, 2025; Kleinert and Volkmann, 2019; Lahiri et al., 2025; Lee and Wahal, 2004; Liu, Maula and Pinkham, 2024; Loeher, 2017; Mansouri and Momtaz, 2022; Milosevic, Le Pendeven and Fendt, 2020; Nahata, 2008; Oo et al., 2023; Ozmel, Reuer and Gulati, 2013; Parhankangas and Ehrlich, 2014; Petkova, Rindova and Gupta, 2013; Pontikes, 2012; Roosenboom, van der Kolk and de Jong, 2020; Seigner et al., 2023; Tian, 2012

Resource acquisition	Applied R&D (19)	Tech. Entr. (8) Entr. Fin. (11)	Bottazzi, Da Rin and Hellmann, 2008; De Prijcker et al., 2019; Dushnitsky and Lavie, 2010; Fernandez Alles, Camelo Ordaz and Franco Leal, 2015; Gompers et al., 2010; González-Uribe, 2020; Hoehn-Weiss and Karim, 2014; Hsu, 2007; Kalcheva, Mc-Lemore and Pant, 2018; Kang, Nanda and Park, 2021; Kolympiris, Kalaitzandonakes and Miller, 2011; Ozmel and Guler, 2015; Pahnke, Katila and Eisenhardt, 2015; Park and Steensma, 2013; Rosenbusch, Brinckmann and Müller, 2013; Shi, Sorenson and Waguespack, 2024; Wasserman, 2003; Wang, Huang and An, 2021; Wasserman, 2003; Weik, Achleitner and Braun, 2024
	Commercialization (15)	Tech. Entr. (7) Entr. Fin. (8)	Banerjee and Cole, 2012; Bertoni, Colombo and Grilli, 2011; Boeker and Wiltbank, 2005; Colombo and Grilli, 2010; Davila, Foster and Gupta, 2003; Ewens and Marx, 2018; Garg and Bingham, 2025; Gerasymenko, De Clercq and Sapienza, 2015; Haeussler, Hennicke and Mueller, 2019; Hochberg, Lindsey and Westerfield, 2015; Kaplan, Klebanov and Sorensen, 2012; Kelly and Kim, 2018; Kim, 2018; Ouimet and Zarutskie, 2014; Samila and Sorenson, 2010
Social networking	Applied R&D (12)	Tech. Entr. (4) Entr. Fin. (8)	Colombo, D'Adda and Quas, 2019; Colombo et al., 2022; Ferretti et al., 2022; Gu et al., 2023; Hunter, Perry and Currall, 2011; Kim, Steensma and Park, 2019; Steier and Greenwood, 2000; Ter Wal et al., 2016; Tian, 2011; Wang, 2016; Wuebker, Hampl and Wüstenhagen, 2015; Zhang, Wong and Ho, 2016
	Commercialization (8)	Tech. Entr. (3) Entr. Fin. (5)	Dimov, Shepherd and Sutcliffe, 2007; Echols and Tsai, 2005; Ferrary, 2010; Makarevich et al., 2019; Ozmel, Robinson and Stuart, 2013; Taglialatela and Barontini, 2023; Weber and Weber, 2011; Zhang and Guler, 2020

Diversity	Applied R&D (14)	Tech. Entr. (4) Entr. Fin. (10)	Aernoudt and De San Jose, 2020; Becker-Blease and Sohl, 2007; Bengtsson and Hsu, 2015; Brush et al., 2018; Butticè, Croce and Ughetto, 2023; Calder-Wang and Gompers, 2021; Claes and Vissa, 2020; Forrester and Neville, 2021; Franke et al., 2006; Guzman and Kacperczyk, 2019; Harrison and Mason, 2007; Lauto, Salvador and Visintin, 2022; Liu, Park and Velamuri, 2023; Schreiber et al., 2024
	Commercialization (5)	Tech. Entr. (1) Entr. Fin. (4)	Gompers, Mukharlyamov and Xuan, 2016; Koch, Berger and Kuckertz, 2025; Makarevich, 2018; Seigner, McKenny and Reetz, 2024; Snellman and Solal, 2023
Knowledge spillovers	Applied R&D (3)	Tech. Entr. (0) Entr. Fin. (3)	Gill, Heller and Michel, 2024; Mathews, 2006; Wonglimpiyarat, 2016
	Commercialization (34)	Tech. Entr. (8) Entr. Fin. (26)	Alakent, Goktan and Khoury, 2020; Alperovych, Groh and Quas, 2020; Alvarez-Garrido and Dushnitsky, 2016; Balachandran, 2024; Balachandran and Eklund, 2023; Bernstein, Giroud and Townsend, 2016; Bertoni, Le Nadant and Perdreau, 2020; Bronzini, Caramellino and Magri, 2020; Chemmanur, Hull and Krishnan, 2016; Chemmanur, Krishnan and Nandy, 2011; Christopoulos, Koeppl and Koppl Turyna, 2022; Clayton, 2024; Croce, Martí and Murtinu, 2013; Croce et al., 2021; De Bettignies and Brander, 2007; Dong and Shi, 2024; Dutta and Folta, 2016; Fernhaber, McDougall Covin and Shepherd, 2009; Garg, Howard and Pahnke, 2025; Gompers et al., 2020; Granz, Lutz and Henn, 2021; Hellmann, 2002; Hellmann and Puri, 2000; Hellmann and Puri, 2002; Inderst and Müller, 2009; Kim and Park, 2021; Maula, Autio and Murray, 2009; Parhankangas and Landstrom, 2006; Proksch et al., 2017; Siefkes, Bjørgum and Sørheim, 2025; Vanacker, Collewaert and Paeleman, 2013; Veer, Yang and Riepe, 2022; Zahra and Hayton, 2008; Zhang, Meng and Liu, 2024

Building strong relationships	Commercialization and Applied R&D (16)	Tech. Entr. (4) Entr. Fin. (12)	Ademi et al., 2022; Batjargal and Liu, 2004; Baum et al., 2022; Busenitz, Fiet and Moesel, 2004; Bygrave, 1987; Carayannis, Kassicieh and Radosevich, 2000; Cerpentier et al., 2022; Colombo, Montanaro and Shafi, 2024; De Clercq and Sapienza, 2006; Drover, Wood and Fassin, 2014; Fairchild, 2011; Mannor et al. 2019; Matusik and Fitza, 2012; Müller and Wöhler, 2023; Park and Tzabbar, 2016; Warnick et al., 2018
Optimizing capital structure	Applied R&D (0)	Tech. Entr. (0) Entr. Fin. (0)	N/A
	Commercialization (7)	Tech. Entr. (0) Entr. Fin. (7)	Conti, 2018; De Rassenfosse and Fischer, 2016; Deloof, La Rocca and Vanacker, 2019; Vaznyte and Andries, 2019; Walthoff Borm, Schwienbacher and Vanacker, 2018; Winton and Yerramili, 2008; Wu, Si and Wu, 2016
Intellectual property rights	Applied R&D (14)	Tech. Entr. (1) Entr. Fin. (13)	Arqué-Castells, 2012; Block et al., 2014; Colombo et al., 2023; Colombo and Shafi, 2016; Forti, Munari and Zhang, 2020; Haeussler, Harhoff and Mueller, 2014; Hoenen et al., 2014; Hoenig and Henkel, 2015; Mann and Sager, 2007; Minola, Vismara and Hahn, 2017; Mohammadi and Khasbabi, 2021; Tumasjan, Braun and Stolz, 2021; Wry and Lounsbury, 2013; Zhou et al., 2016
	Commercialization (5)	Tech. Entr. (1) Entr. Fin. (4)	Bayar et al., 2025; Lahr and Mina, 2016; Paik and Woo, 2017; Useche, 2014; Uzuegbunam, Ofem and Nambisan, 2019

Signaling

Signaling is a prevailing mechanism in entrepreneurship theory (Hoenig and Henkel, 2015) and the most dominant mechanism in the studies reviewed. Early-stage ventures and intermediaries use signals to communicate hard-to-observe information about the quality and opportunity of a venture or technology to potential partners, such as customers, strategic partners, and investors (Kleinert et al., 2022; Spencer, 1973). Signals can reduce information asymmetry by signaling reputation (Gulati and Higgins, 2003), legitimacy (Davila, Foster and Gupta, 2003), credibility and protection (Block et al., 2014), and certification (Nahata, 2008), which leads to reducing the (perceived) liability of newness (Wry and Lounsbury, 2013), search costs, and friction (Mohammadi and Khashabi, 2021) for TVs.

Applied R&D phase. Signals within the applied R&D phase are a means to (1) attract capital, (e.g., Guerini and Quas, 2016; Hoenig and Henkel, 2015) (2) attract resources (e.g., Colombo, Cumming and Vismara, 2016a; Minola, Vismara and Hahn, 2017) and (3) protect IP or other assets (e.g., Block et al., 2014; Haeussler, Harhoff and Mueller, 2014). Example sources of signals include patents, trademarks, and copyrights (e.g., Haeussler, Harhoff and Mueller, 2014; Honjo and Kurihara, 2023), achievement of technical milestones (Wright et al, 2006), industry-specific experience and media prominence (Tumasjan, Braun and Stolz, 2021; Vanacker and Forbes, 2016), signals of competence (industry, experience, and market knowledge), cooperativeness (coachability and involvement with advisors and mentors), previous funding from public funds or government-backed VCs (Ayoub, Gottschalk and Müller, 2017; Colombo, Cumming and Vismara, 2016a), research alliances (Hoenig and Henkel 2015), and formal business planning documents (Kirsch, Goldfarb and Gera, 2009; Latifi, Grilli and Herrmann, 2024).

Within the applied R&D phase, patent applications are a more important signal than granted patents (Hoenen et al., 2014). Moreover, new ventures applying both patents and trademarks yield higher funding amounts, especially in the initial round (Block et al., 2014; Zhou et al., 2016). Many signals can have multiple uses, such as patents that have a protection function toward competitors as well as an information function for attracting capital (Hoenig and Henkel, 2015). Because signals can be perceived differently per receiver and means of sending (Vanacker and Forbes, 2016), linguistic strategies are important in the way signals are communicated (Pan et al., 2020). In sum, within the applied R&D phase, signals are mainly used in the forms of intellectual property rights (patenting, trademarking, copyrights), team composition, and business planning to obtain capital and resources, and as a protection function.

Commercialization phase. Within the commercialization phase, signals continue to be a means to (1) attract capital (e.g., Cumming et al., 2024; Hochberg, Serrano and Ziedonis, 2018), (2) attract resources (Blevins and Ragozzino, 2018; Chang, 2004), and (3) protect assets (Lahr and Mina, 2016), but also expand toward (4) setting up alliances and agreements (Blevins and Ragozinno, 2018; Kleinert et al., 2022), and (5) as a signal toward exit candidates (e.g., Lee and Wahal, 2004; Mohammadi and Khashabi, 2021). Within the commercialization phase, the most important additional signals

are the successful raising of (initial) VC funding from reputable investors (Blevins and Ragozinno, 2018; Nahata, 2008) and employee growth (Davilla et al., 2003). These signals also serves to reduce search costs and friction for subsequent financiers and potential buyers (Mohammadi and Khashabi, 2021). The VC signal might even replace the quality signal of patents (Arqué-Castells, 2012; Lahr and Mina, 2016). However, first-round VCs can also experience a negative signaling effect on outside VC investors, in the case of follow-on fundraising (Milosevic, Le Pendeven and Fendt, 2020).

Several studies focus on which communication styles adopted by ventures achieve the most effective signaling effects. For example, less ambiguous external labels may be more effective for reaching different target audiences (Pontikes, 2012), by attracting higher levels of industry media attention and social media post attention (Petkova, Rindova and Gupta, 2013; Seigner et al., 2023), focusing on certain levels of organizational promotion for effectivity (Parhankangas and Ehrlich, 2014), types of speech acts (Oo et al., 2023), and the usage of entrepreneurial vision and optimism (a Schumpeterian entrepreneurial digital identity) to increase the chance of acquiring resources (Block, Fisch and Diegel, 2022). In sum, within the commercialization phase, ventures move from intellectual property rights (IPR) to fundraising as quality signals. Studies in this area largely focus on *how* ventures communicate to leverage the signaling mechanism as effectively as possible toward their target audiences.

Resource acquisition

Resource acquisition is a foundational mechanism in the resource-based view (Fernandez Alles, Camelo Ordaz and Franco Leal, 2015), emphasizing the importance of securing both financial and non-financial resources to support venture development. These resources may be obtained from external actors, such as investors, corporate partners, or alliances, or developed internally through human capital formation.

Applied R&D. In the applied R&D phase, resource acquisition is critical for venture survival and early-stage development. Ventures typically lack sufficient internal resources and must rely on external sources to fund R&D activities, hire technical staff, and build foundational capabilities. Financial resources are often obtained from venture capitalists, government grants, or public funding schemes (e.g., De Prijcker et al., 2019; Kolympiris, Kalaitzandonakes and Miller, 2011), while non-financial resources, such as

technical expertise, infrastructure, and strategic guidance, are accessed through alliances or corporate partnerships (e.g., Dushnitsky and Lavie, 2010; Pahnke, Katila and Eisenhardt, 2015). Corporate venture capital (CVC) investors are particularly valuable in this phase, as they can provide both capital and access to proprietary technologies or R&D facilities (Kang, Nanda and Park, 2021; Wang, Huang and An, 2021). For example, CVCs with a strong technological fit can offer knowledge spillovers that enhance venture performance and increase the likelihood of a successful exit. Signaling mechanisms often precede resource acquisition: entrepreneurs with a successful track record (Gompers et al., 2010), formalized alliances (Hoehn-Weiss and Karim, 2014), or affiliations with prestigious institutions (Ozmel and Guler, 2015) are more likely to attract external support. These early signals help reduce perceived risk and build credibility with potential resource providers. Moreover, the spatial distribution of resources plays a role in venture location decisions. Ventures often relocate to regions with better access to capital and talent (De Prijcker et al., 2019; Kalcheva, McLemore and Pant, 2018), and proximity to VC hubs increases the likelihood of funding (Colombo, D'Adda and Quas, 2019). In sum, resource acquisition in the applied R&D phase is about building the foundation for future growth by securing the necessary inputs to develop a viable product or technology.

Commercialization. In the commercialization phase, the focus of resource acquisition shifts from securing basic inputs to building the organizational infrastructure needed to scale. Human capital becomes the most critical resource, particularly in the context of venture growth and market expansion. Studies emphasize the importance of recruiting skilled employees (Kelly and Kim, 2018), implementing effective organizational design (Haeussler, Hennicke and Mueller, 2019), and managing leadership transitions (Wasserman, 2003). A life cycle perspective is particularly relevant in this phase. As ventures grow, the complexity of operations increases, requiring different managerial competencies and organizational structures (Boeker and Wiltbank, 2005). For example, early-stage CEOs with strong technical skills may be replaced by leaders with commercialization expertise as the venture matures (Banerjee and Cole, 2012). This transition reflects a shift from problem-solving and innovation to scaling and execution. VC backing continues to play a key role in facilitating access to talent and supporting organizational development. Gerasymenko, De Clercq and Sapienza (2015) show that VC involvement positively influences the composition

and evolution of top management teams, enabling ventures to adapt to changing demands. Moreover, the presence of reputable investors serves as a signal to potential employees, making it easier to attract high-quality talent (Ouimet and Zarutskie, 2014; Samila and Sorenson, 2010). In conclusion, resource acquisition in the commercialization phase is about assembling the right team and organizational capabilities to support rapid growth. While financial capital remains important, the emphasis shifts toward acquiring and integrating human capital to execute the venture's scaling strategy effectively.

Social networking

Social networking refers to the structure and quality of a venture's social ties and how these influence access to resources, legitimacy, and decision-making (Echols and Tsai, 2005). It is conceptually related to the resource-based view but emphasizes relational capital and embeddedness in social ecosystems. Social networking is distinct from diversity, as it focuses on the strength and structure of social ties rather than the composition of individuals within a team or network.

