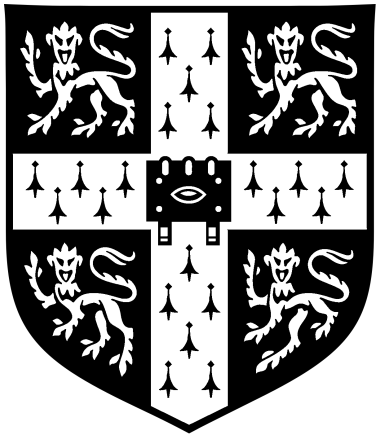
FROM LAB TO MARKET:
EARLY-STAGE BUSINESS MODELS FOR THE COMMERCIALISATION OF UNIVERSITY TECHNOLOGY IN THE CLEANTECH INDUSTRY



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Ph.D. 2018

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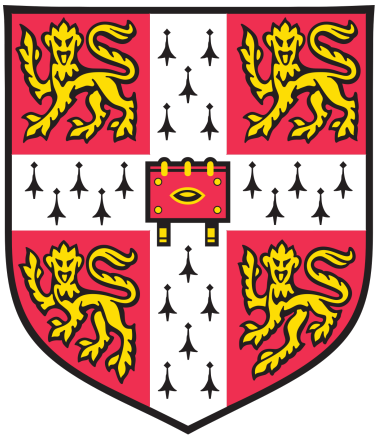

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DEDICATION

To my parents,
Hj Moktar Hj Ahmad & Hjh Rosna Hj Andreas,
who made me who I am today.

DECLARATION

- This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text.
- It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.
- This dissertation complies with the Department of Engineering Degree Committee word limit requirement (64,396 / 65,000 words) and the limit on the number of figures (22 figures and 21 tables / 150 figures and tables).

Zurina Moktar, October 2018

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ABSTRACT

Over the years, scholarly interest in the role of business models to unlock the value of latent technology has increased. It is argued that the commercialisation of new technology requires business models that respond to a myriad of challenges and market needs. However, limited attention has been paid to understand how early-stage business models are developed to commercialise new university technology. Specifically, there are limited studies scrutinising the early-stage business models developed by University Spin-Offs (USOs), despite the fact that these are breeding grounds for new technology with commercial potential. Therefore, this thesis examines how USOs develop early-stage business models to commercialise new technology for the cleantech industry.

To achieve this, an in-depth case study of four cleantech USOs at the University of Cambridge in the United Kingdom was performed. Sixty interviews with multiple stakeholders were conducted, and effectual logic and the concept of opportunity creation were adopted to inform the investigation. The findings, presented in a conceptual framework, suggest that USOs develop early-stage business models through three interlocking mechanisms. First, value is created through flow-field control, which is achieved by taking active control over a firm's resources and capabilities. Second, value is captured through pragmatic kinesis, defined as being sensible when moving towards profit. Third, value network is managed through deliberate temperament, which is used to align stakeholders' expectations. Along with these findings, the thesis also advances COPE principles (i.e. take control, create opportunities, forge partnerships and embrace contingencies) as parameters for the development of early-stage business models.

The empirical evidence offers a critical logical shift in our understanding of early-stage business models development for commercialising university technology in the cleantech industry. The conceptual framework responds to scholarly inquiries to improve the theoretical grounding and construct clarity of business models. The thesis also informs policymakers about the pitfalls and opportunities associated with new technology commercialisation in the cleantech industry, where uncertainties are ubiquitous.

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GLOSSARY

AUTM	Association of University Technology Managers
BNEF	Bloomberg New Energy Finance
CAGR	Compound Annual Growth Rate
CAQDAS	Computer Assisted Qualitative Data Analysis
CDA	Confidential Disclosure Agreement
CEO	Chief Executive Officer
CMI	Cambridge MIT Institute
CO_2	Carbon dioxide
CTO	Chief Technology Officer
EPSRC	Engineering and Physical Sciences Research Council
EU	European Union
FMCG	Fast-Moving Consumer Goods
GBP	Great Britain Pound
GW	Gigawatts
HEFCE	Higher Education Funding Council for England
IP	Intellectual Property
MIT	Massachusetts Institute of Technology
MW	Megawatts
OEM	Original Equipment Manufacturer
OPV	Organic Photovoltaic
PAL	Plastic aluminium laminate
PV	Photovoltaic
R&D	Research and Development
R2R	Roll to Roll
TRL	Technology Readiness Level
TTO	Technology Transfer Office
UK	United Kingdom
US	United States
USD	United States Dollar
USO	University Spin-Off
VC	Venture Capital/ Venture Capitalist
W	Watt
WRAP	Waste and Resource Action Programme

1 INTRODUCTION

1.1 Phenomenon of Interest

Following the landmark 1980 passage of the Bayh-Dole Act[1] in the United States (US) and Margaret Thatcher's 1987 abolition of the monopoly on British academic inventions in the United Kingdom (UK), universities in both countries have been very active in commercialising their academic research through the formation of University Spin-Offs (USOs) (Avnimelech & Feldman 2015; Fini et al. 2017). Over the years, the reported number of new USOs increased dramatically. Between the years 2003 and 2013, an average of 197 USOs were reported being spun annually across UK universities[2]. In the US, more than 11,000 USOs were established from 1995 until 2016[3].

Two decades later, USOs have been acknowledged to fuel regional economy, shape new industries, create jobs and promote innovation (Lambert 2003; Breznitz & Feldman 2012; Fini et al. 2018). In the US, researchers claimed that well-known new industrial clusters, such as Silicon Valley in California, Route 128 in Massachusetts and Research Triangle in North Carolina, were developed in part due to USOs' activities (Saxenian 1996; Link & Scott 2003). In the UK, USOs' activities are the backbone of the Silicon Fen in Cambridgeshire and the Oxford Cluster in Oxfordshire (Kirk & Cotton 2012).

Since 2000, the academic entrepreneurship model has spread to the emerging nations. Governments in developing countries support the establishment of USOs in the hopes of benefitting in the same way as the US and the UK (Stevens 2017). Policy instruments, research and development (R&D) investments, seed funds, Technology Transfer Offices (TTOs) and incubators have been enacted to promote the transfer of research results through the establishment of USOs. Today, university technology commercialisation through the formation of USOs has become a significant global phenomenon and occupies a prominent position in governments' agendas (Siegel & Wright 2015; Fini et al. 2017).

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[1] The Bayh–Dole Act or Patent and Trademark Law Amendments Act (Pub. L. 96-517, December 12, 1980) is the US legislation dealing with IP arising from federal government-funded research which allows universities to retain title to inventions made under federally-funded research program.

[2] Report on the Higher Education Business and Community Survey 2013/14 by the Higher Education Founding Council for England (HEFCE). Available at: http://www.hefce.ac.uk/media/HEFCE,2014/Content/Pubs/2015/201513/2015-13.pdf

[3] Licensing Activity Survey 2016 by the US Association of University Technology Managers (AUTM). Available at: https://www.autm.net/resources-surveys/research-reports-databases/licensing-surveys/fy2016-licensing-survey/

Despite the rapid proliferation of and strong policy interest in the establishment of USOs, only a handful of USOs successfully monetised new technology and became sustainable in the long run (Vohora et al. 2004; Markman et al. 2008). The success of USOs' commercialisation is disproportionately skewed to occur mostly in high-tech clusters with strong technology transfer profiles. However, commercial underachievement is still prevalent in most USOs (Hewitt-Dundas 2015). Many attempts to commercialise new technology take longer than they should, resulting in marginal profit or failure (Mustar et al. 2008).

According to the Enterprise Research Centre's most recent database, the number of UK USOs that survived three years after being established has not improved since 2009 (Hewitt-Dundas 2015). Measures of innovation output—the proportion of firms introducing new or significantly improved goods and services to the market—also show a decline from 24% to 18% between 2008 and 2012, and a slight rise to 19% in 2015[4]. Further, USOs are commonly associated with low sales growth (Wennberg et al. 2011) and low employment growth (Cantner & Goethner 2011).

Scholars argue that an increase in the number of USOs occurs at the expense of their quality (Fini et al. 2017), commercial viability (Lambert 2003) and long-term impact (Grimaldi et al. 2011). Herein lies the perpetual paradox: too much emphasis on the USO phenomenon when too many USOs are struggling to commercialise. Harrison and Leitch (2010) claim that USOs often start and remain small instead of becoming dynamic high-growth firms. Although USOs are assumed to be the catalysts for the economy, they are far less effective for generating economic benefits, particularly for national markets (Markman et al. 2008). In addition, Alvimelech and Feldman (2015) state that USOs' performance in enabling technology-intensive growth trajectories could be better.

Overall, bringing new technology from the university laboratory to the market is a daunting endeavour. The phenomenon invokes growing concern about one of the greatest challenges that precludes USOs from effectively responding to the business challenges: development of the early-stage business model (Morris et al. 2005; Bigdeli et al. 2016; Stevens 2017). While radical governmental support does not appear to have eliminated the barriers to

[4] House of Commons Science and Technology Committee Report 2017: Managing IP and technology transfer. Available at: https://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/inquiries/parliament-2015/managing-intellectual-property-inquiry-16-17/publications/

commercialising university technology, USOs are under pressure to adopt exhaustive business models at the early-stage of commercialisation to monetise university inventions (Lubik & Garnsey 2016).

A report by the McMillan Group claims that weak customer adoption and inability to surpass the barrier to market entry due to poorly devised business models are some of the key issues hindering commercialisation of university technology[5]. Another report published by the Science and Technology Committee that compiled written evidence and responded to the Bridging the Valley of Death[6], recognises business models as important drivers of successful university technology commercialisation, particularly between the ideation and prototyping stage[7]. Poorly developed early-stage business models are the main cause of USO failure despite market opportunities, novel business ideas, adequate resources and talented entrepreneurs (Morris et al. 2005). Thus, better means of developing the early-stage business model are warranted.

From the practitioners' perspective, this pressing issue is highly acknowledged but only partially understood. Similarly, business model development for the commercialisation of university technology in general is emphasised in entrepreneurial practice, but tends to receive limited attention from academic researchers (Morris et al. 2005; Lubik & Garnsey 2016). Success in identifying the challenges facing USO commercialisation have yet to be matched by progress in tackling it. The proper recipe for an early-stage business model that causes USOs to succeed or fail remains an enigma. It is also still unclear how much of the early-stage business model development process can be—and should be—influenced or managed by the USO. Given this, the need to understand the mechanism behind the early-stage business model development for new technology commercialisation has come to the fore.

In general, USOs recognise the importance of a business model for commercialising new technology. However, the modus operandi behind viable business models at the early-stage of

[5] HEFCE, 2015. Report on survey: Higher Education Business and Community Interaction Survey 2013/14, Available at: http://www.hefce.ac.uk/media/HEFCE,2014/Content/Pubs/2015/201513/2015-13.pdf

[6] The Valley of Death is a metaphor used to describe the difficulty of covering the negative cash flow in the early stages of commercialisation before new product is monetised (Osawa & Miyazaki 2006).

[7] House of Commons Science and Technology Committee, Eight Report of Sessions 2012-13: Bridging the Valley of Death: improving the commercialisation of research. Available at: https://publications.parliament.uk/pa/cm201213/cmselect/cmsctech/348/348.pdf

commercialisation is often exclusive to an individual USO. Hence, they are rarely shared beyond the confines of the organisation. Due to this, general lessons cannot be drawn from successful and failed attempts at commercialisation. Since university technology commercialisation does not lend itself to generalisation and openness, USOs are precluded from learning the best practices. As a result, it is difficult to realise the commercial value of university technology.

The state of affairs gives rise to a crucial question: how can a USO develop the early-stage business models to bring university technology into commercial reality. Since practitioners generally keep the inner workings of the early-stage business models tacit, deeper academic investigation is warranted. Unless USOs are armed with a viable business model, most will continue to fail. If this issue is not expounded, realisation of greater value from R&D investments will remain difficult.

1.2 Research Gap and Research Question

The main research gap addressed in this thesis is the lack of a clear understanding of how USOs develop initial business models that are viable enough to position their products in the marketplace. Therefore, the research question asked in this thesis is as follows:

How does a USO develop its early-stage business models to commercialise new technology?

This question, although important, appears to be poorly explored and underrepresented in the academic sphere. There are several reasons for this research gap. First, the dominant scholarly work studies the change and innovation in business models over time rather than how they initially emerged at the early-stage of the commercialisation pipeline. Previous research relies heavily on empirical data, which is mostly derived from successful technology commercialisation cases that survived the initial phases of business model development (Rasmussen et al. 2006). The empirical setting is usually pre-painted by the view that firms have their business models up and running. As a result, scholarly work to understand how the early-stage business models are developed remains scarce. Throughout this thesis, explicit focus is given on the development of the early-stage business model (henceforth referred to as 'business model') rather than the later-stage business model i.e. after the USO launches their product or service in a defined market.

Second, the subject of business model development for university technology commercialisation stems from two traditional streams of literature: university technology commercialisation literature and business model literature. The former emerged in the late 1980s from the academic entrepreneurship field (Shane 2004), and the latter emanated in the 1990s from the strategic management field (Zott et al. 2011). Both streams advanced significantly in silos, and reconciliation between them is relatively recent (e.g. Lubik & Garnsey 2016; Bigdeli et al. 2016). Much has been discussed about USOs in the academic entrepreneurship literature, but not their relation to the concept of the business model. As a stream of knowledge, the academic entrepreneurship field is considered patchy at best (Siegel & Wright 2015). In the strategic management literature, the state-of-the-art has contributed significantly to advancing our understanding of how a business model influences new technology commercialisation (e.g. Chesbrough & Rosenbloom 2002; Andries & Debackere 2007). However, previous studies have not fully sought to understand the process behind the emergence of business models in the university context.

Third, academic work on new technology commercialisation often neglects or generalises the challenges faced by entrepreneurial firms like USOs with corporate firms or incumbents. Due to this, the unique challenges faced by a USO in commercialising new technology seem to be overlooked. There is a limited distinction being made between different challenges faced by USOs during commercialisation. For example, an extensive scholarly work has contributed to the understanding business model development for a start-up firm (e.g. Velu 2017) and an established firm (e.g. Demil & Lecoq 2010). Unfortunately, recommendations made in such empirical settings are not directly translated into practice for USO practitioners (Lubik & Garnsey 2016). Siegel at al. (2003) and Fini et al. (2017) claim that the unique challenges faced by USOs are the result of convergence between science and business, which may not necessarily be encountered by other types of firms and thus require different comprehension.

In summary, although there are significant bodies of academic work regarding business model development and university technology commercialisation, the two have not yet been integrated through a formal and in-depth empirical investigation. Knowledge relating to business models and commercialisation of new technology is still fragmentary in the academic entrepreneurship and strategy literature. This issue underscores an important literature gap that must be addressed urgently.

1.3 Research Overview

Responding to the gap in the literature, this research is conducted with an overarching aim to advance our understanding of how USO develop business models to commercialise new technology. Despite the exigency of researching this topic, previous literature on strategic management and academic entrepreneurship have not fully come to grips with this issue empirically and theoretically.

Given this, extant literature on business models and university technology commercialisation is critically analysed to recapitulate the state-of-the-art and validate gap in the literature. Relevant premises related to effectuation logic and the concept of opportunity creation are adopted as the underpinning theoretical lenses to guide the research. Cursory information is also collected through an explanatory, theory-building, in-depth case study. A qualitative case study of four cleantech USOs based at the University of Cambridge, UK, are performed. All cases are systematically and purposely selected to understand how the firms under study develop their business models to commercialise new technology in response to the market challenges and needs. 60 interviews with multiple stakeholders are conducted and a substantial amount of archival data are gathered to inform the investigation.

Based on the empirical evidence, the findings, presented in a conceptual framework suggests that a USO develop its business model through three interlocking, iterative and mutually reinforcing mechanisms namely by 1) creating value through flow-field control; 2) capturing value through pragmatic kinesis; and 3) managing value network through deliberate temperament. Flow-field control is an approach that aims to craft a proposition and create valuable offering while overcoming the market resistance, by taking active control over a firm's resources and capabilities. Pragmatic kinesis on the other hand, is a measure taken by a USO to capture value and respond to the financial pressure, by being flexible and sensible to move towards where the profit lies. Lastly, deliberate temperament constitutes a measure that aims to manage conflicting value network, by aligning stakeholders' expectations which results in a mutually beneficial outcome. The thesis also proposes COPE principle as the foundation for the business model development process. COPE principle resembles a set of parameters a USO needs to consider when developing its business model, (i.e. take control, create opportunities, forge partnerships and embrace contingencies).

This research contributes mainly to the business model literature and to some extend also providing useful insights to the academic entrepreneurship literature as well as to the ongoing debate of effectuation logic. To this end, the findings forges a closer link between multidisciplinary theories which previously existed in isolation despite their important potential connection. Additionally, this thesis also offers a critical logical shift to a more systematic understanding about the commercialisation of technology in a new empirical setting where understanding is partial and highly needed. The empirical evidence, new set of metaphors and principles embedded in the conceptual framework respond to the scholarly inquiry into improving business model theoretical grounding, construct clarity, contingencies, and outcomes.

From a broader perspective, the findings of this thesis reveal a subtle yet critical reflection about the inner workings of the initial business model emergence rather than how it evolves, changes or gets innovated. To achieve this, the thesis introduces new approaches for business model development which could support previously held conjectures about business model evolution and business model innovation. From the practitioner viewpoints, the finding informs policymakers about the pitfalls and opportunities associated with new technology commercialisation in cleantech industry where uncertainties are ubiquitous.

Throughout the thesis, some terminologies are repetitively used across all chapters. To enhance interpretational consistency and avoid semantic misunderstanding, the terminologies are defined in Table 1-1.

Terminology	Definition
Business model	The architecture of interdependent components of value proposition, value creation and value capture that are dynamically configured by a networked stakeholder.
Commercialisation	A process of bringing new technology into the market to be exploited in return for business profits.
Cleantech firms	Firms that seek to increase performance, productivity and efficiency by minimising negative impact to the environment.
Effectuation	Decision-making mechanism for entrepreneurial pursuance that takes a given set of means and focuses on selecting the effects that can be created with that set of means.
Intellectual Property (IP)	Creations of the mind, such as inventions, literary and artistic works, designs and symbols, names and images used in commerce.
Opportunity creation	A notion that recognises that opportunities are not always objective phenomena created by change in a market but may be proactively created by the actions of an entrepreneur.

Technology transfer	The translation of university research into commercial success.
Technology transfer office (TTO)	A company often established by the university dedicated to identifying commercially viable research results and formulating strategies to exploit them.
University spin-off (USO)	A new firm created to exploit commercially the knowledge, technology or research results developed within a university.

Table 1-1: Terminologies used in this thesis

1.4 Structure of the Thesis

The remainder of this thesis is structured into three main components (Figure 1-1). Component 1 (Chapters 2 and 3) reviews the literature upon which this research is founded and the methodological approach. Component 2 (Chapters 4 and 5) presents the research case studies and findings of the research. Component 3 (Chapters 6 and 7) is dedicated to the discussion of the results and the conclusion.

Chapter 2 (Literature Review) reviews relevant literature to elucidate the state-of-the-art and validate the gap in the literature. It also presents the theoretical lenses and premises used in the current investigation.

Chapter 3 (Methodological Approach) describes the research philosophy to justify the chosen methodological approach, scope and procedures for selecting cases and collecting and analysing data. Research quality issues and ethical considerations are also discussed in this chapter.

Chapter 4 (Case Studies) reports the individual case studies that serve as primary sources of evidence to answer the research question. Each case is reported in a descriptive way, based on the USOs' technology commercialisation journey and its resulting business models.

Chapter 5 (Findings) performs a cross-case comparative analysis of the findings. It also synthesises the data and presents the overall findings in an integrative conceptual framework.

Chapter 6 (Discussion) discusses and interprets the findings in more depth in light of what was already known in the existing literature. It also presents new insights about the problem under investigation.

Chapter 7 (Conclusion) concludes the thesis by summarising key findings, implications of the thesis to theory and practice, limitations of the study, and finally suggestions for future research.

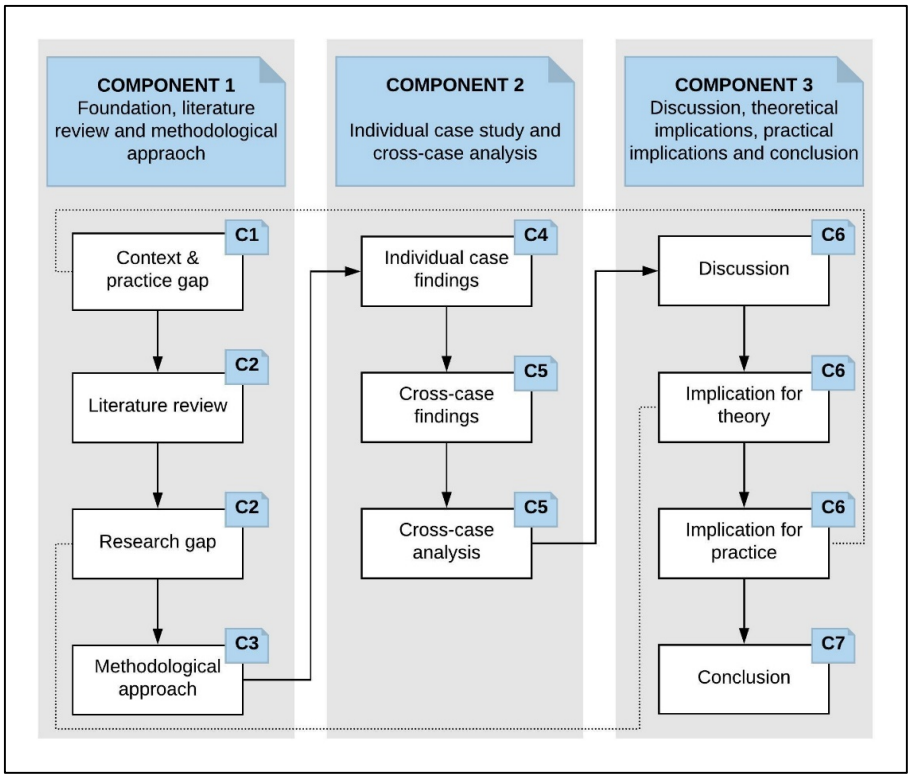

Figure 1-1: Thesis layout (dotted lines indicate the links between chapters)

1.5 Chapter Summary

This chapter has outlined the background of this research. It has also clarified the motivation for this research, the research question to be answered and a brief overview about the research approach, findings and contributions. The following chapter will critically evaluate prior academic work on the problem under investigation. It will also discuss the theoretical lenses through which this thesis assesses the problem.

2 LITERATURE REVIEW

2.1 Chapter Introduction

This chapter assesses previous scholarly work concerning business models and university technology commercialisation as these areas of study are deemed to be relevant to the research question of this thesis. The former generally stems from strategic management literature, while the latter emerges from academic entrepreneurship literature. The fragmented nature of both streams means that they must be separately assessed. Thus, this chapter is split into five main sections.

Section 2.2 presents an overview of the business model literature, covering the origin and definitions of a business model. It then presents current knowledge obtained from academic work concerning business models and highlights the utility of business models for commercialising new technology. It also discusses the limited research being done in relation to business models for technology commercialisation in the USO context. Section 2.3 explores the state-of-the-art academic studies concerning business models for commercialising university technology in USO settings in an in-depth manner. It strives to narrow the scope of this thesis by looking at the unique challenges encountered by most USOs related to business model development. Section 2.4 further articulates the challenges associated with different value components of business model development. Following that, section 2.5 describes the effectuation logic and concept of opportunity creation as well as their merit as potential lenses with which to answer the research questions. It also presents the central premises borrowed from both domains, which help to identify suitable operationalisation measures to answer the research question. Finally, section 2.6 concludes the literature review chapter.

2.2 Overview of Business Models

The concept of the business model has been widely used by practitioners in multiple discourses for a long time, predominantly to conceptualise the core element of a business (Teece 2010a). The concept has grown in significance, achieving global impact (Wirtz et al. 2016), and it has been widely applied in research and corporate practice alike. The next section provides a comprehensive overview of the business model literature and its origin, definitions, current knowledge and role in technology commercialisation.

2.2.1 Origin and Definitions of the Business Model

The formal use of the term 'business model' in academia can be traced back to the late 1950s. Ostewalder and Pigneur (2005) argue that the term first appeared in an academic article in 1957[8] and in the title and abstract of a paper published in 1960[9]. Today, the business model has become prevalent in academic literature. A search of the term 'business model' in the titles of academic articles published between 1957 and 2018 returned more than 14,000 results. Of these, only 32 were published before the year 1990. This analysis suggests that the popularity of the business model is recent but increased dramatically in the late 1990s. The business model literature has expanded four times faster than the dynamic capability literature, which emerged about the same time (Foss & Saebi 2017).

Despite its rapid proliferation, the business model still lacks a definitional consistency (Zott et al. 2011; Wirtz et al. 2016). Although the business model is highly regarded as a useful managerial tool, attempts to achieve definitional uniformity have been criticised:

> *"The definition of a business model is murky at best. Most often, it seems to refer to a loose conception of how a company does business and generates revenue. Yet, simply having a business model is an exceedingly low bar set for building a company."* (Porter 2001, p.73)

Similarly, Hedman and Kalling (2003) claim that the business model is defined according to its intended use, which causes excessive polarisation and insufficient grounding in theory. However, despite the lack of consensus regarding the definition of the business model, most literature is building congruence towards a comprehensive understanding of business models based on the notion that a business model summarises the architecture and logic of a business (Baden-Fuller & Morgan 2010) and defines the organisation's value proposition and approach to value creation and value capture (Teece 2010a).

In general, scholars attempt to define the business model implicitly and explicitly at two levels of abstraction: 1) a depiction concept using terms like 'design', 'tool', 'structure', 'architecture'

[8] Bellman, R., Clark, C.E., Malcolm, D.G., Craft, C.J. & Ricciardi, F.M., 1957. On the construction of a multi-stage, multi-person business game. Operations Research, 5(4), pp.469-503.
[9] Jones, G.M., 1960. Educators, electrons, and business models: A problem in synthesis. The Accounting Review, 35(4), p.619.

or ‘configuration’ and 2) a structural concept detailing the core components of a business model (Osterwalder & Pigneur 2005). Table 2-1 presents several commonly cited business model definitions and their components.

Author(s)	Definition	Components
Amit and Zott (2001)	A business model depicts the content, structure and governance of transactions designed to create value through the exploitation of business opportunities.	Transaction content, transaction structure, transaction governance.
Chesbrough and Rosenbloom (2002)	A business model is the heuristic logic that connects technical potential with the realisation of economic value.	Value proposition, market segment, revenue generation mechanisms, value chain, complementary assets, cost structure and profit potential of the offering, position of the firm within the value network of suppliers and customers, competitive strategy.
Magretta (2002)	Business models are stories that explain how enterprises work. A good business model answers Peter Drucker’s age-old questions: Who is the customer? What does the customer value? It also answers the fundamental questions every manager must ask: How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?	Customer, customer value proposition, value delivery method, economic logic that supports delivery of value to the customer at an appropriate cost.
Morris et al. (2005)	A business model is a concise representation of how an interrelated set of decision variables concerning venture strategy, architecture and economics are addressed to create a sustainable competitive advantage in defined markets.	Value proposition, customer, internal processes/competencies, external positioning, economic model, personal/investor factors.
Osterwalder and Pigneur (2010)	A business model describes the rationale of how an organisation creates, delivers and captures value.	Customer segment, value propositions, channels of distribution, customer relationships, revenue streams, key resources, key activities, key network partnerships, cost structure.
Teece (2010a)	A business model articulates the logic, data and other evidence that support a value proposition for the customer and a viable structure of revenues and costs for the enterprise delivering that value.	Market segment, value proposition, mechanism to capture value, isolating mechanism.

Zott et al. (2011)	The business model is a system of interdependent activities that transcend the focal firm and span its boundaries.	Transaction content, transaction structure, transaction governance.
Baden-Fuller and Haefliger (2013)	A business model is a system that solves the problem of identifying the customer(s), engaging their needs, delivering satisfaction and monetising value.	Customers, customer engagement, value delivery and linkage, monetisation.
Wirtz et al. (2016)	A business model refers to the ability and extent to which the firm is able to create and capture value.	Value proposition (product offering, service offering, pricing model), value creation (core competences, key resources, governance, complementary assets, value networks), value delivery (distribution channels, target market segments), value capture (revenue model, cost structure, profit allocation), and value communication (communication channels, ethos and story).

Table 2-1: Commonly cited definitions of the business model

The context for definitions of the business model may be either static or dynamic. Existing literature has mostly adopted a static perspective on business models. However, a more pragmatic approach to understanding business model development involves engagement with the dynamic perspective (Casadesus-Masanell et al. 2010; Cavalcante et al. 2011) because different components of business models dynamically interrelate (Johnson et al. 2008) and should allow changes whenever entrepreneurs improve their knowledge of available opportunities and resources (Druilhe & Garnsey 2004; Demil & Lecocq 2010).

Moving away from Porter's (2001) and Hedman and Kalling's (2003) critics about business model definition being murky and inconsistent, the current thesis employs the dynamic view and strengthens the definitional context for the business model by reconciling relevant definitions and offering a comprehensive definition: a business model is an architecture of interdependent components of value proposition, value creation and value capture that dynamically exist within a networked stakeholder.

This definition is deemed appropriate given the dynamism of business models, which requires value to be co-created for a wide range of networked stakeholders (e.g. Zott & Amit 2010). In this definition, business model's depiction and components are combined. Following

Chesborough (2003), Richardson (2008) and Osterwalder and Pigneur (2010), the key components of the business model includes value proposition, value creation, value capture and value network (see Table 2-2).

Component	Explanation
Value proposition	The technology encapsulated in a product or service that creates value for a specific customer.
Value creation	The value created for users by the product or service containing the new technology.
Value capture	The revenue-generating mechanisms for the USO, including the cost structure and profit margins of producing the product or service.
Value network	The network of internal and external stakeholders that makes a business model work.

Table 2-2: Key components of business models

The definition of business models employed in this thesis claims that both value creation and value capture occur in a value network. Unlike most definitions, the definition used in this thesis explicitly mentions the value network as it is an outward-looking conjecture that complements internal values. The value network includes suppliers, partners, distribution channels, competitors, customers and coalitions that extend the company's resources (Hamel 2000). By elucidating this network, the current thesis fills the gap in prior literature on business models, which adopted a view of value creation that separates firms as producers (e.g. innovators) and customers as consumers (e.g. adopters) of market offerings (Vargo & Lusch 2011).

Now that the origin and definitional context of the business model have been discussed, the next section will dissect current wisdom, presenting a comprehensive view of state-of-the-art research and highlighting the gaps in business model literature that are worth addressing.

2.2.2 Current Wisdom of Business Model Literature

Discussions of the business model in the 1990s mainly occurred in the field of information systems and coincided with the advent of the Internet. The Internet was—and remains—one of the principal drivers of scholarly interest in business models (Magretta 2002; Osterwalder & Pigneur 2005). Beyond information systems, the concept of the business model gradually dispersed to strategy and management literature. The year 2000 saw a sharp increase in

publications on business models in the fields of information systems, strategy and management (Hedman & Kalling 2003; Osterwalder & Pigneur 2005). However, at that stage, the concept of the business model was still nascent and, as a research area, poorly understood.

Ten years later, in early 2010, the three areas of interest remained relatively similar but tended to explicate each domain more deeply. In information systems literature, effort was made to understand e-business; in strategy literature, focus was placed on competitive advantage, firm performance and value creation; and in management literature, researchers focused on technology management and innovation (Zott et al. 2011). During that time, the cumulative development of business model literature was hampered because the concept of the business model was discussed in silos, resulting in heterogeneous comprehension. Scholars' work did not build upon each other.

Although the concept of the business model is used to address an important phenomenon, it lacks theoretical grounding because the concept is mostly discussed independently from established theories (Teece 2010a; Sosna et al. 2010). Despite being discussed in the literature for over 50 years, it can be argued that the business model is still undergoing consolidation (Foss & Saebi 2017). Scholarly work related to business model appeared to be rapidly adopted by strategy scholars, whose interest is partly driven by business model's expediency for extending the traditional wisdom in the strategy literature.

In conventional strategy literature, focus is placed on competition, value capture and competitive advantage. The business model extends this, involving co-operation, partnership and joint value creation (Magretta 2002; Mäkinen & Seppänen 2007). As a result, current research on business models revolves mainly around three aspects, namely, 1) the networked nature of value creation; 2) the relationship between business models and firm performance; and 3) the distinction between the business model and other strategy concepts. Since strategy scholars are generally interested in a firm's activities, most business model conceptualisations are centred on the notion of the activity system. Zott and Amit (2010) suggest a set of parameters that activity system designers need to consider when developing a business model: its content, structure and governance.

Additionally, the concept of the business model involves value proposition and a generalised emphasis on the role of the customer, which appears to be less pronounced elsewhere in the strategy literature. There is a strong consensus that the business model revolves around customer-focused value creation (Chesbrough & Rosenbloom 2002; Mansfield & Fourie 2004). Viewed from this perspective, the business model encompasses the firm's pattern of economic exchanges with external parties (Zott & Amit 2008), and it outlines the essential details of a firm's value proposition for its various stakeholders and the activity system the firm uses to create and deliver value to its customers (Zott & Amit 2010).

As an immature but growing field of literature, the business model has been developed from multiple angles. Wirtz et al. (2016) argue that the phenomenon is growing in four new domains: innovation, change and evolution, performance and control and design. Despite failure to come to a consensus regarding the definition of the business model and the lack of construct clarity, the literature has moved towards the innovation sub-stream. Scholars like Foss and Saebi (2017) perform scholarly work on business model innovation and claim that business model innovation is gaining increasing attention among academics and practitioners. However, based on 150 papers published between 2000 and 2015, Foss and Saebi (2017) argue that business model innovation literature faces problems with respect to construct clarity and has gaps regarding the identification of antecedent conditions, contingencies and outcomes. These findings are unsurprising since the fundamental issues associated with the business model have not been fully resolved.

The rapid growth of business model innovation literature has left the foundation of the business model weak; scholars hastily pursued the new sub-stream without fully answering fundamental questions like 'what is a business model', 'how is it developed' and 'what roles does it play'. Therefore, instead of furthering the discussion of business model innovation, the current research seeks to strengthen the elementary comprehension of business model literature by investigating aspects of business model development and the role it plays in commercialising new technology.

The previous section discussed the lack of a unified definition of the business model as a critical gap in the literature. Other areas of study that seem to be underexplored are the way in which a business model emerges and the role that it plays (Palo & Tähtinen 2013). Despite the

growing importance of developing a novel business model, the scarcity of empirical studies on business model development has hindered practical use of the concept of the business model (Im & Cho 2013). The limited research on business model development has a narrow focus on the relationships between elements of value conceptualisation and organisations in which business models undergo a linear development process (i.e. they are first designed and then implemented). There is a need to improve our understanding of the connective mechanisms and dynamics involved in business model development through study of networked business model development (Palo & Tähtinen 2013; Dmitriev et al. 2014).

A search of academic papers on business model development and configuration between 1990 and 2018 yielded only 60 papers. After a careful review, only 34 studies appeared to deal with business model development in a non-marginal way (i.e. they used business model development as the unit of analysis and explored how a business model is developed). These papers can be categorised as those discussing ways in which a business model is developed (e.g. Andries et al. 2013; Palo & Tähtinen 2013; Im & Cho 2013; Dmitriev et al. 2014; Reymen et al. 2017), antecedents to successful business model development (e.g. Storbacka et al. 2013) and framework development based on empirical results (e.g. Schillebeeckx et al. 2012; Ebel et al. 2016). Of these papers, only 12 explicitly deal with business model development. Spieth et al. (2014) note a lack of research exploring the processes involved in the design and implementation of business models. Thus, there is a need for extensive work to understand the logic behind business model development.

Due to its heterogeneous development, the business model plays multifaceted roles. Based on the elements of a business model and how they interact as a dynamic process, Zott et al. (2011) posit that a business model represents a holistic approach to explaining how firms do business at the systemic level. Some scholars refer to a business model as a conceptual tool or model (Osterwalder & Pigneur 2005; George & Bock 2011), a structural template (Amit & Zott 2001) or a framework (Morris et al. 2005). In light of this, Chesbrough (2003) suggests that there are at least five roles a business model should play: 1) articulation of the value proposition; 2) identification of the market segment; 3) definition of the value chain; 4) specification of the revenue-generating mechanisms of the organisation; and 5) formulation or specification of a competitive strategy that will enable the organisation to gain and maintain an advantage over rivals that offer competing technologies.

Given the many roles of a business model, scholars claim that a business model is essential for every organisation. In particular, an organisation can benefit from a business model due to its ability to capture the value of new technology (Baden-Fuller & Haefliger 2013). However, despite its importance, this area of study has not been fully explored (Gambardella & McGahan 2010). The next section will discuss the academic work investigating the role of the business model in the commercialisation of new technology.

2.2.3 Business Model and Technology Commercialisation

Generally, technology commercialisation refers to the launch of a product in a defined market (Jolly 1997). The role of a business model in the commercialisation of technology is part of a broader discussion of innovation and technology management (see Zott et al. 2011). Since the proliferation of business model literature, much has been discussed about the role of the business model in unlocking the value of latent technology (e.g. Chesbrough & Rosenbloom 2002; Chesbrough 2003; Johnson et al. 2008; Doganova & Eyquem-Renault 2009; Baden-Fuller & Haefliger 2013; Gaus & Raith 2016).

Pioneering studies argue that bringing technology to the market for commercialisation requires more than scientific knowledge; rather, the process needs to be sustained by a viable business model that evolves in response to challenges and market needs (Chesbrough 2007). This echoes Schumpeter's (1983) claim that technology push[10] and market pull[11] are equally pertinent entry points for business model development into value proposition creation (Lubik et al. 2012; Dmitriev et al. 2014). Business models also matter for half-polished applications sold at intermediate stages of development, which upstream firms license to downstream firms rather than developing the final product themselves (Gambardella & McGahan 2010).

Scholars agree that the business model is an innovative tool that complements the traditional subjects of process, product and organisational innovation and involves new forms of co-operation and collaboration. In addition to embedding technology in attractive products and services, a firm needs to design a unique business model to fully realise its commercial potential (Teece 2010b). Technological innovation alone might not be sufficient to guarantee

[10] Technology push is when research and development in new technology, drives the development of new products.
[11] Market pull is when the need/requirement for a new product or a solution to a problem comes from the market place.

a firm's success (e.g. Doganova & Eyquem-Renault 2009) because technology per se has no inherent value (Chesbrough 2007).

For example, based on evidence from Xerox Corporation's technology spin-offs, Chesbrough and Rosenbloom (2002) demonstrate that technologies might not be profitable using a traditional business model but may be highly rewarding when commercialised with the right model. According to the authors, discovery-oriented research often creates spill-over technologies that lack a straightforward path to the market and the business model construct plays a critical role in extracting value from those technologies. Chesbrough (2007, p.12) stresses that *"[a] better business model often will beat a better idea or technology."* Further, Chesbrough (2010, p.354) argues that *"[a] mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model."*

While the technological development associated with breakthrough innovations is truly challenging, creating markets to stimulate use of such innovations may be an even more daunting barrier to successful commercialisation (O'Connor & Rice 2013). As a result, firms constantly review and reiterate their business models to reach the market (Johnson et al. 2008). A business model is mainly seen as a mechanism that connects a firm's innovative technology to customers' needs and the firm's resources. It is conceptually placed between a firm's input resources and market outcomes, and it embodies the organisational and financial architecture of the business (Chesbrough & Rosenbloom 2002; Teece 2010a; Dmitriev et al. 2014).

Different organisations construct different types of business models to commercialise technology in response to competitive landscapes. Despite the emphasis placed on the utility of business model for capturing value in latent technology, studies of knowledge-intensive organisations such as universities appear to be severely underrepresented in the literature (Bigdeli et al. 2016; Lubik & Garnsey 2016). Scholars mainly employ corporate and established firms as empirical settings, although universities are breeding grounds for new technology with commercial potential; Gaus and Raith (2016) and Fini et al. (2018) argue that most commercially viable technology originates from the university rather than corporate firms. In addition, Ndonzuau et al. (2002) claim that a significant proportion of the products and processes that are sold and used could not have been developed without academic research.

The scarcity of academic work on university technology commercialisation indicates the need for further research. Thus, the current thesis delves deeper and narrows its focus to business models for commercialising new technology developed in universities. Prior to examining previous work on business models and commercialisation of university technology, the next section will build a fundamental understanding of the USO phenomenon as a common way to commercialise university technology.

2.3 Overview of University Spin-off (USO)

USO is a vehicle for the commercialisation of the results of research performed in university laboratories, which contributes to economic growth (Lockett & Wright 2005; Fini et al. 2017). It is one of the most effective mechanisms for transferring technology between universities and industries (Ndonzuau et al. 2002; Markman et al. 2008). The following section provides an overview of the USO phenomenon and research on the use of business models for commercialising university technology through the creation of a USO.

2.3.1 USO and University Technology Commercialisation

Research concerning USO that focuses on new technology-based firms is gaining interest among scholars and has been part of the academic landscape for decades[12]. Such research has led to many attempts to define a USO, hindering clarity concerning the topic. To enhance understanding of USOs, Table 2-3 presents commonly cited definitions. For consistency, current thesis adopts the definition offered by Pirnay et al. (2003), which is derived from extensive examination of USO typologies.

Authors	Definition
Smilor et al. (1990, p.63)	A company that is founded; 1) by a faculty member, staff member or student who left the university to start a company or who started the company while still affiliated with the university and/or 2) around a technology or technology-based idea developed within the university.
Klofsten and Jones-Evans (2000, p.300)	A new firm or organisation to exploit the results of the university research.
Pirnay et al. (2003, p.356)	A new firm created to exploit commercially some knowledge, technology or research results developed within a university.

Table 2-3: Commonly cited USO definitions

[12] Cooper, A., 1971. Entrepreneurial environment. Industrial Research 1971; 74–76.

As a new venture, a USO is endowed with a distinct legal status as neither an extension nor a controlled subsidiary of the university as the parent organisation, but an autonomous structure pursuing profit-making activities (Pattnaik & Pandey 2014). To exploit knowledge produced by academic activities, a USO includes not only technological innovations or patents (Smilor et al. 1990) but also scientific and technical know-how accumulated by an individual during academic activities.

From an operational point of view, a USO is established primarily to transfer (Cohen & Philipsen 2010) and commercialise university technology (Pattnaik & Pandey 2014). At least two common ways in which a USO commercialises technology are provision of an official platform for firms to further develop and commercialise early-stage inventions with high uncertainty (Etzkowitz 2003) and a mechanism to ensure the inventor's involvement in the development of university technologies (Di Gregorio & Shane 2003).

Scholars argue that a USO plays a crucial role in maximising the returns of IP (Lockett & Wright 2005) and, subsequently, contributing to regional economies (Fini et al. 2017). Through the formation of a USO, the commercial benefit of research is extended beyond the narrow confines of the academic community. In addition, a USO provides inventors with equity holdings more easily than established firms because the distribution of equity when a firm is founded does not involve transfer of equity from one individual to another, as is the case when equity is distributed after firm foundation.

The creation of a USO is usually explained within the technology transfer discourse. Scholars decipher the mechanism underlying USO creation through multiple stages and lenses (see Ndonzuau et al. 2002; Siegel et al. 2003; Di Gregorio & Shane 2003; Vohora et al. 2004; Lockett & Wright 2005; Pattnaik & Pandey 2014). Building upon Siegel et al.'s (2004) work, the current thesis extends the technology transfer process beyond USO creation to the market entry stage. This is done to unify the definition of technology commercialisation to a defined market. Figure 2-1 illustrates the most common process of university technology commercialisation and the key stakeholders involved in each stage.

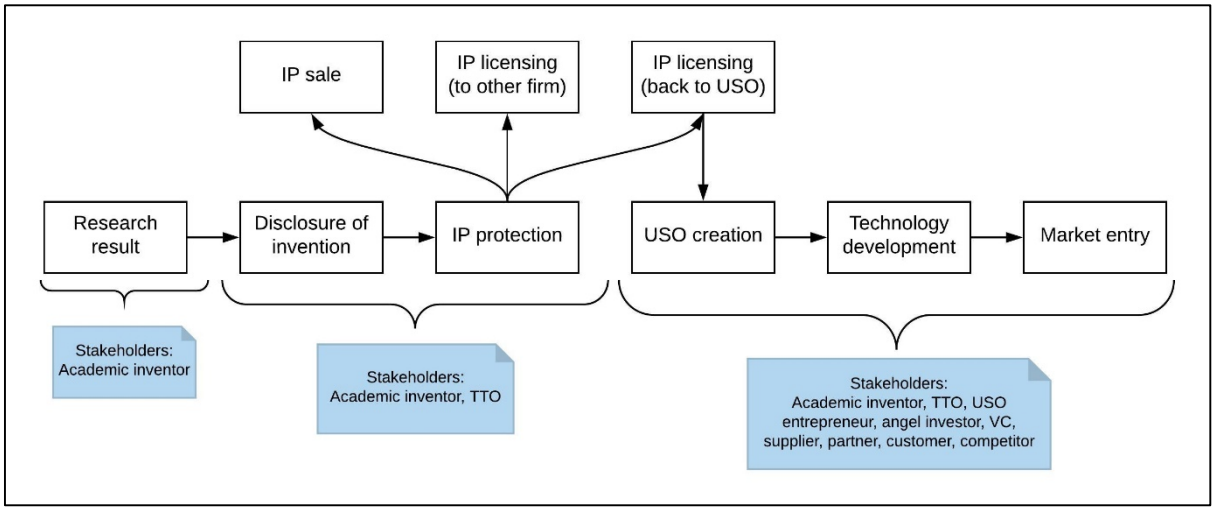

Figure 2-1: University technology commercialisation process and the key stakeholders involved (not necessarily in this order; see Siegel et al. 2003; Locket et al. 2005)

The commercialisation of university technology usually commences when an academic inventor of a new technology discloses the invention to a TTO, which then seeks IP protection. Based on the limited monopoly provided by a patent, the TTO can either sell the IP, license the IP to established firms or create a USO to which the IP is licensed. Practically, a USO emerges after separation from the university, which contributes to its financial, human and intellectual capital. Together with other relevant intangible assets, the university also transfers to the new legal entity the obligations and risks associated with commercialisation of the technology (Pattnaik & Pandey 2014).

Licensing the IP to established firms is the most common route for university technology commercialisation. In this process, an IP right holder gives another entity the authority to exploit the IP and, in return, the licensee pays royalties to the IP right holder (Siegel et al. 2003). Technology licensing gives the inventor the opportunity to be less involved in commercial matters (Minshall et al. 2007). However, not all technology can be easily transacted via a licensing agreement. Furthermore, the university may not be able to capture the full value of technology through a licensing arrangement and therefore may seek more direct involvement through a USO (Franklin et al. 2001). In line with this, Ndonzuau et al. (2002) contend, one of the most effective ways to transfer research results to the marketplace is through establishment of a USO.

Figure 2-1 illustrates that the types of key stakeholders involved in the university technology commercialisation process evolve over time. As the firm transitions from the academic network to the commercial network, more stakeholders with different roles, motivations and cultures become involved (Siegel et al. 2004). Table 2-4 presents the key stakeholders involved in university technology commercialisation and their motives and cultures. This is by no means an exhaustive list of stakeholders; for example, the federal government, which funds these research projects, can also be viewed as a stakeholder.

Stakeholder	Action	Primary motive	Secondary motive	Culture
Academic inventor	Discovers new technology	Recognition within the scientific community - publications, grants	Financial gain	Scientific
TTO	Structures deal	Protection and marketing of the technology	Facilitation of technological diffusion	Bureaucratic
USO entrepreneur	Commercialises new technology	Financial gain	Maintenance of control over proprietary technologies	Entrepreneurial
Investor, venture capitalist (VC)	Allocates capital to the USO	Financial gain	Provision of short-term financial support to the USO	Business
Supplier, partner, customer, competitor	Adds, delivers, receives, reduces value	Financial gain	Engagement in the value chain	Business

Table 2-4: Key stakeholders involved in university technology commercialisation (See Siegel 2004)

2.3.2 Business Model and University Technology Commercialisation

As previously discussed, research on business models and commercialisation of technology is gaining attention in mainstream literature, but it has been mostly investigated in corporate settings. Scholars like Dagonova and Eyquem-Renult (2009), Lehoux et al. (2014), Dmitriev et al. (2014), Bohnsack et al. (2014) and Reymen et al. (2017) seek to investigate the evolution of the business model in the new corporate venture setting. In addition, Demil and Lecoq (2010) and Sitoh et al. (2014) advance the understanding of how a business model plays a role in technology commercialisation in the context of an established firm. However, similar research conducted at the university setting is scarce.

A systematic literature review between 1990 until 2018 returned only eight papers discussing business models and technology commercialisation in the university context (Table 2-5). These papers can be divided into studies focusing on business models' evolution (e.g. Druilhe & Garnsey 2004; Lubik & Garnsey 2016; Bigdeli et al. 2016), role (e.g. Gaus & Raith 2016), antecedents (e.g. McAdam et al. 2017) and those that merely employ the business model as a lens with which to conceptually understand related issues (e.g. Mustar et al. 2006; Patton 2014; Still 2017). Still, very few studies explicitly investigate the efficacy of business models for commercialising university technology in the USO setting (e.g. Druilhe & Garnsey 2004; Mustar et al. 2006; Lubik & Garnsey 2016; Bigdeli et al. 2016).

Author(s)	Research objective	Unit of analysis	Unit of observation
Lubik and Garnsey (2016)	To investigate how USOs' business models often develop by trial-and-error in response to their unique challenges.	USO	Business model evolution
Bigdeli et al. (2016)	To examine the evolution of USOs' business models throughout different development phases.	USO	Business model evolution
Druilhe and Garnsey (2004)	To explore the typologies of companies that originate in universities.	USO	Business model evolution
Mustar et al. (2006)	To develop a taxonomy of USOs.	USO	Business model antecedents
Gaus and Raith (2016)	To analyse how an entrepreneurial university creates, delivers and captures value by characterising its business model.	University	Business model role
Still (2017)	To explore how the lean start-up paradigm, which validates the market for a product with a business model, can sustain subsequent scaling.	University	Business model antecedents
McAdam et al. (2017)	To explore how greater engagement with industry and end users has influenced the TTO business model.	TTO	Business model antecedents
Patton et al. (2014)	To analyse and evaluate the potential of incubation for strengthening the business model of new technology firms.	University incubators	Business model antecedents

Table 2-5: Academic papers discussing business models and university technology commercialisation

The literature examining business models in relation to university technology commercialisation is sparse for several reasons. First, investigations of business models within the domain of strategic entrepreneurship represent a new stream of research (Demil et al. 2015). In addition, study of business models in relation to the commercialisation of university technology has recently emerged as a hybrid between two established streams of literature: business model literature and university technology commercialisation literature. Hence, research on business models in relation to university technology commercialisation became more visible in the mainstream literature only recently (e.g. Lubik & Garnsey 2016; Bigdeli et al. 2016).

Second, scholars often fail to separate USO from corporate and established firms and hence assume that USO faces challenges similar to those of corporate and established firms (Druilhe & Garnsey 2004). Yet, universities are distinct in that they initially operate in a non-commercial context (Rasmussen et al. 2011). As a result, recommendations made regarding business models' use for technology commercialisation in other settings are not directly applicable to the USO context (Lubik & Garnsey 2016). In the same spirit, Still (2017), Nelson (2014) and Garud et al. (2014) argue that the organisational context shapes decisions to engage in entrepreneurship and approaches to commercialisation. Third, USOs face multifaceted challenges and are prone to failure. As a result, empirical data with which to study business model development are limited and difficult to obtain. Therefore, only a relatively small number of studies aim to understand the development of a business model for university technology commercialisation in response to the unique challenges (Mustar et al. 2008).

The few studies focusing on the development of business models for technology commercialisation agree that business models are key to unlocking the value of immature university technology (e.g. Gaus & Raith 2016). Additionally, they argue that business models are developed through a dynamic (e.g. Dmitriev et al. 2014) and iterative or trial-and-error process (e.g. Demil & Lecocq 2010; Sosna et al. 2010).

Dmitriev et al. (2014) investigate the connective mechanisms and dynamics involved in the development of business models for commercialising innovations. They contend that specific elements of business model development that involve the conceptualisation of value and organisation for value creation are integrated in the dynamic and cyclical process of

commercialisation of technological innovations. More recent work by Lubik and Garnsey (2016) aims to identify the appropriate business models for USOs attempting to commercialise generic technologies. They argue that business models are often developed by trial-and-error in response to unique challenges. Lubik and Garnsey's (2016) findings echo those of Sosna et al. (2010) and Cavalcante et al. (2011), who argue that a firm's business model should fulfil two interlinked purposes: to provide stability for development of a firm's activities and to be flexible enough to allow for change.

Inspired by Penrosian's resource-based view[13] and Vohora et al.'s USO development phases[14], Demil and Lecoq (2010) and Bigdeli et al. (2016) argue that business model development evolves as a process of fine-tuning process of permanently linked core components. They find that firm sustainability depends on anticipation of and reaction to sequences of voluntary and emerging change. In parallel with this, Chesbrough (2010, p.356) suggests that business model development *". . . is not a matter of superior foresight ex ante – rather, it requires significant trial-and-error, and quite a bit of adaptation ex post."*

Scholarly efforts to promote a more iterative method of technology commercialisation have pragmatically moved away from the conventional commercialisation process, which promotes a linear go/no-go process (e.g. Hindle & Yencken 2004). Modern literature mostly adopts the perspective of dynamic business model development. Markman et al. (2008) claim that private universities are championing technology commercialisation because of its agility at the commercialisation stage. This notion suggests that a flexible business model allows firms to test an assumption, rapidly adapt to the business model and create a foundation for commercialisation. Likewise, Chesbrough (2003) and Clarysse et al. (2011) posit that, to identify the value of new technology, effective USO governance should promote experimentation and adaptation in response to highly uncertain environments.

While most studies agree that a USO business model is developed through an iterative process, very few scholars explicitly examine how the iterative process unfolds (Andries et al. 2013; Sitoh et al. 2014), and the extent to which a USO can influence the process is still debated.

[13] Penrose, E., 1959. The theory of the growth of the firm. New York, JohnWiley & Sons.
[14] Vohora, A., Wright, M. and Lockett, A., 2004. Critical junctures in the development of university high-tech spinout companies. Research policy, 33(1), pp.147-175.

Although Andries et al. (2013) and Sitoh et al. (2014) do not use USOs as empirical settings, their findings shed light on current research. Both adopt Sarasvathy's (2001) effectuation and causation theory as a theoretical lens. Their findings navigate current research, adopting appropriate established theory to understand the iterative process. Consideration of how business models are iteratively developed for commercialisation also raises questions regarding how new technologies will meet the market's needs.

With regards to the discussion about the commercialisation of new technology that satisfy market needs, Lehoux et al. (2014) analyse how USO respond to the market needs. They sought to address the value expectations of users and capital investors and how business models and technology designs influence each other. At the early-stage of USO development, business models are reframed and refined for various reasons. First, this occurs as a reactive or proactive response to changing market needs. Second, the business model is seen as a market device that allows entrepreneurs to explore a market and plays a performative role by contributing to the construction of the techno-economic network of an innovation. In this sense, business models are developed in response to market needs (Still 2017).

Bohnsack et al. (2014) discuss how business models transform the specific characteristics of sustainable technologies to create economic value and overcome the barriers to market penetration and how incumbent and entrepreneurial firms' path dependencies have affected the evolution of business models for electric vehicles. Still (2017) uses a lean start-up paradigm that validates the market for a product with a business model that can sustain subsequent scaling, which has led to use of a new process model to accelerate innovation. It is known that a USO should proactively interact with the market while developing a business model. However, the way in which market needs are validated is less adequately addressed. Still (2017) argues that the phase of value proposition discovery is less understood and that the phase of growth discovery, which emphasises building of a scalable, sustainable business, is not addressed by innovation approaches from the research context.

Although the myriad of study concerning business model and technology commercialisation has been instrumental in informing current thesis investigation, they are not sufficient to respond to the peculiar challenges faced by USOs in commercialising university technology. As compared to other types of firms, a USO faces all the challenges encountered by other firms

with added obstacles stemming from the low technology readiness level (TRL), conflicts among academic and commercial stakeholders, the urgent need to monetise the licensed IP within a designated period and strict licensing agreement. Table 2-6 depicts a comparison of commercialisation challenges faced by an established firm, a generic start-up, a technology start-up and a USO.

Firms / typical commercialisation challenges	Market uncertainty	Liability of newness	Product validation	Technological uncertainty	Low technology readiness level (TRL)	Academic /commercial stakeholders conflict	Monetisation of IP	IP licensing agreement
Established firms (an established firm that has positioned itself in a defined market)	√	-	-	-	-	-	-	-
Generic start-up (a new firm created to address a market need through a commercially viable product/service)	√	√	√	-	-	-	-	-
Technology start-up (a new firm created to address a market need through a commercially viable technological solution)	√	√	√	√	-	-	-	-
USO (a new firm created to exploit commercially some knowledge, technology or research results developed within a university)	√	√	√	√	√	√	√	√

Table 2-6: Comparison of commercialisation challenges faced by an established firm, a generic start-up, a technology start-up and USO.

Since a USO is a unique type of firm (Druilhe & Garnsey 2004) that faces specific obstacles to commercialisation (Bigdeli et al. 2016), business models must be understood in a different way (Lubik & Garnsey 2016). In this thesis, to understand the strategy underpinning development of a viable business model to commercialise university technology, the challenges faced by a USO across business model components are explored. Following that, current wisdom regarding the measures used to disentangle the identified problems is reviewed.

2.4 Unique Challenges Concerning Business Model Development

Early in its formative years, a USO must develop its technology while finding the appropriate market to plot its course. At this stage, a new firm needs to cope with the various challenges stemming from its nascent status (Aldrich & Fiol 1994) and overcome difficulties that are unique to USOs, such as technological immaturity (Lehoux et al. 2014), market uncertainty (Etzkowitz et al. 2000), conflicts between stakeholders with different motives (Siegel et al. 2003) and long time to market (Doganova & Eyquem-Renault 2009).

In the USO context, technology is usually limited to low technology readiness levels (TRLs; TRL1 to TRL2) when it is first discovered and may not be validated beyond the laboratory environment (TRL4) (Minshall et al. 2007). As depicted in Figure 2-2, a USO usually has a long way to go before it can create value and place value in products or services for potential customers (Doganova & Eyquem-Renault 2009). This is evident at all stages of the development of new laboratory discoveries into commercial reality (i.e. ideation, prototyping and commercialisation) and produces barriers that affect technology development and, eventually, commercialisation.

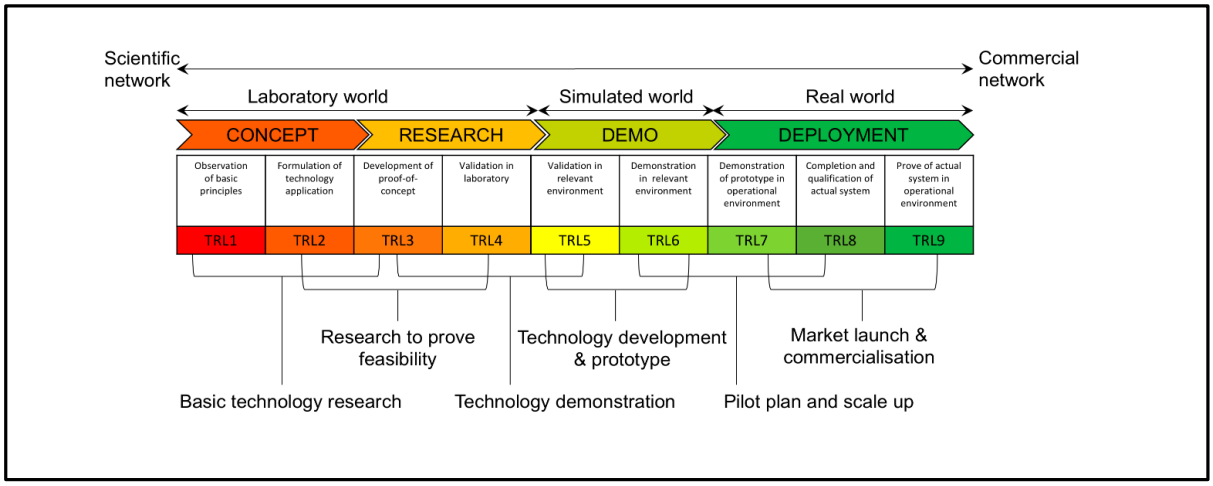

Figure 2-2: Technology readiness level (See Mankins 1995)

In response to these challenges, a viable business model is warranted. However, for a USO, developing a business model is a strenuous pursuit in itself and is partly exacerbated by the lack of a reference business model for a similar technology (Pries & Guild 2011; Lehoux et al. 2014) and a lack of industrial perspective (McAdam et al. 2017). Therefore, it is crucial to carefully identify the difficulties faced by USOs that directly affect the business model development process. To this end, business model value components are grouped into three main blocks based on the main challenges facing each segment: value proposition and value creation, value capture as well as value network. The following section explores the distinct challenges facing USOs that directly affect business model development across these three blocks.

2.4.1 Challenges Concerning Value Proposition and Value Creation

At its commercial infancy, a USO is at a disadvantage for creating value and embedding it in a proposition due to the liability of newness (Karlsson & Wigren 2012) and premature offerings (Doganova & Eyquem-Renault 2009). Hence, technology needs to achieve a high TRL before the value is apparent (Minshall et al. 2007). As a USO slowly begins to gather resources, create value and move to higher TRLs, it faces resistance to adoption of new technology. As previously noted by scholars, creating value from technology is not simply a matter of managing resource constraints and technical uncertainty; one must also consider the inherent uncertainty within the economic domain due to market ambiguity (Chesbrough & Rosenbloom 2002).

As a result, creating value and embedding it in a proposition for a difficult market resemble a bigger set of challenges that a USO must overcome. The persistent gap between value creation and adoption complicates the encapsulation of value in a proposition. This is jointly caused by legitimate resistance to change, sceptical customers and high market inertia, which can be termed 'market resistance' (Bond & Houston 2003). Indeed, market resistance to a new idea has a long academic history. Schumpeter (1934, p.87) describes the phenomenon as *"... social ostracism and finally to physical prevention or to direct attack."*

Many potential customers shy away from new technology because it tends to interrupt existing routines. In fact, the nature of any market is to prefer equilibrium and resist new ideas. To a great extent, the networked players within an equilibrium market usually erect formidable

barriers to the adoption of new technology (Chakravorti 2004). Given this, firms like USOs are known to provide insufficient incentive for customers to adopt or switch to new technologies. Additionally, new products usually rest outside customers' routines and, hence, have increased apparent risk. Radical innovations are even riskier; they are outside a customer's cognitive space and their attributes are difficult to understand, let alone value (Aldrich & Fiol 1994; Anderson & Gatignon 2008).

As commonly acknowledged in the literature, value creation for any firm involves finding novel ways to create value and satisfy market needs (Zott et al. 2011; Velu 2017). Schumpeter (1983) argues that the entry point to value proposition and value creation is either technology or market needs. However, in the USO context, technology is usually discovered prior to analysing the market needs (if there are any), and therefore, they tend to be more strongly oriented towards technology (Markman et al. 2008; Lubik et al. 2012). In most cases, the market is ambiguous and beset with resistance.

Since successful value creation can only be embedded in a viable proposition adopted by customers, a deeper understanding of how a USO can creatively create value and become an advocate for change is needed. Despite this, there seems to be inadequate understanding of how the process takes place. Furthermore, new ventures generally have limited foresight about the future, preventing them from making predictions (Kim & Mauborgne 1999). The underlying questions of how a USO moves to a higher TRL and how the market can generate need for a new technology warrant exploration. In summary, a way to significantly improve value creation and promote rapid adoption in the face of market resistance needs to be developed.

2.4.2 Challenges Concerning Value Capture

In the business model development process, value creation and value capture are highly interlinked. However, when value is created, a reward does not necessarily follow, which means that value creation and value capture are mutually exclusive (Amit & Zott 2001). Likewise, technology does not create wealth on its own (Chesbrough & Rosenbloom 2002). Rather, the products generated by application of technological inventions through commercialisation create wealth (Vohora et al. 2004). In a similar vein, scholars argue that university technology, although perceived to be theoretically ground-breaking, is still far from the end customer (Lubik & Garnsey 2016).

The value capture of a new technology is directly related to the ability of the USO to match the new technological solution to the market need. As Bower and Christensen (1996) argue, as long as there remains incompatibility between the offering and market needs, technologically interesting propositions can only excite the market and never generate profits. However, in the USO context, the value capture strategy is not immediately obvious at the USO's commercial infancy due to the incompatibility between the unclear offering and the ambiguous market. Unlike other types of companies that carry on traditions, the way a USO should capture value is distinct. As a new entrant to the market, a USO usually needs to carve out a new space in the market, raise capital from sceptical sources, recruit untrained employees and devise a new way to generate income (Aldrich & Fiol 1994).

For a USO, operations and potential entries to value capture are usually tightly linked to monetisation of the firm's core IP. The latent value of the IP licensed to a USO need to be realised immediately. The longer a firm takes to market the IP, the more likely that the firm will not be able to maximise profits, which exposes the USO to more risk prior to commercialisation (Vohora et al. 2004; Gaus & Raith 2016). Stakeholders' expectation that a technological solution will be rapidly converted into a commercially viable product gives the USO less flexibility to explore potential revenue models beyond immediate application of the technology (Rasmussen et al. 2011).

Apart from the aforementioned challenges, a USO is also expected to generate quick, alternative and sufficient income to fund pre-commercialisation operations (Vohora et al. 2004). Even when the technology is ready for the market, a USO must find a way to capture enough value to cover the high cost of R&D despite having little control over the market price of the technology (Jensen & Thursby 2001). When getting a product into customers' hands, a USO must often reconcile uncertainty regarding profit and risk regarding loss; setting the price too high would not attract customers and setting the price too low would impede growth. The trade off between price and perceived value requires further investigation.

While disentangling this issue from value capture, the literature suggests that incremental technology commercialisation should aim to penetrate an existing market (Pattnaik & Pandey 2014), while radical technology commercialisation should aim to create a new market (King & Tucci 2002). However, the reality is more complicated. Due to the complexity of value capture,

most firms treat it as an afterthought to value creation (McGrath 2010). However, this should not necessarily be the case because delayed decision making could lengthen the amount of time to market, lose revenue and lead to a lack of VC investment (Vohora et al. 2004).

This resulted in another vexing issue: understanding how a USO captures value when the firm faces difficulties related to the pressure of rapid technological monetisation, the urgent need to realise the value of the core IP, financial pressure to fund immature operations, limited control over the market price and a weak charging strategy. The myriad challenges related to financial pressure offer few opportunities for a USO to capture value. Since the wealth of research could not clarify this issue, a pragmatic approach for a USO to capture value despite financial pressure is needed.

2.4.3 Challenges Concerning Value Network

When establishing a value network to commercialise a new technology, a USO needs to transition from the academic network to the commercial network. In doing so, the firm encounters weak support mechanisms beset with conflicts of interest, value, culture and motive among key stakeholders at the individual and organisational levels at both the front and back ends of the commercialisation phase (Siegel et al. 2003; Clarysse & Moray 2004; Miller et al. 2014).

There are many asymmetric motives and cultures related to technology commercialisation. For example, academic inventors are concerned about gaining scientific recognition and less interested in commercialisation (Lam 2010), TTOs safeguard universities' IP through bureaucratic policies (Siegel et al. 2003), investors only participate at late stages of commercialisation (Clarysse & Moray 2004) and entrepreneurs pursue monetisation of technologies purely for financial gain (Siegel et al. 2004). Negativity, including mistrust and scepticism among stakeholders, further polarises motives for commercialisation (Gümüsay & Bohné 2018). Indeed, a USO is characterised by dynamic interactions between complex stakeholders (Clarysse & Moray 2004) trying to exert disparate influences on the commercialisation process (Vohora et al. 2004). The rigid dichotomy related to engagement in commercialisation of a technology raises tension and translates into blockages to technology commercialisation (O'Shea et al. 2005).

Despite conflicting motives, a USO still needs to rapidly strengthen its internal value network and establish trustworthy relationships with external stakeholders (Siegel et al. 2003; Lehoux et al. 2014). Miller et al (2014) contend that a business model is developed as a result of multiple stakeholders' influences. In addition, external pressure is regarded as a main driver of business model development (Chesbrough 2007; Zott & Amit 2010). Further, a USO is dependent on the support of venture capitalists, who tend to foster short-term financial growth (Ackerly et al. 2008), and as a new firm, a USO cannot easily avoid conflicts because they mostly occur with long-standing stakeholders that have strategic importance to USO commercialisation.

Few studies have explicitly focused on USOs' ability to manage business networks with conflicting values. Although the literature has identified the key role of USO stakeholders in the development of business models (Vohora et al. 2004; Miller et al. 2014) and how tensions are detrimental to the commercialisation progress (O'Shea et al. 2005), limited research has investigated the alignment of significant commitments from stakeholders with conflicting interests. Thus, it is necessary to determine how a USO manages stakeholders with conflicting values. In light of this, deeper examination of how a USO could minimise divergent interests and values among stakeholders is warranted.

The following section will discuss previous work that responded to the aforementioned challenges and highlight the remaining gap related to the development of a business model for commercialising new university technology.

2.5 The Remaining Gap

Although multiple theoretical and conceptual lenses have been proposed to understand the development of a business model for commercialising new technology, including Vohora's USO creation process perspective[15] (Clarysse et al. 2011), Penrosian's resource-based view[16] (Demil & Lecocq 2010), the dynamic perspective[17] (Dmitriev et al. 2014), path dependence[18] (Bohnsack et al. 2014) and the lean start-up[19] (Still 2017), there is still an obvious gap

[15] A process to create a USO by overcoming several critical junctures.
[16] A managerial framework used to determine the strategic resources with the potential to deliver comparative advantage.
[17] A connective mechanism and dynamic involved in business model development.
[18] A tendency to become committed to develop in certain ways due to structural properties, beliefs and/or values.
[19] An approach to creating and managing start-ups and get a desired product to customers' hands faster.

concerning how a USO develops its business model in response to the unique challenges it faces. Scholars agree that the business model itself is an interlocking system of values with reinforcing effect that arises in a value network (Hamel 2000). Therefore, the difficulties faced by a USO in establishing value would affect other value components (Lockett & Wright 2005).

Past work recognised the unique challenges associated with USO technology commercialisation. In response to challenges at the macro level (within the marketplace) and micro level (within the firm), the process of developing a business model for commercialisation of new technology is said to take shape iteratively through trial-and-error process (e.g. Chesbrough 2010; Holloway & Sebastio 2010; Sosna et al. 2010; Trimi & Berbegal-Mirabent 2012). McGrath (2010) claims that high market uncertainty requires an exploratory and experimental approach because most decisions related to commercialisation are made on the fly.

While these findings have been useful for advancing our understanding of the iterative nature of business model development, a more important question that remains to be answered is how the iterative process unfolds in response to market resistance, financial pressure and conflicting stakeholders. Furthermore, although research implies that a USO's reaction to exogenous pressures shapes how a business model is developed, there seem to be few investigations of how value is created, captured and, eventually, embedded in a proposition when the technology is nascent, the market is ambiguous and resistance to new technology is high.

Lubik and Garnsey (2016) claim that USOs require different approaches to development of business models in response to the unique challenges they face. However, scholars are precluded from formulating well-grounded explanations of business models for commercialising university technology due to the insufficiency of empirical investigations (Schneider & Spieth 2013). Moreover, the majority of academic literature discusses iterative development of business models to commercialise new technology in the backdrop of validated technology or a ready market (e.g. Chesbrough 2010; Demil & Lecocq 2010; Bohnsack et al. 2014).

Thus, there is a clear need to clarify business model development within the transitional phases of USO development, particularly the commercialisation stage, and better understand how a USO develops its business model in response to specific challenges. Although the antecedents to development of a viable business model are known, how the process unfolds in the face of high market resistance, financial pressure and conflicting stakeholders is black-boxed.

As thoroughly discussed, what is known about the USO business model development process is that 1) a business model is key for bringing new technology from the laboratory to the market; 2) business model components resemble an interlocking system in which a change in one component affects another; 3) the main components of business models are configured iteratively and 4) to develop a viable business model, a USO needs to specifically address challenges to value proposition, value creation, value capture and value network. All these notions are graphically illustrated in Figure 2-3 and will be used to guide data collection and operationalisation of the research.

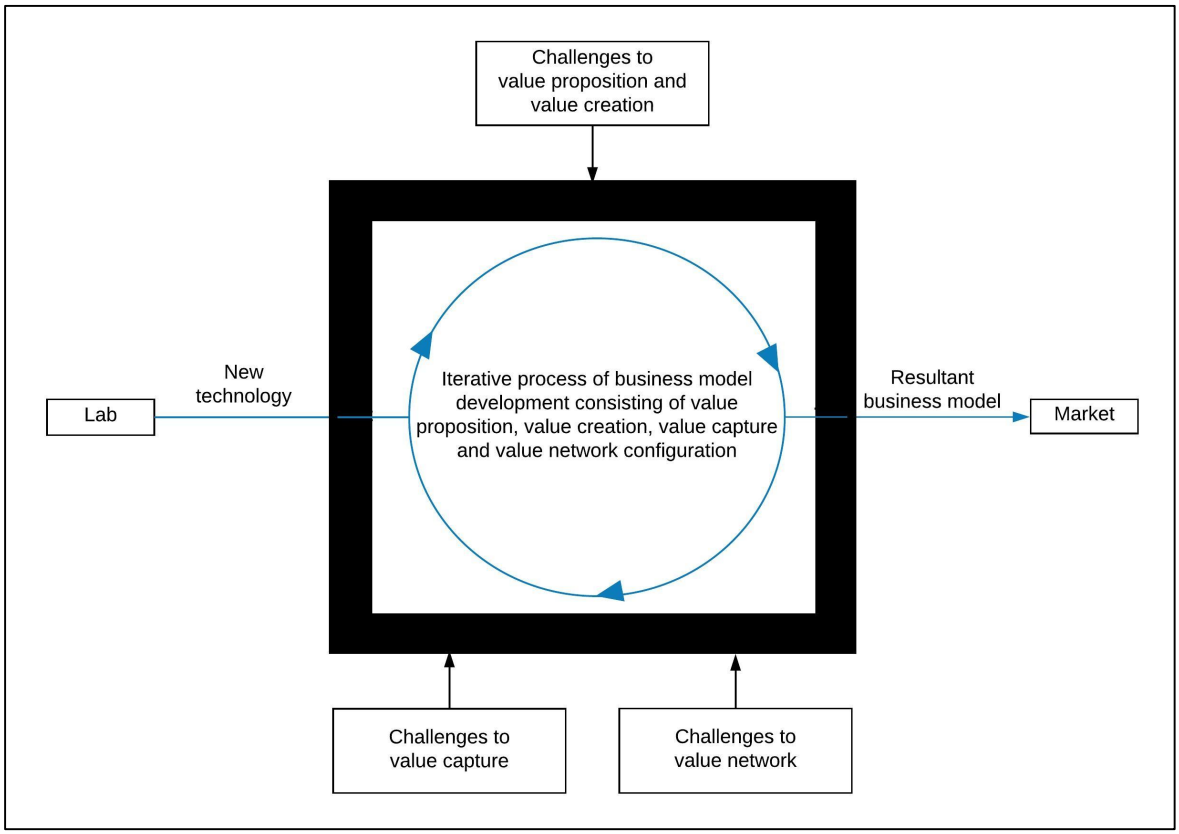

Figure 2-3: Knowledge about business model development for commercialisation of new university technology

Since previous studies could only provide fragmentary explanations to the phenomenon under investigation, this thesis seeks a plausible theoretical explanation of the issue. Six established and relevant theories that could supplement the partial knowledge about business model development for the commercialisation of new university technology (Figure 2-3) were examined based on their utility in addressing issues such as resource management, competitive advantage, changing environment, early-stage iterative process, technological uncertainty, market uncertainty, market creation through commercialisation and firm's flexibility towards goals. The theories and conceptual lens explored were Penrosian's resource-based view, Teece's dynamic capability, Pierson's path dependence, Vargo and Lush's service-dominant logic, Still's lean start-up and Sarasvathy's effectuation. A closer examination (Table 2-7) revealed that Sarasvathy's effectuation logic deemed to be the most promising theory to be employed in addressing the question of *'How does a USO develop its early-stage business models to commercialise new technology?'* The following sections will explain -in greater depth- the practical relevance of effectuation logic for determining how a USO develops a business model for technology commercialisation.

Theory and conceptual lens/ issue addressed	Resource management	Competitive advantage	Changing environment	Early-stage iterative process	Technological uncertainty	Market uncertainty	Market creation	Flexibility towards goal
Penrosian's resource-based view (a managerial framework to determine the resources for competitive advantage)	√	√	√	√	-	-	-	-
Teece's dynamic capability (a theory of competitive advantage in rapidly changing environments)	√	√	√	-	-	-	-	-
Pierson's path dependence (a decision-making logic based on past knowledge trajectory)	-	-	√	-	-	-	-	-
Vargo and Lush's service dominant logic (a framework to explain value creation, through exchange, among configurations of actors)	√	√	√	-	-	-	-	-
Still's lean start-up (a scientific approach to get a desired product to customers' hands faster)	√	√	√	√	√	√	-	-
Sarasvathy's effectuation (a decision-making logic based on the utilisation of a given set of means to achieve flexible goals)	√	√	√	√	√	√	√	√

Table 2-7: Potential theories and conceptual lens to supplement current understanding about business model development for the commercialisation of new university technology

2.6 Theoretical Lens

This section begins by describing the origin of effectuation theory, what it entails, state-of-the-art for effectual business model development and its merits as well as limitations as the theoretical lens of the current research. It then discusses how the concept of opportunity creation supplements effectual logic's limitations regarding advancement of the understanding of the decision-making process for commercialising new technology. The section concludes by presenting premises related to effectual logic and the concept of opportunity creation to guide the investigation in this research.

2.6.1 Effectual Logic

Effectual logic is part of the new wave of strategic entrepreneurship discourse concerning how entrepreneurial opportunities are pursued. Historically, the traditional entrepreneurial decision-making process was strictly described as a goal-driven entrepreneurial pursuit, and opportunities were pursued objectively with a well-defined goal (e.g. Chandler & Jansen 1992). This method of goal-driven entrepreneurial pursuit is also referred to as causation logic by Sarasvathy (2001), the discovery approach by Alvarez and Barney (2007) and the classic approach by Shah and Tripsas (2007).

In the last decade, many scholars have begun to realise that a linear approach encapsulates only a fraction of the strategic entrepreneurship discourse. Scholars argue that entrepreneurs do not necessarily use the goal-driven approach to gain a competitive advantage. Rather, they perform a means-driven process and become more pragmatic when looking for opportunities to employ their actual and limited resources in creative ways, involve different stakeholders along the way and ultimately develop a new product or service that creates value for their customers (Sarasvathy 2001; Sarasvathy & Dew 2005). This process is often analogised to building rather than discovering a mountain.

Following this literature, a paradigmatic shift in the theoretical perspective occurred and scholars began to contrast their own traditional ideologies with alternative ways in which opportunity creation could be understood. For example, Sarasvathy (2001) cognitively contrasts causal logic and its antipodal, termed 'effectuation theory' or 'effectual logic'. Alvarez and Barney (2007) contrast the discover approach with the creation approach, and

Shah and Tripsas (2007) contrast the classic approach with user entrepreneurship. Unlike these scholars, who juxtapose their own ideas, Baker and Nelson (2005) employ anthropology literature[20] to discuss the same phenomenon, which they term 'entrepreneurial bricolage' to describe the means-driven process as creation from a diverse range of available elements. Among these theoretical perspectives, Sarasvathy's (2001) effectuation and Baker and Nelson's (2005) entrepreneurial bricolage are most widely cited. Although both viewpoints complement each other, effectual logic offers a robust explanation of the creation of new ventures under uncertainty and, hence, offers stronger theoretical grounding for modern literature. Since it was proposed, Sarasvathy's (2001) effectuation has gained scholarly interest.

Sarasvathy (2001) claims that, unlike causal logic, which takes a given effect and selects between means to create that effect, effectuation processes take a given set of means and select between possible effects that can be created with that set of means. Causation invokes search and select tactics, and causal thinkers believe, *"[i]f I can predict the future, I can control it"* (Sarasvathy 2001, p.18). Contradictorily, effectuation employs creative and transformative tactics through a heuristics approach (Sarasvathy & Dew 2005), and effectual thinkers believe, *"[i]f I can control the future, I do not need to predict it"* (Sarasvathy 2001, p.18).

Based on Sarasvathy's (2001) study, Sarasvathy and Dew (2005) outline five principles underlying effectual logic. First, it begins with given means and goals. Second, it focuses on affordable loss rather than expected returns. Third, it emphasises competitive analysis or strategic alliances and pre-commitments. Fourth, it explores pre-existing knowledge or leverages environmental contingencies. Fifth, it seeks to influence the future rather than predicting it. The process of effectual logic is depicted in Figure 2-4 below.

[20] Lévi-Strauss, C., 1966. Anthropology: Its achievements and future. Current Anthropology, 7(2), pp.124-127.