Applied R&D. In the applied R&D phase, social networking helps ventures mitigate the liability of newness and gain access to critical resources. Ventures benefit from both direct and indirect social ties, which reduce search costs for investors and increase the likelihood of funding (Wang, 2016; Wuebker, Hampl and Wüstenhagen, 2015). For example, Colombo et al. (2022) and Kim, Steensma and Park (2019) show that personal and professional ties, such as prior employment relationships, can facilitate introductions to investors and validate the trustworthiness of the venture. Social ecosystems also play a critical role. Ventures embedded in strong local networks, such as innovation clusters or university spin-off ecosystems, are more likely to secure early-stage financing (Ferretti et al., 2022; Hunter, Perry and Currall, 2011). Proximity to VC hubs enhances access to capital, as shown by Colombo et al. (2019), while ventures located farther from investors tend to receive smaller investments with shorter durations between rounds (Tian, 2011). However, social networking is not without its limitations. Zhang, Wong and Ho (2016) found that ethnic minority VCs face a "discriminatory price" when investing in mainstream markets, highlighting how social status and perceived legitimacy can influence investment dynamics. In sum, social networking in the applied R&D phase is primarily

focused on leveraging social ties, ecosystems, and status to access capital and reduce uncertainty.

Commercialization. In the commercialization phase, the focus of social networking shifts from the venture to the investor. Studies emphasize the role of social ties in forming syndicates and facilitating follow-on funding (e.g., Makarevich, 2018; Zhang and Guler, 2020). From a VC perspective, embeddedness in tight networks is crucial for attracting co-investors and accessing high-quality deal flow (Echols and Tsai, 2005). Dimov, Shepherd and Sutcliffe (2007) and Ozmel, Robinson and Stuart (2013) show that social standing, prior collaboration, and network centrality are key antecedents of successful syndicate formation. Taglialatela and Barontini (2023) found that while prior ties alone do not predict exit success, the concentration of successful past collaborations does. Moreover, trustworthiness and interpersonal relationships are essential for reducing investment risk and enhancing post-investment collaboration (Müller and Wöhler, 2023). In sum, social networking in the commercialization phase is primarily about building and leveraging investor networks to support syndication, reduce risk, and enhance the likelihood of successful exits. While ventures benefit indirectly from these networks, the primary agency lies with the investors and their ability to mobilize social capital.

Diversity

Diversity is a mechanism rooted in the resource-based view, emphasizing how heterogeneity in teams and investor groups can reduce the risk of social conformity and groupthink, thereby improving decision-making and venture performance (Butticè, Croce and Ughetto, 2023). Unlike social networking, which focuses on relational ties and ecosystems, diversity centers on the composition of individuals, particularly in terms of gender, ethnicity, education, and experience, and how these attributes influence access to resources, collaboration dynamics, and strategic outcomes.

Applied R&D. In the applied R&D phase, diversity is primarily examined through the lens of bias and its impact on funding and team formation. A substantial body of literature highlights how similarity bias affects investor decision-making. For instance, Franke et al. (2006) show that VCs tend to favor teams that resemble themselves in educational background and professional experience, such as preferring engineering-trained founders or those with startup experience. Claes and Vissa (2020) further demon-

strate that social similarity between founders and VCs influences pricing decisions and investment returns. Gender diversity is another critical dimension. Becker-Blease and Sohl (2007) find that women-led ventures receive significantly less angel investment, while Guzman and Kacperczyk (2019) show that female founders face systemic disadvantages in venture funding. Calder-Wang and Gompers (2021) offer a nuanced perspective, revealing that male VCs with daughters are less biased against female entrepreneurs, suggesting that personal experiences can mitigate gender-based stereotyping. Similarly, Liu, Park and Velamuri (2023) find that female CEOs in China face higher IPO underpricing due to institutional biases. Cultural diversity also plays a role. Bengtsson and Hsu (2015) show that shared ethnicity between founders and investors increases the likelihood of investment, pointing to the role of ethnic matching in venture capital decisions. However, this can reinforce exclusionary dynamics, limiting access for underrepresented groups. Despite these biases, diverse teams offer strategic advantages. Butticè, Croce and Ughetto (2023) argue that gender-diverse teams benefit from broader perspectives, enhanced critical thinking, and reduced decision-making biases. Matusik and Fitza (2012) propose a U-shaped relationship between knowledge diversity and performance: ventures benefit either from low diversity (due to processing efficiency) or high diversity (due to access to broad information and problem-solving capabilities), but not from moderate levels. In sum, diversity in the applied R&D phase is a double-edged sword: while biases can hinder access to capital and collaboration, diverse teams can outperform homogeneous ones under conditions of complexity and uncertainty.

Commercialization. In the commercialization phase, diversity is primarily studied from the investor's perspective, particularly in relation to syndication and decision-making. Gompers, Mukharlyamov and Xuan (2016) find that VCs tend to form syndicates with others who share similar demographic and professional characteristics, reinforcing homophily and limiting the benefits of cognitive diversity. Makarevich (2018) explores how performance feedback influences syndicate formation, showing that VCs are more likely to collaborate with similar others after negative performance experiences, potentially exacerbating conformity. Nonetheless, some studies suggest that diverse investment teams may outperform more homogeneous ones. Calder-Wang and Gompers (2021) show that VC firms with greater gender diversity, especially those with partners who have daughters, are more likely to invest in female-led ventures and

achieve superior performance. Seigner, McKenny and Reetz (2024) highlight how age bias in crowdfunding platforms affects funding outcomes, suggesting that diversity-related biases extend beyond gender and ethnicity. In conclusion, diversity in the commercialization phase influences investor behavior, syndicate formation, and portfolio performance. While biases persist, there is growing evidence that diverse teams and investor groups can generate better outcomes, particularly when diversity is embraced as a strategic asset rather than a liability.

Knowledge spillovers

Knowledge spillovers refer to the transfer of expertise, practices, and insights between actors, typically in the form of coaching, mentoring, sharing best practices, or organizational imprinting (Paik and Woo, 2017). It is a key mechanism in the resource-based view, particularly relevant for early-stage ventures that lack internal capabilities and must rely on external sources of knowledge to innovate and grow.

Applied R&D. Empirical evidence on knowledge spillovers in the applied R&D phase is limited but conceptually important. Matthews (2006) provides one of the few studies in this phase, showing how strategic alliances between ventures and corporates can facilitate early-stage knowledge transfer. These alliances often involve access to technical expertise, R&D infrastructure, and regulatory know-how, which are critical for ventures developing complex technologies. However, the literature remains underdeveloped in this area, and more empirical work is needed to understand how knowledge flows from incumbents to ventures during the R&D stage. Despite the limited number of studies, the mechanism is conceptually supported by the high dependency of early-stage ventures on external expertise. For example, ventures often rely on corporate partners or incubators to access specialized knowledge that would be too costly or time-consuming to develop internally (Wonglimpiyarat, 2016). The absorptive capacity of the venture, its ability to recognize, assimilate, and apply external knowledge, is a critical moderating factor in this process (Zahra and Hayton, 2008).

Commercialization. In the commercialization phase, knowledge spillover becomes a central mechanism through which ventures benefit from the expertise, networks, and strategic guidance of external actors, particularly venture capitalists (VCs) and corporate venture capitalists (CVCs). These actors do not merely provide financial capital; they actively contribute to

venture success through a wide array of value-added activities. The majority of studies focus on the role of investors in transferring knowledge to ventures. This includes strategic advice, operational support, and access to broader networks (Croce, Martí and Murtinu, 2013; Dutta and Folta, 2016). For example, Hellmann (2002) shows that VCs can influence the strategic direction of ventures by encouraging professionalization and market orientation. Similarly, Vanacker, Collewaert and Paeleman (2013) find that VCs help ventures manage slack resources more effectively, leading to improved performance. Syndication also facilitates knowledge exchange among investors, enhancing the support available to ventures (Chemmanur, Hull and Krishnan, 2016). Syndicates composed of both local and international VCs provide a more diverse pool of expertise, which can be leveraged to support venture growth and internationalization (Christopoulos, Koeppl and Koppl Turyna, 2022). Prior work has focused on how VCs add value through coaching, connecting, and hiring support (Gompers et al., 2020; Vanacker, Collewaert and Paeleman, 2013; Zhang, Meng and Liu, 2024), by providing (1) financial support, (2) human capital support, (3) governance mechanisms, (4) networks of relevant contacts, (5) support for operational issues, (6) management innovations, and (7) sustainability-value-adding activities (e.g., Proksch et al., 2017; Granz, Lutz and Henn, 2021; Siefkes, Bjørgum and Sørheim, 2025). However, the effectiveness of these spillovers depends on the venture's absorptive capacity and the quality of the investor-entrepreneur relationship (Zahra and Hayton, 2008; Park and Tzabbar, 2016). Beyond traditional value-added support, some studies highlight the imprinting effect of socially responsible investors. Alakent, Goktan and Khoury (2020) and Croce et al. (2021) show that VCs with a strong CSR orientation can influence the long-term strategic behavior of ventures, leading to greater adoption of sustainability practices and improved societal impact. This suggests that knowledge spillovers are not limited to operational or technical domains but can also shape organizational values and culture. In sum, knowledge spillovers are a multifaceted mechanism in the commercialization phase through which ventures gain access to critical knowledge, improve their capabilities, and enhance their chances of success. While most studies focus on investor-to-venture spillovers, there is growing interest in how knowledge flows within syndicates and between ventures and corporate partners.

Building strong relationships

Building strong relationships refers to the development of trust-based, enduring interpersonal and interorganizational ties between ventures and external stakeholders, particularly investors. These relationships are not merely transactional but are embedded in social interactions, mutual understanding, and shared goals (Batjargal and Liu, 2004). In the context of technology venturing, strong relationships can significantly influence investment decisions, venture performance, and the quality of post-investment collaboration.

Unlike other mechanisms, building strong relationships operates across both the applied R&D and commercialization phase. The literature does not sharply distinguish between these phases, as the relational dynamics between entrepreneurs and investors often begin early and evolve over time. During the due diligence and investment decision-making process, investors assess not only the venture's technical and market potential but also the relational fit with the founding team. Studies show that particularistic ties, such as shared backgrounds, prior interactions, or mutual acquaintances, can moderate the influence of technical criteria on investment decisions (Batjargal and Liu, 2004). Entrepreneurs who demonstrate empathy, trustworthiness, and openness are more likely to attract investor interest (Fairchild, 2011).

Once an investment is made, the quality of the venture–investor relationship becomes a key determinant of post-investment collaboration. De Clercq and Sapienza (2006) find that relational capital, built through trust, goal congruence, and social interaction, enhances investors' perceptions of venture performance. Similarly, Park and Tzabbar (2016) show that strong relationships can amplify the positive effects of VC funding on innovation, especially when the CEO possesses structural or expert power. Strong relationships also facilitate knowledge spillovers and resource acquisition. Ventures that maintain high-quality relationships with their investors are more likely to receive ongoing support, including strategic advice, introductions to key partners, and follow-on funding (Busenitz, Fiet and Moesel, 2004; Cerpentier et al., 2022). These relational dynamics are particularly important in high-uncertainty environments, where formal contracts are insufficient to govern all contingencies. Moreover, the relational embeddedness of investors themselves, i.e., their ability to build and maintain strong ties within the VC ecosystem, can influence

the success of syndication and the performance of portfolio companies (Müller and Wöhler, 2023). Trust and prior collaboration among syndicate partners reduce coordination costs and enhance the effectiveness of joint value-added activities. In sum, building strong relationships is a foundational mechanism that underpins many others, including signaling, knowledge spillovers, and resource acquisition. It operates throughout the valley of death and plays a critical role in shaping both the likelihood and quality of venture financing and development.

Optimizing capital structure

Optimizing capital structure refers to the strategic configuration of a venture's financing mix, typically involving equity, debt, and internal funds, to minimize the cost of capital and maximize financial flexibility (Winton and Yerramilli, 2008). This mechanism is grounded in the pecking order theory, which posits that firms prefer internal financing first, followed by debt, and resort to equity as a last option due to its higher cost and potential for ownership dilution.

Commercialization. Empirical studies on capital structure optimization concentrate on the commercialization phase, where ventures begin generating revenue and can access a broader range of financing instruments. In this phase, ventures are no longer entirely dependent on equity financing and can start to consider debt and hybrid instruments as viable alternatives. Several studies highlight the trade-offs ventures face when choosing between equity and debt. For example, equity financing may be preferred when the venture lacks collateral or when the value-added services of investors (e.g., strategic guidance, governance, and network access) outweigh the cost of ownership dilution (Winton and Yerramilli, 2008; Wu, Si and Wu, 2016). Conversely, debt financing becomes more attractive as ventures establish a track record of revenue and profitability, reducing perceived risk for lenders (Deloof, La Rocca and Vanacker, 2019). The timing and sequencing of financing rounds also play a critical role. Vaznyte and Andries (2019) argue that ventures with low entrepreneurial orientation are more likely to prefer equity financing early on, while those with stronger internal capabilities may delay equity issuance in favor of bootstrapping or debt. Subsidies and grants can also serve as early-stage financing tools that improve innovation outcomes and increase the likelihood of attracting follow-on investment (Conti, 2018). Moreover, the monitoring intensity associated with different financing sources influences capital structure

decisions. Equity investors, particularly VCs, often impose stronger governance mechanisms and demand board representation, which may be beneficial or burdensome depending on the venture's stage and strategic goals (Walthoff Borm, Schwienbacher and Vanacker, 2018). In sum, optimizing capital structure in the commercialization phase involves a dynamic balancing act between cost, control, and strategic value. Ventures must weigh the benefits of investor involvement against the implications for ownership and autonomy, while also considering their evolving financial needs and market conditions.

Intellectual property rights

Intellectual property rights (IPR), including patents, trademarks, copyrights, and trade secrets, are critical mechanisms for protecting and leveraging technological innovations. In the context of technology venturing, IPR serves both as a strategic asset and a signaling device, influencing investor decisions, competitive positioning, and commercialization outcomes.

Applied R&D. In the early stages of venture development, IPR plays a dual role: it protects the venture's technological assets and signals quality and legitimacy to external stakeholders. Patents, in particular, are used to safeguard novel inventions and reduce the risk of knowledge misappropriation, especially in collaborations with corporate partners (Colombo and Shafi, 2016). Trademarks, on the other hand, protect brand identity and market positioning. Several studies emphasize the signaling function of IPR in attracting early-stage investment. Patent applications, often more than granted patents, serve as credible indicators of technological potential (Hoenen et al., 2014). Ventures that combine patents with trademarks tend to raise more capital in early funding rounds (Block et al., 2014; Zhou et al., 2016). Moreover, IPR portfolios can signal a venture's growth ambition, market orientation, and commitment to innovation (Tumasjan, Braun and Stolz, 2021; Wry and Lounsbury, 2013). IPR also enables ventures to option between different commercialization paths, such as licensing, strategic alliances, or direct market entry (Forti, Munari and Zhang, 2020). This optionality is particularly valuable in high-uncertainty environments, where flexibility in strategic decision-making is crucial.

Commercialization. As ventures transition into the commercialization phase, the role of IPR shifts from signaling and protection to value ex-

traction and strategic leverage. IPR becomes a key input in valuation models used by investors and acquirers, influencing exit outcomes such as IPO pricing and acquisition terms (Useche, 2014; Lahr and Mina, 2016). Ventures use IPR to strengthen their bargaining position in negotiations with partners, customers, and investors. For example, a strong patent portfolio can serve as collateral for debt financing or as a basis for licensing deals that generate non-dilutive revenue (De Rassenfosse and Fischer, 2016). In some cases, IPR is used to block competitors or create barriers to entry, thereby enhancing the venture's market power. Corporate venture capital (CVC) investors often play a role in helping ventures develop and manage their IPR portfolios, especially when there is a strong technological fit between the corporate parent and the venture (Paik and Woo, 2017; Uzuegbunam, Ofem and Nambisan, 2019). These partnerships can lead to increased patent output, improved IP strategy, and better alignment with commercialization goals. In sum, IPR is a key mechanism that supports both the protection and monetization of innovation. It plays a pivotal role in signaling venture quality, enabling strategic flexibility, and enhancing financial outcomes across the valley of death.

Agencies associated with technology ventures

Agencies refer to the deliberate actions taken by ventures, investors, or both, to activate mechanisms that help overcome the valley of death. These actions are context-dependent and vary across the applied R&D and commercialization phases. Based on the literature synthesis, we identified eight key agencies, each associated with specific mechanisms and outcomes (Table B.2). We address each agency in the remainder of this subsection.