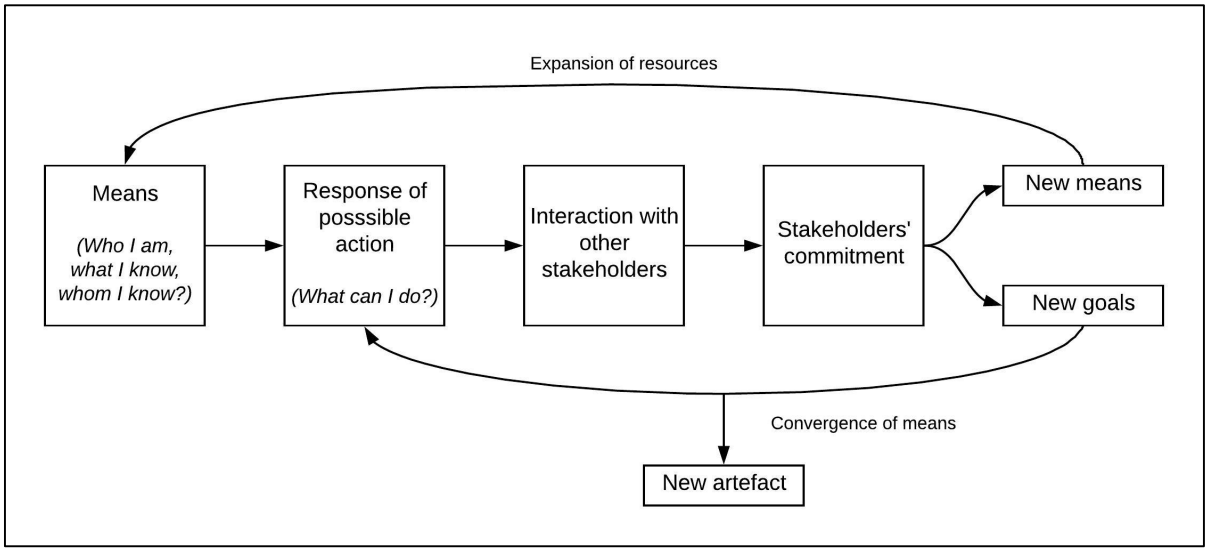

Figure 2-4: A dynamic model of effectual logic (Sarasvathy & Dew 2005)

Although it is a young phenomenon, effectual logic has been extended beyond its conventional context (Perry et al. 2012). While rooted in the entrepreneurship domain, it may also be possible and useful to see how it works in other domains, such as strategy (Wiltbank et al. 2006), marketing (Read et al. 2009) and R&D management (Brettel et al. 2012).

A systematic literature review of effectual business model development for the period between 1990 until 2018 using five databases returned only 28 results. All the retrieved academic papers were critically reviewed, and only 14 papers were identified to employ effectuation as a theoretical backbone to explicitly and implicitly advance the understanding of business model development and innovation (e.g. Chesbrough 2010; Andries et al. 2013; Sitoh et al. 2014; Velu & Jacob 2016; Reymen et al. 2017; Futterer et al. 2018). Some scholars strive to investigate effectual business model development as a secondary pursuit, while their primary pursuit is to use effectuation to understand new venture creation (Becker et al. 2015), uncertainty delimitation (Grichnik et al. 2016) and market creation (Holloway & Sebastio 2010).

As expected, none of the literature examines effectual business model development in the USO context. Although the scholarly discourse has suggested that effectuation is instrumental to business model development and innovation, specific knowledge about effectual business model development in relation to university technology commercialisation is lacking, and the limited knowledge that does exist is scattered among different literature streams. Of the 14

academic papers reviewed, very few scholars attempt to reconcile business model development and effectuation constructs into technology commercialisation discourse.

Chesbrough (2010) is among the pioneers proposing effectuation theory as a promising perspective with which to understand business model innovation. He argues that, to commercialise new technologies, conflicts with existing assets and business models need to be minimised and the understanding of barriers to business model innovation needs to be maximised. In support of his view, Reymen et al. (2017) argue that, to avoid the high costs associated with business model re-configuration, technological and market uncertainty need to be reduced in an effectual manner. Futterer et al. (2018) describe the effectiveness of effectuation at different levels of industry growth. In addition, Teece (2010a) argues that the firm is the central actor in effectuation of innovation and technological change.

Andries et al. (2013) on the other hand, claim that a business model is developed using two approaches: causally, through focused commitment, and effectually, through simultaneous experimentation. Both are worthwhile pursuits, but they are mutually exclusive and often associated with adverse risk to a firm's growth and survival. Striking a balance between the effectuation and causation logics, Becker et al. (2015) propose an integrative view of dynamic multi-stage new venture emergence to show how these approaches can be matched with the life cycle stage of an emerging venture. This finding aligns with earlier work by Sitoh et al. (2014) arguing that effectuation and causation can co-exist and are configured in specific ways during different phases of new product creation.

As previously mentioned, effectuation theory is structured according to five principles, which most literature ardently adopt (e.g. Qureshi et al. 2016). However, there seems to be less work that explicates or extends the principles based on empirical findings. Deeper empirical examination of each principle is also scarce but warranted.

Generally, the literature discusses causal and effectual logics concurrently during empirical discourse (e.g. Andries et al 2013; Sitoh et al. 2014; Becker 2015). Current theory endorses effectual logic as an explanation for a firm's starting point. When the firm gets closer to its goal and acquires sufficient resources, it gradually switches from effectual logic to causal logic

(Chesbrough 2010; Reymen et al. 2017; Futterer et al. 2018). The transition from effectual to causal logic is the heart of Sarasvathy's (2001) earlier work.

This intuitive finding, although novel, seems to have gained universal acceptance and saturated research. Rather than contributing imperceptibly to the conventional theoretical debate, the current thesis seeks to examine the issue by drilling deeper into the effectual logic. Likewise, effectuation opens windows to more interesting exploration because it does not merely validate the universal applicability of the causation and effectuation based models of entrepreneurship but it also enhances the pragmatism of a theory. Additionally, the effectiveness of effectuation when resources are not just constrained, but almost completely lacking, such as in a USO setting, has not been well explored.

2.6.2 The Merit of Effectual Logic as a Theoretical Lens

Effectuation has attained widespread attention as a logic with which to understand the mechanism of artefact creation. Scholars use the term 'artefact' to refer to a new venture (Harms & Schiele 2012), new market (O'Connor & Rice 2013) or new business model (Reymen et al. 2017). Since effectuation is a promising approach to 'demystify entrepreneurial decision making by describing how strategies emerge through the use of specific cognitive approaches' (Dew et al. 2008, p.320), the current thesis uses effectual logic as a basis for uncovering how business models are developed for commercialising university technology. Effectuation logic is useful as a theoretical lens for three reasons.

First, effectuation logic corresponds to the gap highlighted in the business model literature concerning weak theoretical grounding (Porter 2001; Hedman & Kalling 2003; Teece 2010a). Gaining clarity for business model development is an age-old problem, but there is still limited research being done to theoretically understand how a USO develops a business model in response to the unique challenges it faces. In an attempt to start a new venture and, potentially, create a new market, a USO could follow the well-established process of effectual logic. Moreover, effectuation has been proven to be useful to both novices and expert entrepreneurs in highly unpredictable early-stage ventures.

Second, effectuation principles relate to the phenomenon under investigation in the current thesis. Effectuation could explain how a USO creates a business model and market space through an iterative process because it considers the future to be fundamentally unpredictable

but could be influenced through human action, the environment to be constructible through choices and goals to be negotiated residuals of stakeholder commitments rather than pre-existing organisation of preferences. In addition, scholars argue that the development of business models for commercialising new technology requires significant experimentation (McGrath 2010), is highly ambiguous (Bigdeli et al. 2016) and demands commitment from various stakeholders (Siegel et al. 2003; Siegel & Wright 2015).

Third, employing effectual logic to understand business model development enables original contributions to the literature. This stream of knowledge is underexplored as both effectuation and business models are rooted in disparate streams of literature (Trimi & Berbegal-Mirabent 2012; Perry et al. 2012). The current thesis aims to re-contextualise the understanding of the business model using effectuation logic. Effectuation does not merely explain how entrepreneurial opportunities are pursued but also enables the risk of failure to be decreased. Thus, the current thesis may be useful for practitioners and guide the way to fruitful market opportunities.

Based on these reasons, effectuation is deemed to be the most appropriate way to explore the phenomenon of interest. Further, this thesis aims to not only apply effectual logic for comprehension of business model development but also explore the possibility of extending the understanding of the specific challenges faced by USOs when developing a viable business model. This is achieved by determining how a USO develops a business model in the face of unique challenges.

While effectuation theory is practically relevant to the topic under investigation, the logic appeared to have insufficient grounding about how a market creation can be proactively managed in order to commercialise new technology This issue deserves robust deliberation considering the market uncertainty facing university technology commercialisation (i.e. the market is either unclear or non-existent) (Andries & Debackere 2007). Scholars argue that, in commercialising a university technology, the much complex issue lies within the way forward for converting a scientific discovery into marketable product that fits a designated market (Still 2017).

Additionally, the commercialisation of new technology essentially involves the creation of a new business, including new markets, new revenue models and new partners, which requires changes in routines and behaviour (O'Connor & Rice 2013). Despite this, firms developing breakthrough technology often pay less attention to the later phases of the innovation process, which are successful market entry and creation. In the business model literature, the market is often assumed to be pre-existing, thus hampering discussion of how USO entrepreneurs could proactively co-create markets with stakeholders.

Zahra et al. (2014) argue that human agency is the backbone of entrepreneurial endeavour. However, in Sarasvathy's (2001) effectuation, new markets emerge as an outcome of the interaction between networked actors through an adaptive process within a changing competitive landscape. Hence, the emergence of new market appeared to be merely a residual of the effectuation process without fully grasping with the issue as to how entrepreneurs could proactively improve market creation for technology commercialisation (O'Connor & Rice 2013). Although effectuation offers a description of what happens in normal human interactions, as an actor-centric process, it could have been more proactive in creating its own opportunity to realise a new market. Here, a supplementary theoretical lens that could respond to the opportunity creation agency is needed.

After all, effectuation is not an independent doctrine; it builds on and integrates the work of several well-received economics and management theories (Dew & Sarasvathy 2002). The limitation of effectuation regarding proactivity in market creation calls for renewed emphasis on the conversion of university technology into marketable products by employing relevant theories that strengthen effectuation's view on new market creation. Careful review of the literature reveals that the opportunity creation theory proposed by Alvarez and Barney (2007) is a potential lens that can supplement effectual logic.

2.6.3 Concept of Opportunity Creation

The concept of opportunity creation is derived from creation theory, which is a popular logical theoretical alternative to discovery theory. Creation theory has risen in prominence among entrepreneurship theorists as it rationalises the actions that entrepreneurs take to form and exploit opportunities (Aldrich & Ruef 2006). Eminent scholars like Schumpeter (1983), Sarasvathy (2001), Alvarez and Barney (2005) and Baker and Nelson (2005) ground their work

using creation theory. They use the theory to explain entrepreneurial phenomena such as entrepreneurial decision making, the business planning process and the decision to finance an entrepreneurial venture.

In their seminal work, Alvarez and Barney (2007) apply granularity to creation theory and develop the notion of opportunity creation, which recognises that opportunities are not always objective phenomena created by change in a market. Rather, an opportunity may be proactively and endogenously created by the actions of an entrepreneur seeking ways to develop new offerings. The scholars further argue that *"[r]ather than searching for a clear opportunity to be exploited, entrepreneurs creating opportunity might engage in iterative learning process that ultimately could lead to the formation of opportunities"* (Alvarez & Barney 2007, pp.11–12).

Opportunity creation also assumes that opportunities do not necessarily exist independently of the actions taken by entrepreneurs to create them (Baker & Nelson 2005). Linking this to the market creation perspective, objectively pursuing opportunities in a ready and available market appeared to be less valuable because, unlike entrepreneurs with a proactive market orientation (Jaworski et al. 2000), opportunity-creating entrepreneurs do not only aim to satisfy existing market needs because, in some cases, they have to create a new market.

Bringing the phenomenon closer to the USO context, latent technology does not come with clear foresight of a market's needs (Teece 2010b); the market may exist but still unclear, and in some cases, the market may need to be created. Therefore, rather than aiming to enter an available market and/or waiting for the market to ready itself, entrepreneurs could proactively and endogenously take actions to influence the creation of new market. In this way, entrepreneurs do not necessarily have to wait for opportunities to unfold prior to responding because decisions are made using logical incrementalism based on beliefs and available information. When doing so, entrepreneurs should rely not only on technology and networks but also on their own actions to commercialise new technology by creating the market.

Kim and Maubourgne (1999) argue that firms may create new markets and re-create existing ones without any foresight of the future. Instead of looking within the accepted boundaries that define how firms compete, entrepreneurs could systematically gather information across them.

By doing so, entrepreneurs may find unoccupied territory that leads to breakthroughs in value. This can be achieved by looking across substitute markets, strategic groups within industries, chains of buyers, complementary offerings, functional or emotional appeal and/or time. Kim and Mouborgne's (1999) findings align with those of Druehl and Schmidt (2008) concerning the strategy of opening a new market by satisfying a detached market[21].

Alvarez and Barney's (2007) concept of opportunity creation and Sarasvathy's (2001) effectuation logic are not entirely different. Both seek to explain actions that entrepreneurs take to form and exploit opportunities. Most importantly, both agree that opportunities are created rather than discovered. Thus, they build upon each other in a coherent manner. However, they differ in terms of the magnitude of human agency in market creation; the concept of opportunity creation believes that actors have more agency in new market creation compared to effectual logic (O'Connor & Rice 2013).

Supplementing Sarasvathy's (2001) effectuation with Alvarez and Barney's (2007) opportunity creation has important implications for the current thesis's theoretical grounding as it provides information about how USO entrepreneurs' beliefs and actions (not predictions) are valuable sources of viable business models for commercialising new technology.

2.6.4 Borrowed Premises

The current thesis borrows relevant principles from effectuation logic and opportunity creation to guide its investigation. It follows the theoretical viewpoint that effectuation reduces uncertainty by emphasising control over prediction. The four premises borrowed from effectuation logic and opportunity creation are as follows: 1) operations are based on taking control; 2) there is exigency for market creation by creating opportunities; 3) interest in pre-commitment is created by forging partnerships; and 4) firms react to unexpected events by embracing contingencies.

Take control – This premise concerns the basis for taking action to commercialise new technology by focusing on only what the USO has power over instead of what is out of the firm's control. The firm predicts less and takes an available set of individual means as a starting point for decision making. It then focuses on working toward a possible outcome that can be

[21] Preference in the new market that is divergent (detached) from the current market (Schmidt & Druehl 2008).

achieved with these means. By taking control over its own resources and capabilities, a USO could become more pragmatic when influencing outcomes and creating opportunities using their limited means in creative ways. This approach also avoids expending effort on things that cannot be controlled.

Create opportunities – This premise depends on the exigency of creating opportunities through the actions of the entrepreneur. It also assumes that opportunities do not necessarily exist independently of the actions taken by entrepreneurs to create them. Rather than pursuing opportunities objectively in an available market, entrepreneurs strive to proactively and endogenously create the opportunities needed to commercialise new technology.

Forge partnerships – This premise concerns interest in obtaining pre-commitments from the external stakeholders involved in the commercialisation process. A firm tends to build partnerships with self-selecting stakeholders to reduce uncertainty and jointly co-create the new market with interested participants. Also, entrepreneurs interact with and involve other people and organisations in the venture creation process. Venture creation processes are open to, and indeed contingent upon, the involvement of other people and organisations as committed stakeholders. External stakeholders provide access to resources, reduce uncertainty and shape the goals and direction of the firm.

Embrace contingencies – This premise concerns a firm's reaction to unexpected events throughout the technology commercialisation discourse by tolerating contingencies. Since mistakes are inevitable, a USO embraces contingencies that arise from uncertain situations by remaining flexible and not tethered to existing goals. Through an adaptive process, the entrepreneur keeps decision making sufficiently open to leverage unexpected events for the benefit of the firm. Instead of making what-if scenarios to deal with worst-case scenarios, entrepreneurs interpret contingencies as potential clues to create a market.

2.7 Chapter Summary

This chapter has reviewed extant strategic management literature concerning business models and academic entrepreneurship research involving USO technology commercialisation. It has also more deeply and narrowly investigated the challenges facing USOs during business model development and linked the research question to the value components of business models.

After clarifying the research gap, this section identified the most appropriate theoretical lens to answer the posed research questions. The next section will describe the data needed to address the research question, how to obtain such data and how the data was analysed. The rationale of specific procedures concerning the methodological approach are also discussed.

3 METHODOLOGICAL APPROACH

3.1 Chapter Introduction

This chapter describes the methodological approach underpinning the research. Section 3.2 justifies how the research design is determined in accordance with philosophical assumptions. Section 3.3 presents the context of the research and method of case selection. Next, section 3.4 and section 3.5 specify which data are required and how to obtain, manage and analyse them. Section 3.6 discusses the steps taken to ensure research quality, rigour and ethical considerations. Finally, section 3.6 summarises the key points of this chapter.

3.2 Research Philosophy and Research Design

A philosophical standpoint is crucial for determining the research design (Saunders et al. 2000). It informs how a research question is understood, what data are significant and how data should be collected (Easterby-Smith et al. 2015). Withal, Holden and Lynch (2004) argue that research should not be methodologically led; rather, a methodology should be chosen based on the researchers' philosophical stance. It is vital to apply a methodological approach that can be philosophically justified to avoid generation of spurious results (Easterby-Smith et al. 2015). To determine the most suitable research design, the philosophical positions associated with the phenomenon under investigation were examined.

Ontology and Epistemology (Constructivism and Subjectivism)

Ideally, a research philosophy is understood based on its ontological and epistemological standpoints (Johnson & Duberley 2000). The current research aims to understand how a USO develops its business models for commercialising university technology. Given this, the ontology of the research fell on the constructivism spectrum (i.e. there is no single reality, and reality is constructed within social phenomena). Given this, the epistemological orientation of the research fell on the subjectivism spectrum (i.e. understanding the process through which human beings give meaning to the world is important) (Guba & Lincoln 1994).

Philosophical Stance (Interpretivism)

Based on the ontological and epistemological orientations of this research, the interpretivist perspective stood out as the most compatible paradigm because the findings of this research were predominantly shaped by information provided by key stakeholders of USOs. The

interpretivist approach emphasised the meaningful nature of people's participation in social and cultural life and determine the subsequent methodological choice (Holden & Lynch 2004).

Methodological Choice (Inductive)

In parallel with interpretivism philosophy, this research sought to gain rich insight into subjective meanings rather than providing law-like generalisations (Yin 2014). It also aimed to make a broad generalisation based on specific observation by obtaining an in-depth understanding of how the business model development process unfolds. Given this, inductive and interpretive reasoning were deemed to be the most suitable methodological choices to satisfy the research question (i.e. the investigation began with the research question and proceeded to observation, analysis and, finally, theory) (Saunders et al. 2000).

This also meant that the research took a grounded approach to theory building and allowed the theory to emerge without relying solely on any longstanding assumptions (Suddaby 2006; Gioia et al. 2013; Charmaz 2014). Despite this, the initial arguments were still loosely based on the preliminary theories affiliated with the focal phenomenon (i.e. development of business models for commercialising new technology). A grounded approach does not imply that the researcher should enter a field without prior knowledge of the existing research. Rather, it should 'aim to achieve practical middle ground between theory laden view of the world and unfettered empiricism' (Suddaby 2006, p.635).

Data Inquiry (Qualitative)

Inductive reasoning relies heavily on naturalistic methods such as interviewing, observation and analysis of existing texts (Bryman 2001). These methods ensure adequate dialogue between the researchers and informants in an attempt to collaboratively construct a meaningful reality (Yin 2014). As a result, a qualitative approach appeared to be the most appropriate mode of data inquiry. Data were obtained from in-depth investigations with focus samples to understand how business models emerge for the commercialisation of university technology. Qualitative data inquiry also allowed for a rich understanding of the context and, thus, an answer to the 'how' question (Langley 1999). Likewise, this research aims to address the question of *'How does a USO develop its early-stage business models to commercialise new technology?'*

Strategy (Multiple-Case Study)

Since this research involved qualitative and detailed examination of a USO and its related contextual conditions, it integrated research strategies that could satisfy the empirical inquiry and examine a phenomenon in its real-life setting. In this case, the boundaries between the phenomenon (subject) and the context (external) were not clear, and the researcher had no control over these events. As a result, the case study approach was the most suitable research strategy (Yin 2014). According to Van Maanen (1979), the case study approach is an array of interpretive techniques that seeks to describe, decode, translate and come to terms with the meaning of data.

Again, since this research dealt with a 'how' question, it had to be executed in an explanatory manner, which further reinforced that the case study as the best strategy (Langley 1999). This research employed four cases. Multiple case studies allowed the establishment of replication logic and yielded more robust, generalisable theory (Saunders et al. 2000; Eisenhardt & Graebner 2007; Yin 2014). A comparative case study was also appropriate to gain reflective insight into the dynamic organisational phenomenon prior to drawing the generalisation (Eisenhardt 1989; Flynn 1990).

Data Collection (Interview and Archival Data)

The unique strength of case studies is their ability to gather evidence beyond what is available in the conventional historical study (Eisenhardt 1989; Flynn 1990). This research was operationalised through interaction with USO stakeholders who represented small samples that were investigated in depth and over time. Interpretivist philosophy assumes that access to reality is achieved through social constructions, such as language, consciousness, shared meanings and instruments (Lindgren & Packendorff 2009). Given this, data collection occurred primarily through interviews and secondarily through archives.

Time Horizon (Cross-Sectional Analysis)

The time horizon of any research is independent of the research strategy (Saunders et al. 2000). Given the limitations of research duration and resources, a cross-sectional approach was deemed to be the most appropriate as it enabled the researcher to simultaneously capture findings from four different USOs in a snapshot manner. This technique also allowed for

comparison of many different variables without manipulating the study environment (Yin 2014).

Considering the above justifications, the research was pursued using an inductive, cross-sectional, multiple-case study design. The chosen design enabled systematic organisation of research activities so that the empirical data could be connected with the research question in a logical sequence (Yin 2014; Easterby-Smith et al. 2015). Following Saunders et al. (2000), the way in which the research design is determined is illustrated as a 'research onion' in Figure 3-1.

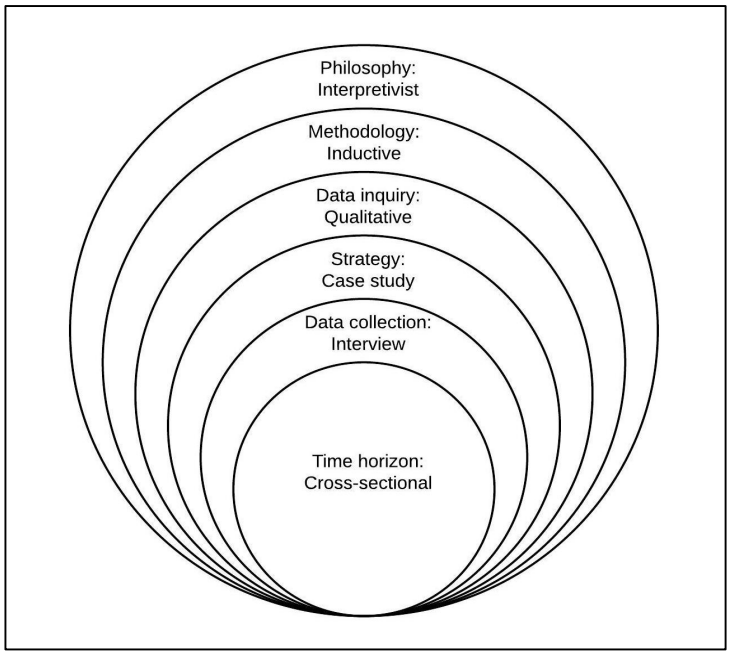

Figure 3-1: Research design illustrated as a research onion (See Saunders et al. 2000)

3.3 Research Context and Case Selection

The research context for a case study is highly linked to the unit of analysis, unit of observation and empirical setting (Yin 2014). The unit of analysis refers to the main entity under analysis in research, and the unit of observation represents the specific data to be observed within theunit of analysis. Defining the unit of analysis is key for determining what data will be collected. Since this research aimed to determine how a USO develops business models for commercialising university technology, the USO was set as the organisational unit of analysis. The approach adopted by the USO to develop its business model was set as the unit of

observation. Throughout this study, the unit of analysis was revisited twice due to new discoveries during data collection.

The empirical setting chosen for this research was USOs originating from academic research conducted at a single university, the University of Cambridge, UK. USOs at the University of Cambridge offered a promising setting in which to address the research question in a way that would enhance generalisability in two ways. First, the University of Cambridge has a strong technology transfer profile supported by its TTO, the Cambridge Enterprise. As a result, it is hailed as the technology transfer benchmark for other universities in the UK and therefore is an exemplary case for identifying best practices (Kirk & Cotton 2012). Second, USOs at the University of Cambridge are governed by the same policies and practices concerning university technology commercialisation employed by many other universities. Most public research universities in the UK and across the globe are governed by similar legislation dealing with the IP arising from government-funded research: universities can claim the IP rights of technologies developed in their laboratories and the government can directly create mechanisms to transfer and commercialise the knowledge produced in universities (Goldfarb & Henrekson 2003; Hewitt-Dundas 2015). This was instrumental for controlling the empirical setting and thus increasing the likelihood that findings will be transferred and generalised into broader domains (Guba & Lincoln 1994).

To distinguish the phenomenon (subject) from the context (external) (Yin 2014), the scope of empirical enquiry was determined based on spatial and temporal boundaries. The spatial boundary was set to include only USOs originating from research conducted at the University of Cambridge and commercialised in the cleantech industry. The temporal boundary was set to include business model development until 01 January 2017. Defining these limitations was useful for establishing the scope of data to be included and fit the time and resource limitations of this research.

Due to the large number of potentially eligible cases, a two-staged, purposive and homogenous case screening technique was employed to systematically select cases for this research (Saunders et al. 2000; Yin 2014). Purposive sampling allowed for pragmatic judgment of case selection and resulted in cases that were particularly informative regarding the research question. Homogenous sampling was performed to select one USO subgroup with similar attributes (Saunders et al. 2000). Both techniques aimed to maximise the comparable

environmental contexts, reduce rival explanations of other causal relationships and enable cases to be studied in great depth (Saunders et al. 2000; Yin 2014).

To minimise sampling bias and prejudice, the entire pool of 64 USOs at the University of Cambridge identified from the Cambridge Enterprise portfolio database were examined as potentially eligible candidates. During the first screening stage, two operational inclusion criteria were employed to align the cases with the research question and reduce the number of candidates to a manageable number (i.e. 12 or fewer) (Yin 2014). The criteria were as follows: 1) the USO must originate from research at the University of Cambridge and 2) the USO must be active at the point of data collection. The first screening procedure, however, failed to reduce the number of eligible cases (i.e. 47) to fewer than 12. Following Lubik and Garnsey's (2016) recommendation and to retain homogeneity of the cases, another inclusion criterion was adopted: only USOs performing commercialisation in the cleantech industry were included. Further justification for this industry selection is explained in section 4.3. The second screening stage resumed after the number of eligible cases was reduced from 47 to eight. Generic information about and access to all the eight USOs were obtained from two technology transfer officers employed at Cambridge Enterprise.

After examining all eight eligible cases, two more qualifying criteria were set for practical reasons: 1) USOs must be willing to participate in the research; and 2) USOs must be able to provide rich and meaningful data. In the end, four USOs originating from research at the University of Cambridge and performing commercialisation in the cleantech industry were deemed to be qualified to serve as the cases for this research. Figure 3-2 depicts the two-staged, purposive and homogenous case screening procedure.

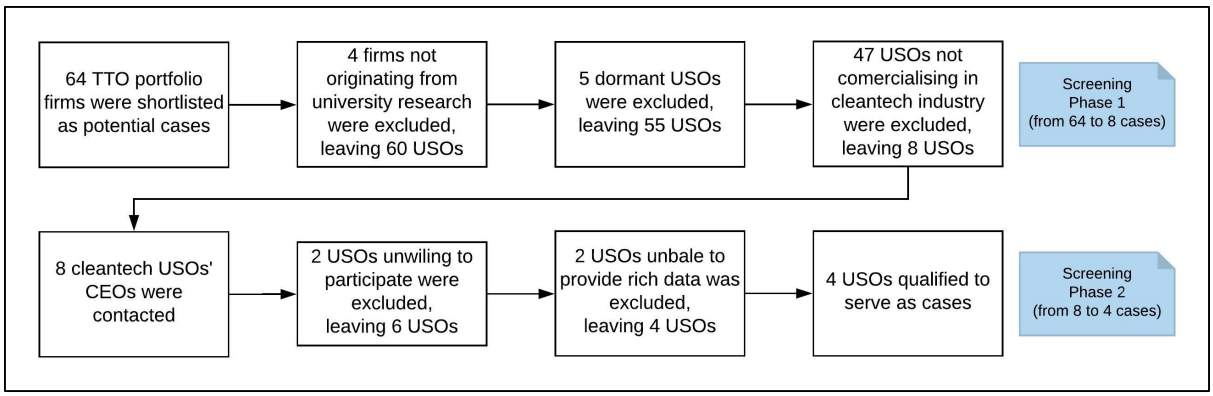

Figure 3-2: Two-staged, purposive and homogenous case screening procedure

According to Eisenhardt (1989), depending on the likelihood that an emergent theory will be developed, a total of four to ten cases is considered sufficient to satisfy a case study inquiry, enhance research validity and facilitate replication logic. Despite this, the perceived assumption was further verified by mapping the selected cases across a two-dimensional matrix known to provide contrasting patterns in the collected data, which included 1) USOs' age; and 2) USOs' commercialisation performance. These dimensions were chosen because they were independent of one another (i.e. there is no strict relationship between sales growth and/or loss with the age of the USO) (Shane 2004; Hewitt-Dundas 2015).

USO age was chosen as the proxy of the firm's maturity. USOs in operation for 10 years or less were considered immature, whereas USOs in operation for more than 10 years were considered mature. Most technology transfer scholars agree that pharmaceutical USOs usually take more than 10 years to commercialise technology (Swamidass & Vulasa 2009), while USOs in other industries usually take 10 years or less (Markman et al. 2005; Han 2017). A USO's ability to introduce a new product or production method into commerce was chosen as the proxy of commercialisation performance. High means that the USO's product is available on the market, and low indicates that it is not. This aligned with Jolly's (1997), Lehoux et al.'s (2014) and Hewitt-Dundas (2015) work on new technology commercialisation.

To observe diverse data, case positioning was performed to map one case in each cell of the matrix and represent individual illustrative USO profiles. As a result, richer findings at polar extremes were identified, and each case was treated as an experiment to confirm or refute the generalisable aspects of observations from other cases (Flynn 1990). The ability to include cases with low commercialisation performance represented another potential contribution to the knowledge because most research on academic entrepreneurship relies heavily on data derived from successful commercialisation and neglects data from less successful attempts at commercialisation (Druilhe & Garnsey 2001; Lubik & Garnsey 2016). The four polar cases are presented as a 2 x 2 matrix in Figure 3-3, and the case firms are described in Table 3-1.

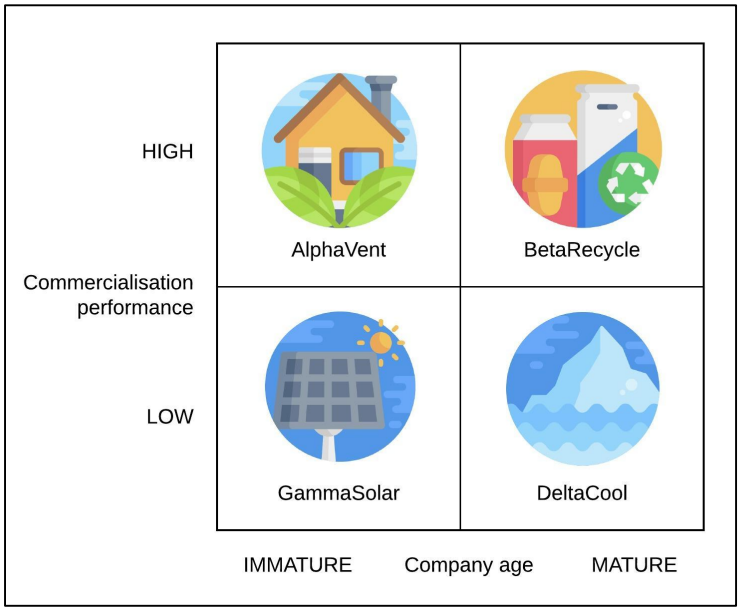

Figure 3-3: Case positioning matrix (Refer to Table 3-1)

USO / Detail	University laboratory	Founding team	Technology	Incorporation, age on 01 Jan 2017	Stage, commercialisation status	Case profile
AlphaVent (AV)	Department of Engineering	A senior lecturer and a professor	Novel natural ventilation system for buildings	16 Jan 2006, 10 years, 11 months (Immature)	Acquired (Product has been commercialised)	Immature USO with commercialised product
BetaRecycle (BR)	Department of Chemical Engineering and Biotechnology	A postdoctoral student and a professor	Novel waste packaging material recovery	23 Feb 2005, 11 years, 10 months (Mature)	Commercial availability (Product has been commercialised)	Mature USO with commercialised product
GammaSolar (GS)	Department of Physics	Three professors	Novel printed plastic solar module	22 Jul 2010, 6 years, 6 months (Immature)	Sample distribution (Product has not been commercialised)	Immature USO without commercialised product
DeltaCool (DC)	Department of Material Science and Metallurgy	A professor, a postdoctoral student and a physicist	Novel low-carbon, gas-free magnetic cooling design	1 May 2003, 13 years, 8 months (Mature)	Prototyping (Product has not been commercialised)	Mature USO without commercialised product

Table 3-1: Case profiles

3.4 Data Collection

With reference to the research questions, data was collected to satisfy three main inquiries: 1) how does a USO create value and embed it in a proposition in the face of market resistance; 2) how does a USO capture value in the face of financial pressure; and 3) how does a USO manage stakeholders with conflicting values? The two types of data collected in this research were interview data and archival data. Data were obtained from multiple sources and at various levels to enable triangulation (Miles et al. 2014; Yin 2014).

In preparation for the interviews with the USOs, efforts were made to understand the USOs' backgrounds and develop interview protocols to be tested in a pilot study. To build sufficient understanding for each case, extensive secondary archival data were gathered from multiple secondary sources. The data were then used to develop a comprehensive chronological timeline of each USO with three transitional stage (i.e. ideation, prototyping and commercialisation) (Vohora et al. 2004; Lehoux et al. 2014) based on TRL. The information provided significant insight into how the USOs developed business models in response to the challenges they faced. An example of a USO chronologic timeline is presented in *Appendix A*.

As discussed in the previous chapter, it was expected that interviewees' perspectives and cultures would be complex (Siegel et al. 2003). In response to this, two different interview protocols with slightly different lines of questioning were prepared. The first protocol was used in interviews with internal stakeholders (e.g. USO founders and CEO), and the second protocol was used in interviews with external stakeholders (e.g. TTOs, investors, partners and competitors). Examples of the interview protocols are available in *Appendix B*.

To refine the interview protocols, trial interviews were conducted with three interviewees: a CEO of an automotive USO based in Oxford, a USO investor based in Cambridge and a CEO of a medtech USO based in London. The interviews took place at Cambridge Science Park, Cambridge, in April 2016; St. John Innovation Centre, Cambridge, in April 2016 and UK IP Office, London, while attending an IP master class in May 2016, respectively. The cases were selected based on their convenience, accessibility and geographic proximity (Yin 2014). Each interview was guided by the protocol and lasted for 60 to 90 minutes.

The line of questioning in each round of the trial interviews allowed for progressive optimisation and minimisation of bias (Yin 2014). The scope of the pilot case inquiry was broadest in the beginning and narrowed as the protocol was optimised. As a novice interviewer, the pilot study exercise was effective for building confidence in the researcher's ability to conduct qualitative interviews and becoming familiar with probing follow-up questions based on interviewees' responses. In addition, scholars have argued that piloting provides the qualitative researcher with a clear definition of the focus of the study and its logistics, which in turn helps the researcher to concentrate data collection on a narrow spectrum of projected analytical topics (Easterby-Smith et al. 2015).

Upon gaining confidence and access to the cases, four sets of three-way Confidential Disclosure Agreement (CDA) were prepared. Prior to data collection, the agreements were signed by the chancellor, masters and scholars of the University of Cambridge, the researcher and the CEO (or equivalent) of the USO. An example of the agreement is presented in *Appendix C*. Then, stakeholders of each USO were interviewed one-on-one using the semi-structured interview technique guided by the refined protocols. Interviews were intended to gain insight into how business models were developed and why decisions were made.

Using a narrative approach (Rubin & Rubin 2011), each interviewee was first asked to describe his or her involvement in and knowledge of the USO from its inception to the present, with minimum interruption by the interviewer. Then, semi-structured interview questions were posed. The use of narrative interviewing minimised the influence of personal views and theoretical perspectives on data collection (Yin 2014). Contrary evidence was tolerated as diligently as possible. The interviews resembled guided conversations rather than structured questions, and the line of inquiry and stream of questions was fluid (Rubin & Rubin 2011). Each interview lasted for 60 to 90 minutes.

When performing data inquiry, caution was taken to avoid over-reliance on the input of key information, which may be biased due to reflexive influence (Eisenhardt & Graebner 2007). To factor in the bigger context of phenomenon under study, interviewees included participants who were external to the USO but had contributed considerably to the overall technology commercialisation process (e.g. TTOs, investors, partners, competitors, customers). Also, 12 additional interviews were conducted with technology commercialisation experts from around

Cambridge who were not directly related to the USOs. Interviewees were chosen based on their contribution to the evolving theory and experience. Decisions regarding whom to interview in each round were informed by ongoing analysis using a snowballing technique[22] (Saunders et al. 2000; Rasmussen et al. 2011). Interviewees with multiple positions in the USO were interviewed based on their different functional and hierarchal roles (e.g. academic inventor, CEO and investor).

Interview sessions were arranged and conducted at regular intervals throughout a 35-weeks period (May 2016 until January 2017). By the end of the data collection period, 48 interviews were conducted with key stakeholders directly related to the USO and 12 interviews were conducted with technology commercialisation experts. Although ten interviews were intended for each case, only eight interviews could be conducted with informants from AlphaVent. This was partly attributed to scheduling conflicts and unavailability of the key informant during the data collection period. In addition, the data collection process was interrupted by the USO's internal issues when AlphaVent was in the process of being incorporated by a larger company. This shortcoming was counterbalanced with external interviews and archival data collected from secondary sources. To enhance reliability, all 60 interview sessions were audiotaped with prior consent. The list of interviewees is presented in Table 3-2, and a detailed list of interviewees is available in *Appendix D*.

Informant / USO	AlphaVent	BetaRecycle	GammaSolar	DeltaCool
Academic founder	1	2	2	2
Board of director	1	3	3	3
TTO	3	4	3	3
Investor/partner	3	7	4	2
Competitor/other	0	1	1	0
Total interviews	**8**	**17**	**13**	**10**
Total verbatim transcription (pages)	**65**	**142**	**96**	**81**

Table 3-2: List of interviews

To avoid overabundance of data, all material was triaged and indexed based on its apparent relevance to the research inquiry. A list of the data collected from the interviews and the archives is presented in Table 3-3 and the overall steps of data collection is presented in Figure 3-4.

[22] Nonprobability sampling technique where existing study subjects recruit future subjects from among their acquaintances.

Data	Source	Data collected
Primary	Interviews	▪ Audio interviews conducted by the researcher with 8 informants from AlphaVent, 17 from BetaRecycle, 13 from GammaSolar, 10 from DeltaCool and 12 technology commercialisation experts from around Cambridge between May 2016 and Jan 2017 ▪ 65 pages of verbatim interview transcription for AlphaVent ▪ 142 pages of verbatim interview transcription for BetaRecycle ▪ 96 pages of verbatim interview transcription for GammaSolar ▪ 81 pages of verbatim interview transcription for DeltaCool ▪ 24 pages of interview notes extracted for commercialisation experts
Secondary	Interviews	▪ Audio/video of interviews with USOs conducted by other journalists on television/radio programmes (e.g. Naked Science, BBC)
	Archival data	▪ Information about USOs retrieved from their websites
		▪ Information about USOs retrieved from the House of Companies UK website
		▪ Published articles about USOs from the Cambridge Enterprise website and SpinoutsUK database
		▪ Published articles, news, news releases, reports and comments/commentaries about USOs retrieved from Factiva and Bloomberg
		▪ Full credit report of USOs downloaded from the Jordans Group Limited website
		▪ U.S. patents awarded to USOs retrieved from the U.S. Patent and Trademarks Office database and Espacenet database

Table 3-3: List of data collected

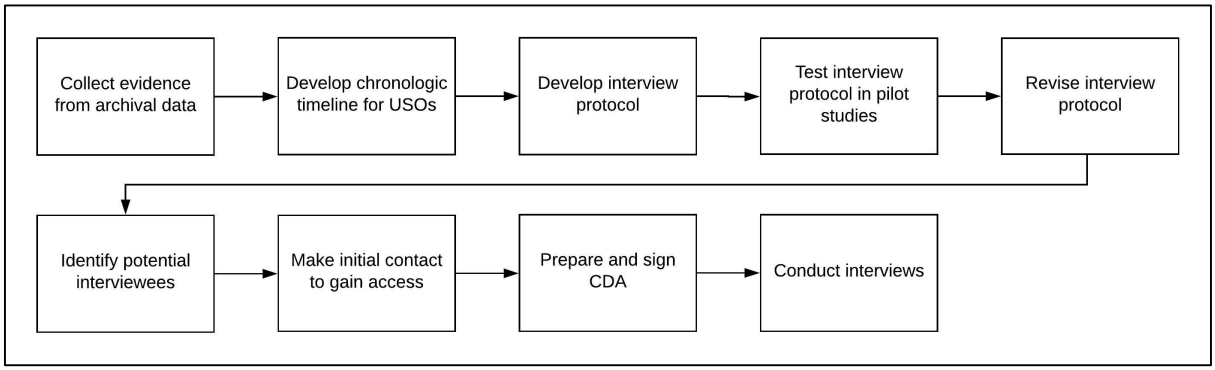

Figure 3-4: Steps for data collection

3.5 Data Analysis

Prior to data analysis, all 48 key interviews were transcribed verbatim using ExpressScribe, a professional audio player software designed to help transcribe audio recordings. Transcription allowed familiarity to be developed with the collected data (Charmaz 1996). The procedure was then followed by a careful vetting process to correct inaccuracies that occurred in the generated transcripts. 12 non-key interviews conducted with technology commercialisation experts were not transcribed verbatim; instead, the audio data were replayed and key points from the interviews were extracted and typed. The transcription and extraction of key points for all 60 recorded interviews took 17 weeks (February until June 2017) to complete and resulted in 384 pages of transcriptions and 24 pages of notes (Times New Roman, 11 point, single spacing).

The transcriptions and notes were then reduced to eliminate redundancy, filler, mispronunciations and incomplete and repeated sentences. At this stage, caution was taken to not eliminate information based on assumptions of what counts as significant data. This exercise resulted in cleaner data for analysis (Miles & Huberman 1994; Easterby-Smith et al. 2015). To enable triangulation, the reduced data was cross-mapped against the USO's chronologic timeline, which was developed using archival data. The chronological sequence of key events and key data from informants were validated, and inconsistencies were investigated. The data were then ready for analysis.

To build a theory from a case study, the current thesis employed a grounded approach to analyse the data (Glasser & Strauss 1967; Corley & Gioia 2004). Scholars argue that a grounded approach is suitable for discovering and defining complex process (Corbin & Strauss 1990; Charmaz 1996; Gioia et al. 2013). During the late stage of the analysis, the template analysis approach (King & Brooks 2012) was also used to link the emergent findings with the four premises borrowed from effectuation theory and the concept of opportunity creation. Data analysis performed using the grounded approach allowed a theory to emerge from the data. Template analysis, which is an extension of a grounded approach, identifies systematic interference from qualitative data that has been structured by a set of concepts (Easterby-Smith et al. 2015).

Reconciliation of both self-reinforcing techniques represented a means of triangulation and was useful to avoid forgoing empirical knowledge that leads to the production of an unstructured manuscript that would only contribute to the literature marginally (Suddaby 2006). In addition, the most prevalent abuse of the grounded approach as a means of analysing data occurs when researchers have insufficient prior knowledge of the extant literature (Suddaby 2006). Easterby-Smith (2015) states that template analysis is located at the interface between content analysis (in which codes are strictly predetermined) and grounded theory (in which codes emerge during analysis) and hence is an appropriate method of triangulation.

The overall coding process was segmented into four rounds, each of which involved constant comparison to assure the emergence of substantive theory (Glaser and Strauss 1967; Gibbert and Ruigrok 2010). The first round of intra-case, line-by-line, open coding[23] was conducted manually using a pen and paper. This was done to independently identify the key events involved in the commercialisation of university technology in each USO. Throughout the coding process, key depictions of ways in which USOs developed business models in response to multifaceted challenges were identified. Since the concepts have yet to be proven to be theoretically meaningful, data were analysed without imputing any motives (Charmaz 1996). Results of the first round of intra-case open coding is presented as descriptive case studies in Chapter 4.

Once all the individual cases were manually framed and data familiarisation was obtained, the second-round coding was conducted. This round involved electronic inter-case, open coding using QSR NVivo 11 software, a computer-assisted qualitative data analysis (CAQDAS) programme (Rubin & Rubin 2011). This time, open coding was conducted to identify the measures adopted by USOs across four cases to develop business models. At this stage, tentative labels were assigned to the data based on their respective meanings. Following Sudabby (2006), the four borrowed premises from the effectuation logic and concept of opportunity creation (i.e. take control, create opportunities, forge partnerships and embrace contingencies) were loosely employed to guide the coding process. Through a creative leap (Langley 1999), insights that emerged across cases were cross-compared to identify similarities and differences (Eisenhardt & Graebner 2007). The similarities and differences were registered

[23] Open coding is the processes of analysing textual content which involves tentative labelling of concepts. Basically, a researcher reads through data and create tentative labels for chunks of data observed.

in the form of comments, annotations and memos. To enhance the visibility of data, tables with three main queries based on the research questions were built and filled (Miles & Huberman 1994).

The third round of inter-case coding was performed to structure and synthetise the data across the four cases. This time, the codes were aggregated at a higher level of abstraction (Miles & Huberman 1994). All categories were grouped into higher-level themes through axial coding[24] and aggregate dimensions through selective coding[25.] Axial coding consists of identification of relationships among open codes, and selective coding was used to identify the core variable that includes all of the data (Charmaz 1996).

Finally, selective coding using template analysis approach was performed to formally track the connection between the codes and the four borrowed premises and to explain business model development. The premises were employed as placeholders for predefined themes (Gibbs 2002). The multiple rounds of coding was laborious and required repetitious visitation of data until category saturation was achieved (Corbin & Strauss 1990). The process was highly iterative, taking about 21 weeks (July until December 2017) to complete. It also required a second and third round of interviews with several key informants. Throughout this process, this thesis acknowledged the dynamic process of field research, as new patterns emerged during data analysis (Edmondson & Mcmanus 2007).

Since the process of data analysis relied heavily on the researcher's interpretation, which might be biased due to subjectivity, inter-coder assessment was undertaken (Corley 2002) to enhance the robustness of the data and demonstrate the plausibility of the emergent findings (Lavrakas 2008). Four assessors not involved in the research—three postdoctoral researchers and one doctoral student at the Institute for Manufacturing, University of Cambridge, UK—were enlisted to assist the exercise. Using a Q-sort technique[26,] the assessors were asked to replicate

[24] Axial coding is the processes of breaking down of core themes via a combination of inductive and deductive thinking. Basically, a researcher identifies the connections among the open codes.
[25] Selective coding is the process of choosing one category to be the core category, and relating all other categories to that category. Basically, a researcher selectively codes any data that relates to the core variable identified.
[26] Systematic study of participant viewpoints used to examine complex subjective structures like opinions, attitudes and values. In Q-sort technique, participants are asked to sort a set of statements representing a broad diversity of opinions and perspectives on the phenomenon being investigated (Kitzinger 1987).

the coding process by matching 21 randomly selected interview quotes with 21 categories, 21 categories with six themes and six themes with three aggregate dimensions.

The inter-coder reliability coefficients ranged from 0 (complete disagreement) to 1 (complete agreement). In most studies, coefficients of 0.90 or greater are considered highly reliable, while coefficients of 0.80 or greater are considered reliable (Corley 2002; Lavrakas 2008). The level of agreement achieved between the researcher's coding efforts and those of four independent assessors is presented in in Table 3-4 below.

Assessor	Codes – categories match	Categories – themes match	Themes – dimensions match	Average agreement
Assessor # 1	1.00	0.83	0.67	0.83
Assessor # 2	0.83	0.75	1.00	0.86
Assessor # 3	1.00	0.83	1.00	0.94
Assessor # 4	1.00	0.75	1.00	0.92
Average agreement	0.96	0.79	0.92	**0.89**

Table 3-4: Inter-coder assessment results

Although the inter-coder agreement was well within the range of reliability, the disagreements between the researcher and assessors were discussed at the end of the assessment. The discussion revealed that none of the disagreement was rooted in poor operational definitions and hence did not result any alternative perspectives. Rather, it was mostly caused by overlap of themes due to the interrelatedness of business model components (e.g. measures taken to create value may also be applicable to measures taken to capture value). Following Van Maanen (1979) and Gioia et al. (2013), once data were synthesised and finalised, they were tabulated as a data structure consisting of the first-order category, second-order themes and aggregate dimension structure (Figure 3-5).

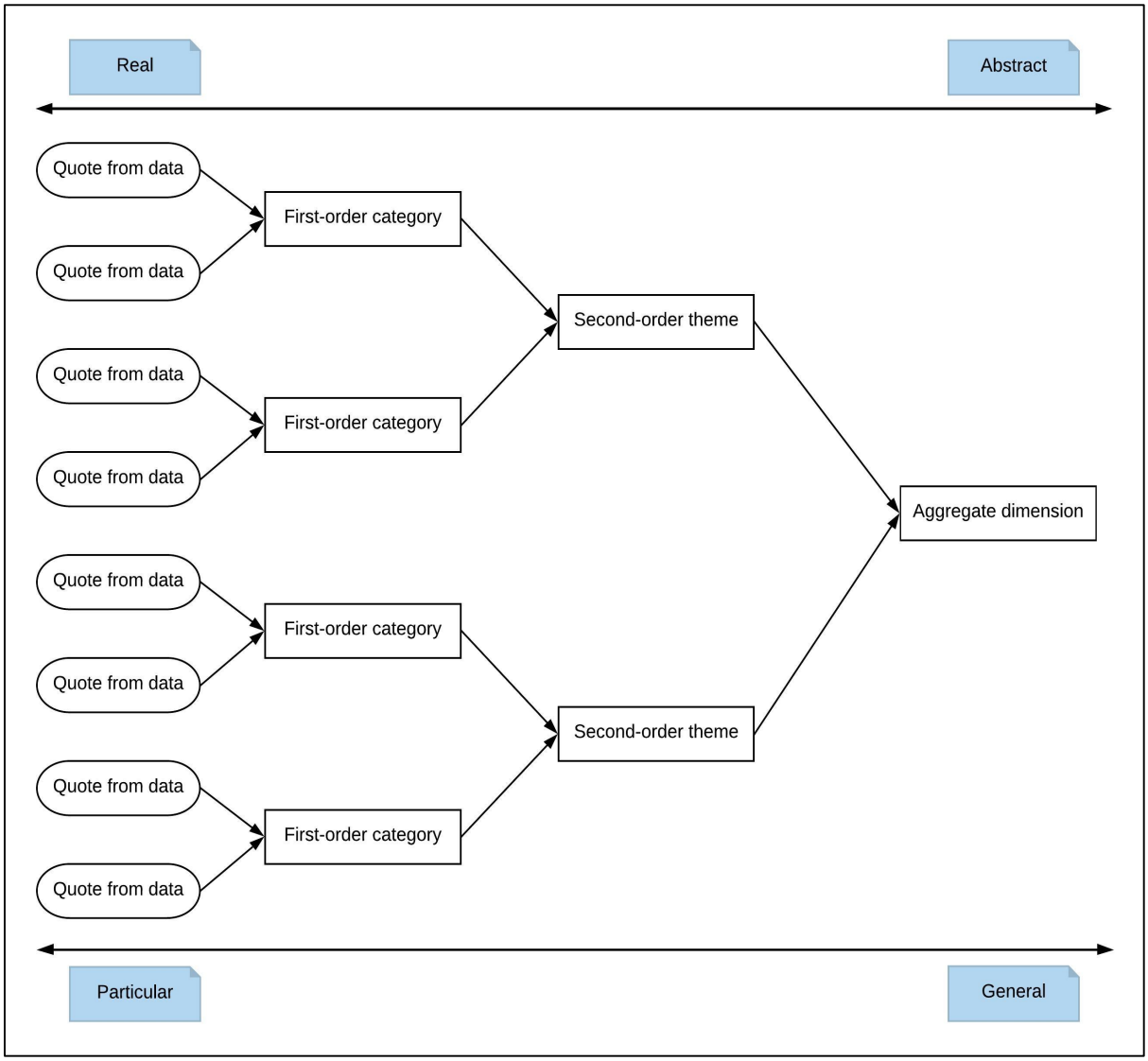

Figure 3-5: Template for data structure (See Van Maanen 1979; Gioia et al. 2013)

Synthetised data were further analysed based on the extant literature and integrated in a conceptual framework in Chapter 5, which illustrates the key findings of the research. Each case was thoroughly analysed to identify the relationships between constructs, and cases were compared with each other to progressively develop a richer theoretical framework. Throughout this process, the literature was frequently re-examined to relate the findings with extant theories (Miles & Huberman 1994). A summary of the overall steps taken to analyse the collected data is illustrated in Figure 3-6.

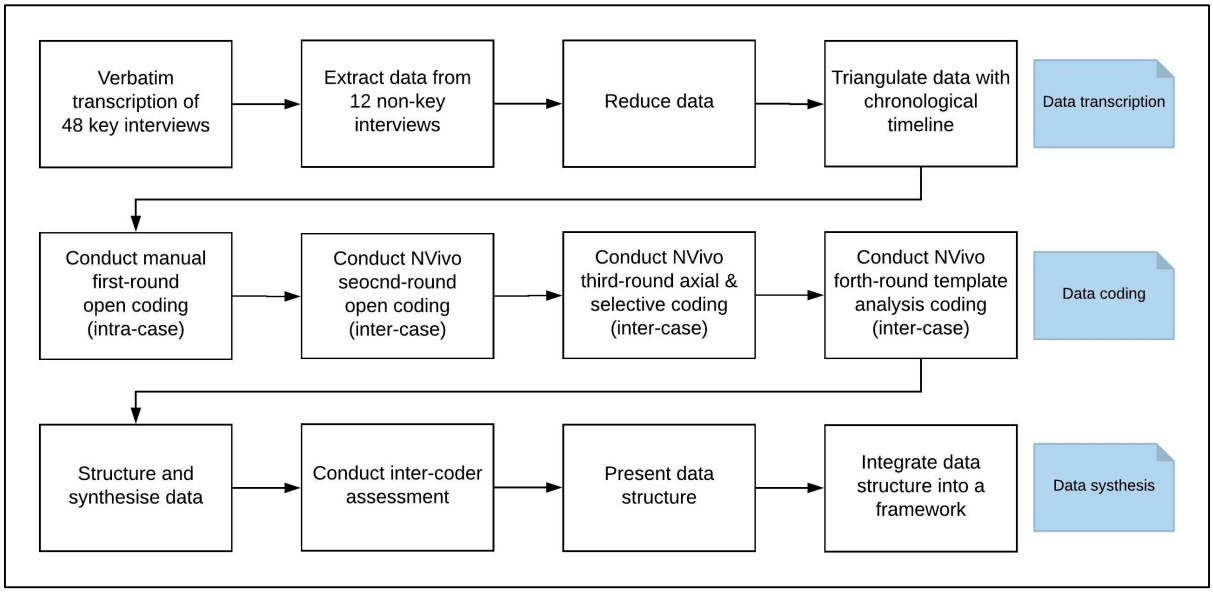

Figure 3-6: Data analysis steps

3.6 Research Quality, Rigour and Ethics

The research design described in the previous sections represents a logical set of statements that can be judged through several tests commonly used to validate the quality and rigour of empirical social research (Yin 2014; Easterby-Smith et al. 2015). In this study, four tests were conducted to substantiate the construct validity, internal validity, external validity and reliability of the research in an effort to enhance its quality and rigour.

First, to improve the quality of this study based on construct validity, multiple sources of evidence were used to build a chain of evidence. Key informants were also included to review the draft of the case study report. Second, to enhance internal validity, pattern matching was conducted to assure that the sequence was checked for the presence of constituents and potential rival explanations were systematically addressed. In addition, inter-coder assessment was conducted to enhance the plausibility of findings. Third, to enhance the generalisability of the findings, the comparability of the environmental contexts of the USOs in this study and the USOs in other universities was maximised (Yin 2014). Finally, to ensure reliability, every procedure involved in the protocol and database was documented and systematically stored (Miles & Huberman 1994; Saunders et al. 2000; Yin 2014). All tactics used to ensure the quality and rigor of research are summarised in Table 3-5.

Test	Aim	Tactics used by this research	Phase
Construct validity	To identify the correct operational measures for the concepts being used	▪ Used multiple source of evidence ▪ Established chain of evidence ▪ Had key informants review a draft of the case study report	▪ Data collection, data analysis
Internal validity	To establish a causal relationship whereby certain conditions are believed to lead to other conditions	▪ Conducted pattern matching ▪ Addressed rival explanations ▪ Conducted inter-coder assessment	▪ Data analysis
External validity	To define the domain in which findings can be generalised	▪ Used replication logic in multiple-case studies ▪ Retained a homogenous case setting	▪ Research design
Reliability	To demonstrate that the operations of a study can be repeated with the same results	▪ Systematically documented procedure ▪ Used case study protocol ▪ Used multiple cases	▪ Data collection

Table 3-5: Tactics to ensure the quality and rigour of the research

Research ethics are defined as the appropriateness of a researcher's behaviours in relation to the rights of those who become the subject of work or are affected by it (Saunders et al. 2000). This research aspired to the highest possible ethical standards and maintained strong professionalism and competence by, for example, keeping up with related research, ensuring accuracy, striving for credibility and divulging methodological qualifiers and limitations (Yin 2014). Three measures were adopted to ensure that the ethical considerations of the research were adhered to. The measures were manifested during the research design, data collection, data analysis and reporting stages.

First, during the research design stage, cases were equitably selected using a two-staged, purposive and homogeneous sampling procedure to ensure that no group was excluded or included unnecessarily. A case study is not a way to substantiate a preconceived position (Yin 2014). Second, during data collection, informants' confidentiality was protected to ensure that they were not unwittingly put in an undesirable position. The signed CDA required the researcher to ensure that the outcomes of the inquiry did not interfere with the business of the companies and people that contributed information. Thus, all communications with informants were treated with strict confidentiality. In addition, any data that could reveal the identity of participants were intentionally omitted from this manuscript. After scrutiny of the nature of the case study and formally soliciting volunteers, each interviewee also provided informed consent

to participate in this research. Lastly, during the data analysis and reporting stages, the collected data were interpreted justly and reported correctly. This study tolerated contrary findings. The confidentiality and anonymity of the cases and informants were continuously maintained throughout the reporting stage. The overall research design and process are presented in Figure 3-7.

3.7 Chapter Summary

The aim of this chapter was to describe and justify the methodological approach adopted in this study, in particular, the plan of enquiry to answer the question posed earlier. Based on its philosophical stance, this research was conducted using an inductive, cross-sectional, multiple-case study design. Four cleantech USOs were purposely selected. Data from 60 interviews and a substantial amount of archival data were collected using multiple triangulation techniques. The collected data were analysed using the grounded approach and template analysis approach. The next chapter will individually describe each case. A detailed examination is performed for each case's journey to commercialisation of new university technology and the resultant business models.

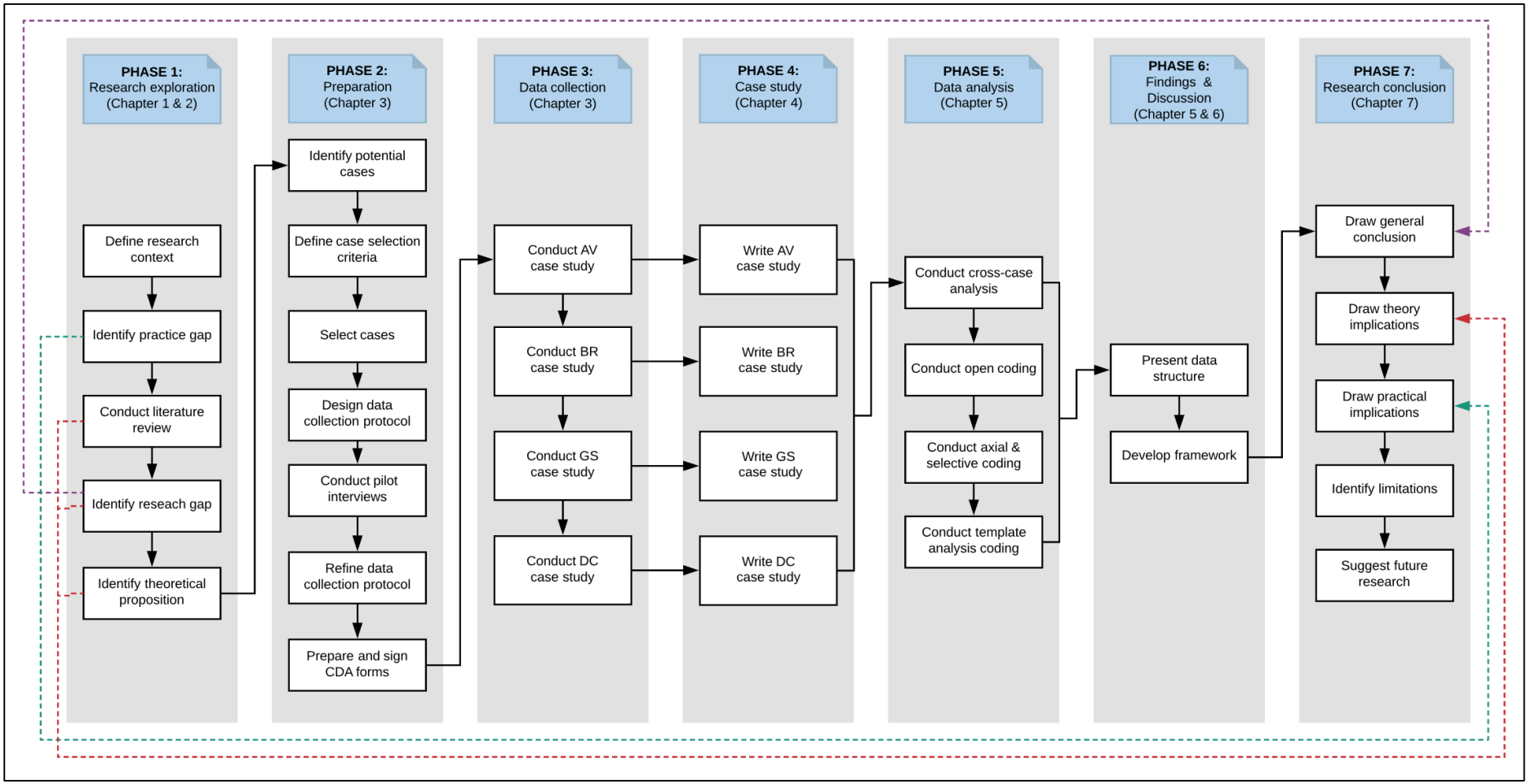

Figure 3-7: Research design and linkages between chapters

4 CASE STUDIES

4.1 Chapter Introduction

This chapter details the four case studies used as primary sources of evidence to satisfy the research question earlier posed. Section 4.2 provides a general background of the cleantech industry and justifies the selection of cleantech as the industry of choice. Following that, sections 4.3, 4.4, 4.5 and 4.6 present the case studies for AlphaVent, BetaRecycle, GammaSolar and DeltaCool, respectively. Each case is reported in a descriptive way, following the history of technology commercialisation throughout the ideation and incorporation, prototyping and commercialisation stages. The resulting business models are also discussed. Finally, section 4.7 summarises this chapter.

4.2 Industry Background

Also referred to as clean technology, 'cleantech' is an industry term and investment theme used in multiple settings but lacking a standard definition. Some practitioners argue that cleantech is not an industrial sector in itself, and its definition involves the congruence of technologies focusing on sustainability, mitigation and adaptation to climate change or reduction of natural resources (Caprotti 2012). Similarly, Kachan and Fugere (2013) define cleantech as new technology and/or related business models intended to provide a diverse range of products, services and processes using renewable materials and energy sources while reducing the use of natural resources and cutting or eliminating emission and waste. It also aims to provide superior performance at low costs. Cleantech is often used interchangeably with the term 'greentech', which is an umbrella term encompassing investment assets, technology and business sectors that include clean energy, environmental and sustainable or 'green' products and services[27].

Cleantech is a relatively new technology sector which rose in prominence starting 2002 (Kachan & Fugere 2013). The primary interest of cleantech industry lies in the decline of the relative cost of clean technology and increased understanding of the link between industrial design in the 19th century and in the early 20th century (Cohen & Philipsen 2010). Going forward, the driving forces of cleantech are intensified partly because of resource scarcity, resource independence, climate change, changing policy and regulatory requirements (Kachan & Fugere

[27] What is Cleantech? (Dikeman, N., 2015). Available at: http://www.cleantech.org/what-is-cleantech/

2013). Historically, the general perception of cleantech was limited to clean energy. However, growing investments in clean infrastructure, technology and services are being made across all sectors of the economy, including storage, efficiency, water, clean industry and transportation. As depicted in Figure 4-1, the categorisation of cleantech is complex and spans diverse industrial sectors, with wind and solar (part of the clean energy sector) constituting the biggest subsector.

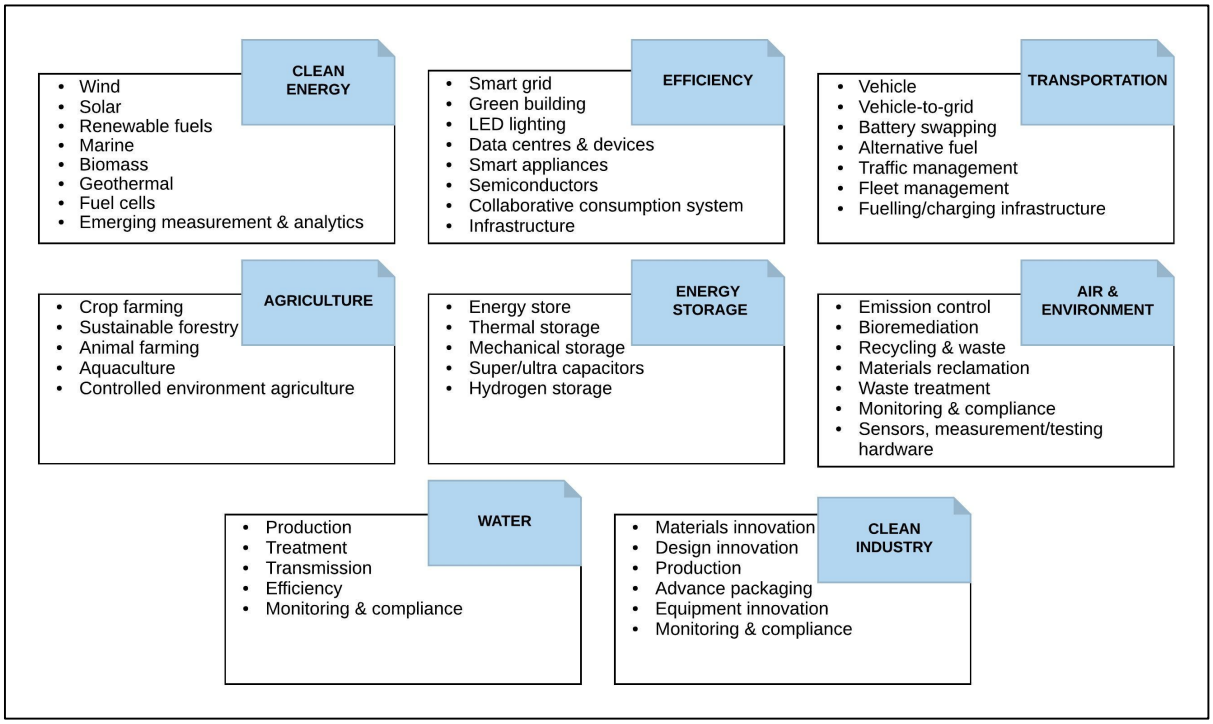

Figure 4-1: Major groupings of cleantech sectors (Source: Kachan & Fugere 2013)

Presently, cleantech is becoming more ubiquitous and is poised for even more rapid expansion. In addition, it is recognised as a tool to achieve sustainable industrialisation. A new analysis by Bloomberg New Energy Finance (BNEF) (Figure 4-2) showed that, in 2017, global spending on clean energy (the biggest cleantech subsector) projects reached USD 333.5 billion. This represented an increase in 3% from the previous year and was only 7% short of the record USD 360 billion spent in 2015. In addition, cumulative spending on clean energy has reached USD 2.5 trillion since the start of the decade.

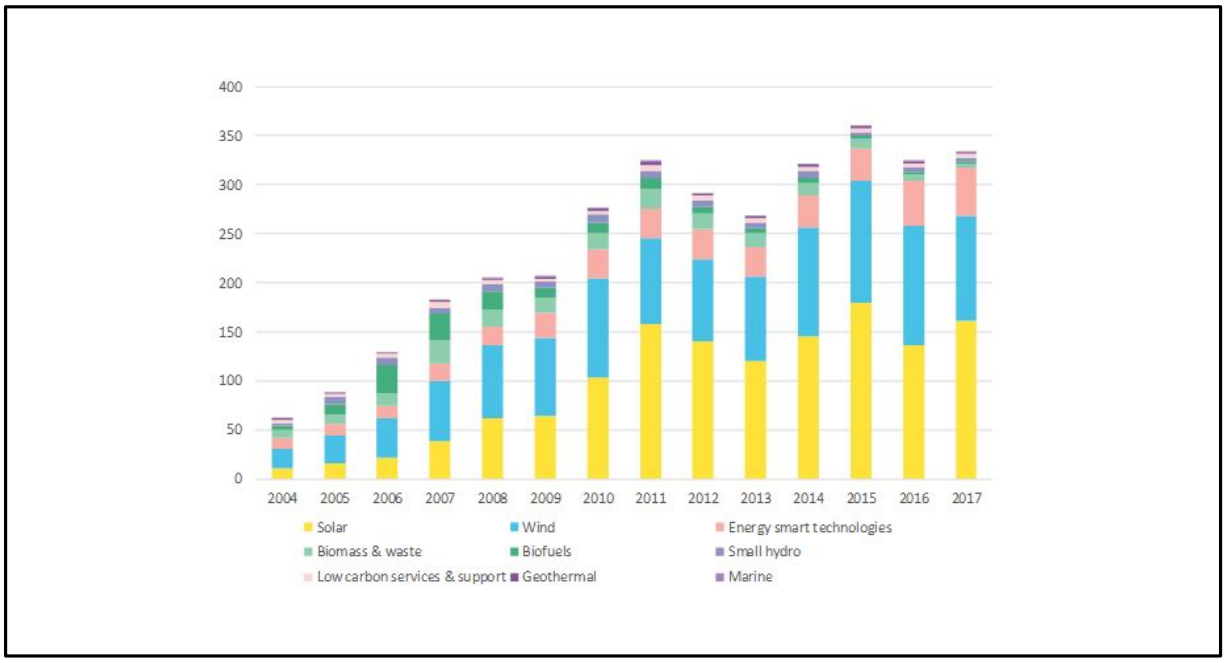

Figure 4-2: New global investment in the clean energy sector (in billion USD) (Source: Bloomberg New Energy Finance (BNEF))

With the steady investments in cleantech, more cutting-edge technologies are able to respond to the global energy and climate challenge issues. Cleantech firms are now at the forefront of technological advancement and the transition to a sustainable industry (Del Río 2005). Mrkajic et al. (2017) argue that most of these breakthrough technologies originate in entrepreneurial ventures like USOs rather than incumbent corporations. However, few cleantech USOs manage to transform their technology into big commercial successes (Migendt et al. 2017). Moreover, the establishment of a cleantech USO is not as common as other technology USOs, like those focusing on software, biotech and medtech (Lubik & Garnsey 2016). Unlike incumbent corporations, cleantech USOs seem to encounter all the challenges faced by USOs in other industries with added uncertainty associated with existing in a high-inertia and commodity-driven industry.

First, cleantech USOs are least preferred by inventors and VCs because they are uncompetitive in commodity markets, and hence, investors struggle to find attractive risk-reward premiums for their investments (Knight 2012). The conflicting motivations of cleantech entrepreneurs and investors usually only result in short-term financial gain (Migendt et al. 2017). Unfavourable cleantech investments are prevalent at the early-stage and further exacerbated by the financial crisis in 2008 (McCrone et al. 2012). Second, the length of cleantech commercialisation cycles is generally greater than in other fields, such as biotech, software and

medtech because scaling up is difficult. Due to its nascent stage, a cleantech USO always requires complementary innovations because it is still remote from the end customer (Lubik & Garnsey 2016). Finally, cleantech USOs demand stronger market pressure from the critical mass of the private sector, government and academic actors that support widespread adoption (Giudici et al. 2017).

Bocken (2015) and Migendt et al. (2017) argue that the factors affecting cleantech USOs' success are the novelty of the business model and collaboration with different firms. Despite this, limited work has focused on business models suited to the commercialisation of scientific research on celantech, and there seems to be relatively little information available on the ecosystem of young cleantech enterprises (Gaddy et al. 2017) A thorough investigation to understand the underlying strategy for a viable business model underscores an upmost importance in the transition to sustainable economies.

4.3 Case 1: AlphaVent

AlphaVent is a company developed within the Department of Engineering in 2006 following the discovery of a propriety e-stack mixing ventilation system. The realised business model involves manufacture, customisation and sale of cheaper, more efficient and greener natural ventilation systems to building owners. AlphaVent was incorporated about six years after the idea was fleshed out. After two years of successful prototyping, the USO launched its product into the market and managed to hit the first sales milestone within the same year. In 2016, AlphaVent was acquired by a bigger firm. In 2017, AlphaVent was 10 years old and had already launched its product into the market. Hence, it was a case of an immature USO with commercialised products. The firm's commercialisation journey across TRLs and commercialisation stages is presented in Figure 4-3.

Ideation and Incorporation (2000–2006)

AlphaVent technology was developed based on research conducted by a senior lecturer from the Department of Engineering and an eminent professor from the X Institute focusing on low-energy natural ventilation. The lecturer previously worked as a strategy consultant at a financial firm, and the professor was the head of the X Institute in Cambridge. The research was funded by an international oil and gas firm as part of the Cambridge–MIT Institute (CMI) Partnership Programme, which aimed to exploit research findings for the benefit of society and the

economy of the UK. In line with the aspiration of the CMI Partnership Programme, the lecturer aligned his research with feedback from the architects to devise a novel solution for ventilating buildings with fresh air in the winter months without freezing the occupants.

In 2003, the inventors discovered a new way to provide natural ventilation to buildings by adopting a propriety e-stack mixing ventilation system, which was claimed to have the potential to reduce heating bills by as much as 50%. The new technology exploited the heat produced by people, lights and sunlight and avoided wasteful use of radiators. Provision of energy to buildings accounts for around 40% of the energy consumption in the developed world[28]. In 2004, the inventors applied for a patent on their passive ventilation stack invention. While waiting for the patent to be filed, the inventors talked with other people from the industry to refine the technology and develop it into products with the maximum impact on the marketplace. The patent was then filed in May 2005. According to the inventor,

> *"When we filed the Cambridge University patent, we knew we were onto something big. No one had previously understood the energy saving achieved by mixing in a natural ventilation scheme. All the natural ventilation system on the market simply dumped cold air in winter, or used energy-hungry radiators to try and overcome cold draughts."*

In January 2006, AlphaVent was founded, with the lecturer assuming the role of CEO and the professor assuming the role of technical director. In January 2010, four years after its incorporation, AlphaVent changed its name to one that is more relatable to its technology. Having successfully established a company, the funder, TTO and the founders acknowledged the commercial terms that allowed the funder and the TTO to hold shares in the USO through an equity-only agreement, and AlphaVent was given royalty-free, exclusive commercial rights to the university-owned technology.

[28]Source: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

Prototyping (2006–2008)

With ongoing funding from the international oil and gas firm for the development of its prototypes, AlphaVent spent the first two years concentrating their efforts on the proof of concept and validation of the technology in a real environment. Since the technology was not fully developed, it was agreed up front that once the product is market-ready, either AlphaVent or the funder will be the commercial entity associated with the new technology; if the funder commercialised the technology, then they would pay AlphaVent an ongoing royalty, or vice versa.

In 2006, AlphaVent piloted the first version of its eco-ventilation system in schools across the UK. The gathered data were used to determine the appropriate control algorithm for multiple e-stack systems in the winter prior to proposing practical applications to contractors and architects who declared interest in the technology. While actively advocating its technology, AlphaVent also invested in market research and constantly reviewed current and upcoming regulations that would support their offerings.

By 2008, the firm managed to optimise its ventilation system with energy savings of 10 to 50 megawatt (MW) per hour of pre-heat, equivalent to carbon dioxide (CO_2) emissions of two to 10 tonnes per year. Compared with a mechanically air-conditioned system, savings of 40MW per hour per year, equivalent to eight tonnes of CO_2 emissions, were achieved. The firm began to enjoy greater traction among investors and customers. AlphaVent also established a positive market presence because its technology was novel and it had received many awards, including the Project of the Year at the 2008 RICS Pro Yorkshire Awards.

Commercialisation (2008–2017)

AlphaVent started to commercially introduce the e-stack system into the market in 2008 and began to sell its ventilation systems and commercial projects within the same year. However, the sales made during that time were only sufficient for its survival as a start-up. Given what AlphaVent achieved as a young firm, consensus was achieved between the funder and AlphaVent that AlphaVent would continue to be the commercial entity. However, rather than receiving ongoing royalties from AlphaVent, the funder decided to sign an equity-only agreement partly because the USO's core business did not align with the funder's commercial business concerning oil, gas and related technologies.

Around 2008, the industry was hit by the recession and, as a result, AlphaVent decided to compete based on price. The CEO described the competition as harsh in his interview:

> *"The competition was really harsh. You're competing on price for an equal or approved product. If it's a better product, then we learned that you can't charge much of a premium for it. It's not, given the structure market, if anything at all, but if you're offering a better product, then people are very interested in talking to you."*

In the following years, AlphaVent tried twice, unsuccessfully, to outsource its sales function, missed its sales forecast and almost lost its momentum. Despite this, a deal with a VC was signed in 2009, allowing the USO to invest in product development while extending its sales team. In 2014, AlphaVent's patent was infringed upon, causing a loss of five projects worth approximately GBP 300,000 of potential income.

Over the years, the firm continued to create value for building owners, with operations revolving around quicker and higher returns on investment. The benefits of mixing ventilation became clearer when written into regulations, such as the BB101 Guidelines on Ventilation, Thermal Comfort and Indoor Air Quality in Schools. Since then, AlphaVent's technology has been implemented in more than 300 buildings in the UK. In the 2015/16 financial year, the firm exceeded its revenue forecast of more than 30% growth with average three-year sales growth of 52.25% and recorded sales of GBP 7.8 million. In December 2016, after 10 years of establishment, AlphaVent's entire share was bought by an international supplier of ventilation products to the residential and commercial construction markets.

4.4 Case 2: BetaRecycle

BetaRecycle was incorporated in 2005 following the discovery of a novel technology to recover useful materials from plastic aluminium laminate (PAL), which is widely used in packaging but is not fully recyclable. The research was conducted at the Department of Chemical Engineering and Biotechnology as a PhD research in 1997 and advanced as a postdoctoral research in 2002. After spending about two years prototyping, BetaRecycle assembled a bench scale demonstration unit and launched its proven technology in 2008. The business model involved customisation and sale of greener PAL recovery plants for waste handlers. However, the USO has not made any sales yet. In 2017, BetaRecycle was 11 years

old and represented a case of a mature USO with products and service that were already launched in the market. The firm's commercialisation journey across TRLs and commercialisation stages is presented in Figure 4-4.

Ideation and Incorporation (1997–2005)

The ideation of BetaRecycle can be traced back to a PhD research that investigated the environmental applications of microwave heating of carbon, specifically, microwave-induced pyrolysis for plastics. It was steered by a young researcher and supervised by a well-known professor, who was the former head of the Department of Biochemical and Environmental Engineering. Using the pyrolysis process, both scientists discovered a novel technology that could recover oil and aluminium from PAL. The findings translated into a new approach to the recycling of PAL, which is widely used in product packaging and was not previously fully recyclable. It is estimated that roughly 160,000 tonnes of PAL rubbish is disposed of in UK landfills each year[29]. BetaRecycle's technology offers a solution to eliminate the need to send PAL waste to landfills or incinerators and prevents valuable resources from going to waste.

In 2002, while pursuing his postdoctoral research, the researcher approached the technology transfer unit to discuss the future of the newly discovered technology. During that time, the university TTO had not yet been established and the IP policy for revenue distribution was not fully articulated. It was agreed that the university would bear the cost of patenting the new technology and would co-own the patent, the researcher would get two-thirds of the royalties of the patent and the university would get one-third. A patent for the microwave-induced pyrolysis reactor and method was applied for in 2002 and filed in December 2003. According to the CEO, he initially did not anticipate founding a company after his research discovery:

> *"I went to the research service division when I was halfway through postdoc work, I said, 'We have this idea we think is commercial, what do we do?' I knew nothing, absolutely nothing, about how to commercialise this, I didn't even know where to start. To be quite honest, I did not foresee founding a company, I just knew that there was a potential commercial opportunity and I wanted someone to do something with it."*

[29]Source: https://www.cam.ac.uk/research/features/where-theres-muck-theres-aluminium-if-not-brass

Through one of the initiatives in the technology transfer unit, called the Challenge Fund, the researcher was put in contact with entrepreneurial mentors. The mentors convinced the researcher to establish a company so that there would be an official platform to develop and validate the technology. This suggestion led to the incorporation of BetaRecycle as a private limited company in February 2005, with the researcher assuming the role of CEO and the professor acting as chairman of the board.