Table B.2 Key agencies of Technology Venturing

Actor	Agency (# of referrals)	Perspective (# referrals)	Definition	Referrals
Venture	R&D strategies (10)	Tech. Entr. (2) Entr. Fin. (8)	The research and development of patents, trademarks, and copyrights to subsequently develop a product or service that can be commercialized (Mann and Sager, 2007)	Block et al., 2014; Haeussler, Harhoff and Mueller, 2014; Hoenen et al., 2014; Lahr and Mina, 2016; Mann and Sager, 2007; Mohammadi and Khashabi, 2021; Tumasjan, Braun and Stolz, 2021; Useche, 2014; Veer, Yang and Riepe, 2022; Wry and Lounsbury, 2013
	Commercialization strategies (16)	Tech. Entr. (9) Entr. Fin. (7)	Commercialize new technologies to create significant value for stakeholders and gain legitimacy to increase access to resources and accelerate organizational growth (Petkova, Rindova and Gupta, 2013)	Bayar et al., 2025; Boeker and Wiltbank, 2005; Dong and Shi, 2024; Echols and Tsai, 2005; Gill, Heller and Michel, 2024; Hellmann and Puri, 2000; Hunter, Perry and Currall, 2011; Kirsch, Goldfarb and Gera, 2009; Lahiri et al., 2025; Liu, Maula and Pinkham, 2024; Makarevich and Kim, Steensma and Park, 2019; Petkova, Rindova and Gupta, 2013; Pontikes, 2012; Seigner et al., 2023; Steier and Greenwood, 2000; Zahra and Hayton, 2008
	Expanding team (19)	Tech. Entr. (15) Entr. Fin. (4)	Acquire human capital to enable a timely execution to take advantage of early mover advantages (Davila, Foster and Gupta, 2003)	Banerjee and Cole, 2012; Baum et al., 2022; Bertoni, Le Nadant and Perdreau, 2020; Block, Fisch and Diegel, 2022; Butticè, Croce and Ughetto, 2023; Calder-Wang and Gompers, 2021; Clayton, 2024; Colombo and Grilli, 2010; Davila, Foster and Gupta, 2003; Ewens and Marx, 2018; Fuller and Rothaermel, 2012; Garg, Howard and Pahnke, 2025; Garg and Bingham, 2025; Garg, Howard and Pahnke, 2025; Gompers et al., 2010; Haeussler, Hennicke and Mueller, 2019; Kaplan, Klebanov and Sorensen, 2012; Kim, 2018; Ouimet and Zarutskie, 2014; Wasserman, 2003

Actor	Agency (# of referrals)	Perspective (# referrals)	Definition	Referrals
Investor	Syndicating (20)	Tech. Entr. (1) Entr. Fin. (19)	Syndication is a means of augmenting available financial resources: investors pool their means (e.g., resources, experience, and complementary skills) in order to increase deal financing and boost their performance and that of their portfolio firms, and fosters the exchange of information between investors, to reduce risk exposure (Milosevic, Le Pendeven and Fendt, 2020)	Alperovych, Groh and Quas, 2020; Bygrave, 1987; Chahine, Saade and Goergen, 2019; Chemmanur, Hull and Krishnan, 2016; Christopoulos, Koeppl and Koppl Turyna, 2022; Colombo et al., 2023; Ferrary, 2010; Gompers, Mukharlyamov and Xuan, 2016; Hellmann, 2002; Hong, Guerini and Haemin, 2025; Kim and Park, 2021; Makarevich, 2018; Milosevic, Le Pendeven and Fendt, 2020; Nahata, 2008; Parhankangas and Landstrom, 2006; Taglialatela and Barontini, 2023; Ter Wal et al., 2016; Tian, 2012; Wuebker, Hampl and Wüstenhagen, 2015; Zhang, 2019
	Requesting support (18)	Tech. Entr. (2) Entr. Fin. (16)	Advance new innovative technologies toward a commercializable product or service (Park and Tzabbar, 2016)	Balachandran, 2024; Bernstein, Giroud and Townsend, 2016; Blevins and Ragozzino, 2018; Busenitz, Fiet and Moesel, 2004; Croce, Martí and Murtinu, 2013; de Bettignies and Brander, 2007; Fernandez-Alles, Camelo Ordaz and Franco Leal, 2015; Gompers et al., 2020; González-Uribe, 2020; Granz, Lutz and Henn, 2021; Hellmann and Puri, 2002; Inderst and Müller, 2009; Kang, Nanda and Park, 2021; Kolympiris, Kalaitzandonakes and Miller, 2011; Park and Tzabbar, 2016; Proksch et al., 2017; Siefkes, Bjørgum and Sørheim, 2025; Vaznyte and Andries, 2019
	Fundraising & investing (102)	Tech. Entr. (17) Entr. Fin. (85)	Attracting external capital or investing capital to commercialize unproven technologies (Hochberg, Serrano and Ziedonis, 2018)	Ademi et al., 2022; Aernoudt and De San Jose, 2020; Alakent, Goktan and Khoury, 2020; Arqué-Castells, 2012; Ayoub, Gottschalk and Müller, 2017; Batjargal and Liu, 2004;

Actor	Agency (# of referrals)	Perspective (# referrals)	Definition	Referrals
				Becker-Blease and Sohl, 2007; Bengtsson and Hsu, 2015; Bertoni, Colombo and Grilli, 2011; Bottazzi, Da Rin and Hellmann, 2008; Bronzini, Caramellino and Magri, 2020; Brush et al., 2018; Butticè, Di Pietro and Tenca, 2022; Carayannis, Kassicieh and Radosevich, 2000; Cerpentier et al., 2022; Chan, Park and Patel, 2018; Chemmanur, Krishnan and Nandy, 2011; Claes and Vissa, 2020; Colombo, D'Adda and Pirelli, 2016b; Colombo, D'Adda and Quas, 2019; Colombo et al., 2022; Colombo, Montanaro and Shafi, 2024; Colombo and Shafi, 2016; Conti, 2018; Croce et al., 2021; Crosetto and Regner, 2018; Cumming et al., 2024; De Prijcker et al., 2019; De Rassenfosse and Fischer, 2016; Deloof, La Rocca and Vanacker, 2019; Dimov, Shepherd and Sutcliffe, 2007; Drover, Wood and Fassin, 2014; Dutta and Folta, 2016; Fairchild, 2011; Forrester and Neville, 2021; Forti, Munari and Zhang, 2020; Franke et al., 2006; Gerasymenko and Arthurs, 2014; Gerasymenko, De Clercq and Sapienza, 2015; Gompers, 1996; Gu et al., 2023; Guerini and Quas, 2016; Guzman and Kacperczyk, 2019; Harrison and Mason, 2007; Hochberg, Lindsey and Westerfield, 2015; Hochberg, Serrano and Ziedonis, 2018; Hoenig and Henkel, 2015; Honjo and Kurihara, 2023; Hsu, 2007; Huang and Pearce, 2015; Islam, Fremeth and Marcus, 2018; Kalcheva, McLemore and Pant, 2018; Kelly and Kim, 2018; Kim, Steensma and Park, 2019;

Actor	Agency (# of referrals)	Perspective (# referrals)	Definition	Referrals
				Kleinert et al., 2022; Kleinert and Hildebrand, 2025;Kleinert and Volkmann, 2019; Koch, Berger and Kuckertz, 2025; Latifi, Grili and Herrmann, 2024; Lauto, Salvador and Visintin, 2022; Lee and Wahal, 2004; Liu, Park and Velamuri, 2023; Loeher, 2017; Mannor et al., 2019; Mansouri and Momtaz, 2022; Matusik and Fitza, 2012; Maula, Autio and Murray, 2009; Minola, Vismara and Hahn, 2017; Müller and Wöhler, 2023; Oo et al., 2023; Pahnke, Katila and Eisenhardt, 2015; Paik, 2014; Paik and Woo, 2017; Pan et al., 2020; Parhankangas and Ehrlich, 2014; Park and Steensma, 2013; Roma, Vasi and Kolympiris, 2021; Roosenboom, van der Kolk and de Jong, 2020; Rosenbusch, Brinckmann and Müller, 2013; Samila and Sorenson, 2010; Schreiber et al., 2024; Seigner, McKenny and Reetz, 2024; Shi, Sorenson and Waguespack, 2024; Snellmann and Solal, 2023; Svetek, 2022; Tian, 2011; Uzuegbunam, Ofem and Nambisan, 2019; Vanacker, Collewaert and Paeleman, 2013; Vanacker and Forbes, 2016; Walthoff Borm, Schwienbacher and Vanacker, 2018; Wang, Huang and An, 2021; Wang, 2016; Warnick et al., 2018; Weik, Achleitner and Braun, 2024; Winton and Yerramilli, 2008; Wright et al., 2006; Wu, Si and Wu, 2016; Zhang, Wong and Ho, 2016; Zhang, Meng and Liu, 2024; Zhou et al., 2016

Actor	Agency (# of referrals)	Perspective (# referrals)	Definition	Referrals
	Alliance creation (16)	Tech. Entr. (7) Entr. Fin. (9)	An alliance refers to an enduring relationship between ventures that share resources and coordinate value chain activities (Dushnitsky and Lavi, 2010)	Alvarez-Garrido and Dushnitsky, 2016; Balachandran and Eklund, 2023; Brinster, Hopp and Tykvova, 2020; Chang, 2004; De Clerq and Sapienza, 2006; Dushnitsky and Lavie, 2010; Fernhaber, McDougall Covin and Shepherd, 2009; Ferretti et al., 2022; Gu and Lu, 2014; Gulati and Higgins, 2003; Hoehn-Weiss and Karim, 2014; Mathews, 2006; Ozmel, Reuer and Gulati, 2013; Weber and Weber, 2011; Wonglimpiyarat, 2016; Zhang and Guler, 2020

R&D strategies

R&D strategies are focused on creating intellectual property rights (IPR), such as patents, trademarks, and copyrights, and thereby serve as a signaling function and a foundation for knowledge spillovers. This agency is predominantly activated by the venture. R&D strategies are especially relevant in the applied R&D phase, where ventures aim to build a credible IPR portfolio to attract funding and partnerships. IPR allows ventures to progress more effectively through the venture capital cycle, including the number of funding rounds, total investment, and longevity (Hoenen et al., 2014; Mann and Sager, 2007). Moreover, R&D strategies serve as a signaling function for showcasing sustainable differentiation (Tumasjan, Braun and Stolz, 2021), protection from imitation (Colombo and Shafi, 2016), and a broadcasting function of R&D results (Veer, Yang and Riepe, 2022). The combination of patents and trademarks has been shown to be particularly effective in early-stage fundraising (Block et al., 2014; Zhou et al., 2016). Thus, R&D strategies are a foundational agency for activating the mechanisms of signaling, knowledge spillovers, and IPR.

Commercialization strategies

Commercialization strategies refer to the actions taken to bring new technologies to market and create value for stakeholders, thereby gaining legitimacy and accelerating growth. This agency is predominantly activated by the venture. These strategies become increasingly important as ventures transition from the applied R&D phase to commercialization. They include business planning, market entry decisions, branding, and customer engagement (Petkova, Rindova and Gupta, 2013). Effective commercialization strategies enhance the venture's ability to signal quality and legitimacy (Kirsch, Goldfarb and Gera, 2009; Pontikes, 2012), build social networks (Steier and Greenwood, 2000), and attract funding (Seigner et al., 2023). They also influence the structure and culture of the organization, such as fostering invention disclosures (Hunter, Perry and Currall, 2011) and selecting appropriate beachhead markets (Makarevich and Kim, 2019). In sum, commercialization strategies activate signaling, social networking, knowledge spillovers, and IPR mechanisms, and are critical for venture development and successful market entry.

Expanding the team

Expanding the team refers to the acquisition of human capital to enable timely execution and take advantage of early mover advantages. This

agency is predominantly activated by the venture. As ventures mature, they must grow their teams to acquire new skills and scale operations. This is particularly relevant in the commercialization phase, where organizational complexity increases (Wasserman, 2003). The effectiveness of team expansion depends on diversity (Butticè, Croce and Ughetto, 2023), signaling (Davila, Foster and Gupta, 2003), and the venture's identity (Block, Fisch and Diegel, 2022). For example, ventures with strong social networks and diverse founding teams are more likely to attract high-quality talent (Colombo and Grilli, 2010). VCs also play a role by signaling legitimacy, which helps ventures recruit skilled employees (Gerasymenko, De Clercq and Sapienza, 2015). Studies show that VC-backed ventures tend to hire younger, more skilled workers and often pay a wage premium (Kim, 2018; Ouimet and Zarutskie, 2014). Thus, expanding the team activates mechanisms such as resource acquisition, diversity, signaling, and knowledge spillovers, and contributes to venture development and productivity.

Fundraising & investing

Fundraising & investing refer to the activities of attracting external capital or deploying capital to commercialize unproven technologies. This agency is activated by both ventures and investors. This is the most frequently observed agency in the literature and spans both the applied R&D and commercialization phases. It includes efforts by ventures to raise capital and by investors to deploy it strategically. Fundraising & investing activate all eight mechanisms identified in the review, including signaling, resource acquisition, knowledge spillovers, and building strong relationships. Studies have examined the effects of investment (e.g., Colombo, D'Adda and Pirelli, 2016b), the antecedents of investment decisions (e.g., Minola, Vismara and Hahn, 2017), and the dynamics within investor organizations (e.g., Matusik and Fitza, 2012). This agency is central to enabling venture development, innovation, and ultimately, exit performance. It also plays a key role in shaping the capital structure of the venture and in facilitating syndication and alliance formation.

Requesting support

Requesting support refers to the venture's proactive engagement with investors, partners, or incubators to obtain strategic, operational, or technical assistance. This agency is activated by both ventures and investors. This agency is particularly relevant in contexts where ventures lack internal capabilities and must rely on external expertise. It activates mechanisms

such as knowledge spillovers, resource acquisition, and building strong relationships. For example, ventures benefit from the social capital of their investors, which enhances their ability to attract additional capital (Ter Wal et al., 2016). The act of receiving support from an investor can also serve as a signal of quality to other stakeholders (Blevins and Ragozzino, 2018). Moreover, the effectiveness of support depends on the relational quality between the venture and the investor, including procedural fairness and the CEO's structural power (Busenitz, Fiet and Moesel, 2004; Park and Tzabbar, 2016). Thus, requesting support is a critical agency for enabling knowledge transfer and resource mobilization.

Alliance creation

Alliance creation refers to the formation of enduring relationships between ventures and external partners to share resources and coordinate value chain activities. This agency is activated by both ventures and investors. Alliances are instrumental in acquiring resources, accessing knowledge, and building relational capital. They activate mechanisms such as resource acquisition, knowledge spillovers, social networking, and building strong relationships. The quality of alliances enhances the effectiveness of knowledge transfer and increases the venture's legitimacy (De Clercq and Sapienza, 2006). Geographical proximity and prior collaboration history are important antecedents of alliance success (Ferretti et al., 2022). Alliances also serve as signals to external stakeholders, indicating that credible partners are willing to collaborate (Gulati and Higgins, 2003). In sum, alliance creation is a vital agency for overcoming resource constraints and enhancing venture development.

Syndicating

Syndicating refers to the pooling of resources, experience, and complementary skills by multiple investors to co-finance a venture and reduce risk exposure. This agency is predominantly activated by investors. Syndication enhances the diversity of expertise and facilitates knowledge exchange among investors. It activates mechanisms such as signaling, knowledge spillovers, diversity, and social networking. Syndicates with reputable lead investors are associated with higher IPO probabilities (Kim and Park, 2021). Prior co-investment experience among syndicate members improves coordination and exit outcomes, particularly in the U.S. context (Taglialatela and Barontini, 2023). Syndication also enables the transfer of best practices and strategic insights to ventures (Chemmanur, Hull and Krishnan, 2016).

Thus, syndicating is a powerful agency for amplifying investor value-added support and improving venture performance.

Conclusion about agencies

The review of the technology entrepreneurship and entrepreneurial finance literature demonstrates that many referrals involve the same underlying mechanism. To synthesize both streams of literature and create a common understanding in terms of key mechanisms, we carefully grouped together identical and highly similar referrals. These efforts resulted in eight higher-order mechanisms, based on 182 referrals. These mechanisms are listed and defined in Table B.2 and are further categorized based on a temporal perspective. The latter two phases of the valley of death have been used to further clarify the referrals and mechanisms from a temporal perspective. Based on where each referrals appears to generate most impact, we have positioned the referrals to each mechanism in the applied R&D or commercialization phase of the valley of death. There was a clear possibility to classify referrals from the temporal perspective except for the building strong relationships mechanism. So far, empirical studies have mainly focused on the social relationship between venture-investor, which could take place in both phases (e.g., Cerpentier et al., 2022; De Clercq and Sapienza, 2006; Warnick et al., 2018). Moreover, in analyzing referrals to the optimizing capital structure mechanism it became clear that all studies so far have merely focused on the commercialization phase. Based on the literature at hand, it could be concluded that the optimizing capital structure mechanism is not applicable to the applied R&D phase, as ventures have not yet the option to decide between funding options. Finally, only a single study could be clearly classified as main contribution to the applied R&D phase of the mechanism knowledge spillovers. However, it would be evident that during this phase, there are sufficient grounds for the spilling of knowledge between several types of alliance- or industrialization partners and the venture. Within analyzing the mechanisms, it became evident that several mechanisms cannot always be activated in isolation, such as the resource acquisition mechanism and the signaling mechanism. Hence, there are clear potentials for future research.

Agency-mechanisms relationships

Based on the classification of higher-order agencies (previously outlined), we subsequently identified various agency-mechanism linkages. Table B.3 depicts the strength of these relationships based on the evidence—in

terms of the number of empirical studies—found. It is evident that the agents fundraising and investing are the dominant agency that influences each identified mechanism. Fundraising & investing is the most important agency within the applied R&D and commercialization phases to fuel the negative cash flows of a venture which classify the valley of death. Social networking can be triggered by the agencies of alliance creation, commercialization strategies, fundraising & investing, and syndication. By contrast, diversity can be triggered by fundraising & investing, syndication, and team expansion. The agencies related to social networking are mainly related to the potential effects toward external actors while diversity is also about the dynamics within an organization. The agencies related to building strong relationships (alliance creation, fundraising & investing, and requesting support) are also predominantly focused on the dynamics within an organization. Signaling can be triggered by all agencies. Knowledge spillovers are related to the agencies that could enable knowledge transfer, such as alliance creation, R&D strategies, requesting support, and fundraising & investing. While knowledge spillovers are related to R&D strategies, resource acquisition is not. That could be related to the fact that resource acquisition is about being actively seeking (non-) financial resources to capture as organization, while knowledge spillovers are about the soft transition of knowledge, that could be for a limited time only. Finally, IPR as a mechanism is solely linked to the strategies of R&D, commercialization, and fundraising & investing and is not influenced by other agencies.

Table B.3 Identified agency-mechanism relationships

Agency	Mechanism (# of referrals)	Referrals
Alliance creation	Signaling (5)	Brinster, Hopp and Tykvova, 2020; Chang, 2004; Gu and Lu, 2014; Gulati and Higgins, 2003; Ozmel, Reuer and Gulati, 2013
	Resource acquisition (2)	Dushnitsky and Lavie, 2010; Hoehn-Weiss and Karim, 2014
	Social networking (3)	Ferretti et al., 2022; Weber and Weber, 2011; Zhang and Guler, 2020
	Knowledge spillovers (5)	Alvarez-Garrido and Dushnitsky, 2016; Balachandran and Eklund, 2023; Fernhaber, McDougall Covin and Shepherd, 2009; Mathews, 2006; Wonglimpiyarat, 2016
	Building strong relationships (1)	De Clercq and Sapienza, 2006
R&D strategies	Knowledge spillovers (1)	Veer, Yang and Riepe, 2022
	Intellectual Property Rights (9)	Block et al., 2014; Haeussler, Harhoff and Mueller, 2014; Hoenen et al., 2014; Lahr and Mina, 2016; Mann and Sager, 2007; Mohammadi and Khashabi, 2021; Tumasjan, Braun and Stolz, 2021; Useche, 2014; Wry and Lounsbury, 2013
Requesting support	Signaling (1)	Blevins and Ragozzino, 2018
	Resource acquisition (4)	Fernandez Alles, Camelo Ordaz and Franco Leal, 2015; González-Uribe, 2020; Kang, Nanda and Park, 2021; Kolympiris, Kalaitzandonakes and Miller, 2011
	Knowledge spillovers (10)	Balachandran, 2024; Bernstein, Giroud and Townsend, 2016; Croce, Martí and Murtinu, 2013; De Bettignies and Brander, 2007; Gompers et al., 2020; Granz, Lutz and Henn, 2021; Hellmann and Puri, 2002; Inderst and Müller, 2009; Proksch et al., 2017; Siefkes, Bjørgum and Sørheim, 2025
	Optimizing capital structure (1)	Vaznyte and Andries, 2019
	Building strong relationships (2)	Busenitz, Fiet and Moesel, 2004; Park and Tzabbar, 2016

Agency	Mechanism (# of referrals)	Referrals
Syndicating	Signaling (6)	Chahine, Saade and Goergen, 2019; Hong, Guerini and Park, 2025; Milosevic, Le Pendeven and Fendt, 2020; Nahata, 2008; Tian, 2012; Zhang, 2019
	Social networking (4)	Ferrary, 2010; Taglialatela and Barontini, 2023; Ter Wal et al., 2016; Wuebker, Hampl and Wüstenhagen, 2015
	Diversity (2)	Gompers, Mukharlyamov and Xuan, 2016; Makarevich, 2018
	Building strong relationships (1)	Bygrave, 1987
	Intellectual Property Rights (1)	Colombo et al., 2023
	Knowledge spillovers (6)	Alperovych, Groh and Quas, 2020; Chemmanur, Hull and Krishnan, 2016; Christopoulos, Koeppl and Koppl Turyna, 2022; Hellmann, 2002; Kim and Park, 2021; Parhankangas and Landstrom, 2006
Fundraising & investing	Signaling (29)	Ayoub, Gottschalk and Müller, 2017; Butticè, Di Pietro and Tenca, 2022; Chan, Park and Patel, 2018; Colombo, D'Adda and Pirelli, 2016b; Crosetto and Regner, 2018; Cumming et al., 2024; Gerasymenko and Arthurs, 2014; Gompers, 1996; Guerini and Quas, 2016; Hochberg, Serrano and Ziedonis, 2018; Honjo and Kurihara, 2023; Huang and Pearce, 2015; Islam, Fremeth and Marcus, 2018; Kleinert et al., 2022; Kleinert and Hildebrand, 2025; Kleinert and Volkmann, 2019; Latifi, Grilli and Herrmann, 2024; Lee and Wahal, 2004; Loeher, 2017; Mansouri and Momtaz, 2022; Oo et al., 2023; Paik, 2014; Pan et al., 2020; Parhankangas and Ehrlich, 2014; Roma, Vasi and Kolympiris, 2021; Roosenboom, van der Kolk and de Jong, 2020; Svetek, 2022; Vanacker and Forbes, 2016; Wright et al., 2006
	Resource acquisition (16)	Bertoni, Colombo and Grilli, 2011; Bottazzi, da Rin and Hellmann, 2008; de Prijcker et al., 2019; Gerasymenko, De Clercq and Sapienza, 2015; Hochberg, Lindsey and Westerfield, 2015; Hsu, 2007; Kalcheva, McLemore and Pant, 2018; Kelly and Kim, 2018; Ozmel and Guler, 2015; Pahnke, Katila and Eisenhardt, 2015; Park and Steensma, 2013; Rosenbusch, Brinckmann and Müller, 2013; Samila and Sorenson, 2010; Shi, Sorenson and Waguespack, 2024; Wang, Huang and An, 2021; Weik, Achleitner and Braun, 2024

Agency	Mechanism (# of referrals)	Referrals
	Social networking (9)	Colombo, D'Adda and Quas, 2019; Colombo et al., 2022; Dimov, Shepherd and Sutcliffe, 2007; Gu et al., 2023; Kim, Steensma and Park, 2019; Ozmel, Robinson and Stuart, 2013; Tian, 2011; Wang, 2016; Zhang, Wong and Ho, 2016;
	Diversity (15)	Aernoudt and de San Jose, 2020; Becker-Blease and Sohl, 2007; Bengtsson and Hsu, 2015; Brush et al., 2018; Claes and Vissa, 2020; Forrester and Neville, 2021; Franke et al., 2006; Guzman and Kacperczyk, 2019; Harrison and Mason, 2007; Koch, Berger and Kuckertz, 2025; Lauto, Salvador and Visintin, 2022; Liu, Park and Velamuri, 2023; Schreiber et al., 2024; Seigner, McKenny and Reetz, 2024; Snellmann and Solal, 2023
	Knowledge spillovers (8)	Alakent, Goktan and Khoury, 2020; Bronzini, Caramellino and Magri, 2020; Chemmanur, Krishnan and Nandy, 2011; Croce et al., 2021; Dutta and Folta, 2016; Maula, Autio and Murray, 2009; Vanacker, Collewaert and Paeleman, 2013; Zhang, Meng and Liu, 2024
	Building strong relationships (11)	Ademi et al., 2022; Batjargal and Liu, 2004; Carayannis, Kassicieh and Radosevich, 2000; Cerpentier et al., 2022; Colombo, Montanaro and Shafi, 2024; Drover, Wood and Fassin, 2014; Fairchild, 2011; Mannor et al., 2019; Matusik and Fitza, 2012; Müller and Wöhler, 2023; Warnick et al., 2018
	Optimizing capital structure (6)	Conti, 2018; de Rassenfosse and Fischer, 2016; Deloof, La Rocca and Vanacker, 2019; Walthoff Borm, Schwienbacher and Vanacker, 2018; Winton and Yerramilli, 2008; Wu, Si and Wu, 2016
	Intellectual property rights (8)	Aque-castells, 2012; Colombo and Shafi, 2016; Forti, Munari and Zhang, 2020; Hoenig and Henkel, 2015; Minola, Vismara and Hahn, 2017; Paik and Woo, 2017; Uzuegbunam, Ofem and Nambisan, 2019; Zhou et al., 2016

Agency	Mechanism (# of referrals)	Referrals
Commercialization strategies	Signaling (6)	Kirsch, Goldfarb and Gera, 2009; Lahiri et al., 2025; Liu, Maula and Pinkham, 2024; Petkova, Rindova and Gupta, 2013; Pontikes, 2012; Seigner et al., 2023
	Social networking (4)	Echols and Tsai, 2005; Hunter, Perry and Currall, 2011; Makarevich and Kim, 2019; Steier and Greenwood, 2000
	Intellectual Property rights (1)	Bayar et al., 2025
	Knowledge spillovers (4)	Dong and Shi, 2024; Gill, Heller and Michel, 2024; Hellmann and Puri, 2000; Zahra and Hayton, 2008
	Resource acquisition (1)	Boeker and Wiltbank, 2005
Expanding team	Signaling (2)	Block, Fisch and Diegel, 2022; Fuller and Rothaermel, 2012
	Resource acquisition (11)	Banerjee and Cole, 2012; Colombo and Grilli, 2010; Davila, Foster and Gupta, 2003; Ewens and Marx, 2018; Garg and Bingham, 2025; Gompers et al., 2010; Haeussler, Hennicke and Mueller, 2019; Kaplan, Klebanov and Sorensen, 2012; Kim, 2018; Ouimet and Zarutskie, 2014; Wasserman, 2003
	Knowledge spillovers (3)	Bertoni, Le Nadant and Perdreau, 2020; Clayton, 2024; Garg, Howard and Pahnke, 2025
	Building strong relationships (1)	Baum et al., 2022
	Diversity (2)	Butticè, Croce and Ughetto, 2023; Calder-Wang and Gompers, 2021

Figure B.1 depicts the agency-mechanism relationships that have a moderate to strong evidence base in the literature. Figure B.2 provides an overview of agency-mechanism relationships that have a nascent (i.e., currently limited) evidence base. As shown, fundraising & investing has the strongest empirical evidence, while several causal relationships provide opportunities for future work on enhancing the empirical evidence.

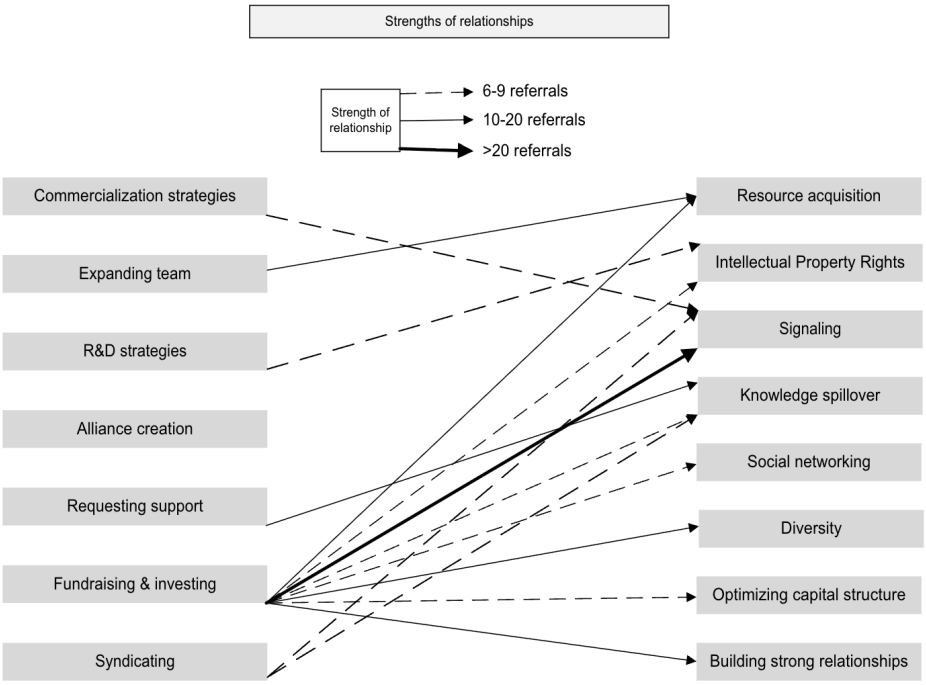


Figure B.1 Overview of agency-mechanism relationships with moderate to strong evidence

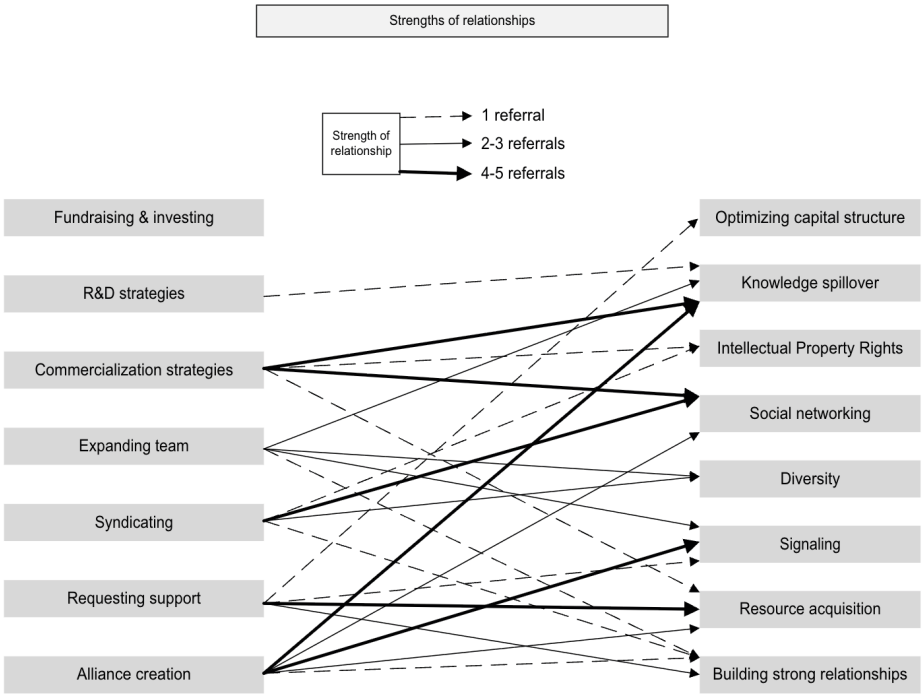


Figure B.2 Overview of agency-mechanism relationships with limited evidence

Potential outcomes of technology venturing

Outcomes represent the tangible and measurable results that emerge from the interplay of agencies and mechanisms as ventures navigate the valley of death. These outcomes reflect different stages of venture progress and success, ranging from early indicators of development to ultimate financial performance. Based on the literature synthesis, five key outcomes were identified, as depicted in Table B.4.