Prototyping (2005–2007)

In May 2005, with the help of the mentors in the Challenge Fund, the USO developed a business plan and entered two university entrepreneurial competitions, the 50k Business Creation Competition and the People, Planet, Productivity Cambridge University Entrepreneurs Business Plan Competition. Although no prototype was established, BetaRecycle won both competitions and secured a seed investment of GBP 200,000. However, the investors agreed to release the investment fund only if BetaRecycle managed to produce a small-scale prototype. The Challenge Fund agreed to invest in a small-scale prototype with a convertible loan. The prototype was then developed over several months.

The seed investment allowed BetaRecycle to build its execution team and kick-start the work for its first demonstration unit prototype over the nine months. From 2006 onwards, the firm was focused on validating the technology in a relevant environment. One of the angel investors requested to join the board, after which he became heavily involved in BetaRecycle. After about a year of sitting on the board, he took over BetaRecycle's chairmanship in September 2006. The professor, who was the former chairman, still sits on the board as a non-executive member. As a novice entrepreneur, the CEO received coaching advice mostly from the new chairman, who was a serial entrepreneur.

While BetaRecycle was working on the demonstration unit prototype, several fast-moving consumer goods (FMCG) firms and government agencies, expressed their interest and wished to support the development of the technology to gain early access to its industrial applications. However, the prototyping stage was challenging and, as a result, BetaRecycle took longer than expected to build the demonstration unit. They only moved from the proof of concept stage to the prototyping stage in 2007, when the firm finally managed to get the prototype unit working. During that time, BetaRecycle was still the first firm in the world to use microwave-induced

pyrolysis technology to recycle PAL, with a break-even point of 3.5 years. The previous chairman described the long time required to take the product to market as follows:

> *"…it has taken us much longer time to iron out the problems of operating this technology at scale, I'd say nobody had ever done it before, so we had to solve unforeseen issues as we went and I think it's fair to say that it has taken us longer than we had ever hoped."*

Commercialisation (2007–2017)

Upon completion of its demonstration unit, BetaRecycle actively promoted its proven technology and tried to gain stronger traction among potential customers involved in the PAL value chain. It aimed to customise and build recycling plants for FMCG companies, local authorities and waste handlers. Unfortunately, the 2008 financial crisis caused a significant collapse in demand for industrial commodities. As a result, potential customers were no longer interested in buying the plant. According to the CEO,

> *"Whoever a few years ago had said, 'Oh yeah, we'll buy a plant for sure, whenever you're ready, here's the cheque,' kind of thing, now are saying, 'Well, with the price of commodities and how they are, I'm not interested now.' You can shout at them as much as you want, show them any number of studies showing that the price of oil and the price of commodities will not stay at the levels that they are at now, they just don't care."*

BetaRecycle faced a challenging commercialisation stage when none of the targeted customers seemed to perceive the value as how the USO had wished to advocate it. Further, there was still no segregation platform that would separate PAL from other general waste, and therefore adoption of the technology meant that waste handlers needed to have capital not only to buy the plant but also to invest in waste segregation. Moreover, when it comes to recycling, stakeholders still had the option to bypass the recycling process because the conventional method of dumping waste at the landfill or incinerating it was still legal. Scaling up was also difficult partly due to the lack of regulation or policies to drive the technology forward.

In 2011, BetaRecycle entered a partnership with the Waste and Resource Action Programme (WRAP) to fund a trial which successfully proved that BetaRecycle's process was technologically and environmentally sound. In the same year, the USO received the Best New Technology award at the National Recycling Awards. In 2012, the USO decided to build its first commercial-scale plant to allow the technology to be fully commissioned and demonstrate the capabilities and economics of the process to investors and waste handlers. In 2013, three FMCG giants agreed to co-finance the establishment of the plant and, in return, were given the right to use BetaRecycle ecolabels on their food packaging. In 2016, when the plant was fully operational, BR entered negotiations with a serious buyer who wanted to buy a plant. BR was also in an arrangement with a PAL manufacturer to recycle its industrial scrap for less than what they would have spent sending it to landfill.

4.5 Case 3: GammaSolar

GammaSolar is a firm developed within the Department of Physics in 2012 that aimed to produce lower-cost solar energy using organic photovoltaics (OPV). The intended business model involved manufacture, customisation and sale of higher-performance OPV modules for off-grid users. The prototyping stage started at the end of 2010 and is still ongoing. GammaSolar was about six years old in 2017 and had not officially launched its product in the market. Therefore, the USO represents a case of an immature USO without commercialised products. The firm's commercialisation journey across TRLs and commercialisation stages is presented in Figure 4-5.

Ideation and Incorporation (2007–2010)

GammaSolar was founded after three professors at University of Cambridge's Department of Physics won a Carbon Trust-funded project aimed to unlock the potential of OPV to deliver lower-cost solar energy in October 2007. Prior to winning the competition, the research group had already carried out fundamental studies on different aspects of organic semiconductor materials, including OPV. The group was led by a professor who is a world-renowned expert pioneering the study of plastic electronic properties. An initial GBP five million investment was used to fund the first three years of a long development process. Recalling the founding of the USO, the founder acknowledged the support received from Company Y, a British based technology commercialisation company:

"GammaSolar was a company that started in a rather peculiar way. There was a competition launched by the Carbon Trust for what they called PV Accelerators. We made a pitch. It seemed that it was a good idea at the time. The pitch was to make use of a lot of know-how in the research labs here as to how to make printed solar cells based on organic semiconductors. We won the competition, we had quite a lot of support from Company Y for their bid. Once we won, we then had a lot of work involved in deciding what to do."

In an effort to improve the efficiency of OPV, the research group discovered a breakthrough technology that could provide solar power at a lower price than that of earlier solar generations by manufacturing high-performance OPV cells for markets with high growth of volume using roll to roll[30] (R2R) technology. The discovery was aligned with Carbon Trust's desire to deploy more than one gigawatt (GW) of OPV by 2017, which could deliver CO_2 savings of more than 1 million tonnes per year. The market for OPV has the potential to reach USD two billion by 2020 and could save up to 900 million tonnes of CO_2 by 2050[31].

GammaSolar was incorporated in July 2010, with the professors acting as the director of the board. Few months after incorporation, GammaSolar employed a serial entrepreneur as the USO's CEO. Within the same year, an international specialty chemicals firm co-invested in GammaSolar. A patent was filed in June 2012 and licensed back to GammaSolar to be exploited.

Prototyping (2011–2017)

The subsequent commercial phase aimed to develop prototypes backed by ongoing funding from Carbon Trust and an international specialty chemicals firm. Due to the complexity of the technology, prototype development was lagged. While advocating the technology, the CEO saw an untapped market opportunity for solar energy in the African market, which did not require the GammaSolar prototype to be fully established. In July 2012, GammaSolar developed GammaSolar2 to commercialise pay-as-you-go solar boxes using older-generation silicon panels. The intention was to substitute the silicon panel with OPV once the prototype was ready. Both GammaSolar and GammaSolar2 became independent, and GammaSolar shareholders held shares of GammaSolar2. In 2013, a new CEO of GammaSolar was

[30] The process of creating electronic devices on a roll of flexible plastic or metal foil.
[31] Source: https://www.oecd.org/env/cc/49082173.pdf

appointed. One of the major revamps led by the new CEO was to change GammaSolar strategy from being technology pushed to be market pulled. As the new CEO said in the interview,

> *"When I came, we didn't have any customers. The company was emotionally focused on engineering development of technology and you know that's fatal. It's okay for a while because you have some point but it is never too soon to get customers involved and the company needed challenging. Right, we are going to change this, we are going to shift the emphasis around, board meeting and management meeting around. It get to the point where I can make some samples, now I need customers telling me what samples to make."*

In 2014, the solar industry became even more challenging after gas became very cheap and there was a collapse in desire for renewable energy. Many solar companies faced bankruptcy. Despite this, in November 2014, GammaSolar secured additional funding of GBP one million to further develop its proprietary production processes to prepare for high-volume manufacturing and to expand its commercial activities. The new equity financing was led a British-based IP firm, with support from existing investors.

In 2016, GammaSolar optimised its R2R coating plant to produce up to 200,000 meter squared (m^2) OPV per year. Although the final product was not ready yet, GammaSolar actively distributed solar module samples and discussed price points with potential customers. It aimed to commercialise OPV in two other niche markets: 1) the wireless and Internet of things market, which enabled micro-generation for a world of connected smart devices and the building of automation and security, monitoring and tracking and consumer electronics; and 2) the retail market, which enabled determination of point-of-sale advertising, pricing, signage and the logistics of transitioning from the shelf to warehouses through engagement with on-shelf displays and store stock tracking.

4.6 Case 4: DeltaCool

DeltaCool was incorporated in 2003 as part of postdoctoral research at the Department of Material Science conducted in 2002 following the discovery of magnetocaloric refrigerant. The intended business model involved manufacture, customisation and sale of more efficient and environmentally friendly cooling devices for domestic fridge manufacturers. In 2017,

DeltaCool was still dealing with the technical aspects of its prototype and was not able to launch a finished product in the market. The firm has existed for 13 years but has not officially launched its product in the market. Thus, this case represents a mature firm without a commercialised product. The firm's commercialisation journey across TRLs and commercialisation stages is presented in Figure 4-6.

Ideation and Incorporation (2002–2004)

The incorporation of DeltaCool preceded a research on magnetic refrigeration by a postdoctoral researcher, who was supervised by an eminent professor at the Material Science laboratory, conducted in May 2002. The professor was the head of the Department of Materials Science and Metallurgy. The researcher investigated the potential of a gadolinium-containing alloy to be to be used in lower-cost magnetic refrigeration by extracting rare-earth elements from the material. Within three years of Enginnering and Physical Science Resaecrh Council (EPSRC) funding, a year was spent unsuccessfully investigating the gadolinium-containing alloy. In 2003, DeltaCool turned to an alternative material, cobalt manganese silica. The USO was founded in May 2003, with the professor sitting at the board, the scientist assuming the role of Chief Technology Officer (CTO). A physicist joined the USOs and then was appointed as the CEO. Within the same year, a patent was applied for and filed in September 2005. According to the founder of the USO, the decision to start a company was partly motivated by the commercialisation potential of the material he was investigating:

> *"So, those materials themselves have not achieved commercialisation but we said, 'Okay, let's think about commercialising them.' Because at that time we didn't know their limits. We didn't know could they work, could we optimise, could we make them as good as possible? And so, we said, 'Okay, let's start a company that would maybe take those materials, well it would design and build kind of magnetic cooling engines.'"*

The first year and a half after incorporation was spent raising funds in preparation for the prototyping stage. In 2006, DeltaCool conducted market research and discovered a weak market signal for the technology among fridge and air conditioning manufacturers because they were comfortable with conventional gas compressor technology. Despite this, the European refrigeration industry was interested in alternative technologies, and legislative incentives created a climate for higher-efficiency devices. To illustrate, the magnetic refrigeration market

is expected to reach USD 315.7 million by 2022, with a compound annual growth rate (CAGR) of 98.7% between 2017 and 2022[32]. Given this, the founders were convinced that among methods of solid-state cooling, magnetic cooling was the most disruptive technology.

Prototyping 1 (2004–2008)

DeltaCool's prototyping stage started around 2004 but was not successful because the material optimisation process was more complex than anticipated. Additionally, the market space was quickly saturated by multiple companies optimising different materials. After approximately four years of unsuccessful attempts to optimise cobalt manganese silica, in 2008, DeltaCool brought its material prototyping to a halt and switched to a different niche within the magnetic cooling industry.

Ideation 2 (2008)

Instead of focusing on material optimisation, DeltaCool shifted its aim to design a magnetic cooling device that could be embedded in domestic refrigerators for a more efficient, less noisy and environmental-friendly cooling system. A new patent on the design and fabrication of multi-material blades used as active regenerative regenerators in active regenerative magnetocaloric or electrocaloric engines was applied for in 2009 and filed in June 2012. The CEO described the USO's shift of focus as follows:

> *"So, it is not anymore about taking this particular material and making it useful, it's been about designing a low cost, small, compact, refrigeration system, that could use any material, ideally. In the future, just pick the best one [material] available. There are two families of materials that have come through the literature and into semi-commercial production by chemical companies."*

In order to achieve higher-efficiency cooling using conventional technology, refrigerator's wall needs to be wide and thick or use expensive insulation material. With the new patent, DeltaCool's technology could overcome this problem by reducing costs and cutting energy usage by 40%. With its new technology, DeltaCool gained a healthy reputation within the

[32] Source: http://www.marketsandmarkets.com/Market-Reports/magnetic-refrigeration-market-243034247.html

refrigeration industry. The firm survived the subsequent R&D stage mainly due to grants from, for example, the Carbon Trust and the EU. It also collaborated with researchers from other universities. In 2008, the USO appointed a business developer.

Prototyping 2 (2008–2017)

Although in principle the firm's concept was successful, getting the technology to work unattended for a long time was still a challenge. As the USO continued to accelerate the development of its technology, fridge manufacturing still moved very slowly; it has not changed for the past 50 years. The magnetic refrigeration industry saw a relatively weak drive to develop cooling device, and hence the network chain was insufficient for bringing DeltaCool's technology into commercial reality. There were very few companies similar to DeltaCool who served as competitors, but due to years of experience in magnetic refrigeration, DeltaCool managed to retain a competitive advantage by having less expensive designs than its competitors.

In 2017, DeltaCool was still optimising its technology and operated like a virtual company. However, backed by an unshakeable belief that the novel technology would be welcomed by the industry, the firm continued to bring value to its potential customers. By 2018, DeltaCool planned to evaluate the fridge it assembled for fridge manufacturers. Next, it planned to focus on finalising the device and design based on a new patent. The firm aimed to license its technology to the fridge manufacturer once the technology was ready.

4.7 Chapter Summary

This chapter has described the general background of the cleantech industry and justified it as the industry of choice for operationalisation of this research. It also presented the four case studies and their business models in great depth. The next chapter will examine the themes, similarities and differences across the four cases to collectively mobilise the findings that are useful for answering the research question of this thesis.

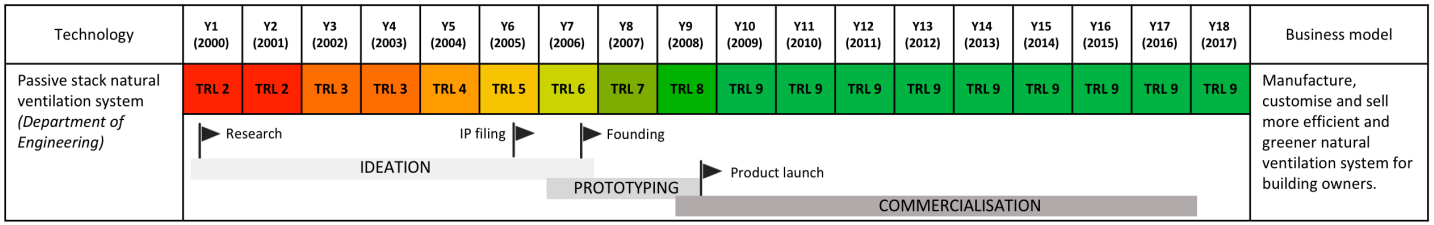

Figure 4-3: AlphaVent's technology, commercialisation journey and realised business model

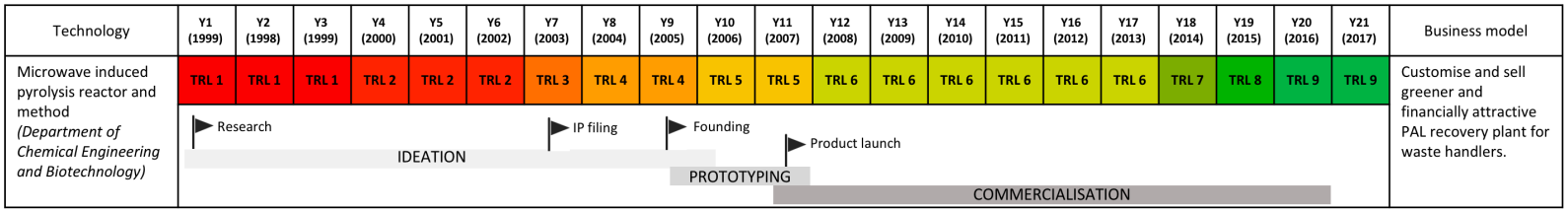

Figure 4-4: BetaRecycle's technology, commercialisation journey and realised business model

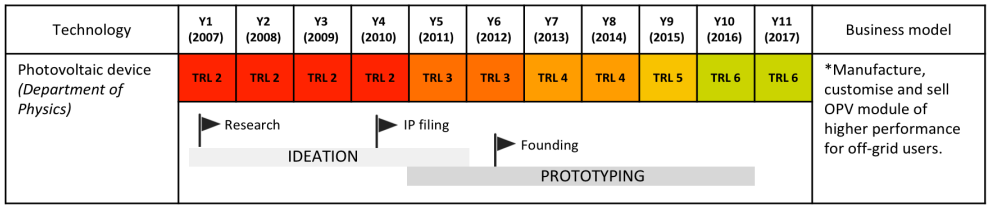

Figure 4-5: GammaSolar's technology, commercialisation journey and intended business model

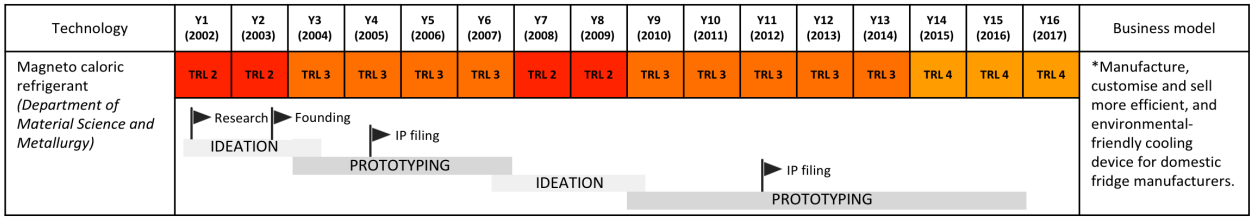

Figure 4-6: DeltaCool's technology, commercialisation journey and intended business model

TRL1: Observation of basic principles

TRL2: Formulation of technology application

TRL3: Development of proof of concept

TRL4: Validation in laboratory

TRL5: Validation in relevant environment

TRL6: Demonstration in relevant environment

TRL7: Demonstration of prototype in operational environment

TRL8: Completion and qualification of actual system

TRL9: Proof of actual system in operating environment

* Indicates business model that is still under consideration (yet to be finalised)

5 FINDINGS

5.1 Chapter Introduction

In the previous chapter, each case was described individually based on the technology commercialisation journey and its resulting business model. This chapter collectively substantiates the findings across cases to identify common patterns and, therefore, answer the research question*: how does a USO develop its early-stage business models to commercialise new technology?* Chapter 5 is split into six main sections. Section 5.2 presents the cross-case, open coding, axial coding and selective coding findings which depict the three mechanisms for business model development. Sections 5.3, 5.4 and 5.5 further elaborates the findings and provide evidence that enables understanding of how a USO 1) creates value through flow-field control; 2) captures value through pragmatic kinesis; and 3) manages value network through deliberate temperament. Next, section 5.6 presents the underlying principles used to guide the findings in the template analysis. The conceptual framework summarising the key findings is graphically presented in Section 5.7. Finally, section 5.8 summarises this chapter.

5.2 Three Mechanisms for Business Models Development

The second-round open coding and third-round axial as well as selective coding analysis resulted in key depictions that illuminated the approaches taken by USOs to develop business models while responding to external challenges. To reiterate the overarching purpose of the analysis, the findings that arose from the analysis, which resembled the emerging categories, were viewed in parallel with the unique challenges faced by the USOs across the business model components. A summary of the results of inter-case coding analysis are presented in Table 5-1.

The categories that emerged from the analysis were further synthesised through constant reviewing until theoretical saturation was achieved[33]. The categories were then structured to aggregate the categories into higher levels of abstraction. The resulting data structure, which

[33] The phase of qualitative data analysis in which the researcher has continued sampling and analysing data until no new data appear and all concepts of the theory are well- developed (Morse 2004).

provides a graphical context in which to understand the derivation of the second-order themes and the aggregate dimensions, is outlined in Figure 5-1.

Value components	Unique challenges	Emerging categories
Value proposition and value creation	Crafting value proposition and creating value in the face of market resistance	▪ Create transcending solution ▪ Create sintering solution ▪ Propose new regulation ▪ Ride the wave of regulatory reform
Value capture	Creating value in the face of financial pressure	▪ Explore auxiliary revenue stream ▪ Enter substitute market ▪ Employ customisation strategy ▪ Employ cost efficiency strategy
Value network	Managing stakeholders with conflicting values	▪ Forge co-operation ▪ Forge co-opetition ▪ Trade-off incompatible values ▪ Tolerate divergent values

Table 5-1: Results of cross-case, open-coding analysis

Linking the analysis results back to the research question, the empirical findings suggest that a USO develops its business models through three interlocking, iterative and interdependent mechanisms namely: 1) value creation through flow-field control; 2) value capture through pragmatic kinesis; and 3) value network management through deliberate temperament. The findings cast new light into the partial explanation of business model development that usually depicts a business model as a block, hence, suggests a vague description of business model development approach whereby the intricateness of a business model that constitute several sub-components has been widely disregarded.

Based on the data structure, the following sections provide in-depth descriptions of each mechanism at three levels of abstractions (i.e. aggregate dimensions, second-order themes and first-order categories). Exemplary quotes from the interviews and archival data are also presented within the sub-sections to more explicitly portray how a USO creates value and embeds it into a proposition, captures value and manages its value network.

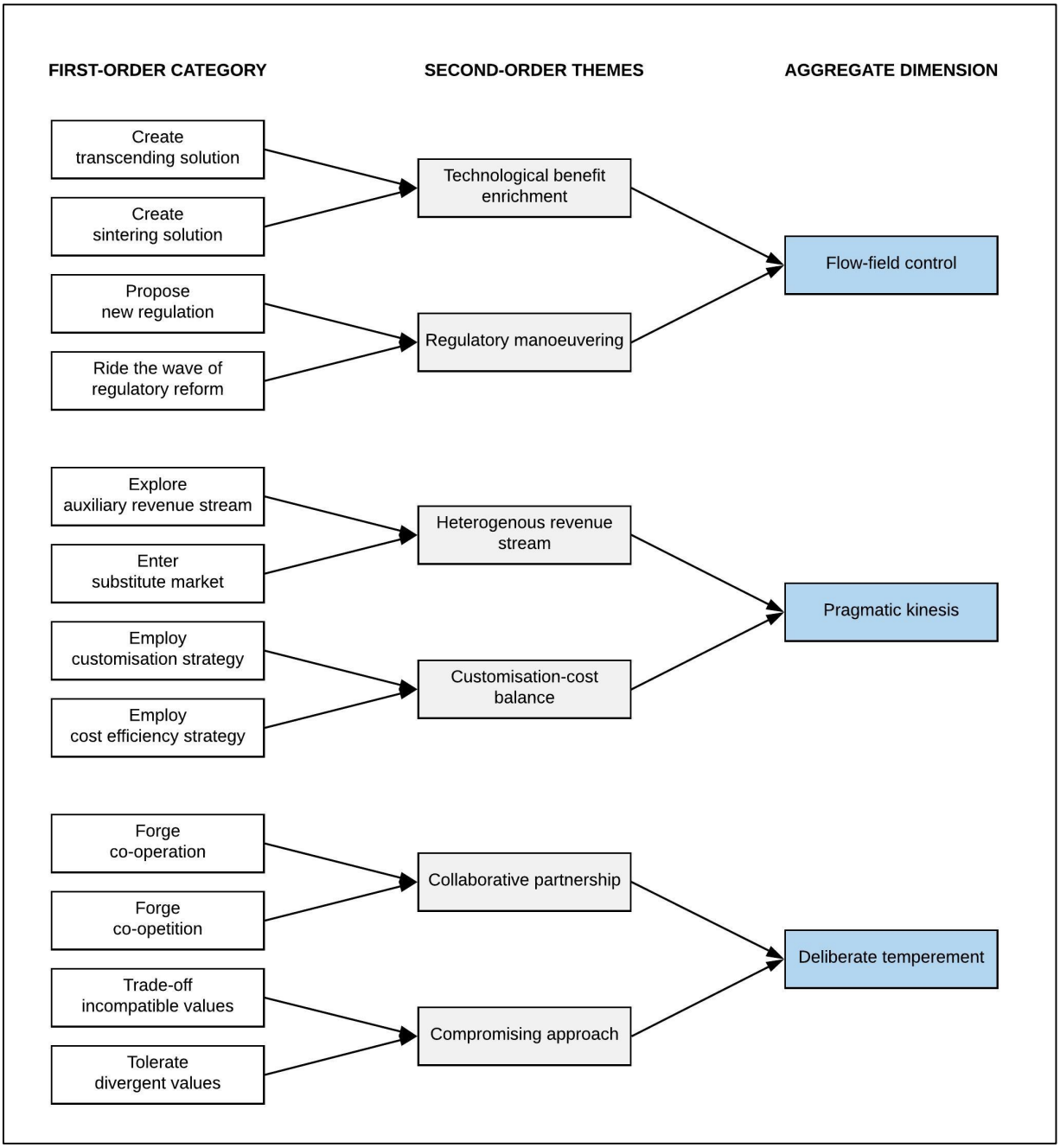

Figure 5-1: Data structure

5.3 Value Proposition and Value Creation through Flow-Field Control

When resistance to new technology was high, USOs across cases created and incorporated value in their propositions by devising flow-field control[34]. Flow-field control is a mechanism

[34] Flow-field control is performed by a fish to control the water flow while swimming. It is intended to enhance propulsion, reduce drag, and coordinate feeding and locomotion. As the water friction slows down the fish's movement, the fish propels through water by pushing back and forcing their way through the incompressible medium. Flow-field control is an analogy used to describe how USOs take active control over their resources and capabilities to proactively craft propositions, create value and overcome market resistance.

orchestrated by USOs that proactively exerts endogenous force within the firms' control and influences exogenous forces (from its partners) to create value.

Across cases, USOs were disadvantaged by weak signal and pushback from the market, which were exacerbated by the infancy of the technology and ambiguity of the market. As DeltaCool's director of business development said, *"[t]here was a weak signal from the market. You have to be able to intercept before you know."* Similarly, DeltaCool's inventor highlighted that *"[t]he fridge manufacturing industry over the past 50 years, they haven't changed."* In addition, BetaRecycle's CEO remarked, *"[w]e are changing the business model to be able to accelerate that [the technology] because the waste management sector is so risk and technology-averse, they haven't changed for so many years."*

Two ways of creating value through flow-field control observed in this study were 1) enrichment of technological benefits; and 2) regulatory manoeuvring. The data structure for the aggregate dimension, termed flow-field control, is presented in Table 5-2. For data reporting, key quotes are depicted within the sub-sections and additional quotes that mapped to the first-order category are provided in Table 5-3.

First-order category	Second-order theme	Aggregate dimension
Create transcending solution	Enrichment of technological benefits	**Flow-field control** *(an approach taken by a USO to craft propositions, create valuable offerings and overcome market resistance by taking active control over its resources and capabilities)*
Create sintering solution		
Propose new regulation	Regulatory manoeuvring	
Ride the wave of regulatory reform		

Table 5-2: Data structure for the aggregate dimension of flow-field control

5.3.1 Enrichment of Technological Benefits

The analysis indicated that a USO crafted a viable proposition and created value by enriching the properties of the technological solution beyond what the targeted customer expected. In this sense, the USO challenged incumbent corporations by solving a problem for customers before they explicitly asked for a solution or even before the problem arose. By doing so, the USO created unique value, shifted customers' perception of what was valuable, avoided being average and raised the bar for competition. In other words, USOs did not just reactively respond

to changing market dynamics; rather, they proactively solved customers' problems to gain a competitive advantage.

Two major approaches to value creation that aim to enrich the technological benefits observed in the case studies were a) creation of a transcending solution; and b) creation of a sintering solution. The former is concerned with providing a better solution than the targeted customer envisioned, and the latter is concerned with combining different solutions into one proposition that was previously unavailable.

a) Create a transcending solution

A transcending solution solves problems for customers and goes beyond the customers' expectations. USOs across cases created value by responding to different types of problems faced by customers, including those that were only partly addressed by incumbent corporations, problems that were perceived as unsolvable, problems that were perceived as insignificant or problems that customers did not realise they had. In most cases, customers were generally satisfied with the status quo and hence did not actively seek a new solution and tended to resist new solutions. Given this situation, the USOs were forced to be proactive in creating indispensable propositions that would encourage adoption of their technology.

For example, AlphaVent created value by providing a better solution to an old problem. The USO observed the market conditions and took advantage of the inefficiency of the current solution provided by incumbent corporations. Rather than responding reactively to customers' apparent need, which was being served by the incumbents, the USO investigated hidden market gaps and filled them with the new technology.

Through interactions and partnerships with the architects, AlphaVent identified an accepted paradox in the conventional method of ventilating buildings. The firm then utilised its patented technology to improve the method of ventilating buildings, proposed a new solution and, eventually, took sales away from the existing natural ventilation market. As stated in an article published on 18th July 2016 in the Cambridge Enterprise[35], AlphaVent technology was described as 'a completely new way of ventilating buildings' that revolutionised the classic

[35] Source: https://www.enterprise.cam.ac.uk/case-studies/breathing-buildings-develops-natural-building-ventilation-technology/

British open-windows-plus-radiators approach to ventilating buildings. The article reported that *"[i]nstead of the classic British open-windows-plus-radiators approach, AlphaVent's technology consists of an exterior opening, a mixing chamber and two low-energy fans."*

Similarly, DeltaCool partnered with cooling appliance manufacturers to identify problems with the current method of cooling a refrigerator using a gas compressor. Although the manufacturers were not actively looking for a better solution, the USO persistently promoted their technological solution and proposition. According to the inventor,

> *"The actual method that we used for cooling is much more efficient than the present method…using the existing technology, they either have to make the walls of the fridge very much wider, thicker, which means there's less room for your cabbage, or they have to use very expensive insulation materials. Our technology should overcome that because it actually reduces the cost of the cooling."*

In a report dated 9th February 2016[36], BetaRecycle was reported to offer 'one solution to tomorrow's plastic problem' as a novel way to recycle PAL while saving energy as part of the journey to a circular economy. In the report, the inventor also stated that, *"[w]e just hope that in the future, it's [the technology] remembered as a turning point for how modern society deals with the enormous amount of plastic products we all use and consume."* The statement implied that BetaRecycle created value by responding to the future consequence of waste handling.

Across cases, USOs were seen to create value by attending to unmet needs that might exist but were hidden or did not exist at all. They mostly attacked incumbent corporations at their weak points to gain a competitive advantage. The evidence also implied that the creation of value involved the escalation of customers' expectations for improved products. Focusing narrowly on filling an apparent market gap might cause the USO to converge with competitors who aimed to address the same problem. Due to this, crafting a transcending solution enabled USOs to create value more pragmatically.

[36]Source: http://www.enval.com/enval-offering-one-solution-tomorrows-plastic-problem-ellen-macarthur-report/

b) Create a sintering solution

Creation of a sintering[37] solution is a process that creatively combines multiple solutions and embeds them in a proposition without losing the core value of the new technology. A solution to customers' problem with a sintering approach was created at the intersection between distinctive priorities. In the case studies, USOs created a new product with multiple elements that were either currently unavailable or being served by different providers. This avoided the complication of seeking complementary value from multiple providers, eventually resulting in a competitive advantage. Apart from solving multiple problems, this approach may also solve problems the customers will face as the market evolves.

Having successfully commercialised its technological solution, AlphaVent represented the epitome of a USO that successfully created value through the sintering approach. From a functional perspective, the firm provided a novel proposition that combined solutions for ventilation problems during winter and summer. As the inventor said, *"[y]ou worry about the summer, but everyone forgets about the winter, whereas we spend most of our time in the UK under winter conditions, we have solutions for both."*

Upon realising the need to merge natural and powered ventilation syetem, AlphaVent forged a strategic partnership with Company N to offer their customers a full range of ventilation systems. This was reported in an article published by Cambridge Enterprise on 10th February 2011[38]:

> *"AlphaVent is collaborating with a leading UK ventilation company in the first real partnership between the natural and mechanical ventilation industries. Company N, the UK market leader in the design, manufacture and distribution of powered ventilation and air movement solutions, has teamed up with natural ventilation expert, AlphaVent to offer customers a full range of both powered and natural ventilation systems, thereby lowering energy bills and consumption."*

[37] Sintering is a borrowed scientific term that refers to the process of compacting and forming a solid mass of material with heat without melting it.
[38] Source: https://www.enterprise.cam.ac.uk/news/breathing-buildings-announces-major-collaboration-project/

From the customer's perspective, AlphaVent's technology was beneficial because it reduced costs, reduced energy consumption and increased ventilation efficiency. Another example of value creation achieved through the sintering approach can be observed in AlphaVent's founding, which preceded the need to provide solutions for building design and building equipment. AlphaVent took the problem as a clue to provide a new offering. This was articulated by the CEO of the firm when he said,

> *"In 2005, I decided to form the business. I was 38 at the time. I had been frustrated with building contractors changing designs of buildings I had developed. They were using the argument that there were no companies able to provide the equipment I suggested. It seemed that the only way to get the building industry to adopt my ideas was to set up a company and offer equipment ourselves."*

The same trend of creating value using the sintering solution was observed in DeltaCool. The firm sought to offer improved performance and efficiency, reduced energy consumption and reduced environmental impact with its solid-state cooling technology. According to the inventor, *"[w]ithin the solid-state cooling, this [technology] is one of the most promising and potentially would be a disruptive technology for cooling industries. We are looking at dramatically reducing the energy consumption with lesser cost to the environment."*

When creating a sintering solution, a USO needs to be visionary, as potential customers may not explicitly ask for combined solutions because they were comfortable finding desired solutions from different providers. Creation of a sintering solution is a highly proactive approach whereby a USO creates an opportunity to satisfy multiple needs with one proposition. Instead of envisioning how the market would unfold, the USO exploits its resources and capabilities to fulfil customers' unmet needs.

5.3.2 Regulatory Manoeuvring

USO's ability to manoeuvre regulations was another catalyst for value creation. Regulatory enforcement proved to have a significant effect on how value was created as it could pave the way for technological adoption. Conversely, a new technological solution could also become a springboard for imposing new regulations. The importance of regulations was even more

pronounced in the cleantech industry as regulatory enforcement usually led to a change of habit among the customers. According to one of the investors interviewed,

> *"They're [cleantech businesses] mostly written by regulations. The market itself is almost always a function of the regulation. You can call it access to the market or whatever, but, the reason that many cleantech companies exist is because there is a regulation requiring something to happen."*

DeltaCool's CEO also stated that, *"[g]enerally speaking, the change of legislation helps us enormously."*

Since new technology could stimulate new regulation and new regulation could prompt new technology, most USOs did not only reactively respond to enforcement of a new regulation; they went further, proposing a new regulation that favoured their value proposition and rode the wave of regulatory reform, which was still in the solidifying phase. To manoeuvre regulations and create value, USOs in the case studies 1) proposed new regulations; and 2) rode the wave of regulatory reform.

a) Propose new regulations

New regulations trigger competition in the regulated industry and stimulate new product development. Proactive USOs did not wait for a regulatory change to take place but influenced and proposed regulations that favoured their offerings. For example, according to the AlphaVent website, *"[A]lphaVent's CEO sat on the advisory board and was involved in the drafting of Building Bulletin 101 Guidelines on ventilation, thermal comfort and indoor air quality in schools."* AlphaVent clearly showed how the barrier to market entry stemming from market resistance could be overcome through the introduction of new regulations. The USO took the lead, selling ventilation systems that complied with the new regulation for which it lobbied.

Stakeholders across cases repeatedly emphasised the importance of regulation for accelerating new technology. This was captured in a statement made by one of the investors in BetaRecycle who said,

"Cleantech companies are all struggling with regulations. They're all potentially global. Many of them are cash strapped because the cleantech sector has never been a hot spot for venture capital but they can't persuade regulatory change…It's a fallacy to think that they exist because people want to save the planet."

The investor implied that a change in regulation is crucial for galvanising technological adoption, without which a difficult market would remain in inertia. A similar comment was made by BetaRecycle's CEO,

"If there is a change in law and policy then it's a different story… It will become a market-driven thing, but it is a market that there are such immense flaws that they do require policy and law intervention in the beginning or otherwise it just doesn't start. The inertia and the business of burning stuff on the ground is just way too much."

The creation of value for BetaRecycle was partly held back by the absence of necessary regulations regarding mandatory segregation of PAL to push the technology forward. Despite this challenge, the firm continued to pressure regulators to commit to regulatory reform. This was mentioned by one of BetaRecycle's partners who mentioned, *"[o]ur goal is to get commitment and buy-in from the whole value chain, including from the local authorities and regulators. This is essential to ensure the broad-based adoption and implementation of what we are developing for flexible packaging in a circular economy."*

b) Ride the wave of regulatory reform

Most USOs in the case study created value by complying with new regulatory requirements. Commercialisation of the technologies developed by AlphaVent, GammaSolar and DeltaCool was partly enabled by regulations related to energy efficiency and renewable energy. Interestingly, these firms did not wait for regulatory change. Rather, they sensed the potential for regulatory reform and took advantage of the situation, riding the wave of regulatory reform in the cleantech industry.

AlphaVent, for example, followed the developments of Directive 2009/125/EC of the European Parliament, which established a framework for eco-design requirements for energy-related products, including ventilation systems for buildings. The firm developed its

technology in parallel with upcoming regulations. When the new regulations officially came into effect, the USO thrived by offering natural ventilation solutions. This was described in the interview with AlphaVent's CEO,

> *"When choosing the right target market, we hired a student to come and help us just to investigate different sectors… We went and dug out industry reports, which were the sectors that were buoyant, that were growing and ones where the regulations were appropriate for our kind of offering and where regulations were potentially changing that would help us."*

Likewise, BetaRecycle proactively explored regulations that would allow it to become a leading firm. As the CEO noted, *"[E]uropean packaging regulations translate into various national laws in the EU. All of this will definitely help BetaRecycle to grow in the future."* The USO exploited regulatory reform as a platform to accelerate its technology. According to Bloomberg[39], *"[B]etaRecycle focuses on providing specialist solutions and addressing environmental and regulatory challenges across industrial, commercial and municipal sectors to deliver value from waste to its customers."*

In the case of GammaSolar, regulatory incentive regimes for photovoltaic installation were a primary driver of the establishment of the USO. The USO made a strong case for adding value to the customer while benefitting the economy and the environment. Although the USO struggled to deliver value when the industry was slowing down, GammaSolar exploited regulators' efforts to combat rising carbon emissions and efforts to wean the global addiction to fossil fuels. DeltaCool on the other hand, scrutinised regulations related to low carbon cooling and energy efficiency when developing its prototype. In particular, the USO followed regulations that set the maximum allowable electricity consumption for a cooling appliance. DeltaCool gained stronger traction when such regulations were enforced.

All the studied USOs developed technological solutions in a way that favoured changing regulations. Realising the increased emphasis regulators placed on environmental concerns, they extrapolated the benefit of new technological solutions to trigger or respond to these

[39] Bloomberg company overview. Available at: https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=30197594

regulations. Therefore, USOs developed a technology that harmonises technological advancement with environmental resilience and, at the same time, acted proactively regarding regulatory reform.

First-order category	Quotes
Create transcending solution	"*Our product is the result of the smallest, the lightest, and the cheapest. It meets the requirements of the appliance manufacturers, and we're working, let's say, with the three novelties that you would probably pick."* – DeltaCool's director of business development *"We are dealing with the pressing problem of the future. The need might not be clear now but when the time has come, this technology would make its way."* BetaRecycle's Chairman
Create sintering solution	*"AlphaVent has developed a completely new way of ventilating buildings that have the potential to reduce heating bills by as much as 50% while drastically reducing energy consumption. The natural ventilation technology concept exploits the heat produced by people, lights, IT and even sunlight, avoiding the wasteful use of radiators."* – AlphaVent's website *"Through years of experience in this industry, we manage to offer our customers a complete, integrated energy autonomous solution."* – GammaSolar's CEO
Propose new regulation	"*Our patented technology is allied to smart controls and superb engineering has changed that [how a building is ventilated] forever. The benefits of mixing ventilation are now so clear that it has been written into regulations, a testimony to evidence we can show you of making it work."* – AlphaVent's CEO *"It's now up to the local authorities and the waste handling contractors to start buying this technology from us so they can recycle it. So, one way of leveraging the technology is to infuse this in thinking, not just to the customer but also to the regulators ... The major problems that even the segregation is non-existent, just like Mexico. Even the municipal local authorities, they just don't care, they don't see the value of this kind of new technology. It's horrible, absolutely horrible!"* – BetaRecycle's CEO
Ride the wave of regulatory reform	*"At the turn of the century, European companies were hit with regulations forcing them to pay more attention to the amount of packaging that they were putting into the market."* – BetaRecycle's CEO *"There's a weak signal from the market. You have to be able to intercept before you know. You need to be clear about the legislation in force. Now in Europe for example, you are only allowed to sell fridge of least A+ energy efficient."* – DeltaCool's CEO

Table 5-3: Additional selected quotes for the first-order categories

5.4 Value Capture through Pragmatic Kinesis

When USOs' technology was immature, they were forced to generate sufficient revenue to fund operations. When the technology was ready for the market, USOs were expected to create an attractive mechanism for charging customers that would retain a percentage of the value. The findings indicated that both goals were achieved through an approach termed pragmatic kinesis[40] that is intended to capture value by being flexible and sensible when moving towards profit.