Table B.4 Key outcomes of Technology Venturing

Outcome (# of referrals)	Perspective (# referrals)	Definition	Referrals
Exit performance (17)	Tech. Entr. (4) Entr. Fin. (13)	The company has been acquired or has been listed through an Initial Public Offering (Bottazzi, Da Rin and Hellmann, 2008)	Bayar et al., 2025; Bottazzi, Da Rin and Hellmann, 2008; Brinster, Hopp and Tykvova, 2020; Chahine, Saade and Goergen, 2019; Chang, 2004; Christopoulos, Koeppl and Koppl Turyna, 2022; Clayton, 2024; Gompers, 1996; Gulati and Higgins, 2003; Hoehn-Weiss and Karim, 2014; Hong, Guerini and Park, 2025; Lee and Wahal, 2023; Liu, Park and Velamuri, 2023; Matusik and Fitza, 2012; Roosenboom, van der Kolk and de Jong, 2020; Taglialatela and Barontini, 2023; Useche, 2014
Funds (not) raised (74)	Tech. Entr. (16) Entr. Fin. (58)	(Un)Successful raising of funding for the ongoing operations of the enterprise (Hsu, 2007)	Aernoudt and de San Jose, 2020; Alpervoych et al., 2020; Ayoub, Gottschalk and Müller, 2017; Batjargal and Liu, 2004; Block et al., 2014; Block, Fisch and Diegel, 2022; Brush et al., 2018; Butticè, Di Pietro and Tenca, 2022; Cerpentier et al., 2022; Chan, Park and Patel, 2018; Claes and Vissa, 2020; Colombo, D'Adda and Pirelli, 2016b; Colombo, D'Adda and Quas, 2019; Colombo et al., 2023; Colombo, Montanaro and Shafi, 2024; Conti, 2018; Crosetto and Regner, 2018; Davila, Foster and Gupta, 2003; De Clercq and Sapienza, 2006; De Prijcker et al., 2019; De Rassenfosse and Fischer, 2016; Deloof, La Rocca and Vanacker, 2019; Dimov, Shepherd and Sutcliffe, 2007; Drover, Wood and Fassin, 2014; Fairchild, 2011; Ferretti et al., 2022; Franke et al., 2006; Guerini and Quas, 2016; Guzman and Kacperczyk, 2019; Haeussler, Harhoff and Mueller, 2014; Harrison and Mason, 2007; Hochberg, Lindsey and Westerfield, 2015; Hochberg, Serrano and Ziedonis, 2018; Hoenen et al., 2014; Hoenig and Henkel, 2015; Honjo and Kurihara, 2023; Hsu, 2007; Islam, Fremeth and Marcus, 2018; Kim, Steensma and Park, 2019; Kirsch, Goldfarb and Gera, 2009; Kleinert et al., 2022; Kleinert and Hildebrand, 2025; Kleinert and Volkmann, 2019; Koch, Berger and

Outcome (# of referrals)	Perspective (# referrals)	Definition	Referrals
			Kuckertz, 2025; Latifi, Grilli and Hermann, 2024; Lauto, Salvador and Visintin, 2022; Loeher, 2017; Mannor et al., 2019; Mansouri and Momtaz, 2022; Milosevic, Le Pendeven and Fendt, 2020; Mohammadi and Khashbabi, 2021; Oo et al., 2023; Pan et al., 2020; Parhankangas and Ehrlich, 2014; Roma, Vasi and Kolympiris, 2021; Seigner, McKenny and Reetz, 2024; Shi, Sorenson and Waguespack, 2024; Snellman and Solal, 2023; Svetek, 2022; Ter Wal et al., 2016; Tian, 2011; Tumasjan, Braun and Stolz, 2021; Walthoff Borm, Schwienbacher and Vanacker, 2018; Wang, 2016; Warnick et al., 2018; Weik, Achleitner and Braun, 2024; Winton and Yerramilli, 2008; Wright et al., 2006; Wry and Lounsbury, 2013; Wuebker, Hampl and Wüstenhagen, 2015; Zhang, Wong and Ho, 2016; Zhang, 2019; Zhang and Guler, 2020
Venture development (83)	Tech. Entr. (26) Entr. Fin. (57)	The growth of a company in terms of number of employees or sales (Colombo and Grilli, 2010)	Ademi et al., 2022; Alakent, Goktan and Khoury, 2020; Alvarez-Garrido and Dushnitsky, 2016; Banerjee and Cole, 2012; Becker-Blease and Sohl, 2007; Bengtsson and Hsu, 2015; Bertoni, Colombo and Grilli, 2011; Bertoni, Le Nadant and Perdreau, 2020; Blevins and Ragozzino, 2018; Boeker and Wiltbank, 2005; Bronzini, Caramellino and Magri, 2020; Busenitz, Fiet and Moesel, 2004; Butticè, Bygrave, 1987; Calder-Wang and Gompers, 2021; Carayannis, Kassicieh and Radosevich, 2000; Chemmanur, Hull and Krishnan, 2016; Colombo and Grilli, 2010; Croce et al., 2021; Cumming et al., 2024; De Bettignies and Brander, 2007; Dong and Shi, 2024; Dushnitsky and Lavie, 2010; Echols and Tsai, 2005; Ewens and Marx, 2018; Fernandez Alles, Camelo Ordaz and Franco Leal, 2015; Fernhaber, McDougall Covin and Shepherd, 2009; Ferrary, 2010; Forrester and Neville, 2021; Forti, Munari and Zhang, 2020; Fuller and Rothaermel, 2012; Garg, Howard and Pahnke, 2025;

Outcome (# of referrals)	Perspective (# referrals)	Definition	Referrals
			Gerasymenko and Arthurs, 2014; Gill, Heller and Michel, 2024; Gompers et al., 2010; Gompers, Mukharlyamov and Xuan, 2016; Gompers et al., 2020; Granz, Lutz and Henn, 2021; Gu et al., 2023; Gu and Lu, 2014; Hellmann, 2002; Hellmann and Puri, 2000; Hellmann and Puri, 2002; Huang and Pearce, 2015; Inderst and Müller, 2009; Kaplan, Klebanov and Sorensen, 2012; Kelly and Kim, 2018; Kim and Park, 2021; Kolympiris, Kalaitzandonakes and Miller, 2011; Lahiri et al., 2025; Lahr and Mina, 2016; Liu, Maula and Pinkham, 2024; Makarevich and Kim, 2019; Makarevich, 2018; Mann and Sager, 2007; Maula, Autio and Murray, 2009; Minola, Vismara and Hahn, 2017; Müller and Wöhler, 2023; Nahata, 2008; Ouimet and Zarutskie, 2014; Ozmel and Guler, 2015; Ozmel, Reuer and Gulati, 2013; Ozmel, Robinson and Stuart, 2013; Pahnke, Katila and Eisenhardt, 2015; Parhankangas and Landstrom, 2006; Pontikes, 2012; Proksch et al., 2017; Rosenbusch, Brinckmann and Müller, 2013; Samila and Sorenson, 2010; Schreiber et al., 2024; Seigner et al., 2023; Siefkes, Bjørgum and Sørheim, 2025; Steier and Greenwood, 2000; Tian, 2012; Vanacker and Forbes, 2016; Vanacker, Collewaert and Paeleman, 2013; Vaznyte and Andries, 2019; Veer, Yang and Riepe, 2022; Wasserman, 2003; Weber and Weber, 2011; Zahra and Hayton, 2008; Zhang, Meng and Liu, 2024; Zhou et al., 2016;
Venture innovation (17)	Tech. Entr. (4) Entr. Fin. (13)	The expansion of innovative capabilities and the generation of intellectual property rights thereof (Park and Steensma, 2013)	Arqué-Castells, 2012; Balachandran, 2024; Balachandran and Eklund, 2023; Baum et al., 2022; Bernstein, Giroud and Townsend, 2016; Colombo and Shafi, 2016; Dutta and Folta, 2016; González-Uribe, 2020; Hunter, Perry and Currall, 2011; Kalcheva, McLemore and Pant, 2018; Kang, Nanda and Park, 2021; Paik and Woo, 2017; Park and Tzabbar, 2016; Park and Steensma, 2013; Uzuegbunam, Ofem and Nambisan, 2019; Wang, Huang and An, 2021; Wu, Si and Wu, 2016;

Outcome (# of referrals)	Perspective (# referrals)	Definition	Referrals
Venture productivity (10)	Tech. Entr. (3) Entr. Fin. (7)	The efficiency in the use of inputs (e.g., capital and labor) toward a certain output (Croce, Martí and Murtinu, 2013)	Chemmanur, Krishnan and Nandy, 2011; Croce, Martí and Murtinu, 2013; Garg and Bingham, 2025; Gerasymenko, De Clercq and Sapienza, 2015; Haeussler, Hennicke and Mueller, 2019; Kim, 2018; Mathews, 2006; Paik, 2014; Petkova, Rindova and Gupta, 2013; Wonglimpiyarat, 2016;

Exit performance

Exit performance captures the successful transition of a venture into a new ownership structure, typically through an acquisition or an initial public offering (IPO). It is widely regarded as the ultimate indicator of venture success and investor return (Bottazzi, Da Rin and Hellmann, 2008). This outcome is shaped by a combination of mechanisms, most notably signaling, resource acquisition, building strong relationships, and diversity. For instance, alliances with reputable investment banks or VC firms prior to an IPO can enhance exit outcomes by signaling credibility and reducing uncertainty (Gulati and Higgins, 2003). Similarly, a strong technological posture, reflected in the venture's IPR portfolio, can increase IPO proceeds (Useche, 2014). The ability to acquire non-financial resources, such as strategic guidance and operational support, also plays a role in improving exit performance (Hoehn-Weiss and Karim, 2014). Moreover, the diversity of knowledge within the investor's organization has been linked to better portfolio performance and more successful exits (Matusik and Fitza, 2012). In sum, exit performance is the culmination of multiple reinforcing dynamics and serves as a key benchmark for both ventures and investors.

Funds (not) raised

Funds raised, or not raised, reflects the venture's success or failure in securing external financing to sustain operations and fuel growth. It is a critical intermediate outcome that influences a venture's ability to progress through the valley of death (Hsu, 2007). This outcome is most frequently associated with the signaling mechanism. Observable assets such as patents, alliances, and team experience are known to influence investor perceptions and funding decisions (Hoenig and Henkel, 2015). For example, ventures that disclose information effectively, through business plans, media presence, or prior public funding, are more likely to attract capi-

tal (Kirsch, Goldfarb and Gera, 2009; Ayoub, Gottschalk and Müller, 2017). Social networking also plays a role, as ventures with strong personal ties to investors often enjoy preferential access to funding (Wuebker, Hampl and Wüstenhagen, 2015). However, biases related to gender, ethnicity, and cultural background can negatively affect fundraising outcomes (Brush et al., 2018; Zhang, Wong and Ho, 2016). Intellectual property rights further contribute by signaling technological quality and reducing information asymmetries (Mohammadi and Khashabi, 2021). Thus, the ability to raise funds is shaped by a complex mix of signaling strength, social capital, and perceived legitimacy.

Venture development

Venture development refers to the growth of the organization in terms of size, structure, and capabilities, typically measured by increases in headcount, revenue, or market presence (Colombo and Grilli, 2010). This outcome is primarily driven by the mechanisms of knowledge spillovers and resource acquisition. Ventures benefit from external knowledge through alliances, investor support, and peer learning (Fernhaber, McDougall Covin and Shepherd, 2009; Vanacker, Collewaert and Paeleman, 2013). For example, VCs can influence organizational design, hiring practices, and strategic direction, thereby accelerating development (Gompers et al., 2010; Gerasymenko, De Clercq and Sapienza, 2015). Access to financial and non-financial resources, such as human capital, infrastructure, and networks, enables ventures to scale operations and professionalize their structures (Samila and Sorenson, 2010). Signaling also contributes by enhancing the venture's visibility and attractiveness to stakeholders (Cumming et al., 2024). In essence, venture development reflects the cumulative effect of acquiring and integrating resources, capabilities, and external knowledge.

Venture innovation

Venture innovation captures the venture's ability to generate novel products, services, or processes, often reflected in the creation of intellectual property or the introduction of breakthrough technologies (Park and Steensma, 2013). This outcome is closely linked to knowledge spillovers and resource acquisition. Strategic alliances with corporates, CVC investments, and VC coaching all contribute to enhancing a venture's innovative capacity (Dutta and Folta, 2016; Paik and Woo, 2017). For instance, corporate investors can provide access to R&D facilities, regulatory expertise, and technical mentorship, which are particularly valuable in deep-tech sectors

(Uzuegbunam, Ofem and Nambisan, 2019). Building strong relationships also plays a role, as relational trust facilitates the exchange of tacit knowledge and encourages experimentation (Park and Tzabbar, 2016). Additionally, optimizing capital structure, such as leveraging informal debt, can support product innovation by providing flexible financing (Wu, Si and Wu, 2016). Venture innovation is thus the result of a venture's ability to absorb, adapt, and apply external knowledge in novel ways.

Venture productivity

Venture productivity refers to the efficiency with which a venture transforms inputs, such as capital, labor, and knowledge, into outputs like revenue, products, or intellectual property (Croce, Martí and Murtinu, 2013). This outcome is predominantly influenced by knowledge spillovers and resource acquisition. For example, VC-backed ventures often exhibit higher productivity in the early years following investment, due to improved governance, strategic focus, and access to expert advice (Croce, Martí and Murtinu, 2013; Gerasymenko, De Clercq and Sapienza, 2015). Team expansion and alliance creation also contribute by enhancing operational capabilities and enabling more effective resource utilization (Kim, 2018; Mathews, 2006). Productivity gains are not only important for internal performance but also serve as signals to external stakeholders, reinforcing the venture's credibility and attractiveness. In short, venture productivity reflects the venture's ability to do more with less, an essential trait for survival and growth in resource-constrained environments.

Conclusion about outcomes

We found several intermediate outcomes arising from technology venturing agencies and mechanisms within the valley of death. For a venture to successfully transition from the applied R&D phase to commercialization, the venture should be successful in venture innovation, venture productivity, and venture development. More specifically, ventures should build alliances to foster knowledge spillovers and acquire resources (Dushnitsky and Lavie, 2010; Mathews, 2006), expand and strengthen its team, while considering diversity (e.g., Butticè, Croce and Ughetto, 2023; Calder-Wang and Gompers, 2021; Wasserman, 2003), raise funds mainly through leveraging the social networking and signaling mechanisms to fuel these activities (e.g., Arqué-Castells, 2012; Paik and Woo, 2017) and request support from those investors (e.g., González-Uribe, 2020; Kolympiris, Kalaitzandonakes and Miller, 2011). Through these activities ventures should build an IPR

portfolio to ensure sufficient signals can be used to start commercialization and raise (subsequent) funding for the commercialization (Mann and Sager, 2007; Minola, Vismara and Hahn, 2017; Zhou et al., 2016). In essence, a venture can only start the commercialization if it has two things in place: (1) lead customer(s) to start commercialization (which requires a good enough product and technology) to validate the market gap and (2) funding to fund the activities until the venture becomes cash-flow positive. Both activities require a venture to have strong observable signals in place to convince these actors, which is based on (1) the team, (2) IPR, and (3) alliances. Once a venture has entered the commercialization phase, the venture gradually reduces its focus to innovate and increasingly focus on its productivity and the development of the venture through successful commercialization of a first product-market fit solution. Table B.5 depicts what agencies lead to specific outcomes and through which mechanisms.

Table B.5 Agency-Mechanism-Outcome relationships

Agency	Mechanism (# of referrals)	Outcome	Referrals
Alliance creation	Building strong relationships (1)	Funds (not) raised	De Clercq and Sapienza, 2006
	Social networking (2)		Ferretti et al., 2022; Zhang and Guler, 2020
	Knowledge spillovers (2)	Venture development	Alvarez-Garrido and Dushnitsky, 2016; Fernhaber, McDougall Covin and Shepherd, 2009
	Resource acquisition (1)		Dushnitsky and Lavie, 2010
	Signaling (2)		Gu and Lu, 2014; Ozmel, Reuer and Gulati, 2013
	Social networking (1)		Weber and Weber, 2011
	Knowledge spillovers (1)	Venture innovation	Balachandran and Eklund, 2023
	Knowledge spillovers (2)	Venture productivity	Mathews, 2006; Wonglimpiyarat, 2016
	Signaling (3)	Exit performance	Brinster, Hopp and Tykvova, 2020; Chang, 2004; Gulati and Higgins, 2003
	Resource acquisition (1)		Hoehn-Weiss and Karim, 2014
R&D strategies	IPR (6)	Funds (not) raised	Block et al., 2014; Haeussler, Harhoff and Mueller, 2014; Hoenen et al., 2014; Mohammadi and Khashabi, 2021; Tumasjan, Braun and Stolz, 2021; Wry and Lounsbury, 2013
	IPR (2)	Venture development	Lahr and Mina, 2016; Mann and Sager, 2007
	Knowledge spillovers (1)		Veer, Yang and Riepe, 2022
	IPR (1)	Exit performance	Useche, 2014
Requesting support	Knowledge spillovers (7)	Venture development	de Bettignies and Brander, 2007; Gompers et al., 2020; Granz, Lutz and Henn, 2021; Hellmann and Puri, 2002; Inderst and Müller, 2009; Proksch et al., 2017; Siefkes, Bjørgum and Sørheim, 2025
	Resource acquisition (2)		Fernandez Alles, Camelo Ordaz and Franco Leal, 2015; Kolympiris, Kalaitzandonakes and Miller, 2011

Agency	Mechanism (# of referrals)	Outcome	Referrals
	Building strong relationships (1)		Busenitz, Fiet and Moesel, 2004
	Signaling (1)		Blevins and Ragozzino, 2018
	Optimizing capital structure (1)		Vaznyte and Andries, 2019
	Building strong relationships (1)	Venture innovation	Park and Tzabbar, 2016
	Resource acquisition (2)		González-Uribe, 2020; Kang, Nanda and Park, 2021
	Knowledge spillovers (2)		Balachandran, 2024; Bernstein, Giroud and Townsend, 2016
	Knowledge spillovers (1)	Venture productivity	Croce, Martí and Murtinu, 2013
Syndicating	Signaling (2)	Funds (not) raised	Milosevic, Le Pendeven and Fendt, 2020; Zhang, 2019
	IPR (1)		Colombo et al., 2023
	Social networking (2)		Ter Wal et al., 2016; Wuebker, Hampl and Wüstenhagen, 2015
	Knowledge spillovers (1)		Alperovych, Groh and Quas, 2020
	Signaling (2)	Venture development	Nahata, 2008; Tian, 2012
	Building strong relationships (1)		Bygrave, 1987
	Social networking (1)		Ferrary, 2010
	Diversity (2)		
	Knowledge spillovers (4)		Chemmanur, Hull and Krishnan, 2016, Hellmann, 2002; Kim and Park, 2021; Parhankangas and Landstrom, 2006
	Signaling (2)	Exit performance	Chahine, Saade and Goergen, 2019; Hong, Guerini and Park, 2025
	Social networking (1)		Taglialatela and Barontini, 2023
	Knowledge spillovers (1)		Christopoulos, Koeppl and Koppl Turyna, 2022

Agency	Mechanism (# of referrals)	Outcome	Referrals
Fund-raising & investing	Signaling (21)	Funds (not) raised	Ayoub, Gottschalk and Müller, 2017; Butticè, Di Pietro and Tenca, 2022; Chan, Park and Patel, 2018; Colombo, D'Adda and Pirelli, 2016b; Crosetto and Regner, 2018; Guerini and Quas, 2016; Hochberg, Serrano and Ziedonis, 2018; Islam, Fremeth and Marcus, 2018; Kleinert et al., 2022; Kleinert and Hildebrand, 2025; Kleinert and Volkmann, 2019; Latifi, Grilli and Herrmann, 2024; Loeher, 2017; Mansouri and Momtaz, 2022; Oo et al., 2023; Pan et al., 2020; Parhankangas and Ehrlich, 2014; Roma, Vasi and Kolympiris, 2021; Svetek, 2022; Wright et al., 2006
	Building strong relationships (7)		Batjargal and Liu, 2004; Cerpentier et al., 2022; Colombo, Montanaro and Shafi, 2024; Drover, Wood and Fassin, 2014; Fairchild, 2011; Mannor et al., 2019; Warnick et al., 2018;
	Resource acquisition (5)		De Prijcker et al., 2019; Hochberg, Lindsey and Westerfield, 2015; Hsu, 2007; Shi, Sorenson and Waguespack, 2024; Weik, Achleitner and Braun, 2024
	IPR (1)		Hoenig and Henkel, 2015
	Optimizing capital structure (5)		Conti, 2018; de Rassenfosse and Fischer, 2016; Deloof, La Rocca and Vanacker, 2019; Walthoff Borm, Schwienbacher and Vanacker, 2018; Winton and Yerramilli, 2008
	Social networking (7)		Colombo, D'Adda and Quas, 2019; Colombo et al., 2022; Dimov, Shepherd and Sutcliffe, 2007; Kim, Steensma and Park, 2019; Tian, 2011; Wang, 2016; Zhang, Wong and Ho, 2016
	Diversity (10)		Aernoudt and de San Jose, 2020; Brush et al., 2018; Claes and Vissa, 2020; Franke et al., 2006; Guzman and Kacperczyk, 2019; Harrison and Mason, 2007; Koch, Berger and Kuckertz, 2025; Lauto, Salvador and Visintin, 2022; Seiger et al., 2024; Snellmann and Solal, 2023
	Signaling (4)	Venture development	Cumming et al., 2024; Gerasymenko and Arthurs, 2014; Huang and Pearce, 2015; Vanacker and Forbes, 2016
	Building strong relationships (3)		Ademi et al., 2022; Carayannis, Kassicieh and Radosevich, 2000; Müller and Wöhler, 2023

Agency	Mechanism (# of referrals)	Outcome	Referrals
	Resource acquisition (6)		Bertoni, Colombo and Grilli, 2011; Kelly and Kim, 2018; Ozmel and Guler, 2015; Pahnke, Katila and Eisenhardt, 2015; Rosenbusch, Brinckmann and Müller, 2013; Samila and Sorenson, 2010
	Knowledge spillovers (6)		Alakent, Goktan and Khoury, 2020; Bronzini, Caramellino and Magri, 2020; Croce et al., 2021; Maula, Autio and Murray, 2009; Vanacker, Collewaert and Paeleman, 2013; Zhang, Meng and Liu, 2024
	IPR (3)		Forti, Munari and Zhang, 2020; Minola, Vismara and Hahn, 2017; Zhou et al., 2016
	Social networking (2)		Gu et al., 2023; Ozmel, Robinson and Stuart, 2013
	Diversity (4)		Becker-Blease and Sohl, 2007; Bengtsson and Hsu, 2015; Forrester and Neville, 2021; Schreiber et al., 2024
	Resource acquisition (3)	Venture innovation	Kalcheva, McLemore and Pant, 2018; Park and Steensma, 2013; Wang, Huang and An, 2021
	Knowledge spillovers (1)		Dutta and Folta, 2016
	IPR (4)		Arqué-Castells, 2012; Colombo and Shafi, 2016; Paik and Woo, 2017; Uzuegbunam, Ofem and Nambisan, 2019
	Optimizing capital structure (1)		Wu, Si and Wu, 2016
	Signaling (1)	Venture productivity	Paik, 2014
	Knowledge spillover (1)		Chemmanur, Krishnan and Nandy, 2011
	Resource acquisition (1)		Gerasymenko, De Clercq and Sapienza, 2015
	Signaling (3)	Exit performance	Gompers, 1996; Lee and Wahal, 2004; Roosenboom, van der Kolk and de Jong, 2020
	Building strong relationships (1)		Matusik and Fitza, 2012
	Resource acquisition (1)		Bottazzi, Da Rin and Hellmann, 2008
	Diversity (1)		Liu, Park and Velamuri, 2023

Agency	Mechanism (# of referrals)	Outcome	Referrals
Commercialization strategies	Signaling (1)	Funds (not) raised	Kirsch, Goldfarb and Gera, 2009
	Signaling (4)	Venture development	Lahiri et al., 2025; Liu, Maula and Pinkham, 2024; Pontikes, 2012; Seigner et al., 2023
	Social networking (3)		Echols and Tsai, 2005; Makarevich and Kim, Steensma and Park, 2019; Steier and Greenwood, 2000
	Resource acquisition (1)		Boeker and Wiltbank, 2005
	Knowledge spillovers (4)		Dong and Shi, 2024; Gill, Heller and Michel, 2024; Hellmann and Puri, 2000; Zahra and Hayton, 2008
	Social networking (1)	Venture innovation	Hunter, Perry and Currall, 2011
	IPR (1)	Venture productivity	Petkova, Rindova and Gupta, 2013
	IPR (1)	Exit performance	Bayar et al., 2025
Expanding team	Signaling (1)	Funds (not) raised	Block, Fisch and Diegel, 2022
	Resource acquisition (1)		Davila, Foster and Gupta 2003
	Signaling (1)	Venture development	Fuller and Rothaermel, 2012
	Resource acquisition (7)		Banerjee and Cole, 2012; Colombo and Grilli, 2010; Ewens and Marx, 2018; Gompers et al., 2010; Kaplan, Klebanov and Sorensen, 2012; Ouimet and Zarutskie, 2014; Wasserman, 2003
	Knowledge spillovers (2)		Bertoni, Le Nadant and Perdreau, 2020; Garg, Howard and Pahnke, 2025
	Diversity (2)		Butticè, Croce and Ughetto, 2023; Calder-Wang and Gompers, 2021
	Building strong relationships (1)	Venture innovation	Baum et al., 2022
	Resource acquisition (3)	Venture productivity	Garg and Bingham, 2025; Haeussler, Hennicke and Mueller, 2019; Kim, 2018
	Knowledge spillovers (1)	Exit performance	Clayton, 2024

Although many outcomes are qualitative in nature, some studies also refer to several possibilities to quantify (intermediate) outcomes of TV. From a venture innovation perspective, the most important quantitative measurement is IPR strength (Useche, 2014). From a venture development perspective, the most important quantitative measurements are employment growth (Bertoni, Colombo and Grilli, 2011), number of (relevant) alliances

(Chang, 2004), profitability (Bronzini, Caramellino and Magri, 2020), CSR accountability (Alakent, Goktan and Khoury, 2020), and commercialization rate or revenue growth (Dutta and Folta, 2016). From a venture productivity perspective, the key measurement is productivity growth (Croce, Martí and Murtinu, 2013). Funds (not) raised as an outcome is only a means to reach the outcomes (Davila, Foster and Gupta, 2003) and can be quantified for example by amount of funding raised. Exit performance is the ultimate outcome for a VC investor (Black and Gilson, 1998) and can be quantified by exit valuation, money multiple, or internal rate of return (Barber, Morse and Yasuda, 2021; Gerasymenko and Arthurs, 2014).

APPENDIX C: FUTURE RESEARCH QUESTIONS (CHAPTER 2)

Table C.1 provides a detailed list of promising research questions for future studies, of which section 2.4.3 provides a more concise overview.

Table C.1 Future research questions

Mechanism	Proposed research questions for future work
Signaling	- How do R&D partnerships with corporates help with fundraising? - How do R&D partnerships with corporates help in convincing a lead customer? - What are the most important signals to convince a lead customer? - How does the credibility of supply chain partners help in customer acquisition?
Resource Acquisition	- How can a venture benefit from the technology knowledge of corporates during the R&D phase? - How can a venture benefit from supply chain knowledge from corporates during the R&D phase? - What optimal multi-sourcing strategies should ventures investigate? - How can VCs optimize cross-fertilization between their portfolio companies?
Social Networking	- What is the optimal syndicate to maximize social networking effects for a successful exit? - How can social networking influence venture innovation? - How can social networking influence R&D strategies?
Diversity	- What is the optimal venture team structure for effective R&D? - How can the female founder gap be further reduced? - What is the impact of immigrant founders on the subsequent organization structure? - How can VCs improve diversity within their investee companies?
Knowledge Spillovers	- How can sustainable product design and sustainability indicators be implemented in ventures from the start? - What is the optimal VC team set-up to invest in the applied R&D phase? - How can VCs support ventures most effectively during the applied R&D phase? - How does lead user involvement affect R&D development? - How do knowledge spillovers from R&D partnerships influence product development? - How can VCs further integrate impact and sustainability in their assessment? - How can VCs assess the sustainability impact value of a venture and how is this related to ultimate exit value? - How can VCs incorporate social return on investment in their investment decisions and reporting?

Mechanism	Proposed research questions for future work
	- What is the impact of changing regulations on sustainable finance on VC-backed ventures? - How do syndication partners facilitate knowledge spillovers?
Building Strong Relationships	- What elements of team dynamics within the founder group influence successful innovation? - How can founders manage team dynamics within a growing organization? - What elements of team dynamics have a significant impact on venture development? - How is building strong relationships affecting VC decision-making?
Optimizing Capital Structure	- What are the effects of subsidies on the optimization trade-off for the capital structure for subsequent investors? - How does the capital structure of a venture affect the decision of a corporate to engage in an R&D partnership? - How does the capital structure of a venture affect the ability to convince a lead customer? - What novel methods are available for ventures in the applied R&D phase to attract debt? - How do founders interpret optimizing capital structure in relation to giving away shareholder rights? - Is there an optimal debt-to-equity ratio for VC-backed ventures?
Intellectual Property Rights (IPR)	- How do filed patents (vs. granted patents) influence seed-stage investment decisions? - What effect does alliance creation have on venture innovation through the creation of IPR? - How can shelved IP from corporates be used to strengthen the IP position of ventures? - How does IPR influence the make-or-buy decision for potential competing corporates? - How does IPR influence exit valuation?

APPENDIX D: INTERVIEW PROTOCOL (CHAPTER 3)

The interview protocol was developed to test whether fund investors were potentially interested in investing in a VC fund based on our design. This is a semi-structured interview protocol, including only a limited set of pre-defined questions:

- *Fund presentation:* Short presentation of the investment thesis and governance approach of the proposed DeepTechXL fund (by two of the authors)
- *Question 1: Is the investment thesis clear? If not, what needs to be clarified?*
- *Question 2: Is the governance approach transparent? If not, which elements need clarification?*
- *Question 3: Are you (on behalf of the company / institutional investor / family office you represent) interested in exploring a potential investment as a limited partner in this fund? If you're (not) interested, please explain why (not).*
- *Question 4 (only raised if the interviewee expressed an initial interest in response to the previous question): Which elements of DeepTechXL's investment thesis or governance approach need to be adapted to better fit your investment strategy? Any specific compliance issues we need to address?*

APPENDIX E: TRL SCALE (CHAPTER 3)

The horizontal axis in Figure 3.2 draws on the Technology Readiness Level (TRL) scale, which is widely used to understand how deep-tech technologies are turned into commercially successful ventures (EARTO, 2015; European Commission, 2014; Hensen et al., 2015; Mankins, 2009). It is a nine point-scale for determining the development or maturity of an invention and its readiness for market uptake and potential investments (EARTO, 2015). TRL 1 is the lowest level at which the basic principles of the novel technology are documented; TRL 9 is the highest, where industrial production (for at least one large customer) starts.

Notably, while some DTVs develop products for consumer markets, the vast majority of DTVs (seek to) serve industrial business-to-business markets. These industrial markets can involve large volumes of products being sold, but some of them operate on the basis of low volumes of products with extremely high prices and added value (e.g., the aircrafts produced by Airbus and Boeing and the lithographic machines sold by ASML). In the latter case, TRL9 can possibly be accomplished by means of a single lead customer.

The full scale used in the study in Chapter 3 is as follows:

Table E.1 TRL scale

TRL	Definition
TRL 1	Basic principles are observed and codified
TRL 2	The technology concept is formulated
TRL 3	An experimental proof-of-concept of the technology is delivered
TRL 4	The technology is validated in the lab
TRL 5	A prototype of the technology is tested and validated by at least one industrial user (for a B2B market) or a substantial number of consumers (in case of a B2C market)
TRL 6	Pre-production capability is demonstrated in a pilot plant
TRL 7	Production capability is demonstrated at low scale
TRL 8	The entire system required (incl. fully established supply chain and distribution processes) is complete and qualified
TRL 9	The value proposition is proven to be sufficiently competitive and attractive for several lead customers (or at least one major customer) and the supply chain, production and distribution capabilities are effectively scaled up to serve these customers.