When value is created, a reward does not necessarily follow. Logically, the higher the value that is created, the higher the value that is expected to be captured. However, in the case studies, not all firms that effectively created value also effectively captured value. All four USOs were able to create significant value for their target customers, but only AlphaVent and BetaRecycle were successful in capturing the value they created. Nevertheless, all USOs constantly exercised diversified but pragmatic revenue models that allowed them to grow profitably.

Across cases, USOs actively strived to pragmatically generate enough value to operate and grow profitably. They did this in two ways: 1) heterogeneous revenue streams; and 2) customisation–cost balance. The data structure for the aggregate dimension, termed pragmatic kinesis, is presented in Table 5-4.

First-order category	Second-order theme	Aggregate dimension
Explore auxiliary revenue streams	Heterogeneous revenue streams	**Pragmatic kinesis** *(approach taken to capture value and respond to financial pressure by being flexible and sensible when moving towards profit)*
Enter substitute markets		
Employ customisation strategy	Customisation–cost balance	
Employ cost efficiency strategy		

Table 5-4: Data structure for the aggregate dimension of pragmatic kinesis

5.4.1 Heterogeneous Revenue Stream

A heterogeneous revenue stream is the result of proactive diversification of income sources depending on where revenue or profit can be obtained. The purpose of a heterogeneous source

[40] Kinesis is a biological term that refers to the undirected movement of an organism in response to an external stimulus.

of income is to enhance financial security and, in the case of USOs, primarily to avoid running out of funds during the pre-commercialisation stage. As a new and under-resourced firm, USOs across cases did not rely on the core revenue stream when profit is still uncertain and the market is increasingly competitive.

The way USOs across cases attempted to have multiple sources of income can be traced in two events which were by exploring more widely the different methods that can be employed to generate income and by investigating the alternative markets. Two mutually reinforcing ways in which USOs generated heterogeneous sources of income were by 1) exploring auxiliary revenue streams and; 2) entering substitute markets.

a) Explore auxiliary revenue streams

The findings across cases implied that USOs with early-stage and complex technology required a long time to enter the market due to the technical complexity of the technology and imperfect description of the market. To generate sufficient income during the transition from ideation to commercialisation, all USOs survived financially through supplementary sources of income such as grants and research-related activities. For example, according to the AlphaVent website, before the firm could sell its full range of ventilation systems, *"[A]lphaVent started with consultancy and retail projects to local primary schools and there is a substantial pipeline of new projects for which AlphaVent is actively engaged in supplying e-stack systems to commercial buildings."*

Other USOs also spent their early years obtaining research grants, testing material and consulting with clients for revenue before the commercialisation stage. For example, when it was founded, BetaRecycle received proof of concept funding from Cambridge Enterprise Seed Funds to further develop the recycling process. According to the inventor, *"[t]he proof of concept funding made a massive difference in the development of our recycling process, as it gave us valuable leverage."*

GammaSolar's inventor also noted that supplementary revenue streams in the form of grants and material evaluations were crucial for the USO to survive financially:

"Our OPV business was surviving mainly through doing grants and some evaluation of materials site work. So, they (entrepreneurs) had quite a number of grants and they are very good at raising grant money to help them do some of the fundamental research and materials evaluation without always needing equity to do it. And that's how the company moves forward a bit…because it's so early-stage and we haven't got to maturity point yet. You can sort of see how that happened."

DeltaCool's inventor also emphasised the importance of obtaining supplementary sources of revenue, especially when technology is not ready for commercialisation. He argued that the USO initially survived due to research grants and consultation work. However, he envisioned that the primary source of income would eventually change once the technology reached maturity. This was neatly encapsulated in the interview when he said,

"Well, historically, let's say our source of revenues is grants. So, we raise some capital from investors, and what we've done is we have basically matched that capital against grant funding…At this point, the technology's not quite ready for that sector, so we raised a few revenues through consulting, sort of looking, sort of getting people to pay us to teach them about the technology. I would say that most revenues came from the automotive sector, there's a lot of interest in our technology there... It's not a lot of money, but it's brought in some revenues. That's in some sense free money, and also a very useful tool to enable collaboration with multiple partners. But now we're at a point where actually our revenue picture is going to change somewhat."

Based on the evidence, it seems necessary for a USO to pursue a different and indirect kind of revenue stream prior to realising its long-term value capture strategy. Upon entering the commercialisation stage, AlphaVent, as a case in point, continued to generate income by employing auxiliary or non-core revenue streams. The strategy proved useful for enhancing the margins of the core revenue stream. An article published by Business Weekly on 11th September 2015[41] stated:

[41] Source: https://www.businessweekly.co.uk/news/cambridgetorchbearers/fitzgerald-breathing-new-life-building-design

"While the primary focus of the [AlphaVent] business was to develop, and commercialise natural ventilation systems derived from a patent it had filed at the university, the company also had a secondary revenue stream from design consulting; however, the main focus was to get the equipment manufacturing side established."

As knowledge-intensive businesses, research grants and consulting activities appeared to be effective ways for USOs to monetise their intellectual assets. The revenue from these activities was put back into the business to support the firm's operations prior to commercialisation.

b) Enter substitute market

When generating sufficient revenue to induce profitable return, USOs with less differentiated products, like GammaSolar, struggled to capture value in existing markets. As a result, GammaSolar entered non-traditional markets in which OPV was not mainly commercialised. In other words, GammaSolar scrutinised untapped markets for its technological solution. In this way, the USO efficiently captured value while engaging in indirect competition with incumbent companies. This was articulated by the inventor:

"I don't think we have a strong, unique asset. We are not the only one who is doing this [commercialising OPV]. There are many others who are doing what we are doing. To be able to sell, we need to look more widely across markets, beyond what the competitors are doing."

Although GammaSolar had not reached the stage at which income could be generated from the technological solution, the USO had actively explored beyond the traditional market and attempted to exploit its technological solution as a complement to existing solutions in non-traditional markets. In doing so, the USO effectively created a new market category. A new market category exists when two or more products are perceived to be substitutes for each other to satisfy market demand.

Rather than trying to capture value only from off-grid users, GammaSolar offered its integrated energy-autonomous solution to a broader range of other markets, such as the Internet of Things, retail and healthcare. In the retail market, for example, the USO offered new solutions for engaging on-shelf displays, stock tracking, point-of-sale advertising and pricing signage. In

this way, the USO positioned itself between the traditional off-grid market and untapped retail market. This was exemplified in a statement made by one of the inventors:

> *"To be able to grow, the company does run through where the markets are. An interesting market, rather, generally described would be things that there is a market for the powering of autonomous senses or objects that there's quite a large market for it. There's a marketed option for plastic solar. Retail signage, smart homes, wireless sensing."*

GammaSolar made the right decision to enter a substitute market, especially since the entire OPV industry was experiencing severe cost pressures, which resulted in small margins. Although the USO was still in its infancy, unfavourable market conditions prompted the USO to look for another way to commercialise its technology and capture value. According to the former CEO,

> *"The market for lighter weight solar panels that are plastic based and has not got away, it's very attractive, but it's not really. I think it will come, but it's not what's there at the moment. The industry was battered by the collapse in sentiment about renewable energy as gas became very cheap. There's spectacular bankruptcies in the solar industry. GammaSolar have to find a different way to do things."*

By entering a substitute market, the USO managed to capture value in a different space and avoided convergence with incumbent corporations' space. This strategy allowed the firm to generate income by remaining far from a mature market and competing technologies.

5.4.2 Customisation–Cost Balance

Along with a heterogeneous source of income, a USO captures more value through a customisation strategy without undermining its ability to scale. Since customisation often incurs a high cost, such a strategy is counterbalanced with a cost-efficiency strategy. In this way, a USO captures value by responding to customers' willingness to pay as well as the market prices of old and competing technologies. Adopting a dual approach to value capture has a profound effect on USOs' flexibility to generate income through different ways of

encasing the technology in its products, such as by charging premium price through customisation whilst reducing costs through efficiencies measures.

In striking a balance between product personalisation and its high cost, USOs harmonise seemingly opposite approaches to monetise their technological solutions. The two dominant strategies utilised by USOs for value creation in this study were 1) a customisation strategy and/or; 2) a cost-efficiency strategy. The former is concerned with capturing value from customers through personalisation, and the latter is concerned with capturing value based on standardisation and cost-efficient production that results in competitive pricing.

a) Customisation strategy

To capture value, USOs across cases were attuned to potential customers' different needs and willingness to pay. All USOs in the case studies adopted customisation strategies to add value for the customer and capture additional value for themselves. To satisfy the growing demand for choice, the USOs were careful to ensure that the complexity added to the standard offering was worth the incurred cost and would not decrease profitability. By capturing value for different customers, USOs charged premium prices for personalisation.

AlphaVent, for example, diversified its offering to suit different customers' needs but still retained its generic proposition (i.e. to offer a better ventilation system for buildings). By doing so, the USO provided its customers with options they truly valued. As the CEO put it, *"[w]e now have more different products to suit different needs, but the actual kind of thing that we offer our customers is the same."* The USO's customisation strategy was successful as a result of the disparate ventilation challenges that arose in poorly ventilated buildings.

Similarly, BetaRecycle offered a bespoke solution that involved designing and manufacturing recycling plants based on clients' specifications. BetaRecycle's website stated that *"[B]etaRecycle can design and manufacture plants according to our clients' individual requirements. As a modular process, the plan can be economically operated at a variety of scales, allowing for local treatment."* BetaRecycle's previous chairman also stressed the urgency of satisfying customers' needs through different ways of selling its products:

"…I'm fairly sure that some customers would rather lease than buy and some companies might rather manufacture themselves than buy it from us, so I think the market is there. It's the business model that needs iteration. It's not only what we want, it's what they want, and it's driven by the market appetite towards our offering."

Realising the extra value that can be obtained through a customisation strategy, GammaSolar supplemented its standardised OPV with customised OPV in the hope of capturing higher value amidst still at the prototyping stage. The USO engaged in a tiered approach to value capture in which higher-end customers were provided tailored products and services to match the value they represent. GammaSolar's website mentioned that,

"GammaSolar can supply standard and customised OPV modules for indoor energy harvesting or for outdoor, off-grid applications…We can advise on the best size and specifications. We can customise the performance and appearance of our OPV modules to suit most applications."

Done correctly, a customisation strategy could make competition difficult as USOs tailor their offerings to individual preferences. The trade-off between the value of customisation and high cost are counterbalanced by charging a premium price. In doing so, USOs achieve significant profit margins. A customisation strategy can also serve as a tool for understanding what customers want, which allowed the studied USOs to control their production in a way that enhanced long-term profitability.

b) Cost-efficiency strategy

One of the challenges faced by USOs regarding value capture to commercialise new technological solutions was setting a reasonable price point that would entice payment from customers and in the same time capture enough value for the USO. Given limited control over the market price and high prototyping expenditures, it is difficult for a USO to offer products at a competitive price. In the case studies, the USOs pursued cost-efficiency strategies as stepping stones to scaling up, reducing costs, offering competitive prices and, eventually, capturing value.

To compensate for the high cost associated with the customisation strategy, a cost-efficiency strategy was adopted to produce more homogenous or standardised products through a simplified supply management chain and production efficiencies. In an effort to ensure that the firm would end up with a product that has benefits and a price point customers would value, DeltaCool performed a market assessment. It suggested that if the firm wanted to sell its products, it should not charge customers more than USD 100 per engine, although the cost of production was much higher. Therefore, the firm engineered its manufacturing process to meet the set price. This was encapsulated in a statement made by the Director of Business Development:

> *"Because the market price is the price made by the market, internally their process to insert this vacuum was more than 100 dollars... Our economic proposition is that, throughout the world, you are talking about 200 million fridges sold every year. We need to be able to manufacture at scale and at lower cost, and sell our engine for less than 100 dollars. So, being able to offer 80 dollars per fridge is what got the interest from fridge manufacturers to work with us."*

With a monopoly on PAL waste handling in a niche market, BetaRecycle could potentially charge a premium price for its technology. Despite this untapped pricing power, the USO was still unable to charge customers in a profitable way because of the weak market signal for its offering. As a result, BetaRecycle shifted its focus to achieve cost efficiency through a simpler value chain so that the USO could offer an attractive price to customers.

All the studied USOs applied their technological solutions to products with reasonable prices that could capture the maximum value for the customers and USOs. The USOs prioritised not only optimising a technological solution but also offering an affordable solution. Therefore, they designed products at a cost that ensured a sufficient profit margin by charging customers cost-effective prices. As proclaimed by BetaRecycle;s CEO, *"[t]he margins in environmental services are very small, and there is little taste for environmental processes which are expensive. That is why we try to scale and make our process as cost-efficient as possible."*

For global USOs, like GammaSolar, a cost-efficiency strategy results in product standardisation, which allows a larger customer base to be served. Through a partnership

forged in T Project, GammaSolar managed to reduce the cost of production and offer European customers a competitive price. As stated in an article published on 4th March 2016 on phys.org[42], the reduction of cost was vital for moving towards the commercialisation pipeline:

> *"The T Project was a success for GammaSolar as it made a significant contribution to the reduction in manufacturing cost of the plastic solar cells…It is an essential step towards the commercialisation of GammaSolar's OPV based on technology developed and produced in Europe."*

Cost efficiency to capture value enhances the likeliness that a USO can offer reasonable prices for its products. By reducing the cost per unit and increasing the total output, a USO can also boost its competitive advantage by achieving cost competency and benefits from economies of scale. The cost-efficiency strategy also helps address the high cost of customisation, which may decrease profit.

First-order category	Quotes
Explore auxiliary revenue stream	*"DeltaCool have been clever at garnering non-dilutive grant funding and have, so far, consistently found solutions to the performance setbacks encountered in developing a novel technology."* – DeltaCool's lead investor *"That time [the prototyping stage], we sold some commercial projects, a few during that period."* – AlphaVent's CEO
Enter substitute market	*"As we looked for the potential market, we quickly saw that it has vastly saturated and we need to find application somewhere else."* – GammaSolar's inventor *"For retail, if you want to power a device up in a retail outlet that might be displaying some promotional information, it's too expensive to plug it into the mains. This is an attractive market to have something which already harvests light."* – GammaSolar's Director of the Board/inventor
Employ customisation strategy	*"As each [AlphaVent] project generates potentially different challenges, AlphaVent offers a design consultancy to customise the company's overall system installations. This enables them to work within a building's architectural restraints and avoids the possibility of temperature stratification that can lead to undesirable cold or hot zones."* – Bloomberg *"The company [GammaSolar] has a clear position in the value chain as a manufacturer of solar cells on a roll for supply to tier-one OEMs that integrate solar*

[42] Source: https://phys.org/news/2016-03-technological-breakthrough-cheaper-flexible-solar.html

	cell modules into end products for their selected markets. The robustness, low weight, flexibility and ease of customisation combine to make the product a significant step up from existing solutions for the intended markets." – GammaSolar's partner
Employ cost-efficiency strategy	*"So, for an air conditioning system for a house, residence or even for a car you are talking about a cooling capacity so the cooling power required at least 5,000 W. For a fridge, you're talking about 50 W. So, you are talking about a factor one thousand and looking at the technology. You know we started small, it's a modular approach. So, we thought we would be more successful to match the budget that would reach 50 watts instead of 5,000 W target."* – DeltaCool's CEO *"The costs and challenges of ventilation vary from project to project, but natural ventilation can usually be a cost-effective option."* – AlphaVent's website

Table 5-5: Additional selected quotes for the first-order categories

5.5 Network Management through Deliberate Temperament

When a USO transitioned from an academic network to a commercial network, many conflicts arose among stakeholders because of divergent values and unmet expectations. USOs across cases dealt with these tensions through deliberate temperament[43], an approach that aims to solve tensions among stakeholders by aligning stakeholder's expectations, which results in a mutually beneficial outcome and lessens initial conflicts. Deliberate temperament was crucial for balancing the trade-off between the expected benefit and the amount of risk undertaken by the USO.

The conflicts observed in the studied cases are due to differing interests, values, motives and cultures. As a new firm, a USO cannot easily avoid such conflicts because they occur mostly among long-standing stakeholders with strategic importance to the USO's commercialisation and growth. Due to this, the conflicts cannot be sidestepped or ignored. Additionally, USO entrepreneurs were precluded from preventing future conflicts as they were not usually evident before their occurrence.

Therefore, rather than envisioning the future and avoiding conflicts, the USO entrepreneurs examined in this study made informed judgments about stakeholders' motives and attempted to negotiate solutions that could satisfy opposing needs. This was done through 1) collaborative

[43] In the field of acoustics, temperament refers to adjustments to the tension of the strings of a musical instrument to properly align the intervals between their tones so that the instrument is in tune and dissonance is minimised. The adjustments result in a desired pitch.

partnerships and; 2) a compromising approach. The data structure for the aggregate dimension of deliberate temperament is presented in Table 5-6. Key quotes mapped to the data structure are discussed in the following sections, and additional quotes are provided in Table 5-7 at the end of this section.

First-order category	Second-order theme	Aggregate dimension
Forge co-operation (with non-competitive partners)	Collaborative partnership	**Deliberate temperament** *(approach to manage stakeholders by aligning stakeholder's expectations, which results in a mutually beneficial outcome and lessens conflict)*
Forge co-opetition (with competitive partners)		
Trade-off incompatible values	Compromising approach	
Tolerate divergence of values		

Table 5-6: Data structure for the aggregate dimension of deliberate temperament

5.5.1 Collaborative Partnership

Despite discrepancies related to value, interest, motive and culture, USO stakeholders across cases were observed to collaborate. Here, collaboration refers to working together to achieve a shared goal. Through collaboration, all involved parties recognise the need to work together to create value and suppress current or potential tension. In contrast to compromise, collaboration produces mutually satisfactory results. The level of assertiveness and co-operation achieved through collaboration is slightly higher when collaborating than when compromising.

USO stakeholders that work collaboratively obtain greater resources, recognition and rewards when competing for finite resources. USOs tend to be assertive about their needs and co-operate with other stakeholders. In the case studies, collaborative results were achieved through 1) co-operation with non-competitive partners; and 2) co-opetition with competitive partners.

a) Forge co-operation with non-competitive partners

Co-operation is a collaborative tool that USOs across cases usually forged with non-competitive partners. Conflicts that were resolved with co-operation were mostly conflicts of interest and value that stemmed from incompatible goals or beliefs. Rather than letting the conflict further polarise stakeholders, USOs proactively turned conflict into co-operation by merging their goals with those of stakeholders to seek win-win solutions.

In most cases, USOs with new technologies were challenged by sceptical and risk-averse stakeholders who had different beliefs regarding how the technology would accelerate. For example, although the FMCG companies were not ready to adopt BetaRecycle's technology, both parties agreed on a strategic alliance to co-finance the establishment of a commercial plant. In return, the the FMCG companies were allowed to use BetaRecycle's ecolabel to educate consumers about the recyclability of their packaging. As stated in an article published by Cambridge Science Park News[44] on 28th July 2011, *"[B]etaRecycle, a leading provider of recycling and environmental technology solutions, announces that it has partnered with Company K to support the construction of the first commercial-scale plant."*

Despite the clashing beliefs about the utility of BetaRecycle's technology, co-operation between the USO and FMCG companies resulted in a cross-marketing partnership; BetaRecycle allied with FMCG companies offering products that complemented (but did not compete with) its product offering. Both parties streamlined their goals to build the commercial plant.

In the case of DeltaCool, the USO co-operated with white goods companies who initially had opposing interests and values regarding their technology. When DeltaCool first introduced its technology, the majority of white goods companies were not interested in it. However, as the benefit of the technology became clearer, DeltaCool managed to convince the companies to collaborate. Co-operation forged between DeltaCool and the white good companies enabled the integration of the USO's magnetic cooling technology into industrial applications. This was articulated by the Director of Business Development who said,

> *"We experienced some fight with a company owned by W; they wanted to kill us. Then there's Company P. We gathered consensus that gas compressor for fridges has reached the technological plateau. We came in with new ideas which are not something that has already been explored, after that then they were interested to talk with us. They are now partners."*

[44] BetaRecycle Pratners with Company K on its First Commercial Plant. Available at: http://cambridgesciencepark.staging.engineserver.co.uk/enval-partners-with-kraft-foods-on-its-first-commercial-plant/

Through co-operative partnerships, conflicts among stakeholders were dealt with mutuality and more constructively. Across cases, disputants that worked co-operatively to negotiate a solution were more likely to develop a relationship of trust and develop mutually beneficial options. Co-operative relationships also allowed USOs to not only access resources but also resolve occurring and emerging conflicts.

b) Forge co-opetition with competitive partners

Co-opetition is a collaborative tool usually forged with competitive partners to achieve a mutually beneficial outcome. Competitors co-operate with each other to create higher value compared to the value achieved when creating it without interaction. Through co-opetition, companies with partially congruent interests interact and explore the knowledge of new product together.

AlphaVent's success in leading a profound transition from mechanical to natural ventilation systems undermined the leading mechanical ventilation companies. This friction could lead to rivalry between firms in an attempt to gain a competitive advantage. Rather than continuously competing, AlphaVent and its competitors teamed up to offer their customers a full range of both powered and natural ventilation systems. Through this approach, AlphaVent complemented its competitors' strengths and won a market segment that neither AlphaVent nor the competitor could penetrate alone. As written in an article published by Cambridge Enterprise on 10th February 2011[45], *"[A]lphaVent forged a major collaborative project with a leading UK ventilation company in the first real partnership between the natural and mechanical ventilation industries."*

BetaRecycle created an opportunity to align the goals of competing companies through the establishment of B Consortium, which was comprised of organisations with a vested interest in the success of BetaRecycle. Through the B Consortium, the USO streamlined its supply chain and enhanced its economies of scale. Despite competition among waste handlers, the consortium allowed the financial risk of technological development to be spread between different players at different stages of the supply chain. According to the CEO of BetaRecycle,

[45] Source: https://www.enterprise.cam.ac.uk/news/breathing-buildings-announces-major-collaboration-project/

"The B Consortium brings together key players who are set to benefit from changes in waste management in their supply chain, to fund development, spread risk and put public pressure on waste handlers. This novel collaboration produces positive results for all stakeholders, despite competition between them."

Similarly, DeltaCool envisioned that small companies would team up with larger companies. The USO entrepreneur also believed that failure to optimise materials was primarily attributed to failure to merge the goals of competing companies. This was reflected in the CEO's interview:

"I think in the European context, what we're seeing is the trend of smaller companies that are teaming up among them and even with larger industry. So, I think that explains why ten years ago, the market for material wasn't quite optimised."

Co-opetition initiated by USOs led to significant synergy that not only allowed for better firm performance but also resolved conflicts between competitive partners. Proactive USOs took this as an opportunity to survive and generate profit without stealing their partners' customers or damaging their credibility.

5.5.2 Compromising Approach

Across cases, the USOs compromised with stakeholders regarding the negotiated outcome by giving up part of their demand to reach an equitable agreement or mutually acceptable middle solution. Unlike a purely win-win solution, compromising did not focus on fair standards for settlement, instead splitting the difference between disparate solutions. The approach turned divergent values into strengths by compensating for risks taken and rewards achieved.

In some cases, compromise appeared to be the best or only viable solution to deal with conflicts among stakeholders regarding, for example, royalty splitting and product design. The analysis revealed that USO entrepreneurs compromised with scholars, TTOs, investors and customers and vice versa. This proactive measure resolved disputes immediately, which was crucial for avoiding derailment of the technology commercialisation process. It also prevented conflict from escalating in the future. To arrive at a compromise, USO entrepreneurs and stakeholders 1) traded-off between incompatible values; and 2) tolerated divergence of values.

a) Trade-off between incompatible values

Value trade-off is one way to deal with conflicting stakeholders with incompatible desires. It involves the loss of one quality, quantity or property in return for other gains. It usually ends with a binding contract that ensures the consent of all parties to the provisions.

In most cases, disputes concerning the equity and royalty terms initiated by a TTO were one of the major sources of conflict that provoked tension between scholars, licensing officers and entrepreneurs. This strife was resolved by recognising an agreeable return from commercial development of the new technology. For example, in the case of AlphaVent, the inventor, investor and TTO agreed to commercial terms that allowed the TTO to hold a share of the firm through an equity-only agreement while the USO enjoyed royalty-free, exclusive commercial rights to the university-owned technology. This was described in the interview with the CEO:

> *"It was a case of then figuring out what the right kind of arrangement was for the company to access and have right to the IP, which was further complicated at the time by the fact that the university didn't have exclusive rights to the IP because our funder, Investor X also had rights to it. The agreement between Investor X and the university was that if there was any IP that was generated by the research that Investor X had funded, that Investor X would have worldwide, non-exclusive, royalty-free rights to the technology. Then Cambridge University can do whatever else they want with it. I fought obnoxiously hard for this [licensing agreement]."*

By engaging in value trade-off, the conflicting parties are usually only partially satisfied. In the case of a licensing agreement, each party gains a reasonable (but not necessarily equal) share of the available 'pie'. This type of solution was crucial for enabling new technology commercialisation, particularly when stakeholders' engagement was desired or they could not be easily removed from the network. This type of solution was exemplified when BetaRecycle gave up the company's royalties to the TTO and expected financial support for patenting. BetaRecycle's inventor described the trade-off during his interview:

> *"In the case of royalties coming to the inventors, I was going to get two-thirds to their one third. In the case of a split in the company ownership, if a company were going to be founded, it would be 60 me, 20 the co-founder, 20 the university. So, as much as I*

knew it was a negotiation simply because I owned a substantial part of the IP myself, at the same time I didn't have a penny to go and patent this myself. So, I said, 'Look, if Cambridge provides me with the money to patent this thing that will cost some money, I don't have anything tangible, why not?'"

To be able to trade-off incompatible values, the USOs across cases carefully considered how their decision would impact the other party. Although a compromise-based solution can only achieve partial satisfaction, it was still useful for resolving seemingly valid demands posed by key stakeholders with a different values, interests, motives or cultures.

b) Tolerate divergence of values

Tolerance of different values refers to one's willingness to accept a value that differs substantially from his or her ideal. Unlike value trade-off, tolerance is usually uncountable and is mildly inclined towards accommodating the other party. Tolerating differences is the result of acknowledgement, respect and appreciation for different ways of perceiving things. Similar to value trade-off, USO entrepreneurs may only achieve partial satisfaction as a result of tolerance-based solutions. USOs that exhibited tolerance usually did not achieve immediate rewards but reaped longer-term gains. In addition, tolerance of difference values not only resolved conflicts but also accelerated the pace of commercialisation.

Inventors in USOs usually had strong opinions about product design that did not necessarily align with the entrepreneur's vision or the customers' need. The inventor and USO entrepreneurs overcame such conflicts by acknowledging, prioritising and tolerating the customers for whom the value was created. As a result, most inventors altered the way in which technological designs were optimised and co-created value with the customers. For example, BetaRecycle developed its technology by tolerating the different values of customers. As the BetaRecycle's inventor proclaimed, *"[w]e have had to tailor what we offer to the market as time has gone on. And we were deliberate, fairly flexible about what we were going to offer. It all depends on what they [the customers] want."*

Similarly, the entrepreneurs involved in GammaSolar also tolerated customers' values even though these values did not fully align with theirs. To some extent, the USO involved

customers in the optimisation of its technological solution by providing samples to potential customers in exchange for useful feedback. GammaSolar's CEO stated,

> *"So, we have now reached the point where we do have customers who tell us what they want and it's actually moving forward really quite well and exciting. So, we got to that point. You could argue that we could've got there earlier but we are where we are but now, we are in a position where we got real customer paying us money to develop samples that they are going to try in the field and if that's successful it's going to scale to volume. It is never too early to get the customers involved."*

Tolerance occurred not only among external stakeholders but also internally within the USO. For example, BetaRecycle's previous chairman, who came from an academic background, tolerated differences in motivation and culture between himself and the new chairman, to whom he was willing to give up the chairmanship: *"[I] was very much in favour of passing the chairmanship over to somebody much more experienced in that area, and that's the current chairman. Given his experience and motivation, I was very happy to pass on the chairmanship."*

In summary, in the USO context, where diversity in values may interfere with how the commercialisation process unfolds, stakeholders with different aspirations tolerate differences of value to allow for expansion of the network that drives commercialisation. USOs across cases did not blindly tolerate differences to move forward; rather, they provided valid arguments to defend their tolerance and understand the extend they could tolerate. Intolerance of differences is one of the causes of laggard commercialisation.

First-order category	Quotes
Forge co-operation (with non-competitive partners)	*"When we were building the power plant, three brand owners actually gave us a donation to help us with the cost of it. And they've been very supportive, because for them, they can turn around to the public and say we're doing something now. As a result, they enjoy healthy market reputation."* – BetaRecycle's CEO *"It [the collaboration between DeltaCool and white goods companies] was not easy but we start to realise that we tend to achieve more by working together."* – DeltaCool's CEO

Forge co-opetition (with competitive partners)	*"Most buildings require a combination of both mechanical and natural ventilation for the different room types involved. We passionately believe in delivering the right answer for a client – since this usually involves both mechanical and natural ventilation, the industry needs a supplier offering clients the best of the best in both areas. We are really excited to be working with Company N to enable procurement of building-wide ventilation solutions."* – AlphaVent's CEO *"For many clients developing commercial buildings such as schools and retail outlets, considering a ventilation strategy has always meant a choice between powered or natural ventilation. Thanks to this partnership… we can now offer customers a complete solution."* – AlphaVent's partner
Trade-off between incompatible values	*"…You need to position your new technology as the opportunity to create new markets. Eventually you are going to displace the old technology but you will never win trying to fight against them. So always try to find the correct path avoiding confrontational, always try to find the middle ground."* – DeltaCool's Director of Business Development *"We've got investors with very different aspirations and it is very hard to manage. So, you need to have investors as best you can make it with a very common aligned interest."* – AlphaVent's CEO
Tolerate divergence of values	*"One of the beauties of being in touch with the end user is they simply tell you what is needed. Often these adaptations can be provided through partners or with small changes to the offer, but sometimes they highlight a whole new strand that can be added to the product or service. We strongly encourage innovation around our solutions from both partners and customers."* – GammaSolar's CEO *"We have the product for the commercial plans operating and the offering that we had six months ago and the one that we have now is completely different, in this particular case, because of the price of commodities and customers' need."* – BetaRecycle's CEO

Table 5-7: Additional selected quotes for the first-order categories

5.6 COPE Principles for Business Models Development

The results of the fourth-round coding using the template analysis approach validated the relevance of the emergent categories to the four premises borrowed to explain business model development. This thesis abbreviates the four principles as COPE[46] (i.e. take control, create opportunities, forge partnerships, embrace contingencies). The COPE principles appeared to be applicable for explaining how business models were developed. Most importantly, the COPE principles also align well with the emerging categories observed in earlier rounds of

[46] COPE, an abbreviation of the principles that drive business model development. The word 'cope' itself means 'to face and deal with problems, or difficulties, especially successfully or in a calm or adequate manner.'

open coding analysis. The results of thematic template analysis are presented in Table 5-8, which shows selected events that occurred across cases and across business model components in which COPE principles were observed. The following section summarises the COPE principles observed to enable business development in the case studies.

Take control – USOs across cases took active control over their resources and capabilities to move forward in the commercialisation pipeline. They focused mainly only on what they had power over, not things that were out of their control. The USOs also tended to make fewer predictions and based decision making on the sets of individual means available to the ventures. They then focused on working to achieve an outcome that could be created using these means. By taking control over its means, USOs across cases became more pragmatic as it influences outcomes and creates opportunities using limited resources in creative ways. By taking charge of its resources and capabilities to develop a business model, USOs did not expend effort on things that cannot be controlled.

Create opportunities – USOs endogenously created and took advantage of new opportunities, which might not have existed previously, to pursue commercialisation. They also strived to influence exogenous forces at the disposal of partners to create new opportunities. Rather than pursuing opportunity objectively in a readily available market or waiting for an opportunity to emerge, the entrepreneurs in the case studies strove to be more proactive and made an effort to bring their new technologies into commercial reality. The exigency of opportunity creation for USOs determined the adoption of their technology.

Forge partnerships – Across cases, partnerships were crucial for accessing resources, aligning expectations and resolving conflicting values. In addition, they helped reduce uncertainty and enabled joint co-creation of value. Interestingly, USOs built partnerships not only with self-selecting stakeholders but also with individuals who were not initially interested in collaborating with the USOs. Through interaction with these stakeholders, the USO entrepreneurs convinced stakeholders to become involved in the business model development process. Indeed, the business model development process was open for and contingent upon the involvement of other people and organisations as committed stakeholders.

Embrace contingencies – Across cases, contingencies were expected and dealt with by remaining flexible rather than adhering to existing goals. In some cases, the USOs managed to

convert unexpected events into opportunities. USO entrepreneurs leveraged unexpected events for the benefit of their firms. Instead of making 'what-if' scenarios to deal with worst-case scenarios, entrepreneurs interpreted contingencies as potential clues for commercialisation of their technology. Figure 5-2 illustrates the relatedness of the business model components to the COPE principles that drive the development of business models.

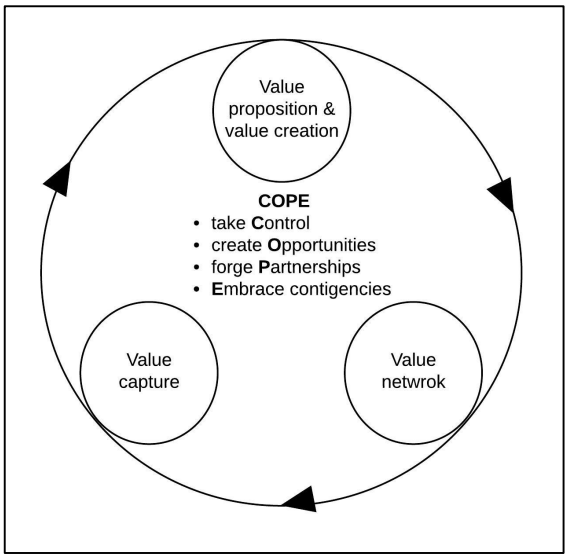

Figure 5-2: The interrelatedness of business model components and COPE principles

COPE principle/Value component	Principle 1: C (take Control)	Principle 2: O (create Opportunities)	Principle 3: P (forge Partnerships)	Principle 4: E (Embrace contingencies)
Value proposition and value creation *(How did the USO use COPE principles to craft propositions and create value?)*	▪ AlphaVent took full authority over its IP (with less intervention from the TTO and the funder) to create a novel proposition and made a cogent argument to influence the decision regarding the royalty-free licensing agreement ▪ BetaRecycle administered its own value creation mechanism when the inventor was still halfway through his postdoctoral research ▪ GammaSolar shifted its emphasis and revamped the way value was created by placing more emphasis on understanding the market's needs ▪ DeltaCool took the lead in value creation within the field of cooling devices and broke away from conventional material optimisation activities	▪ AlphaVent created the opportunity to become an advocator of the natural ventilation system and accelerated its technology when the firm first piloted its technology in schools ▪ BetaRecycle created a new opportunity in a different market by conducting investigations beyond conventional waste recycling and proposing a method for recovering PAL materials, which were not previously entirely recyclable ▪ GammaSolar crated a new opportunity by generating value through its R2R technology to manufacture robust OPV modules ▪ DeltaCool created a new opportunity by exploiting the government's interest in reducing the UK's greenhouse gas emissions through the creation of a new generation of low-carbon cooling devices	▪ AlphaVent partnered with architects to understand the gap in the market and co-create a novel solution to naturally ventilate buildings ▪ BetaRecycle partnered with WRAP to fund a trial that validated the value embedded in its proposition ▪ GammaSolar partnered with Company T to co-create value by developing its prototype ▪ DeltaCool partnered with Company B to co-create a suitable cooling device to be embedded into its products	▪ AlphaVent created value in a lean manner when the firm was affected by the recession ▪ BetaRecycle made its proposition more financially interesting by emphasising the usefulness of material recovery (not just the recyclability of PAL) when the initial proposition did not translate into sales ▪ GammaSolar created value through customisation of OPV when the price of solar energy decreased ▪ DeltaCool stopped prototyping and switched to a different niche to design a magnetic cooling device when the initial material could not be further optimised

Value capture *(How did the USO use COPE principles to capture value?)*	▪ AlphaVent decided to continuously capture value through a non-core channel (consultancy) despite the success of commercialisation of its ventilation system ▪ BetaRecycle decided to include after sales service in its proposition (to capture more value) ▪ GammaSolar separated into GammaSolar1 and GammaSolar2 to capture value separately and more effectively ▪ DeltaCool managed its tacit knowledge and intellectual capital and offered a consultancy service to capture value	▪ AlphaVent diversified its offerings and tapped multiple unmet needs for ventilation to capture multiple types of value ▪ BetaRecycle created new opportunities through several revenue mechanisms ▪ GammaSolar entered substitute markets to capture alternative value ▪ DeltaCool used its funds to develop additional products through ongoing R&D	▪ AlphaVent partnered with company N to capture value in both the natural and powered ventilation industries ▪ BetaRecycle partnered with three FMCG brands to obtain sufficient funds to establish its first commercial plant ▪ GammaSolar partnered with Carbon Trust, Rhodia and IP Group plc to secure funds for the prototyping stage ▪ DeltaCool partnered with Carbon Trust to access funds for its operations	▪ AlphaVent applied competitive prices to increase profitability when the firm was hit by the recession ▪ BetaRecycle diversified its revenue stream to include recycling of industrial scrap (instead of used PAL) when the financial crisis caused a collapse in the price of the commodity ▪ GammaSolar captured value in a different and untapped market (which did not require the technology to be fully developed) after the collapse in the price of solar energy ▪ DeltaCool captured value through an alternative channel to fund its operations after delays in the prototyping stage
Value network *(How did the USO use COPE principles to manage its network?)*	▪ AlphaVent terminated its sales function agreement with its third-party partner due to slow sales growth ▪ BetaRecycle took responsibility for replacing the chairman and terminating non-performing personnel in the company ▪ GammaSolar took charge of the potential range of commercialisation opportunities and technological partnerships with interested parties ▪ DeltaCool selected its partners to include influential white goods companies so it could expand its value network	▪ AlphaVent worked with regulators to influence the enforcement of regulations regarding natural ventilation ▪ BetaRecycle proactively extended its network through establishment of the B Consortium ▪ GammaSolar created a new opportunity to expand its network by becoming a partner in TREASORES (an EU-funded project concerned with cheaper production of OPV) ▪ DeltaCool created a new opportunity to expand its network by sharing the results of the firm's R&D at symposiums and conferences around the world	▪ AlphaVent worked collaboratively with company V and was later acquired by company V ▪ BetaRecycle partnered with the university's Challenge Fund, which invested in the firm's prototype through a convertible loan ▪ GammaSolar partnered with the EU and became part of MUJULIMA (a collaborative research project involving experts and nine EU universities) ▪ DeltaCool partnered with the UK's largest seller of refrigerators in a major pan-European consortium examining energy efficiency from farm to plate	▪ AlphaVent worked with its lawyer to deal with patent infringement issue and gained a healthy reputation upon winning a patent dispute ▪ BetaRecycle actively advocated the pressing need for PAL segregation with interested parties in the public (not just local authorities and regulators) ▪ GammaSolar extended its partnership with SolarAid, a KickStart Sustainable Energy Fund, to provide IndiGo systems to rural, off-grid areas when the initial prototyping stage was delayed ▪ DeltaCool expanded its partnership with stronger partners in the cooling industry upon receiving a weak market signal and high resistance to the technology

Table 5-8: Results of thematic template analysis of the COPE principles

5.7 Conceptual Framework for USO Business Model Development

The previous sections have detailed the findings of the four rounds of analysis. This section presents a conceptual framework that integrates the findings. To describe the context of the emergent framework, it is essential to first reiterate the overarching purpose of this study: to advance the understanding of how a USO develops its business models for commercialising university technology. Past literature on strategic management and academic entrepreneurship addressed this issue only partially. Scholars agree that 1) a USO devises a business model that is viable enough to put its product or service in the marketplace; 2) a USO's business model is developed through iterative trial-and-error and experimentation; and 3) the business model development process faces challenges that are unique to USOs, such as market resistance, financial pressure and conflicting stakeholders.

The first insight obtained from the coding analysis revealed the three approaches to business model development to overcome challenges namely, 1) value proposition and value creation through flow-field control; 2) value capture thorough pragmatic kinesis; and 3) value network management through deliberate temperament. The second insight was that the business model development process hinged upon the COPE principles. This provided a basis for a general understanding of how a USO develops its business model by 1) taking control over its capabilities and resources; 2) proactively creating opportunities; 3) forging partnerships with non-competitive and competitive stakeholders; and 4) embracing unexpected contingencies.