APPENDIX F: INVESTMENT THESIS AND STRUCTURE DEEPTECHXL (CHAPTER 3)

The newly created DeepTechXL fund offers the following investment thesis:

- **Investment scope**: purpose-driven companies (targeting one or more SDGs) that leverage core defendable intellectual property on key enabling technologies within the hardware and manufacturing industries (incl. their supply chains) to make an impact on key societal themes.
- **Geographical scope**: deep-tech companies located in the Netherlands.
- **Intellectual Property (IP)**: core defendable IP.
- **Investment pace**: aims to invest in 15 to 20 deep-tech companies in total; and on average 3 to 4 companies per year.
- **Lifecycle partner:** it can take (co-)lead roles in forming syndicates in the seed-stage and seeks to avoid dilution in subsequent rounds up to series C; the total investment per company is up to €15M (each with help of an extensive network of potential syndicate partners).
- **Value creation focus**: a clear focus on value creation, in terms of product leadership, customer-centric mindset, human resources, operational excellence, and governance. It uses operational tools together with regular meetings to drive operational excellence.
- **Ecosystem support:** DeepTechXL is embedded in the Dutch deep-tech community with the ability to mobilize entrepreneurs, SMEs, corporates, public agencies, and a large community of industry experts. Several support programs with ecosystem partners (such as ASML, TNO, Philips, and others) are in place.
- **Diversity:** the DeepTechXL team and all its portfolio companies embrace diversity, based on a strong belief in the power of varied perspectives, experiences, and skills coming together to drive innovation, collaboration, and adaptability.

DeepTechXL also complies with the following requirements regarding its structure and governance:

- **Economic life:** DeepTechXL is a closed-end fund, with a fixed economic life. This economic life is maximum 15 years, which accommodates the relatively long time-to-market as well as time-to-exit of seed-stage DTVs.
- **Experience:** DeepTechXL is managed by a team that combines significant experience in deep-tech, entrepreneurship, VC investments, (SDG) value creation, mergers and acquisitions, and deep-tech venture build-

ing. Several team members have previously worked together in deep-tech VCs, start-ups, and venture builders. Several team members also have a track record in Dutch (pre-)seed-stage deep-tech investments.

- **SFDR compliance & signatory of UN Principles:** DeepTechXL complies with the Sustainable Finance Disclosure Regulations ("SFDR") Article 9 and is a signatory of the UN Principles of Responsible Investments, with a focus on deep-tech ventures that solve global environmental and/or social challenges.
- **Committees**: Standard committees govern the fund, including an investment committee and a limited partner advisory board.
- **Institutional-compliant operations**: a robust system of administrative organization & internal control is in place.

APPENDIX G: SUSTAINABILITY ASSESSMENT TOOLS FOR EARLY-STAGE VENTURES (CHAPTER 4)

Table G.1 Sustainability assessment tools for early-stage ventures

Family of Approach	Approach	Specific tool	Source
Life Cycle Assessment (LCA) and Environmental Impact Assessment	**Prospective Approaches**	Prospective LCA	Van der Hulst et al. (2020)
		Prospective LCA - Using scenarios from Integrated Assessment Models	Mendoza Beltran et al. (2020)
		Agent-based modeling to enhance LCA	Micolier et al. (2019)
		Diffusion of Innovation Principles integrated into Life Cycle Assessment	Sharp & Miller (2016)
	Anticipatory Approaches	Anticipatory Life Cycle Assessment	Wender et al. (2014)
	Probabilistic Approaches	Probabilistic LCA method	Blanco et al. (2020)
		Combined life cycle assessment (LCA) and Risk Assessment (RA) framework	Barberio et al. (2014)
		Prospective environmental assessment	Cooper & Gutowski (2020)
	LCA for ventures	Life Cycle Assessment and Ecodesign in a Day	Judl et al. (2015)
	Integrated Environmental Economic Assessments	Integrated environmental and economic assessment	Sauve et al. (2023)
		ES2050 approach	Haase et al. (2022)
		Integrated Techno-Sustainability Assessment (TSA) framework	Van Schoubroeck et al. (2021, 2022)

Family of Approach	Approach	Specific tool	Source
Qualitative Assessments	**Explorative Assessments**	Cognitive maps	Nakagawa et al. (2010)
		Constructive Sustainability Assessment (CSA) framework	Matthews et al. (2019)
		Systems level social impact mapping	Hervieux & Voltan (2019)
	Matrix Structure	Responsible Impact Tool	Coffay et al. (2022)
		Triple-Bottom-Line Impact Analysis Framework of Fintech Companies	Varga (2018)
		Sustainability Quick-Check (SQC) model	Halberstadt & Matthew (2014)
		Standards of Evidence for Impact Investing	Puttick & Ludlow (2012)
Future-Oriented Impact Assessments	**Logic model**	Integrated process model of forward-looking impact assessment	Strömmer & Ormiston (2022)
		Social Impact for Local Economies (SIMPLE)	McLoughlin et al. (2009)
		A conceptual framework for investigating sustainability impacts of new ventures	Fichter et al., (2023)
Participatory/ Collaborative Assessments		Triple-Bottom-Line Impact Analysis Framework of Fintech Companies	Varga (2018)
		Workshops	Matthews et al. (2019); Strömmer & Ormiston (2022)
		Stakeholder interviews	Matthews et al. (2019); Strömmer & Ormiston (2022)
Internationally Recognized Sustainability Indicators		Discussion sessions	Trautwein (2021)
		Impact Reporting and Investment Standards – IRIS+	Global Impact Investing Network (GIIN) (2023)
		Global Reporting Initiative (GRI) Standards	Global Reporting Initiative (GRI) (2022)
Monetized Impact Assessments		B-Corp Impact Assessment	Shields & Shelleman (2017)
		Social Return on Investment (SROI)	Arvidson et al. (2013); Corvo et al. (2021); Lingane & Olsen (2004)

APPENDIX H: FIT OF FRAMEWORK AND DESIGN REQUIREMENTS (CHAPTER 4)

Table H.1 Fit of framework and design requirements

Type	Requirements	Fit with framework
Functional requirements	1. provide guidance for an informed and objective investment decision regarding sustainability impact and sustainability risks.	Framework provides two layers for each assessment step, focusing on sustainability impact and risks
	2. provide the ability to compare early-stage technology ventures within the fund.	Impact KPIs and Materiality risk analysis provide ability to compare
	3. be a standardized approach.	The framework is an approach that could be standardized
	4. be financially affordable for early-stage technology ventures.	Framework allows reliance on qualitative assessments and not on expensive external consultants
User requirements	1. be well-structured, easy to use, and easy to interpret.	Evaluation step showed that the framework is well-structured, easy to use, and easy to interpret
	2. significantly reduce the time spent by investment managers on sustainability impact and sustainability risk assessment	the framework did not significantly reduce the time spent by Investment Managers on sustainability impact and ESG risk assessment. Instead, as DeepTechXL did not have a sustainability impact assessment before, it increases the time needed
	3. be easy to implement and easy to update.	DeepTechXL found the framework easy to implement. Moreover, as guidelines for a process and activities are offered, and a strict methodology is not prescribed, the framework is believed to be easy to update

Type	Requirements	Fit with framework
Pre- or boundary conditions	1. adhere to EU regulations and fulfill the SFDR Article 9 requirements.	Based on an assessment by the risk and compliance officer of DeepTechXL, implementing and adhering to this framework will ensure SFDR Article 9 compliance as long as DeepTechXL adheres to its reporting obligations.
	2. be compatible with the investment process of a VC.	DeepTechXL's investment process follows a standard staged approach. The framework is compatible with the investment process of DeepTechXL
	3. be focused on early-stage technology ventures.	The framework has been used for several assessment already for deep-tech ventures. The framework can also be generalized to other early-stage technology startups.

Link to supplementary material of the study reported in Chapter 4

Additional supplementary materials related to Chapter 4 of this dissertation are available by clicking **here** or by scanning the QR code.

APPENDIX I: SEARCH QUERY (CHAPTER 5)

Table I.1 Search query literature review

Publication date	Topic	Journal
1901-01-01 to 2025-12-29	Value Creation AND Venture Capital OR Private Equity	Academy of Management Journal OR Academy of Management Review OR Accounting, Organizations and Society OR Accounting Review OR Administrative Science Quarterly OR American Economic Review OR Contemporary Accounting Research OR Econometrica OR Entrepreneurship Theory and Practice OR Harvard Business Review OR Human Relations OR Human Resource Management OR Information Systems Research OR Journal of Accounting and Economics OR Journal of Accounting Research OR Journal of Applied Psychology OR Journal of Business Ethics OR Journal of Business Venturing OR Journal of Consumer Psychology OR Journal of Consumer Research OR Journal of Finance OR Journal of Financial and Quantitative Analysis OR Journal of Financial Economics OR Journal of International Business Studies OR Journal of Management OR Journal of Management Information Systems OR Journal of Management Studies OR Journal of Marketing OR Journal of Marketing Research OR Journal of Operations Management OR Journal of Political Economy OR Journal of the Academy of Marketing Science OR Management Science OR Manufacturing & Service Operations Management OR Marketing Science OR MIS Quarterly OR MIT Sloan Management Review OR Operations Research OR Organization Science OR Organization Studies OR Organizational Behavior and Human Decision Processes OR Production and Operations Management OR Quarterly Journal of Economics OR Research Policy OR Review of Accounting Studies OR Review of Economic Studies OR Review of Finance OR Review of Financial Studies OR Strategic Entrepreneurship Journal OR Strategic Management Journal OR Technovation OR Journal of Technology Transfer OR Venture Capital

APPENDIX J: OVERVIEW OF STUDIES SELECTED (CHAPTER 5)

Table J.1 Overview of selected studies of the literature review

Journal	Initial selection	Snowballed selection	Final selection
Venture Capital	33	1	11
Journal of Business Venturing	20	4	5
Research Policy	15		5
Journal of Financial Economics	58	1	4
Journal of Finance	33	1	2
Journal of Technology Transfer	10		2
Review of Financial Studies	35		2
Strategic Management Journal	14		2
Organization Science	6		1
Strategic Entrepreneurship Journal	11		1
Academy of Management Journal	6		1
Journal of International Business Studies	11		1
Journal of Management Studies	2	1	1
Management Science	27		1
Review of Finance	13		1
Journal of Applied Corporate Finance	0	1	1
Sustainability	0	1	1
Journal of Banking & Finance	0	1	1
Journal of Financial and Quantitative Analysis	21		
Entrepreneurship Theory and Practice	16		
Harvard Business Review	16		
Journal of Business Ethics	12		
Accounting Review	8		
Journal of Accounting Research	7		
Human Relations	5		
American Economic Review	4		
Administrative Science Quarterly	3		
Journal of Management	3		
Review of Accounting Studies	3		
Academy of Management Review	1		
Contemporary Accounting Research	1		
Journal of Political Economy	1		
MIT Sloan Management Review	1		

Journal	Initial selection	Snowballed selection	Final selection
Organization Studies	1		
Production and Operations Management	1		
Quarterly Journal of Economics	1		
Review of Economic Studies	1		
Technovation	1		
Total	**401**	**11**	**49**

APPENDIX K: CATEGORIES OF VALUE-ADDING ACTIVITIES ACCORDING TO THE LITERATURE REVIEW

Table K.1 Seven categories of value-adding activities based on the literature review

Category (counts)	Definition	Referrals	
Governance & monitoring support (13)	VC oversight and control activities, aimed at reducing agency problems by evaluating venture performance and behavior and ensuring accountability (Sapienza et al., 1996)	Archarya et al., 2013; Bani-Harouni & Hommel, 2025; Berliner et al., 2025; Bonini & Capizzi, 2019; Croce et al., 2013; Cumming, 2007; Dow, 2013; Ehrlich et al., 1994; Indahl & Jacobsen, 2019; Levit, 2020; Sapienza, 1992, Toms et al., 2020; Zaccone & Pedrini, 2020	Busenitz et al., 2004; Gompers et al., 2020; Krysta & Kanbach, 2022; Large & Muegge, 2008; Proksch et al., 2017; Sapienza et al., 1996; Narayanan et al., 2009
Strategic support (6)	VC activities that shape and revise a venture's strategic direction, such as positioning, market approach, and key priorities (Proksch et al., 2017)	Cumming et al.,, 2005; Hellmann & Puri, 200; Indahl & Jabocsen, 2019; Levit, 2020; Milosevic, 2018; Sapienza, 1992;	
Operational support (4)	VC activities aimed at operational improvements, that is, strengthening internal processes and execution capacity so that the venture can scale more reliably (Proksch et al., 2017)	Archarya et al., 2013; González-Uribe, 2020; Hellmann & Puri, 200; Milosevic, 2018	
Human capital & organization support (12)	VC activities that build managerial and organizational capacity, especially through recruiting and/or coaching, shaping HR policies and incentive structures, or replacing key leaders (Hellmann & Puri, 2002)	Bai & Mkrtchyan, 2023; Berliner et al., 2025; Croce et al., 2013; Cumming et al., 2005; Dow, 2013; Ehrlich et al., 1994; Gompers et al., 2016; Hellmann & Puri , 2002; Maas et al., 2020; Sapienza, 1992; Vanacker et al., 2013	

Category (counts)	Definition	Referrals
	VC-oriented and founder-oriented actions that shape the perceptions of and access to external stakeholders (e.g. customers, partners, and co-investors), by increasing legitimacy and improving the venture's ability to mobilize resources from outside audiences (Petkova et al., 2013)	Berre & Le Pendeven, 2023; Bertoni & Tykvová, 2015 ; Chemmanur et al., 2014 ; Cumming, 2007; Edwards & Rahman, 2025 ; Humphery-Jenner & Suchard, 2013; Janney & Folta, 2006; Milosevic et al., 2020; Ozmel et al., 2013; Petkova et al., 2013; Plummer et al., 2016; Sapienza et al., 1996; Sen & Puranam, 2022; Svetek, 2022; Tian, 2012
Financial support (9)	VC activities that provide financial expertise and finance-related assistance, helping ventures secure and structure capital through the investment and growth process (Cumming et al., 2005	Arqué-Castells, 2012 ; Biesinger et al., 2020; Cumming, 2007; Gompers et al., 2016; Pantea & Tkacic, 2025; Toms et al., 2020; Vanacker et al., 2013
Innovation & technology support (11)	VC-enabled activities that help ventures commercialize innovation by accessing complementary innovation resources and knowledge, including exchanges facilitated within VC portfolios (Gonzá lez-Uribe, 2020)	; Bertoni & Tykvová, 2015; Bosio et al., 2026; Castellaneta et al., 2017; Chemmanur et al., 2014; Dutta & Folta, 2016; Edwards & Rahman, 2025; González-Uribe, 2020 Lahr, 2023; Maas et al., 2020; Sapienza et al., 1996; Toms et al., 2020

APPENDIX L: INTERVIEW PROTOCOL (CHAPTER 5)

The interview protocol was developed to test whether fund investors were potentially interested in investing in a VC fund based on our design. This is a semi-structured interview protocol, including only a limited set of pre-defined questions.

The interview protocol was designed to provide both consistency across interviews and flexibility to follow the expertise of participants. The guide was informed by the value-adding categories derived from the literature review and was refined iteratively after the first interviews. The set of pre-defined questions included in this protocol are provided in Table L.1.

Table L.1 Pre-defined interview questions

Topic	Questions

Opening phase	• Introduction of the researcher, study objectives, and interview format.
	• Consent confirmation and permission to record.
	• Background questions to establish context:
	  • Can you briefly describe your role and your involvement with (deep) tech investments?
	  • From your perspective, what distinguishes (deep) tech ventures from more conventional tech startups?

Value creation in practice	• How would you describe the term value creation post-investment? • How do you typically support your deep-tech portfolio companies beyond capital? • Which value-adding activities do you consider most important in early-stage deep-tech investing? • In which phase of the investment do you believe most value is created? (Early stage, Series A, later stage) • Do you see specific themes that receive more attention in (deep) tech support (e.g., IP strategy, regulatory guidance, technical validation, ESG)? • Do you follow a structured value creation model or framework internally? If yes, could you describe it? • If applicable: Do you have any internal playbooks, checklists, or guiding principles? • How do you measure whether your value creation activities are working?