To further enhance our understanding of the approaches to business model development, the findings were integrated and overlaid as a graphical depiction of a conceptual framework that illustrates the fundamental concepts and their interrelatedness. The findings are articulated as a schematic model (Figure 5-3), and the development of business models for commercialisation of new university technology is graphically depicted as an opened black box. It provides new insights into the illustration of the opaque black box previously shown in Figure 2-3.

In Figure 5-3, the USO business model development process is illustrated as an iterative process that configures the right business model across the business model components which also corresponds to the exogenous challenges. It starts with the discovery of new commercially viable technology in the university laboratory that is commercialised through a USO. Then, a USO deals with high market resistance by enriching the technological benefits and

manoeuvring regulations to allow a proposition to be crafted and value to be created. Next, financial pressure is dealt with by devising a heterogeneous revenue stream and balancing customisation with cost to capture value. Finally, conflicting stakeholders are managed through collaborative partnership and a compromising approach. By seeing these three sub-processes as having goals and outcomes to be achieved along the way, it is possible to picture the process constructively and systematically rather than haphazardly. These approaches are interlinked but do not proceed linearly or sequentially. Instead, most of these processes coincide with each other.

As a USO develops its business model iteratively through the three measures, USO entrepreneurs make decisions based on the COPE principles. As previously mentioned, COPE principles provide a basis for general understanding of how a USO develops its business model by 1) taking control over its capabilities and resources; 2) proactively creating opportunities; 3) forging partnerships with non-competitive and competitive stakeholders; and 4) embracing unexpected contingencies. These principles are the heart of business model development and provide a constructive way to think about the business model development process.

The graphical representation in Figure 5-3 provides a context for summarising and interpreting the empirical findings. The theoretical and practical implications of the conceptual framework will be discussed further and in greater depth in Chapter 6.

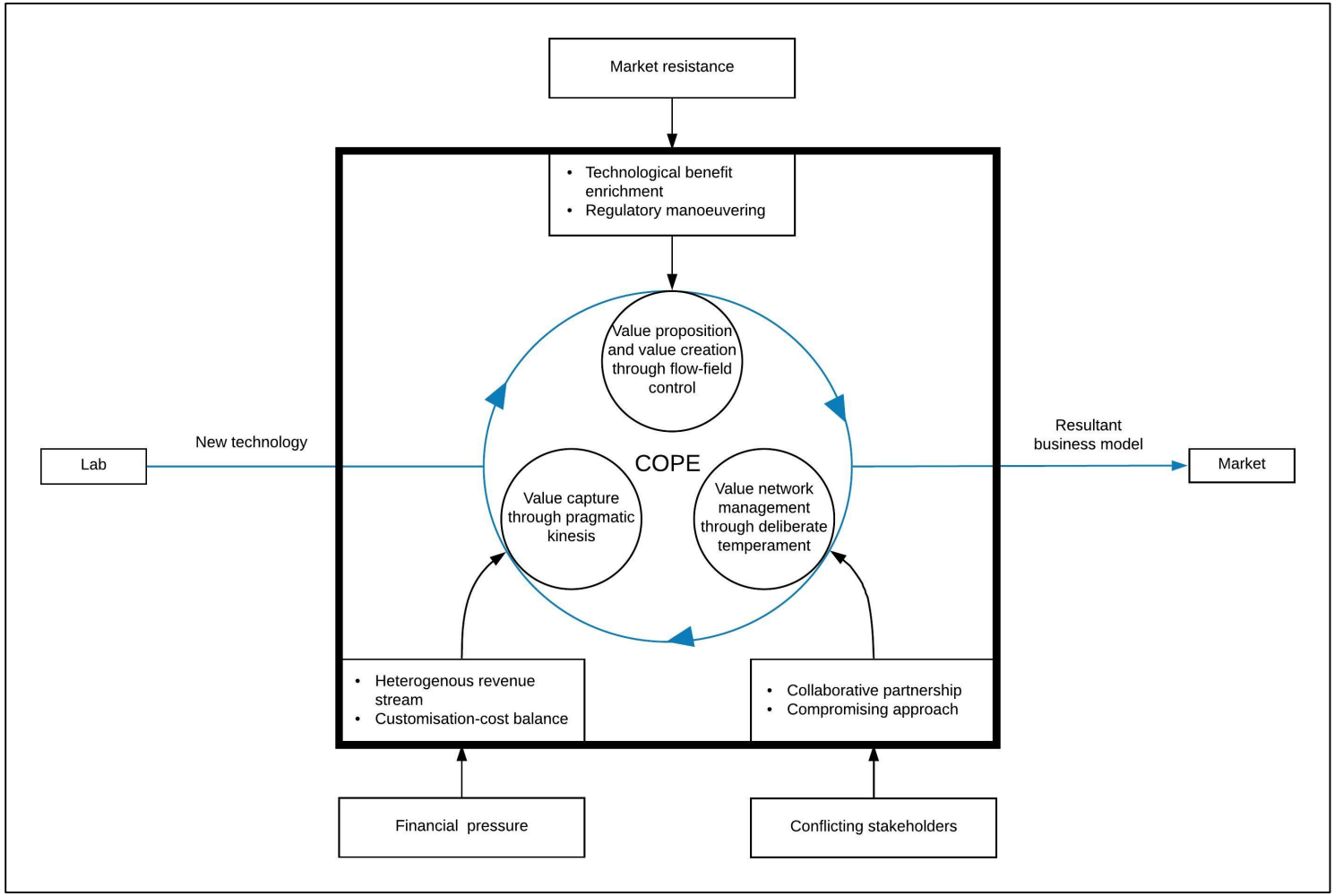

Figure 5-3: The conceptual framework for business model development

5.8 Chapter Summary

This chapter aimed to substantiate the findings obtained from the four cases to identify common patterns and, in doing so, answer the research question: how does a USO develop its early-stage business model for commercialising its technology? Sections 5.3, 5.4 and 5.5, respectively, outlined the evidence that led to the three main approaches to business model development: 1) value creation through flow-field control, 2) value capture through pragmatic kinesis and 3) network management through deliberate temperament. Section 5.6 presented the COPE principles derived from the findings of template analysis. The conceptual model in section 5.7 graphically summarised the key findings of this research. The next section will interpret and describe the significance of the findings in this chapter in light of the extant literature.

6 DISCUSSION

6.1 Chapter Introduction

This chapter will interpret the findings in more depth in comparison to prior studies about the problem under investigation. It is divided into four main sections. Section 6.2 thoroughly discusses the three interlocking, iterative and mutually reinforcing mechanisms for business model development based on the aggregate dimensions derived in the analysis. Next, section 6.3 and section 6.4 discuss the significance of the COPE principles and the emerging conceptual framework, respectively. In each section, the findings are linked with the dominant theories as either supporting, supplementary or contradicting evidence. Following that, the way in which the findings add to the existing knowledge is highlighted. Finally, section 6.5 concludes the discussion chapter.

6.2 Three Mechanisms for Business Model Development

The overall aim of this research was to understand how a USO develops its business models for commercialising university technology. Logical synthesis of the findings revealed three interlocking, iterative and mutually reinforcing mechanisms for business model development: 1) value proposition and value creation through flow-field control; 2) value capture through pragmatic kinesis; and 3) value network management through deliberate temperament. Flow-field control is an approach that aims to craft a proposition and create a valuable offering while overcoming market resistance, by taking active control over a firm's resources and capabilities. Pragmatic kinesis is a measure taken to by a USO to capture value and respond to financial pressure by being flexible and sensible enough to move towards profit. Lastly, deliberate temperament is intended to manage conflicting stakeholders by aligning stakeholders' expectations to produce a mutually beneficial outcome.

These mechanisms explicitly revealed the approaches to business model development across all value constituents collated as an interlocking system and iterative process (i.e. each value component is achieved through continuous experimentation, they are mutually dependent and inextricably linked). Any change in one component would trigger an immediate change in an interlinked component. These findings are consistent with earlier work concerning the interdependencies of business model components (e.g. Morris et al. 2005; Johnson et al. 2008;

Zott & Amit 2010) and learning by trial-and-error (e.g. Chesbrough 2010; Holloway & Sebastio 2010; Sosna et al 2010; Trimi & Berbegal-Mirabent 2012).

Although previous literature acknowledged the interdependencies of business model components, it did not tend to gain a deep understanding of the dynamics between components in response to external challenges. In contrast, this study obtains a more detailed understanding about the establishment of the business model in response to unique challenges. This insight is particularly crucial for providing a rich and nuanced account of the development of the business model in a real-world setting, where a USO should commit to addressing a unique set of obstacles while developing its business model (Mustar et al. 2006; Lubik & Garnsey 2016). As claimed by Alrich and Fiol (1994) and Mustar et al. (2008), many firms fall into the trap of rushing into development of its business model before truly understanding the threats they must overcome. Hence, the findings in this thesis offer credible insight into how a USO manages business model development based on uncertainty and risk rather than an ideal set objective, which can be flawed.

The three mechanisms of business model development also brought greater empirical visibility to Zot and Amit's (2010) conceptualisation of business model design as an activity system perspective. The mechanisms explicated the content and structure of business models as well as how the business model development process is governed. By breaking down the specific activities performed by a USO to create value, capture value and manage its network, greater understanding of the process was offered, which enhanced the conceptual clarity of the activity system perspective. This insight also responded to business model scholars' call for a common language for business model development (e.g. Hedman & Kalling 2003; Morris et al. 2005; Johnson et al. 2008) to help reduce the proliferation of silos (Writz et al. 2016).

With regard to the interrelatedness of business model components, this thesis demonstrated that each value component is equally important and mutually reinforces the overall process of business model development. It added to the classic literature on business model development, which usually placed greater emphasis on value creation in comparison to value proposition, value capture and value network (e.g. Chesbrough & Rosenbloom 2002; Amit & Zott 2001; Zott & Amit 2010; Johnson et al. 2008). The finding also supports Bigdeli et al.'s (2016)

argument that the interactions between core components of business models lead a USO to achieve financial sustainability and operational scalability.

Although extant business model literature purported the importance of an iterative process of alignment of new technology and the market, how the iterative process unfolds remained muddled; some works attempting to clarify the iterative process appeared to be in conflict with each other. For example, Teece (2010a) hints that a firm should work on its technology before identifying its customer segment, whereas Smilor et al. (1990) claim that the market needs to be identified first because it is far more crucial than technological factors in regards to the USO's performance. Other scholars suggested that the business model development process should begin with the establishment of the value proposition (e.g. Johnson et al. 2008; Zott & Amit 2010; Cortimiglia et al. 2016). Taken together, these works appeared to advocate for a sequenced process of iterative business model development.

Whilst the findings in this thesis support the importance of value proposition and the expediency of technology-driven and market-driven commercialisation, there is less obvious evidence for a sequenced business model development process; in fact, the cases demonstrate the non-linearity and complexity of relationships between business model components. The only evidence that could shed light on the issue is; in the process of developing a business model, a USO should exert more control over its resources and prioritise those that the firm controls. That being said, it seems logical for a USO to optimise its technology prior to solidifying the market. However, the notion still does not endorse the strict sequencing of a business model development process because if the USO has achieved high TRL upon its establishment, it could immediately focus efforts on identifying the market in which the technology should be commercialised in. This insight reiterates Schumpeter's (1983) view that the entry point to value creation is either technology or market needs.

The evidence in the case studies supported the importance of technological and market drivers in technology commercialisation. The finding also ascertains that sequencing in the process of business model development is not necessary. This aligns with Reymen et al.'s (2017) argument that the business model development process should not strictly employ rules because how business models are developed is contingent on the USO's market and

technological conditions. The findings also support Osterwalder and Pigneur's (2010) view that the business model development process does not necessarily follow the traditional ladder to growth, in which the value proposition is defined first, the customer segment is characterised next, and the key resources, activities, and other key business model components are determined last.

Although the current thesis juxtaposed scholarly views about sequencing and business model structure (e.g. Smilor 1990; Johnson et al. 2008; Teece 2010a; Zott & Amit 2010; Cortimiglia et al. 2016), it does not imply that the process should be approached haphazardly. Here, the three mechanisms of business model development can be viewed as having their own outcomes, and hence, could coincide or be established at any point during the commercialisation journey.

Previous literature argued that a firm needs to focus on its highest-value technology when pursuing commercialisation (e.g. Chesbrough 2010; Teece 2010a). The results of this thesis cast new light on this issue, highlighting the importance of identifying as many applications of the technology as possible beyond its core benefit prior to the prototyping stage. Since failure to optimise a technology is inevitable, a USO could switch to the alternative application or quickly adapt to meet customers' unforeseen needs if the first proposition fails. In most cases, USOs embrace such contingencies by adjusting some or all components of the technology while fitting into the market. Similarly, trial-and-error processes can allow multiple successful applications to emerge from the same technological invention, which increases its potential returns (Nerkar & Shane 2007; Sosna et al. 2010; Reymen et al. 2017).

Most mainstream literature explained the business model development process using business terms and, sometimes, jargon that may not relate to some audiences' previous experience, thus, have limited cognitive impact. In contrast, the present thesis analogised findings from aggregate dimensions into three metaphors, using simple language that is relevant to managers to describe a complex phenomenon[47]. Metaphors make the strange familiar and allow a large

[47] 'One way to embrace common sense is to use analogy and metaphor in scientific descriptions'. In: Daft, R.L., 1983. Learning the craft of organizational research. Academy of Management Review, 8(4), pp.539-546.

audience to more easily understand new ideas. In the strategy and management field, many theories use metaphors as names for first-order categories (Stubbart 1989). Given this, the metaphors used in this thesis add to existing perspectives and can be easily understood as a mental model of the business model development approach and its value components. The following section will interpret and highlight the significance of three mechanisms of business model development in more depth.

6.2.1 Value Proposition and Value Creation through Flow-Field Control

In the face of high market resistance and the liability of newness, market ambiguity and technological uncertainty, the USOs in the case studies exerted endogenous force on what is within their control and elicited exogenous force from their partners to create value. The significance of this finding lies in USOs' ability to be more controlling when creating their own opportunities to create value and respond to market inertia without relying solely on support from an external network. USOs also tended to prioritise utilisation of resources and capabilities within their control over those that need to be gathered from external stakeholders.

As a new and small firm, a USO is always seen as under-resourced firm, beset with liability of newness and technological immaturity (Doganova & Eyquem-Renault 2009; Karlsson & Wigren 2012). Most scholars have contended that the challenges associated with value creation can be mitigated by the expansion of networks and partnerships (Chesbrough & Rosenbloom 2002; Morris et al. 2005; Rasmussen 2006). In addition, it has been argued that network integration leads to resource integration. Although network integration and expansion for value creation were observed in this study, another workable strategy for value creation was identified: taking control and prioritising existing means prior to seeking them externally. This is a new insight with profound importance for the commercialisation of USO technology because in the USO setting, network expansion usually leads to conflict between the USO and external stakeholders. By prioritising and controlling the resources and capabilities over which a USO has authority, potential conflicts are minimised and the firm can develop creative ways

to create value. Two predominant ways to achieve this are by enriching the benefits of the USO's technological solution and manoeuvring regulations.

Technological benefit enrichment

In the quest to increase the benefits of its technological solution, a USO solves the customer's problem before it becomes obvious. Scholars have long argued that competitive advantage in any firm is achieved through creative creation of new value (Zott & Amit 2010; McAdam et al. 2017; Velu 2017). Such literature referred to Schumpeter's (1934; 1983) classic theory of creative destruction, which claimed that innovation is the source of value creation. The findings of this research not only validate Schumpeter's view but also, most importantly, broaden the notion by showing which type of innovation for value creation could galvanise business model development. In the USO context, the firm crafts a transcending solution and a sintering solution to create more value for its customers.

A transcending solution enables a USO to be more pragmatic in creating value in response to market resistance. As previously discussed, customers have different levels of awareness and willingness to solve a problem by employing a USO's technological solution. Due to this, a USO needs to create value by attending to an unmet need that might exist but is hidden or that does not exist at all. As contended by Chakravorti (2004) and Demil and Lecoq (2010), market disequilibrium presents an opportunity to exploit resources and offer new value propositions. Building on that, the current thesis proposed a transcending solution as one way for USOs to face market disequilibrium, create value and propose new offerings. The finding also enabled comprehension of Doganova and Eyquem-Renault's (2009) argument concerning how a business model allows entrepreneurs to explore a market and plays a performative role by contributing to the construction of the techno-economic network of an innovation.

Most mainstream literature has accentuated recommendations for value creation by identifying gaps in the market and addressing them (e.g. Chesbrough & Rosenbloom 2002; Zott & Amit 2008; Lubik et al. 2012). The current thesis found evidence that such suggestions, although useful, will only lead a USO to converge with competitors that are looking to address the same apparent problem. The understanding about how value is created by escalating customer's expectation of a better product are not well embodied in the literature, hence, represent an

interesting insight for the USO value creation. In this study, a sintering solution was used as a metaphor to describe one of the ways in which a USO could create value.

In a sintering solution, multiple propositions are combined to offer novel value to the customer. Unlike a bundling strategy (Hedman & Kalling 2003; Zott & Amit 2007; Zott & Amit 2010; Bohnsack et al. 2014), a sintering solution does not merely combine different offerings and turn it into a new package. Rather, it is a novel solution created by a USO that does not lose sight of the core value of its IP. This is crucial because one of the purposes of a USO is to monetise IP. Jolly's (1997) argument that technology is not always what sells a product did not directly apply to the USO context because the firm is bound by licensing agreements requiring it to monetise its IP via a technological solution to solve customers' problem.

The source of value creation predominantly discussed in the literature is associated with direct economic value (e.g. Chesbrough & Rosenbloom 2002; Ndonzuau et al. 2002). Another source of value creation that has received scant attention in the literature but was observed in the case studies is social and environmental value. This is in parallel with Fini et al.'s (2018) argument stating that technology commercialisation is an enabler for societal impact. Bocken et al. (2015) also claimed the value of shifting social pressures to new offerings could facilitate the realisation of competitive advantage. Given the context of the cleantech industry, which often requires a change in routine (Chakravorti 2004) and modification of cognitive space (Anderson & Gatignon 2008), social and environmental value are important ways to enhance the value of technological solutions.

Regulatory manoeuvring

Another striking finding of this thesis is the utility of regulation for creating value. A USO, as an entrepreneurial firm, needs to be able to strongly push for technology adoption, which can be achieved through regulatory enforcement. In the case studies, stakeholders across cases repeatedly emphasised the importance of regulation to accelerate new technology. In contrast, none of the previous scholars researching the business model in commercialising new technology in the USO context have make enough distinction about the efficacy of regulatory exploitation for value creation. The only aspect of regulation discussed in the literature was concern about the effect of regulatory red tape on the progress of commercialisation (Druilhe

& Garnsey 2004) and regulatory approval on product launching (Bigdeli et al. 2016). Although not specifically referring to USOs, Gaus and Raith (2016) argued that universities' specific legal regulation of IP has a strong influence on the incentive structure of business model development.

Looking more broadly at the business model literature, scholars have agreed that regulation could act as a driver of compelling value creation strategies (e.g. Casadesus-Masanell et al. 2010; Bocken et al. 2015). According to Bocken (2015), business model innovations for sustainability may not be economically viable at the start but may become so due to, for example, regulatory changes. Regulatory enforcement explains the widespread uptake of some USO technologies, whereas regulatory nonexistence causes poor incentive to adopt several others. Although business model scholars underscored the importance of regulatory intervention for business model development, they have not explored how regulatory enforcement paves the way for technological adoption. In the case studies, to manoeuvre regulations, USOs propose new regulation and ride the wave of regulatory reform.

By proposing new regulation that favours its offering, the USO pushes for technology adoption; the new regulation triggers competition in the regulated industry and stimulates the development of new products. The USO may take the lead in commercialisation of new technology that complies with the new regulation for which it lobbied. For some USOs, the creation of value has been partly held back by the absence of necessary regulations to push the technology forward. New regulation, on the other hand, gives the USO a way to fix customers' problem and implicates governance or regulatory control. In this sense, technological adoption is more driven by regulatory requirements or accounting for compliance. It also escalates the benefit of the created value and convinces the customer that the problem is worth solving using the USO's offering.

The analysis accentuated that a USO rides the wave of regulatory reform but only those that proactively sense the potential for regulatory reform reap the benefit of being a leader in sales. In the case studies, all USOs developed technological solutions in a way that favoured changing regulations. Realising the increased emphasis put on environmental concerns by regulators, they expanded the benefit of new technological solutions to proactively trigger or respond to

these regulations. Therefore, the USOs developed a technology that harmonises technological advancement with environmental resilience and, at the same time, proactively act to achieve regulatory reform. Likewise, when realising a business case for sustainability, firms take advantage of a world characterised by tightening regulations, diminishing resources, climate change, and technological change to achieve global effects (Casadesus-Masanell et al. 2010; Bocken et al. 2015).

By bringing the well-researched role of regulation in business model development into the USO field, this thesis advances the understanding of possible methods of value creation. The findings of this study are important not only for validating the role of regulation in business model development but also, most importantly, prompting USO entrepreneurs to more carefully consider utilisation of regulation as part of their value creation agenda. Since regulation drives adoption of technology and vice versa, this study offers a new range of strategies for value creation through regulatory utilisation, which have not been well explored to date.

Overall, value creation through flow-field control casts new light on existing knowledge about how a USO could craft a proposition and create value amidst market resistance. By escalating the customer's expectation of a better product and through a regulatory push, a USO could create its own opportunity and take charge over the business model development process rather than being impulsive. In this approach, a USO does not need to predict an uncertain future (Kim & Mauborgne 1999); rather, it needs to focus its efforts on influencing the future using the means available to it. Throughout the quest for value creation, the USO's network is expanded discreetly and partnerships are forged when necessary.

6.2.2 Value Capture through Pragmatic Kinesis

As widely asserted in the literature, a USO resembles a platform for commercialising new technologies and represents a source of wealth creation (Fini et al. 2017). However, how a USO captures wealth is not well defined. Although the literature has cautioned that created value is not necessarily captured (e.g. Amit & Zott 2001; Chesbrough & Rosenbloom 2002), firms still neglect to specify their methods of value capture (McGrath 2010). As demonstrated

in the case studies, some USOs create substantial value from new technology without being able to fully capture the value they created.

The findings of this research fill the aforementioned gaps by providing evidence-based insights into several ways a USO could capture value in the face of financial pressure through an indirect, pragmatic and flexible approach defined as pragmatic kinesis. Although an indirect approach to reach a complex goal has been discussed in the management literature before[48], no business model literature has specifically documented the importance of such an approach for capturing value from new university technology. The findings of this study provide an alternative explanation of value capture strategy beyond the parsimonious notion of how incremental technology should aim to capture value from the existing market (Pattnaik & Pandey 2014) and radical technology commercialisation should aim to capture value in a new market (King & Tucci 2002). This is important as cleantech USOs have to deal with a long development time and are forced to use more capital in comparison to other types of firms (Maine & Garnsey 2006).

Two approaches that bridge value creation and value capture in the case studies are a heterogeneous revenue stream and balance of customisation strategy and production cost. Both approaches are deemed to be useful for expanding the understanding of the value capture strategy, which is often reduced to narrow discussions of pricing strategy (e.g. Chesbrough & Rosenbloom 2002; Teece 2010a).

Heterogenous revenue streams

Heterogeneous revenue streams are materialised by having diversified revenue source and by entering substitutes market. The academic entrepreneurship literature has well acknowledged that USOs have diversified sources of funding and revenue streams (e.g. Vohora et al. 2004; Shane 2004; Garnsey & Leong 2008). Such sources may include seed capital, government grants, venture capital, angel investments and funds of the founder. Despite this, most literature

[48] 'Many goals are more likely achieved when pursued indirectly.' In: Kay, J., 2011. Obliquity: Why our goals are best achieved indirectly. London: Profile Books.

has only discerned the type of revenue stream being pursued by a USO without thoroughly specifying the intervention needed to achieve it. This research is valuable because it demonstrates that USOs devise multiple revenue streams by more widely exploring the different methods that can be employed and different markets that can be explored to generate additional income. Building upon Bigdeli et al.'s (2016) argument, this research argues that USOs employ an indirect approach that results in transformation of the cost structure and revenue stream.

Generally, a heterogeneous revenue stream compensates for USOs' long lead time to market (Doganova & Eyquem-Renault 2009). To grow profitably, a USO needs to devise an approach that entices payment and prepares the market (Jaworski et al. 2000). One source of revenue at the early-stages of USO growth observed in this study is research grants. Although an inventor can make use of university facilities to reduce the expenditure on infrastructure while creating an innovative and productive base, research grants are still not sufficient to guarantee a sustainable income (Druilhe & Garnsey 2001). Consulting is another revenue stream that was crucial for the survival of the USOs in this study. As knowledge-intensive businesses, consulting activities appeared to be one of the most effective ways for USOs to monetise their intellectual assets on the side. The revenue made through these activities was put back into the business.

As the literature claimed, the purpose of having a heterogeneous source of income is mainly to enhance financial security and, in the case of USO, to avoid running out of funds while still in the pre-commercialisation stage (Vohora et al. 2004; Lubik & Garnsey 2016). Interestingly, this study found evidence that non-core revenue streams are also important for capturing value after the commercialisation stage. This thesis thus uncovers a previously underexplored use of non-core revenue streams for capturing value for a USO, particularly post-commercialisation.

Another important observation of this research is that not all USOs commercialise radical technology; those with incremental and less differentiated products struggle to capture value in existing markets (Mustar et al. 2008). To avoid directly engaging with incumbent firms, these USOs enter and capture value from substitute markets instead. This strategy fits with USOs' aspiration to break free from competing firms and, hence, create new demand and

capture value where it was non-existent (Kim & Mauborgne 1999). This strategy also allows customers to see themselves benefitting from solutions outside their obvious and conventional applications. The findings of this research shed light on the conditions that might be conducive for USOs with less differentiated technology to capture value.

Previous scholars argued that USO could capture greater value by serving larger market segments in larger industries (Bigdeli et al. 2016). While this notion holds true in some of the case studies, substantial evidence also demonstrated that a USO could reap benefits and capture value in smaller markets with less competition. The current research brings another perspective to value capture that involves entering not only a larger market but also a substitute or smaller market. This finding aligns with Kim and Mauborgne's (1999) stance that firms must be strategic when disengaging with a competitive market.

Furthermore, capturing value from a large and established market may force a firm to sell products at the market price, causing it to gain a smaller percentage of its revenue from monetisation of the new technology (Feldman & Klofsten 2002). This threat may be less obvious for non-entrepreneurial firms, but for a USO, entering a large market entails a high risk to its survival. Overall, the finding that a USO has diverse revenue sources and enters substitute markets aligns with the findings of entrepreneurship literature (e.g. Navis & Glynn 2010).

Customisation–cost balance

Customisation strategy has been widely discussed in the business model and technology commercialisation literature as one way to capture value (Morris et al. 2005; Osterwalder & Pigneur 2010; Bohnsack et al. 2014). As observed in the findings, customisation strategy is deemed appropriate for fending off competition and allows a firm to charge its customers a premium price. By targeting a niche market for specific applications and providing a customised offer, a USO could capture more value (Druilhe & Garnsey 2004). Customisation strategy also serves as a useful approach to understand customers' preferences, which allows the USO to tailor its production in a way that enhances long-term profitability. This finding supports Bower and Christensen's (1996) argument that a firm could capture substantial value by addressing customers' distinctive and changing needs.

Despite this, customisation could also constrict growth and lower profit margins as a result of cost complexity (Oliver et al. 2004). Customisation strategy conflicts with the economies of scale agenda, forcing a USO to consider a trade-off between the strategies. In the business model and technology commercialisation literature, there has been not enough investigation to understand how the drivers of customisation cost that limit a firm's ability to access economies of scale can be minimised. The trade-off between customisation and cost is another valuable finding of this study.

Building upon Strobacka et al. (2013), the findings clarify the approach taken by USOs to capture value by balancing the needs for product customisation and standardisation. This thesis showcases how USOs could adapt two conflicting value capture strategies through simultaneous customisation and standardisation, harmonising the dualistic value capture mechanisms. The analysis argues that both approaches are compliments rather than substitute. In balancing the advantages of customisation with the economies of standardisation, a USO interacts with potential customers to extract information about both the standard and idiosyncratic elements of their preferences (Gambardella & McGahan 2010). Without undermining standardisation opportunities or economies of scale, a USO engages in a tiered approach to value capture in which higher-end customers are provided tailored products and services to match the value they represent. USOs diversify their offerings to capture different customers' needs but retain a generic proposition. By doing so, they provide customers valued options without compromising economies of scale.

Velu and Stiles (2013) argue that a firm can cognitively and economically integrate two very differently configured models that serve the same customers simultaneously. This research, however, finds that a USO could employ two conflicting value capture strategies to generate profit margins. This insight crystalises the arguments by Bohnsack et al. (2014) that the appropriate business model can increase the market attractiveness of a technology, improve the full value capture of an innovation and lead to a competitive advantage. By taking control over the levers of duality, a USO could successfully trade-off between the value of customisation and the cost of complexity through standardisation of the products being commercialised.

In summary, USOs with complex offerings, revolutionary technology and upscale products that are challenged with myriad financial pressures employ circuitous measures to establish product awareness, brand recognition, market creation and, eventually, value capture. Pragmatic kinesis enables robust understanding of USOs' value capture strategies, particularly when the firm's short- and long-term value capture strategies and the need to respond to financial pressure are intertwined.

6.2.3 Value Network Management through Deliberate Temperament

In this thesis, deliberate temperament contributes to the limited understanding of management of conflicting value network. Traditionally, business model scholars have highlighted network expansion for value co-creation and value capture (e.g. Chesbrough & Rosenbloom 2002; Morris et al. 2005; Nenonen & Strosbacka 2010; Rasmussen et al 2011). Academic entrepreneurship scholars, on the other hand, affirm that USOs' quest to commercialise new technology is associated with conflicting objectives amongst key stakeholders, which may adversely impact the firm's growth trajectory (Siegel et al. 2003; Vohora et al. 2004). Despite this, scholars in both fields have been relatively silent about the management of conflicting stakeholders when business models are developed.

One possible way to minimise the adoption of conflicting logics in the management literature is pre-emptively screening problematic stakeholders to prevent the conflict from taking place (Jaworski et al. 2000; Pache & Santos, 2013). While this is a valuable recommendation, evidence from the case study reveals that some USOs, especially those with less entrepreneurial experience, do not have the capability to screen their stakeholders. Similar to the findings of Goel and Karri (2006), this study found that entrepreneurial firms are more likely to be over-trusting and tend to trust more than is warranted. Most conflicts in the management literature appeared to be latent in nature. Additionally, in most cases, a USO could not easily escape conflicts because they involve long-standing stakeholders with strategic importance to the USO's commercialisation goals. As observed in the case studies, collaborative partnerships and a compromising approach are two measures that help USOs to deal with unavoidable conflicts.

Collaborative partnership

In the pluralistic environment of USOs, conflicts are dealt with in mutuality and constructively through collaborative partnerships. This finding is similar to Bocken et al.'s (2015) argument that a sustainable business model is built on collaboration and sharing rather than aggressive competition. Bocken (2015) also contended that, with the rising pressure of global sustainability, collaboration between firms and other key stakeholders is becoming more important. By transforming strife into teamwork, collaborative partnerships represent workable alternatives to the win–lose method, whereby tension is resolved in a more harmonious manner with more motivated and satisfied stakeholders.

Through co-operation and co-opetition, a USO manages conflicting stakeholders by turning misaligned goals into collaborative partnerships. The findings demonstrate that successful external collaboration in a networked environment should aim to achieve common goals and involve some form of co-operation or collaboration (Zot et al. 2011). Likewise, business model scholars have argued that business model development is contingent on co-operation, partnership, and joint value creation (Magretta 2002; Mansfield & Fourie 2004; Mäkinen & Seppänen 2007; Miller et al. 2014). The current thesis extends this notion by demonstrating how collaborative partnerships are key for aligning conflicting goals and, hence, resolving tension.

When developing a viable business model, a USO must determine how its value proposition responds to all the expectations of stakeholders who create value and for whom value is created (Baden-Fuller & Morgan 2010; Lehoux et al. 2014). Appelhoff et al. (2015) argued that entrepreneurial firms that base their actions on their own means usually trigger conflict among their stakeholders. Similar finding is evident in the case studies. Business models relied heavily on the commitment of a network of partners to create value and generate profitable revenue streams. The current thesis further delineates Lehoux et al (2014) findings arguing that collaborative approach is key in resolving tension that results from stakeholders' expectations.

Failure of USOs to pursue collaborative partnerships to resolve conflicts may damage relationships and reduce organisational effectiveness. However, not all resolved conflicts end

in mutual collaborative partnerships. Realistically, some form of the conflict may not result in getting all the stakeholders needs met along the integrative dimension at all. In such a circumstance, a USO and its stakeholders may be better off negotiating their needs through compromise.

Compromising approach

The findings of this study reveal that compromise is key in the USO networked environment, where each stakeholder's role is interdependent. Compromise between competing demands is achieved by navigating tension to reach a common goal through mutual concessions. To deal with conflicting stakeholders, USOs make informed decisions to trade-off between incompatible values and tolerate divergent values to reach a compromise.

This research agrees with Suchman's (1995) argument that conflicting stakeholders could co-exist despite tension, ultimately leading to normative change, compromise and legitimisation. It also answers the call to overcome conflict when stakeholders have disparate objectives and ambiguities concerning commercialisation (Markman et al. 2008). Another important question on which the finding sheds light concerns the condition under which a USO needs to compromise. Based on the cases, compromise is necessary when the decision is urgent and rigidity would not progress the USO's commercialisation. As much as the USO and stakeholders would like to take control over the negotiated outcome, both parties need to consider splitting the difference of the negotiated terms. Generally, conflict results in a compromise and normative change in which different, even seemingly opposed, ideological elements are reconciled (Etzkowitz et al. 2000).

In the USO context, conflicts are not desirable but inevitable (Miller et al. 2014), mainly due to the varying motives of stakeholders with different roles (Siegel et al. 2003). TTO officers typically do not want to have conflicts with the researchers on whom they are dependent for deal flow and invention disclosure (Mustar et al. 2008). Through compromise, USOs, TTOs and other stakeholders could enhance their long-term survival and strengthen their relationships despite their different values. The findings also support the general notion that a compromising approach does not only soften the edges and decreases conflict but also, most

importantly, aims to maximise the impact and commercial success of USO technology commercialisation by addressing the root of the conflict.

Scholars argue that it is important to separate academic and commercial activity to avoid conflicts of interest and cultural barriers due to conflicting goals (Argyres & Liebeskind 1998). However, as the USOs usually have little or no personal experience in the business field, separating these activities is tough. USOs are dependent on the development of good working relationships within their academic and commercial networks. By compromising, a USO and its stakeholders achieve the best outcomes of negotiation and avoid undesirable outcomes. As the cases demonstrate, compromising sometimes may be the only way to reach a decision that would not further lag commercialisation process. Each stakeholder's beliefs need to be respected so that compromises can be sought wherever possible. A compromising approach is also a form of mature decision making.

All in all, a collaborative partnership and compromising approach is key for enabling network management and expansion in a way that facilitates the technology commercialisation process. Unresolved conflict could escalate into ongoing battles and confrontational attitudes, delaying a USO's growth; scholars like O'Shea et al. (2005) have affirmed that tension is detrimental to the commercialisation progress. This thesis provides insight into how tensions are dealt with, arguing that deliberate temperament is a valuable approach to management of USO stakeholders with conflicting values and objectives.

6.3 COPE Principles for Business Model Development

In this thesis, the COPE principles are advanced as a set of parameters that a USO needs to consider when developing its business model. The principles represent a cognitive tool for understanding how business models are established, which may help USOs navigate the turbulent journey of commercialisation. It builds on and explicates the effectual logic proposed by Sarasvathy (2001) and the concept of opportunity creation advanced by Alvarez and Barney (2007). As claimed by Amit and Zott (2001), a cross-theoretical perspective is required to understand the business model development process because no single theory can fully explain the value creation potential of a venture. Therefore, this thesis combined both of the aforementioned theories. The COPE principles provided a new direction for theoretical

development and empirical studies in entrepreneurship by linking business model entrepreneurial cognition, opportunity co-creation and organisational outcomes. The principles were also a response to the lack of construct clarity associated with business strategy (see Porter 2001). The next section will elaborate on the way in which each principle adds to our knowledge about USO business model development.

6.3.1 Principle 1: Take Control

The case studies pursued in this thesis reveal the importance of a USO taking control over its resources and capabilities to develop a viable business model. By doing so, a USO could avoid over-predicting the future, instead influencing the future by making the most of its resources and capabilities. The approach also economizes USOs' efforts and resources when developing a business model by concentrating them where they are more important.

Sosna et al. (2010, p.384) warrant that *"business model development is an initial experiment followed by constant revision, adaptation and fine-tuning based on trial-and-error learning."* Likewise, this thesis has argued that one of the purposes of business model establishment is to enable a firm to achieve its desired results iteratively in an unpredictable but controllable environment. Also, an extended explanation of how to fine-tune the process of business model development by taking charge of a USO's resources and capabilities was provided.

The principles of effectual logic—taking control, paying less attention to prediction and making do with available resources (Dew & Sarasvathy 2002)—are often useful for a USO without a clear market direction. By adopting these principles, a USO could optimise its technology prior to solidifying its market position. USOs' ability to demonstrate their technologies' functionality would help to prepare them for the market since it is difficult to conceptualise a product without demonstrated functionality.

The analysis posited that technology-based products are never going to be perfect as the technology is continually improving. By taking control over only the resources and capabilities within its authority, the USO can get the first version of its product into the market and then see how customers respond to it. From investors' point of view, technology prototypes could demonstrate the feasibility of a USO's idea and lower the risk of investment, therefore

increasing the probability that a USO will be funded (Jolly 1997; Shane 2004; Siegel & Wright 2015). Moreover, in alignment with effectuation logic, a USO is more capable of controlling its own technology but may not be sufficiently credible to fully condition the market (see Sarasvathy 2001; Sarasvathy & Dew 2005).

Effectual logic is based on the ability to control more and predict less. Knowing what can be controlled and taking charge over it is imperative for the development of a viable business model. A USO that takes control also takes responsibility for its future without over-predicting it. This insight contributes to the developing stream of empirical research that investigates entrepreneurial decision making under conditions of uncertainty (Wiltbank et al. 2006; Dew et al. 2008).

6.3.2 Principle 2: Create Opportunities

The opportunity creation principle offers a way to enhance understanding of USO business model development that is distinct from that found in the effectuation debate. Opportunity creation stance is supplemented into the effectual logic and has been advantageous in addressing the lack of human agency in developing a business model. The principle affirms that a viable business model is developed proactively rather than reactively. While most literature has discussed effectual logic in tandem with causal logic, this thesis provided stronger grounding for the theory by explicating the effectuation discourse and supplementing it with the concept of opportunity creation. It did not accept effectual logic as is but strengthened the theoretical grounding prior to employing it to inform the investigation. In doing so, a paradigmatic shift occurred in the effectuation discourse that enhanced the pragmatism of the established theory.

The principle of opportunity creation hinges on the actions of the entrepreneur to create opportunities and assumes that opportunities do not necessarily exist independently of the actions taken by entrepreneurs to create them (O'Cornor & Rice 2013; Zahra 2014). This understanding links the business model and opportunity enactment which enhances the theoretical grounding. Since the principle of opportunity creation overlaps with the principle of taking control, both represent an exciting opportunity to explain how a USO creates and captures value despite its weak entrepreneurial credibility at an early-stage of growth.

Academic entrepreneurship scholars have long characterised USOs as having weak entrepreneurial credibility (Pirnay et al. 2003) and disadvantaged with the liability of newness (Rasmussen et al. 2011). USOs are expected to overcome challenges and transition from one phase of growth to the next (Vohora et al. 2004) by becoming more proactive (Clarysse et al. 2004). Given this situation, creating opportunities is a highly appropriate technique for firms with weak entrepreneurial credibility that need to make decisions. It also informs the extent to which a USO, despite having weak entrepreneurial credibility, could influence the business model development process.

Creating opportunities is part of the business model foundation and complements the discovery approach employed in previous literature (e.g. McGrath 2010). Previous academic research referred to business models as organisational structures that take advantage of a commercial opportunity (Teece 2010a; Amit & Zott 2001; George & Bock 2011). Business model innovation is also commonly represented as a firm-level process to exploit new opportunities, and frameworks that assess strategic flexibility in the context of opportunity identification and exploitation are of particular interest. George and Bock (2011) see business models as opportunity facilitators. Building upon effectual logic, Chesbrough (2010) contend that the business model is the result of experimentation that generates new data, which may point towards previously latent opportunities. To a great extent, theses scholars associate business model development process to the stance of opportunity creation.