Topic	Questions
Challenges in value creation	• What challenges do you encounter when trying to create value in (deep) tech ventures? • How do you deal with longer R&D timelines and the lack of early market feedback in (deep) tech? • Are you familiar with any value creation frameworks from literature or VC practice (e.g., Value Bridge Model, value-adding roles, value disciplines)? • In your opinion, what is missing from current value creation models when it comes to (deep) tech?
Forward-looking perspectives	• Are you noticing any emerging trends that will influence how VCs add value to (deep) tech startups in the coming years (e.g., sustainability, regulatory shifts, AI)?
Case study exploration	• Could you describe a specific (deep) tech investment where value creation worked particularly well? • What actions did you or the team take that made a difference? • Have you experienced a case where value creation efforts did not work out as planned? • What were the key barriers or missed opportunities? • What would you have done differently in that case? • To what extent was the outcome tied to the startup's maturity, the technology, or your own approach? • Is there anyone else in your network you believe would have a strong view on value creation in (deep) tech whom I could speak with?
Activity theme-based questions	• Looking back at our conversation, we haven't really touched on [Activity domain]. Does your fund get involved here at all? If so, how? • In [Activity domain], what would a typical contribution from you look like for an early-stage (deep) tech venture? • Can you share a concrete example where [Activity domain] made a clear difference? What changed as a result? • When you support [Activity domain], is it more direct (hands-on) or indirect (introductions, tools, signaling)? Why? • How does your approach to [Activity domain] vary by stage (pre-seed/seed vs. Series A) or by technological/regulatory complexity?
Closing phase	• Is there anything else you would like to share that we have not touched on?

Link to supplementary material of the study reported in Chapter 5

Additional supplementary materials related to Chapter54 of this dissertation are available by clicking **here** or by scanning the QR code.

SUMMARY

English – Technology ventures play a central role in driving innovation, economic growth, and societal wellbeing, yet most struggle to survive the transition from early-stage technological development to commercial scaling. This survival challenge, known as the *missing middle* or *valley of death*, is characterized by high technological uncertainty, significant capital intensity, long development cycles, and a persistent imbalance between the supply and demand of early-stage funding. These challenges are particularly acute in deep-tech domains, where ventures often require years of R&D investment before generating revenue. Despite the importance of venture capital in addressing these challenges, scholarly and practical knowledge remain fragmented across the fields of entrepreneurial finance and technology entrepreneurship. This dissertation addresses this gap by investigating how venture capital solutions can help technology ventures overcome the missing middle and create economic, societal, and environmental value. It does so through four interconnected studies that integrate mechanism-based theorizing, design science, and a comparative case study.

The study described in Chapter 2 develops a systems-level theoretical foundation. Through a mechanism-based review of 201 peer-reviewed articles, it identifies eight mechanisms, such as signaling, resource acquisition, knowledge spillovers, and capital structure optimization, and seven agency types that shape venture trajectories. These insights are synthesized into a causal loop diagram capturing the dynamic interplay of mechanisms across two phases: applied R&D and commercialization. The resulting framework reframes the missing middle not as a linear funding gap but as a dynamic tipping point governed by shifting feedback loops, illustrating how ventures can become trapped in vicious cycles or propelled into sustainable growth.

The second study (in Chapter 3) translates these theoretical insights into a real-world venture capital fund (VC) for seed-stage deep-tech ventures. Using design science methodology, it develops and implements *DeepTechXL*, a €118 million Dutch VC fund designed to address the structural shortcomings of early-stage deep-tech financing. Chapter 3 identifies critical design requirements, including minimum viable fund size, staged financing strategies, multi-disciplinary teams, and syndication logic, and

codifies them into two design propositions. These propositions highlight the importance of an impact-oriented investment thesis, ecosystem signaling, and an extended fund life to accommodate deep-tech development cycles. DeepTechXL's successful fundraising and early deployment validate the fund's design and demonstrate how design science can be used to develop actionable venture capital solutions.

The third study (in Chapter 4) focuses on the growing requirement for VCs to integrate sustainability into investment decisions, driven by regulatory frameworks such as the EU Sustainable Finance Disclosure Regulation (SFDR). Despite these pressures, VCs lack tools for assessing sustainability impact under conditions of uncertainty and limited data. Chapter 4 develops the VC Green Scheme, a sustainability assessment framework tailored to early-stage technology ventures. Drawing on an extensive literature review and empirical insights from thirteen European VC funds, it synthesizes eight final design principles and operationalizes them into a five-step process integrated throughout the VC investment cycle. Implemented and evaluated at DeepTechXL, the framework demonstrates high usability, compliance, and practical relevance, providing a structured approach to assessing and reporting sustainability impact.

The fourth study (in Chapter 5) examines how VCs create value beyond capital. Although VC involvement is widely considered essential, existing research largely reduces value-adding activities to descriptive lists and overlooks the technological dimension of value creation. Through a comparative case study of twelve European VC funds combined with a structured literature review, Chapter 5 develops the VC value creation framework, a multidimensional model organizing VC involvement across three domains, namely strategic, operational, and technological, and two modes of engagement, labelled direct and indirect. The framework highlights the central role of technological support in reducing technical uncertainty, structuring R&D trajectories, and validating technological progress, especially in deep-tech contexts. It also identifies venture-side and VC-side contingencies that shape the effectiveness of VC involvement and shows how value-adding activities contribute to value-inflection points relevant for follow-on financing and long-term outcomes.

Together, these four studies produce an integrated conceptual understanding of the venture capital–technology venture dyad. Chapter 6 syn-

thesizes the findings into an overarching framework that clarifies how VCs and technology ventures jointly shape progress through iterative cycles of signaling, resource acquisition, capability building, and value creation. At a theoretical level, the dissertation contributes to bridging entrepreneurial finance and technology entrepreneurship, advancing mechanism-based understanding of how technology ventures evolve, and demonstrating the value of design science in developing actionable, context-sensitive solutions. At a practical level, it offers validated tools, a VC fund blueprint, a sustainability assessment framework, and a value creation model, that are already used by VC practitioners and have informed both investment decisions and regulatory compliance.

Overall, this dissertation shows that overcoming the missing middle requires coordinated mechanisms, well-designed venture capital structures, and deliberate involvement in value creation. By integrating theory and practice, it provides a comprehensive roadmap for how venture capital can help technology ventures advance from scientific discovery to societal impact.

Dutch – Jonge technologiebedrijven spelen een centrale rol in het stimuleren van innovatie, economische groei en maatschappelijke welvaart, maar de meerderheid worstelt met de overgang van vroege technologische ontwikkeling naar commerciële opschaling. Deze overgang, bekend als de “missende midden” of de “vallei van de dood”, wordt gekenmerkt door hoge technologische onzekerheid, aanzienlijke kapitaalintensiteit, lange ontwikkelcycli en een structureel onevenwicht tussen vraag en aanbod van vroege-fase financiering. Deze uitdagingen zijn bijzonder sterk aanwezig in deep-tech sectoren, waar ondernemingen vaak jarenlange ontwikkel-investeringen nodig hebben voordat er omzet wordt gegenereerd. Ondanks het belang van venture capital bij het adresseren van deze uitdagingen, blijft zowel wetenschappelijke als praktijkgerichte kennis gefragmenteerd tussen de literaturen over ondernemende financiering en technologie ondernemerschap.

Deze dissertatie adresseert deze lacune door te onderzoeken hoe venture capital-oplossingen technologiebedrijven kunnen helpen de “missende midden” te overbruggen en economische, maatschappelijke en ecologische waarde te realiseren. Het onderzoek bestaat uit vier onderling ver-

bonden studies die mechanisme-georiënteerde theorie, ontwerp onderzoek en een vergelijkende casusstudie combineren.

De eerste studie beschreven in Hoofdstuk 2 ontwikkelt een theoretische basis op systeemniveau. Op basis van een mechanisme-georiënteerde onderzoek van 201 peer-reviewde artikelen worden acht mechanismen, waaronder signalering, middelen verwerving, kennisoverloop en optimalisatie van kapitaalstructuur, en zeven typen agency geïdentificeerd die de ontwikkelingstrajecten van technologiebedrijven vormgeven. Deze inzichten worden samengebracht in een causale-lus diagram (causal loop diagram) dat de dynamische wisselwerking tussen mechanismen weergeeft in twee fasen: de toegepaste onderzoeksfase en de commercialisatiefase. Het resulterende raamwerk herdefinieert de “missende midden” niet als een lineaire financieringskloof, maar als een dynamisch kantelpunt dat wordt gedreven door veranderende feedbacklussen, en laat zien hoe jonge ondernemingen kunnen vastlopen in vicieuze cirkels of juist kunnen doorgroeien dankzij versterkende dynamiek.

De tweede studie (in Hoofdstuk 3) vertaalt deze theoretische inzichten naar de praktijk door een venture capital fonds (VC) voor seed-fase deep-tech ondernemingen te ontwerpen. Met behulp van ontwerp onderzoek wordt DeepTechXL ontwikkeld en geïmplementeerd: een Nederlands VC-fonds van €118 miljoen dat is ontworpen om structurele tekortkomingen in vroege-fase deep-tech financiering te verhelpen. De studie identificeert kritieke ontwerpeisen, waaronder een minimale fondsomvang, gefaseerde financiering, multidisciplinaire teams en een sterke syndicaat logica, en vertaalt deze naar twee ontwerp proposities. Deze benadrukken onder meer het belang van een impact-gedreven investeringspropositie, krachtige ecosysteemsignalen en een verlengde fondshorizon die aansluit bij langlopende deep-tech ontwikkeltrajecten. De succesvolle fondswerving en vroege implementatie van DeepTechXL bevestigen de validiteit van dit ontwerp en tonen hoe ontwerp onderzoek kan worden ingezet voor het ontwikkelen van praktische venture capital-oplossingen.

De derde studie (in Hoofdstuk 4) richt zich op de toenemende noodzaak voor VC-fondsen om duurzaamheid te integreren in hun investeringsprocessen, mede gedreven door regelgeving zoals de EU Sustainable Finance Disclosure Regulation (SFDR). Hoewel deze verplichtingen toenemen, ontbreken in de praktijk robuuste instrumenten om duurzaamheidsef-

fecten van vroege-fase technologiebedrijven te beoordelen. Deze studie ontwikkelt de VC Green Scheme: een duurzaamheidsbeoordelingskader dat is toegesneden op de specifieke context van technologiebedrijven met beperkte data en hoge onzekerheid. Op basis van een literatuurstudie en empirische inzichten uit dertien Europese VC-fondsen worden acht ontwerpprincipes geformuleerd en vertaald in een vijf stappen proces dat door het gehele investeringsproces heen is geïntegreerd. Het raamwerk, dat is geïmplementeerd en geëvalueerd bij DeepTechXL, toont een hoge mate van bruikbaarheid, naleving van regelgeving en praktische toepasbaarheid.

De vierde studie (in Hoofdstuk 5) onderzoekt hoe VCs waarde creëren voorbij het verstrekken van kapitaal. Hoewel VC-betrokkenheid algemeen wordt erkend als essentieel, reduceren bestaande studies vaak waarde-toevoegende activiteiten tot beschrijvende lijsten en wordt vooral de technologische dimensie onderbelicht. Via een vergelijkende casus studie van twaalf Europese VC-fondsen en een gestructureerde literatuur onderzoek ontwikkelt deze studie het VC waarde creatie raamwerk: een multidimensionaal model waarin VC-betrokkenheid wordt geordend langs drie domeinen, genaamd strategisch, operationeel en technologisch, en twee betrokkenheidsvormen, genaamd direct en indirect. Het raamwerk benadrukt de centrale rol van technologische ondersteuning bij het reduceren van technische onzekerheid, het structureren van R&D-trajecten en het valideren van technologische voortgang, met name in deep-tech omgevingen. Tevens worden technologiebedrijven- en investeerders specifieke contextfactoren geïdentificeerd die de effectiviteit van VC-inbreng bepalen, evenals de bijdrage van waarde-toevoegende activiteiten aan cruciale waarde verhogende mijlpalen voor vervolginvesteringen en lange termijn resultaten.

Gezamenlijk leveren deze vier studies een geïntegreerd conceptueel begrip op van de wederzijdse dynamiek tussen venture capital en technologiebedrijven. In Hoofdstuk 6 worden de bevindingen samengebracht in een overkoepelend raamwerk dat laat zien hoe VCs en technologiebedrijven gezamenlijk voortgang creëren via iteratieve cycli van signalering, middelen verwerving, capaciteitsopbouw en waarde creatie. Theoretisch draagt de dissertatie bij aan het verbinden van ondernemende financing en technologie ondernemerschap, aan een mechanisme-gebaseerd begrip van de ontwikkeling van technologiebedrijven, en aan het demon-

streren van de waarde van ontwerp onderzoek voor het ontwikkelen van contextgevoelige, toepasbare oplossingen. Praktisch biedt het gevalideerde instrumenten, een blauwdruk voor een VC-fonds, een duurzaamheidsbeoordelingskader en een waarderingsmodel voor VC-waarde-creatie, die reeds worden toegepast door VC-professionals en bijdragen aan investeringsbeslissingen en regulatoire rapportages.

Deze dissertatie toont aan dat het overbruggen van de “missende midden” vraagt om gecoördineerde mechanismen, doordacht ontworpen venture capitals structuren en doelgerichte waarde-toevoegende betrokkenheid. Door theorie en praktijk te integreren, biedt het onderzoek een samenhangende routekaart voor hoe venture capital technologiebedrijven kan ondersteunen in hun weg van wetenschappelijke ontwikkeling naar maatschappelijke impact.

ABOUT THE AUTHOR



Hessel Glenn Mittelmeijer was born on August 18, 1996, in Nuenen, the Netherlands. He holds a Bachelor's degree in Industrial Engineering from Avans University of Applied Sciences. During his third-year internship at J.A. Raymakers in 2017, a small-to-medium enterprise, Hessel developed a strong interest in bridging theory and practice, an interest that has shaped both his career and this dissertation. Following his internship, he continued working as a Process Engineer, scaling manufacturing processes, while completing his bachelor's studies. He later conducted his graduation thesis at Vanderlande and remained employed there part-time focused on internal improvement projects during his Master's studies. He earned a Master's in Innovation Management from Eindhoven University of Technology and a second Master's in Strategic Management from Tilburg University. During his master's studies, he co-founded and successfully exited EasyBook, a marketplace for affordable study book rentals.

His Master's thesis at HighTechXL addressed the capital gap faced by early-stage deep-tech ventures and ultimately laid the foundation for the creation of DeepTechXL (today known as DeepTech Capital Partners) and the research presented in Chapter 3. Since 2020, Hessel has served as Portfolio Manager at HighTechXL, where he co-led the successful application for the RVO Seed Capital Fund and the creation of DeepTechXL's Fund I (€120M in fund size). Following the establishment of DeepTechXL in 2022, he became Investment Manager and Sustainability Officer, contributing to fund strategy, fundraising, investment activities, sustainability integration, and portfolio support. He also led DeepTechXL's compliance with SFDR and manages its Impact Advisory Committee, as reflected in Chapter 4. He helped develop DeepTechXL's value creation approach for portfolio companies, integrating strategic, operational, and technological support mechanisms (Chapter 5) and has co-led several deep-tech investments and follow-on investments. In 2025, he spearheaded the launch of a pre-seed technology transfer fund in collaboration with all the leading deep-tech universities in the Netherlands. Through his work, he has helped build partnerships

across investors, corporates, universities, and government organizations to strengthen the Dutch and European deep-tech ecosystem. Hessel attained the Certified Investment Professional (NVP) in 2022. Since 2023, he has pursued his doctoral during his private time, continuing his mission to bridge academic insight with real-world application. This dissertation reflects his continued commitment to combining academic rigor with entrepreneurial action to advance the European deep-tech ecosystem.

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could truly accelerate my personal growth. I am extremely proud to what Teska, you, and myself have achieved in the creation of DeepTechXL and that is an achievement that will remain with me for the rest of my life. Thank you for all your advice and effort that you put in me.

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