From a slightly different angle, the current thesis employed opportunity creation as a way to better explain the process of business model development in the USO context. By considering opportunity creation as an independent principle, the thesis added to the understanding of the technology commercialisation that involves market creation (Jaworski et al. 2000). This insight is crucial because objectively pursuing opportunities in a readily available market appeared to be less valuable than proactive market orientation (e.g. Jaworski et al. 2000; Narver et al. 2004). Realistically, entrepreneurs do not only aim to satisfy the existing market needs but sometimes must first create a market that may not existed a priory. By doing so, the future is considered something that a USO cannot fully control but can be influenced by creating opportunities.

The principle of opportunity creation is key for understanding that the success of commercialisation can be influenced by USOs instead of waiting for opportunities to ready itself. It also clarifies how reasons to adopt new technology can be invented through opportunity creation. In the constant search for new opportunity and empowerment, proactive USOs tend to do and achieve more. Firms that create and seize opportunities have different outlooks about commercialisation pursuit. This understanding allows a USO to better improvise means to achieve ends or alter their ends, or do both, in processes that may combine opportunity discovery and creation.

6.3.3 Principle 3: Forge Partnerships

Forging partnerships with external stakeholders is key for development of a viable business model. In the analysis, the imperative of partnership was present in all value components. It was through partnerships that USOs gain access to resources, reduce uncertainty and shape the direction of the firm, and value is created and captured through relationships with networked partners and influenced by alliance activities. These findings parallel scholars' view that the business model development process extends beyond the firm (Zott et al. 2011), expands firms' know-how (Holloway & Sebastio 2010) and catalyses co-creation of value (McAdam 2017).

Within the effectual logic debate, partnership has been deemed important for attracting new funds and defining new direction (Sarasvathy et al. 2008). Partners with complementary skills and assets are willing to share in the upside to encourage engagement in opportunity creation. As argued by Sarasvathy (2001), effectual logic rests on the ability of the entrepreneur to interact with and involve other stakeholders in the venture creation process. By employing the partnership principle to understand business model development, the thesis offered further clarification of the notion that business model development depends on the involvement of other people and organisations as committed stakeholders. As rightly argued by Venkataraman et al. (2012), stakeholders are individuals who dedicate their own resources to co-create new ventures with entrepreneurs.

However, with more partnerships and network expansion comes the risk of more conflicting objectives. The case studies revealed that partnerships could also bring about a different set of challenges and risks for a USO. In response, some USOs were more selective in forging

partnerships and making sure that potential partners have mutual interest in bringing technology to the market by carefully picking their frame of reference within the market and utilising stakeholder's involvement. From the lens of opportunity creation, the essence of opportunity agency provides a supplementary explanation of value network selection. It is through selective acquisition of stakeholders that a firm fabricates a new market (Alvarez & Barney 2007). In this regard, value network recruitment is seen as an endogenous process that is partly controllable (Sarasvathy 2001) through means of selection (Alvarez & Barney 2007), which can be done without assuming stakeholders' trust (Goel & Karri 2006). This is crucial when dealing with the commercialisation process, which is inherently fraught with tension due to symmetrically aligned stakeholder commitments (Siegel et al. 2003; Shane 2004).

However, the ability to choose network members disaccords with Sarasvathy (2001) and Sarasvathy et al.'s (2008) notion theorising that effectual transformation is determined through a self-selecting network rather that a purposive selection process. This resonates O'Connor & Rice (2013) view on effectuation's limitation in evaluating potential network members. Stakeholders morph the original idea into one to which a whole network of stakeholders are committed (Sarasvathy et al. 2008). Read et al. (2009) argue that a market is created as an outcome of the interaction between network actors through non-predictive control of stakeholders' commitment.

In an ideal situation, a USO would screen its network and only forge partnerships that matter. Although a USO could screen its partners to avoid potential conflicts, getting embroiled in a conflict during commercialisation is inevitable because most conflicts are latent in nature (i.e. potential conflicts may not be spotted until they happen). In addition, some conflicts are unavoidable completely as they involve longstanding partners that are crucial to a USO's progress. When that happens, the USO takes a collaborative and compromising approach to address it.

In summary, by embedding the principle of forging partnerships in business model development, this thesis adopted an interesting angle that views partnership as an antecedent to network expansion, a method of value co-creation, a source of conflicting objectives and a potential solution to conflicts. The findings regarding effectual logic have crucial ramifications

on how USOs take charge to restrict stakeholders' membership and strategically solve conflicts through partnership.

6.3.4 Principle 4: Embrace Contingencies

Being able to embrace unexpected events throughout the technology commercialisation process is crucial for developing a viable business model. Since mistakes are inevitable, a USO embraces contingencies that arise from uncertain situations by remaining flexible rather than becoming tethered to existing goals. A USO keeps the decision making sufficiently open to leverage unexpected events for the benefit of the firm (Chandler et al. 2011). Instead of creating what-if scenarios to deal with worst-case scenarios, USOs interpret contingencies and surprises to look for new opportunities to commercialise their technology. This principle is well suited for entrepreneurship processes that are characterised by uncertainties and risks.

Since new technology and market alignment are highly iterative, USOs tend to experiment with different values, face unforeseen turns and, sometimes, reach a dead end. This finding reveals that a USO should terminate its goal and modify its strategy once it is no longer economically beneficial to pursue the initial proposition. While persistence is an immensely valuable trait for reaching a USO's goal, maintaining a faulty strategy in pursuit of a worthwhile goal will not contribute to a USO's commercialisation success. This demonstrates that effectual logic pragmatically leverages contingencies (Sarasvathy 2001; Sarasvathy et al. 2008), shedding light onto the point at which USOs to an alternate proposition.

The observations of the current thesis also show that successful commercialisation is characterised by the need to make decisions and take action in the face of uncertainty (e.g. Sarasvathy 2001; Alvarez & Barney 2005). The findings of the current thesis make this relationship explicit by demonstrating that a decision to widen the scope of a venture leads to an increase in the use of effectual decision making, such as flexibility to adopt a technology in multiple potential markets.

USOs were observed to learn from failed experiments, make the best of unpleasant situations and improve their conditions by exploring new avenues to exploit their technology. Owing to the inability to control the future (Sarasvathy 2001; Sarasvathy & Dew 2005), it is often easier

for a firm to change its technological application than to change the market's preference. Although it is highly case-specific, a USO should not keep using a business model that is no longer profitable because a USO's response to early failure can critically affect how the experimentation process unfolds.

In summary, the findings of the current thesis supported and further explicated scholarly views about effectual and iterative business model development (e.g. Schneider & Speith 2013; Andries et al. 2013; Reymen et al. 2017). As Perry et al. (2012) highlight, the next stage of theory development in effectuation research requires empirical researchers to build a more detailed understanding of the utility of effectuation. This thesis extends prior research by explaining shifts in the use of effectual logic supplemented by the concept of opportunity creation to identify the starting and exist points of the iterative new technology and market alignment.

Apart from advancing the COPE principles as a way to understand business model development, the current thesis combined findings from the grounded approach and COPE principles to devise an integrative framework for business model development in response to the unique challenges USOs face. The next section will discuss the framework developed in this study.

6.4 Conceptual Framework for USO Business Model Development

This thesis proposes an empirically and theoretically grounded conceptual framework for business model development. The framework has multiple strengths and sheds light on the partial understanding of the issue. First, the framework is receptive to the challenges faced by USOs at multiple TRLs. Rather than building the foundation of the framework on ideal, unrealistic, set objectives, the framework offers a more plausible explanation of business model development based on the challenges facing a USO. Second, by synthetising findings from both successful and less successful attempts at commercialisation, the framework offers an inclusive way to explain business model development. In summary, the framework proposed in this thesis promotes USO governance through adaptation of turbulent settings (Clarysse et al. 2011; Rasmussen et al. 2011; Lubik & Garnsey 2016).

Although past literature has been instrumental in informing some generic parts of the framework foundations, it has not provided details regarding how the business model development process unfolds. Generally, the framework supports and extends three main conceptual premises advanced by previous scholars. First, the framework reinforces the notion that a business model is a tool to drive the commercialisation of new technology (e.g. Chesbrough & Rosenbloom 2002). Second, it demonstrates how a USO's business model is developed through iterative trial-and-error and experimentation (e.g. Sosna et al. 2010). Third, the framework acknowledges that the business model development process is challenged by pitfalls that are unique to USOs, such as market resistance, financial pressure and conflicting stakeholders (e.g. Lubik & Garnsey 2016). Thus, the proposed framework clarifies and reveals the inner workings of the business model development process, which previously could be viewed only in terms of its inputs (new technology coming out of the university laboratory) and outputs (the resultant business model).

The three mechanisms of business model development embedded in the framework explicate how business models dynamically interrelate. This notion supports a more pragmatic way of delineating the business model development process through a dynamic rather than static view (e.g. Casadesus-Masanell et al. 2010). As thoroughly discussed in the previous section, effectual logic supplemented with the concept of opportunity creation have been the theoretical underpinnings that strengthen the robustness of the framework. In that sense, the framework directly responds to critiques that business model development lacks theoretical grounding (see Porter 2001; Hedman & Kalling 2003). At the heart of the framework, the COPE principles are proposed to be the foundation of the business model development process across three different value components. The principles capture the salient aspects of effectuation logic (Sarasvathy 2001) and the concept of opportunity creation (Alvarez & Barney 2007). The COPE principles also qualify as a desirable theory because they are accurate and simple (Yin 2014; Makadok et al. 2018), enhancing the likelihood that they will be applicable to a wider set of phenomena[49].

In short, the framework proposed in this thesis adds another layer to the understanding of business model development in the USO context, which features USO-specific challenges, and

[49] A sound theory can be evaluated through its accuracy, simplicity and/or generalisability.

leads to understanding of what facilitates USO activity. It also provides a platform for empirical and theoretical findings in the business model discussion whilst carefully acknowledging the contextual factors of a USO.

6.5 Chapter Summary

This chapter has discussed the findings in relation to the existing literature. It interpreted the key findings of this thesis, covering the three interlocking, iterative and interdependent mechanisms of business model development, the COPE principles and the emergent framework. The chapter has also demonstrated how the findings consistently fit, supplement or extend the existing body of knowledge. The next chapter will conclude the thesis by outlining the key findings and implications for theory and practice. It will also present the limitations of this research and outline recommendations for future research.

7 CONCLUSION

7.1 Chapter Introduction

This chapter aims to recap the arguments made in the preceding chapters in a broader context and highlight the key implications of this research. It begins with section 7.2, which briefly reiterates the key findings of this research. Next, section 7.3 and section 7.4 present the theoretical and practical implications of the completed research, respectively. Section 7.5 outlines the research limitations and, lastly, section 7.6 recommends potential areas for future research.

7.2 Overview of Key Findings

This research was initially guided by the following research question: *How does a USO develop its early-stage business models to commercialise new technology*? This question was answered by describing the main specific approaches taken by USOs to develop their business models while also responding to challenges across the three components of business models. The analysis revealed three key findings.

First, a USO's business model was developed through three interlocking, iterative and mutually reinforcing mechanisms: 1) value creation through flow-field control, 2) value capture through pragmatic kinesis and 3) value network management through deliberate temperament. Flow-field control is an approach that aims to craft a proposition and create valuable offering while overcoming market resistance, by taking active control over a firm's resources and capabilities. Pragmatic kinesis is a measure taken by a USO to capture value and respond to financial pressure by remaining flexible and sensible enough to move towards profit. Lastly, deliberate temperament aims to manage conflicting stakeholders by aligning stakeholders' expectations, which results in a mutually beneficial outcome.

Second, the thesis advanced the COPE principles as the foundation for the business model development process. The principles are based on four premises borrowed from effectual logic (Sarasvathy 2001) and the concept of opportunity creation (Alvarez & Barney 2007) (i.e. take control, create opportunities, forge partnerships and embrace contingencies). The COPE principles are also used as the operationalisation guideline in discovering the three mechanisms

for business model development (i.e. value creation through flow-field control, value capture through pragmatic kinesis and value network management through deliberate temperament).

Finally, all key findings were integrated into a comprehensive conceptual framework that could guide the USO business model development process. The framework revealed the inner workings of the business model development process, which could previously be viewed only in terms of its inputs (new technology coming from the university laboratory) and outputs (the resultant business model).

7.3 Theoretical Implications

The theoretical implications resemble a rationale for the theoretical contribution (Ågerfalk 2014). As discussed in the preceding chapter, this research contributes mainly to the business model literature and, to some extent, provides useful insights for the academic entrepreneurship literature as well as the ongoing debate regarding effectuation logic. The novelty of this research lies in the originality, uniqueness and in-depth empirical evidence gathered to substantiate the measures taken by USOs to develop their business models for commercialising new technology. Hence, the main theoretical contribution of this thesis is its explication of the effectual logic supplemented by the concept of opportunity creation to advance the understanding of the development of business models for commercialising new university technology. The next section will present the extent to which this new understanding can improve existing knowledge in three streams of literature.

7.3.1 Implications for the Business Model Literature

In this thesis, business models were the unit of observation on which the level of analysis was focused. The findings of this research hence have implications for future work on business models. There are at least six theoretical implications of this research for the business model literature.

First, the overall findings of this thesis offer a critical logical shift to a more systematic understanding of business model development. Specifically, the new set of principles, metaphors and conceptual framework introduced in this research respond to scholarly inquiries to improve the clarity, contingencies, and outcomes of the business model construct, which

have been inadequately addressed in the business model literature (see Foss & Saebi 2017). The findings also subtly yet critically reflect the inner workings of initial business model development rather than how such models evolve, change or undergo innovation. This study introduces approaches to business model development that could support previous conjectures about business model evolution (e.g. Demil & Lecoq 2010; Velu 2017) and business model innovation (e.g. Johnson et al. 2008; Sosna et al. 2010).

Second, by investigating business model development in the USO setting, this thesis expands the utility and roles of business models across conventional organisational boundaries. In other words, it shifts from a knowledge frontier, extending the business model discussion to a specific yet essential empirical setting in which it has been rarely explored. By doing so, it exemplifies another crucial empirical setting in which an understanding of business models is desired. Additionally, through empirical execution, the findings of this research also enhance the visibility of current wisdom—which has been mostly investigated conceptually—about the role of business models in technology commercialisation (e.g. Chesbrough & Rosenbloom 2002; Chesbrough 2003; Johnson et al. 2008; Doganova & Eyquem-Renault 2009; Baden-Fuller & Haefliger 2013).

Third, this research provides a stronger theoretical grounding for business model literature. Traditionally, empirical research about business models has lacked theoretical grounding because it has been mostly discussed independently from established theories (Hedman & Kalling 2003; Teece 2010a). By corroborating decision-making logics with effectuation theory, more insight is provided into the complexities and intricacies of empirical reality. The findings also serve as a call to the criticism about the loose theorising between business model and revenue generation strategy (See Porter 2001). Subliminally, this thesis supports the increasing appreciation of the strategic management concept explained through the established theoretical lens.

Fourth, the thesis more closely links multidisciplinary theories that previously existed in isolation despite their important potential connection. The conventional wisdom in the business model literature is that a business model is established through an iterative process. However, how the iterative process unfolds is still only partially understood. This thesis casts new light on the issue by including the entrepreneurship literature within the discussion. Although the

understanding of business model development promoted in this thesis is, so far, only validated to work in the USO setting, the concept of controlling, creating opportunities, forging partnerships and embracing contingencies could guide how business model experimentation is pursued (e.g. Sosna et al. 2010; Andries et al. 2013).

Fifth, this research constitutes a theoretical extension of the work on boundary-spanning transactions between a focal firm and its ecosystem of partners (see Zott & Amit 2008). In particular, the findings of this thesis go beyond firm-centric and customer-focused value creation, which improves our understanding of the connective mechanisms, dynamics and conflicts involved in business model development (e.g. Reymen et al. 2017). It outlines the essential details of a firm's value proposition for various stakeholders as well as the activity system the firm uses to create and deliver value to its customers. By investigating issues concerning the distinctive motives among stakeholders and soliciting recommendations for conflict resolution, this thesis adds a new perspective on how conflicts that occur in a networked business model development process can be resolved. It also contributes to the line of reasoning that forging partnerships not only provides access to resources but also minimises anticipated and unavoidable conflict. In that sense, the findings of the thesis have added to previous work on networked business model development (e.g. Chesbrough & Rosenbloom 2002; Mansfield & Fourie 2004; Palo & Tahtinen 2013).

Finally, the analysis of the findings enhances the visibility of the functional form of business model components. This thesis deeply investigates the interdependent business model components by treating them individually. Although previous conceptual discussions about business models have usually broken the concept of business models into several components, empirical comprehension in the reviewed literature mostly explains the business model development process as a block. By unpacking the underlying building blocks, this research enables more detailed analysis, provides a more robust view of each component and further clarifies the interdependencies of all the business model components.

7.3.2 Implications for the Academic Entrepreneurship Literature

Academic entrepreneurship was employed as the context of investigation of this research. Specifically, USOs represented the unit of analysis or entity being studied at the organisational level. This thesis has at least four implications for the academic entrepreneurship literature.

First, the findings constitute an advance in the analysis of the determinants of a USO's successes and failures in commercialisation beyond conventional mechanisms such as university patenting and licensing (e.g. Link & Scott 2003), incentives (e.g. Lockett & Wright 2005) and entrepreneurial characteristics (e.g. Gümüsay & Bohné 2018). The business model is a crucial dimension of entrepreneurial strategy for USO commercialisation success that has been vastly acknowledged in practice but has received limited attention in the academic realm. The thesis also reveals that the USO's crucial role in maximising the returns on IP (Lockett & Wright 2005) and, subsequently, regional economies (Fini et al. 2017) can be enhanced through a well-developed business model. In the university context, the value of new technology may not be fully materialised through a licensing arrangement (Franklin et al. 2001). In response to this, the findings offer a possible way to enhance the value of a new technology through the development of a viable business model.

Second, by employing established theories to explain USO technology commercialisation, this thesis adds and strengthens the theoretical grounding for university technology transfer in general. Effectual logic and the concept of opportunity creation supplement previous theories used to explain university technology commercialisation, such as Vohora's USO creation process perspective (Clarysse et al. 2011), Penrosian's resource-based view (Demil & Lecocq 2010), the dynamic perspective (Dmitriev et al. 2014), path dependence (Bohnsack et al. 2014) and lean start up (Still 2017).

Third, by having a multidisciplinary (not discipline-based) focus, the study offers a comprehensive description and connection between academic entrepreneurship and business model strategy formulation. This is crucial for enhancing the understanding of the complex relationship between a new university technology and the market. The findings of this research also offer a valuable insight into the business model stream to explicitly address some of the ongoing concerns about academic entrepreneurship literature, such as conflicting motives among stakeholders (Siegel 2003) and insufficient financial return to fund operationalisation of the pre-commercialisation stage (Vohora et al. 2004). Additionally, by maintaning the spirit of networked stakeholders, the findings shift the focus of academic entrepreneurship studies to the dynamics of different stages and players in the commercialisation pipeline and away from

the conventional commercialisation process, which promotes a static or linear go/no go process (e.g. Hindle & Yencken 2004).

Finally, since the analytical set-up of this research is receptive to the unique challenges of USOs, the case studies yield credible measures of the realisation of value from new university technology. It was argued by the business model scholars that only a relatively small number of studies are focused on understanding the development of business models for commercialising university technology. This was partly caused by USOs' prevalent failures, which eventually resulted in data scarcity (Mustar et al. 2008). Additionally, the unique challenges faced by a USO when commercialising its technology seem to be overlooked in the literature (Lubik & Garnsey 2016). By employing credible data with multiple case profiles, treating a USO as an entirely different category of firm and scrutinising its challenges to develop a business model, this thesis offers constructive recommendations for business model development. Further, by using empirical examples from both successful and less successful case studies, the comparative analysis in this research offers a more integrated understanding of why USOs generally succeed or fail to develop a business model viable enough to generate income, grow profitably and become sustainable in the long run.

7.3.3 Implications for the Effectuation Literature

In this research, Sarasvathy's (2001) effectual logic, supplemented by Alvarez and Barney's (2007) concept of opportunity creation, was employed as the main theoretical underpinning of the findings. The thesis goes beyond theory testing and refines both concepts. Through attempts to explain and understand the USO phenomenon within the limits of assumptions, this thesis offers four important implications for effectuation theory.

First, the thesis builds upon and repackages effectual logic into a new theoretical vision that unravels the mechanisms of business model development in the USO context. Specifically, by supplementing effectual logic with the concept of opportunity creation, this research enhances effectuation theory and makes it more relevant to human agency (Zahra 2014) and reflects on the dynamics of entrepreneurial processes (Shane 2004). The understanding that USOs are able to create their own opportunity has consequences when added to the theory of entrepreneurial action, which is an alternative to the predominant view of entrepreneurs as

discoverers of existing opportunities (e.g. Reymen et al. 2017). The compatibility of both theories also provides a fresh perspective on new artefact creation and, in this case, business model development beyond what was already widely discussed within effectual logic literature.

Second, the finding concerning proactive network selection reveals hidden inconsistency in effectual logic when applied in a setting with conflicting stakeholders. Given this, the findings offer an alternative method for network self-selection, which has been the core component of effectual logic and mostly believed to be the best practice (O'Cornner & Rice 2013). This thesis argues that, in the USO context, network self-selection does not necessarily need to be an impulsive process of discovery (e.g. Sarasvathy & Dew 2005). Rather, it can be improved and proactively managed. This finding does not only refine effectual logic but also encourages the rethinking of relationships between effectual principles.

Third, the thesis offers a new direction for research that utilises effectuation and causation reasoning as foundational theory. Most research employing Sarasvathy's (2001) effectuation and causation discuss both logics in tandem. From a slightly different perspective, this thesis shows how valuable insight can be gathered by digging deeply into effectual logic. It adds to the most common empirical conclusion: a firm starts with effectuation and gradually employs causation as it moves closer to its objective (e.g. Sitoh et al. 2014; Reymen et al. 2017)

Finally, the execution of this research enhances the eminence of effectual logic to reflect the underlying reality of the phenomenon in the strategic management and academic entrepreneurship streams of literature. The finding shows consistencies between the developmental states of multiple research streams. By extending the applicability of effectual logic to understand the dynamics of strategic decision making when developing a business model, the thesis strengthens the specific relevance of effectuation to the entrepreneurial setting. Likewise, the decision-making process is an important element in the organisational process of entrepreneurial firms (Alvarez & Barney 2005), but it has rarely been extended to the university context.

7.4 Practical Implications

As highlighted in the first chapter, general lessons concerning USO business model development are rarely shared beyond organisational boundaries, hindering wider managerial

implications. This research offers several contributions pertinent to practitioners. Since the commercialisation of academic research through USO creation has been a high priority for policy in many countries, this research relates to the repercussions of USO strategies pursued by USO entrepreneurs and technological policy advocated by USO stakeholders. The next section describes the practical implications of this research specifically for USO entrepreneurs and stakeholders and more broadly for other firms.

7.4.1 Relevant Findings for USO Entrepreneurs

First, given the ambiguous path to commercialisation, USO entrepreneurs may find the conceptual framework and the guiding principle proposed in this research useful for development of their initial business models. The framework should serve as a conceptual toolbox and offer a common language to assist cognition and lead to the development of organisational interventions that facilitate business model development. This may have further implications for the design and execution of strategies for USO commercialisation, which could improve the commercial underachievement facing many USOs.

Second, when defining their value proposition and creating value, USO entrepreneurs may need to exert more control over their resources and capabilities. The evidence in this thesis hints that the business model development process can and should be influenced or managed by USO entrepreneurs. The findings further affirm that, although technological and market ambiguity is inevitable and the future cannot be controlled, USO entrepreneurs could still create value in a way that influences how the future would unfold. The notion shifts our understanding about the trial-and-error process, which is not necessarily a stochastic event but something that can be proactively influenced through the actions of the USO entrepreneur.

Third, in capturing value, a USO entrepreneur needs to be creative and flexible to sense possible ways of generating revenue in the face of financial pressure. The case studies in this thesis sought to recommend several workable strategies for generating revenue in a way that would also respond to the distinctive challenges faced by USOs, such as multiple revenue streams and the customisation–cost strategy. Since many attempts to commercialise new technology take longer than they should, result in marginal profit or end in failure (Mustar et al. 2008), these strategies for value capture may be useful for USOs to consider.

Fourth, regarding conflicting stakeholders, the evidence in this thesis encouraged USO entrepreneurs to carefully screen their stakeholders prior to soliciting partnerships without over-trusting or over-predicting. However, many types of conflicts are inevitable and USO entrepreneurs may lack experience in screening their partners. In such situations, USO entrepreneurs should attempt to adopt mindful attitudes towards potential tensions among stakeholders with conflicting motives and cultures. When resolving conflicts, USO entrepreneurs may need to first seek common ground and forge partnerships. If such an approach does not work, then the USO may need to consider splitting the difference and negotiate to achieve a compromise. This measure could be instrumental for reducing the risk of continuous conflict that might plague the USO's journey to commercialisation.

Lastly, the thesis carefully considered myriad challenges and common pitfalls faced by USOs led by both experienced and inexperienced entrepreneurs. The thesis also highlighted the need for tailoring a business model that accounts for the nuances and complexities of the market and technological uncertainty. Most USOs that do not account for these caveats are trapped in oversimplified commercialisation strategies that eventually fail. Given this, USO entrepreneurs may want to familiarise themselves with common challenges facing the business model development process. Through familiarisation of anticipated challenges, USO entrepreneurs could deliberately attend to the difficulties ahead of them. This pre-emptive measure may also enable entrepreneurs to operate in otherwise chaotic environments, which are typical in the early-stage of growth of USOs, when both the technology and market are highly uncertain. Previous literature on USO business model development did not sufficiently consider these loopholes and, hence, may arrive at a false impression of what a USO may become despite market opportunities, novel business ideas, adequate resources and talented entrepreneurs (Morris et al. 2005).

7.4.2 Relevant Findings for USO Stakeholders

USO stakeholders include a wide array of practitioners with a stake in the USO and common interest in enhancing university technology commercialisation. They include university management, TTOs, investors, partners and policymakers. The findings of this research provide these stakeholders with relevant insights regarding their respective roles in USO commercialisation.

First, the thesis urges more inclusive collaboration with USO stakeholders, which could help a USO to better comprehend the challenges and opportunities ahead of it. In particular, the evidence in this thesis has repeatedly underscored that successful university technology commercialisation is the result of synergistic collaboration between different stakeholders. Therefore, all the stakeholders need to break different silos. More importantly, the burden of commercialisation should not shouldered only by USO entrepreneurs but collectively by stakeholders both from academic and commercial networks. All expectations regarding stakeholders' vested interest in technology commercialisation should be balanced with their roles in improving the probability of commercialisation success. In doing so, the stakeholders may become more responsive in facilitating the USO business model development process.

Second, within the university setting, university management should consider a wide range of mechanisms to create a conducive ecosystem for academics hoping to commercialise their research. Supportive mechanisms should focus not only on the formation of USOs but also, most importantly, on their sustainable growth. TTOs need personnel with the appropriate skills to support the early—and most crucial—stage of USO growth in creating and capturing value from latent technology. Since patented technology may not necessarily translate into wealth, TTOs may reflect on the fact that IP needs to be sustained by a viable business model because, instead of being a USO's best asset, IP could also be the USO's worst liability. The case studies reveal that USOs supported by less bureaucratic regulations are more likely to survive and prosper. Additionally, when supporting a USO's commercialisation pursuit, a TTO and the university management need to pay more attention on the technology's societal impact rather than just focusing on value creation solely based on the economic value.

Finally, since governmental support does not seem to have eliminated all the barriers to commercialisation of university technology, policymakers may need to reflect on existing policy that affects the survival of USOs. Although, policymakers have acknowledged that poorly devised business models are a key bottleneck hindering university technology commercialisation, interventions are still fragmentary. By adding extra urgency to the issue, policymakers should revise the existing policy, craft a new policy instrument that could help the USO diminish the time to market, enhance profitability and convert USOs into dynamic high-growth firms. Policymakers could also target resources throughout all TRLs and perhaps

map the USOs' performance over time. This approach could enhance USOs' resilience and durability, enabling them to grow in tough environments.

7.4.3 Relevant Findings for Other Firms

The practical implications of this study are related to a sample of decisions made by USO entrepreneurs. Compared with other entrepreneurs beyond the USO setting, USO entrepreneurs are likely to have less business experience and usually deal with new technologies and uncertain markets. Therefore, it can be argued that this study's findings may have useful implications for the wider population of novice entrepreneurs or managers striving to adapt their business models in environments with high market and technology uncertainty.

Despite the specific characteristics of USOs, other firms, like technology start-ups or entrepreneurial firms, have some similarities to USOs. For instance, these firms are normally technology-driven, small, have a high business risk and aim to produce innovative products. The results of this study may thus be applicable to these firms. In addition, the COPE principles proposed in this thesis can be generically applied to the broader set of concerns related to the challenges faced by small firms beset with liability of newness. In summary, since the business model has quickly become a key instrument in technology commercialisation, this thesis provides a valuable opportunity for practitioners to advance their existing knowledge of the measures that need to be considered when developing a business model to bring new technology into commercial reality.

7.5 Research Limitations

Owing to the nature of an inductive case study, this research was exposed to at least four common methodological limitations. This section presents the limitations of this research and measures taken to minimise them.

Limited Generalisability of Findings

Limited generalisability of findings is a typical criticism of case studies, and this research is no exception. There is a high potential for the findings to result in idiosyncrasies, making it difficult to extend them to a broader organisational, industrial and spatial context. Given the uniqueness of the challenges faced by USOs and the fact that the cases are cleantech-focused

and location-specific, it may be difficult to extend the findings to radically different types of firms in different industries and locations. However, the findings may be extended to other entrepreneurial firms experiencing similar obstacles or USOs in other locations with similar IP policies. To enhance generalisability within the USO context, all cases were carefully selected so that each case features a distinctive profile and could predict theoretical replication (contrasting results for anticipated reasons) rather than literal replication.

Less Accurate Inter-coder Assessment Results

The data analysis relied heavily on the researcher's interpretation supplemented by four assessors' feedback which might be biased due to individual subjectivity. Limited samples were used during the inter-coder assessment, i.e. 21 randomly selected interview quotes, 21 categories, six themes and three aggregate dimensions. Due to this, the inter-coder assessment results might not fully reflect the real coding process conducted by the researcher. Additionally, the Q-sort technique employed in the inter-coder assessment may be exposed to bias due to assessors' time constraint and misunderstanding. This limitation was minimised by planning the assessment carefully and by providing the assessors with clear instructions. All assessors' results were also discussed after each assessment.

Limited Causal Inferences

This study was conducted in a cross-sectional, or snapshot, manner, which allowed many variables to be compared simultaneously. Validation of the findings of cross-sectional case studies, however, does not allow valid causal inferences, unlike validation of longitudinal cases. This shortcoming was minimised by conducting in-depth interviews, performing detailed analysis and cross-case comparison to corroborate both current and past events. Retrospective questions were also included in the interviews so that the cross-sectional findings could become a series of snapshots that represent the whole event.

Bias and Preconception

To some extent, the researcher's background and position inevitably influence the angle of investigation, the methods that are judged most adequate, the findings that are considered most appropriate and the framing of conclusions. In this research, bias and preconception were minimised by fostering reflexivity (i.e. attending systematically to the context of knowledge

construction, especially to the effect of the researcher on every step of the research process). The current research also sought to integrate collective feedback to allow data triangulation by engaging more people in dialogue regarding, for example, by conducting the inter-coder assessment exercise. These measures have led to the development of complementary as well as divergent understandings of a study situation, which are useful for unpacking any alternative beliefs, values or perspectives. Most importantly, inclusive triangulation allows assumptions to be revealed and contested.

7.6 Recommendations for Future Research

This research generated several propositions for follow-up studies. The following section presents three areas that deserve to be explored in more detail in future work.

Longitudinal Operationalisation in a Broader Context

Further research using larger samples of USOs from different universities, industries and locations is needed to extend the current findings to a broader context, thus enhancing generalisability, one of the previously identified limitations. Additionally, since this study is cross-sectional, more longitudinal research on the upstream and downstream stages of commercialisation, preferably for longer periods, could bring causal inferences to the process of business model development.

External Stakeholders' Role

This research has suggested that external stakeholders have a striking impact on how business models are developed despite conflicting motives and values. However, this issue has not been explored in detail. Hence, further research could investigate how the range of external actors who have conflicting vested interest (e.g. customers, suppliers, distributors, competitors, investors, universities, government agencies) could influence the business model components' development over time.

Reinforcement of Framework Validity

This thesis proposed a conceptual framework to serve as a theoretical perspective with which to examine the process of business model development in the USO context. Another interesting

direction to extend this work is to reinforce framework validity by testing the conceptualisation in other entrepreneurial firms, such as technology start-ups.

In conclusion, this thesis denotes an attempt to address the theoretical and managerial implications for the business models in commercialising university technology: one of the most challenging issues facing USOs today. The overview of the completed research and linkages between chapters is presented in Figure 7-1. As evidenced in this thesis, the reconciliation of business models and university technology commercialisation literature represent a new stream of knowledge which has already attracted scholarly interest to dismantling issues of significant importance to the business model and technology transfer scholars. It is hoped that this completed research could become a germinal step towards inspiring future work with more rigorous enquiries that could bring this stream of knowledge to the cognisance of the mainstream literature.

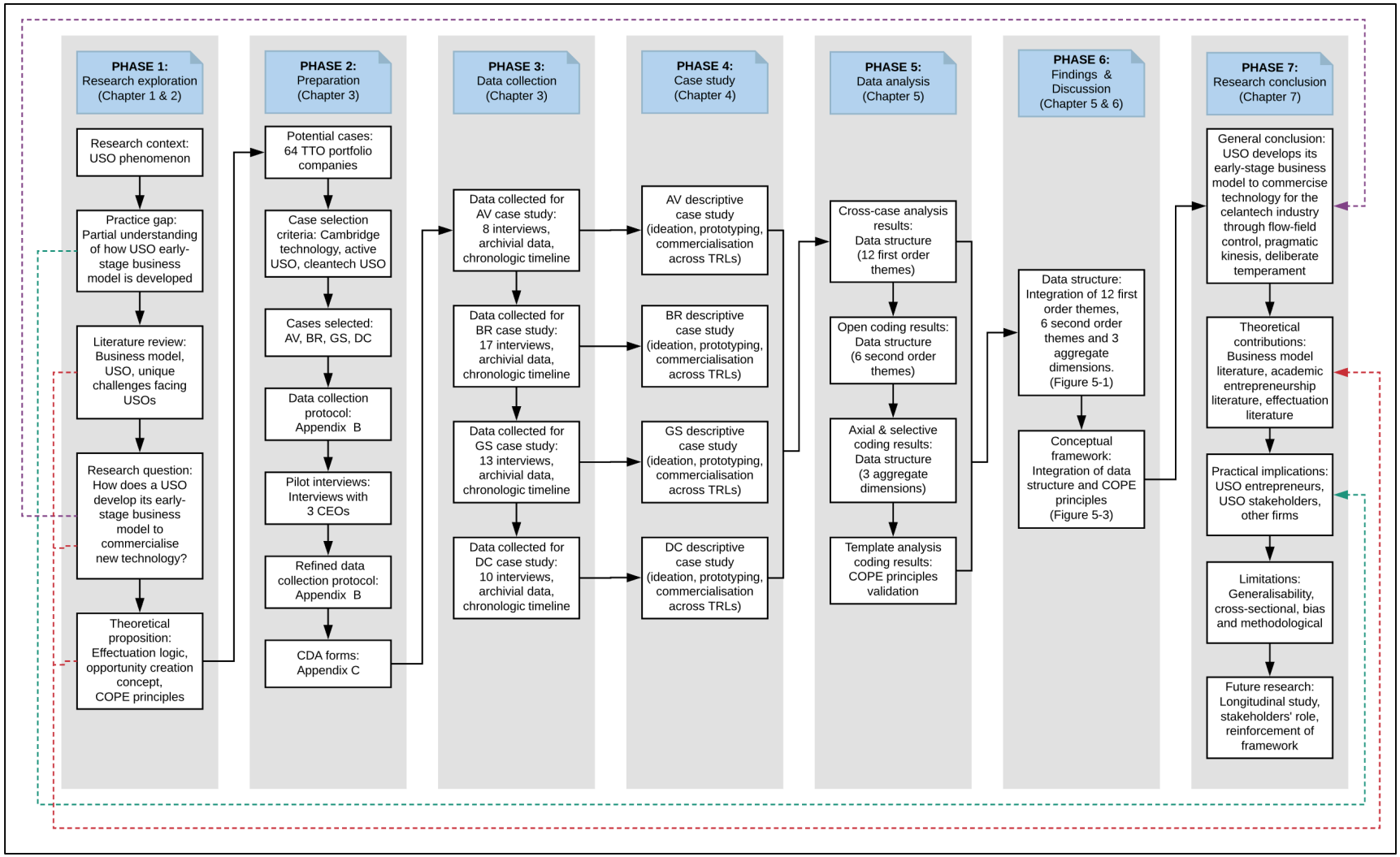

Figure 7-1: Completed research and linkages between chapters

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Appendix A: Chronologic timeline

ALPHAVENT CHRONOLOGIC TIMELINE BASED ON CRITICAL EVENTS (BEFORE 2006- DEC 2010)

Events/year		Before 2006	Year 1 (2006)	Year 2 (2007)	Year 3 (2008)	Year 4 (2009)	Year 5 (2010)
IDEATION/ INCORPORATION	Ideation	-AV's inventor fleshes out idea on natural ventilation system - traditional natural ventilation strategies are just not up to scratch and comes up with a new approach.	-AV's inventor validates idea at Department of Engineering, University of Cambridge.				
	IP/ licensing	-AV applies for IP-passive stack system. (The IP is filed in 2006 and granted in Europe in 2012).	-AV, the funder, TTO acknowledge the commercial terms that allows the funder and the TTO to hold share in the company through an equity only agreement. -AV is given royalty-free, exclusive commercial right to the university technology.	-AV and funder agree right up front that either AV or the funder will be the commercial entity of the USO. -If AV commercialises, the USO would pay ongoing royalty to the funder.	-AV decides that they will be the commercial entity of the USO. -The earlier agreement concerning royalty is abolished – conflicts with the funders aspiration.	-The e-stack natural ventilation system is developed and patented by the TTO.	
	Leadership/ incorporation	-AV's CEO has business experience by jumping out of academic research in 1997. *'I jumped ship completely and worked for a mortgage-strategy consulting firm nothing to do with engineering.'*	-AV is founded. -AV forms a team of highly qualified ventilation experts: the inventor (lecturer/engineer) assumes the role as CEO.				-AV changes its name to the one that is more relatable to its technology.
PROTOTYPING / COMMERCIALISATION	Technology development	-AV discovers proprietary low energy e-stack mixing ventilation system.	-AV aligns feedbacks gathered form architects to devise the technological solution. -AV aims to devise a solution to ventilate buildings with fresh air without freezing buildings occupants. -AV develops and tests prototypes of the e-stack system in labs. -AV gathers useful data to determine the algorithm for the ventilation system.	-AV concentrates efforts on the proof of concept and validation of the technology in the real environment.	-AV optimises its ventilation system with energy saving of 10-50MW/hour (saving of 40MW/hour/year, CO_2 emission of 10 tonnes/ year. -AV commercially introduces the e-stack system to the market. -AV hits its first sale milestone.	-AV selects Dorset School for the testing of its natural ventilation system.	-AV launches new design tool for architects and designers working on school's development projects. -AV designs Sunderland healthcare facility (UK's first primary care facility rated as excellent by BREEAM) -AV adds CAD blocks for all the e-stack range to products page.
	Strategy		-AV hires students to investigate the right target market. -AV invests in market research and constantly reviews current and upcoming regulations related to ventilation system.		-AV advocates the claim that *'the simplest way to reduce fuel costs this winter is to use the heat you already generate yourself!'*		- AV designs Asda ventilation system to manage temperature fluctuations in colder weather (the first store in the UK to operate the BB e-stack system).

PROTOTYPING / COMMERCIALISATION	Financial	-An international oil & gas company funds £2.5M research on the proprietary low energy e-stack mixing ventilation system.				-AV receives £75,000 grant from a VC to create a way of recycling waste heat.	
	Partnerships		-AV forges partnerships with the university through the CMI Partnerships Programme. -AV receives further support from the international oil & gas company.			-AV enters partnership with Dorset School for the testing of natural ventilation system. -Lord Sugar visits AV and discusses with CEO about the support services available to businesses in the region.	-AV strengthens links to the Engineering Department at the University of Cambridge. -AV receives support from UKTI to join GLOBE 2010.
	Market presence				-AV is listed in The Clean Tech Start-up Index.	-AV's CEO is interviewed in Masterclass in Energy Supply and Demand.	-AV takes part in GLOBE 2010 -AV's CEO attends the Business Breakfast at No 10 Downing Street.
	Awards/ recognitions						-AV is selected to join a Clean and Cool Mission 2010 -AV is identified as UK Cleantech Hot Prospect by Wired Magazine. -AV is included in Business Weekly's Killer 50. -AV is shortlisted for Green Business of the Year in Real Deals, Growing Business Awards. -AV is included in Cleantech Connect Top 25
	Challenges		-AV fights hard for a royalty free licensing agreement -AV faces harsh competition in the market-competing on price for equal approved products (cannot charge much of a premium).		-Sales made during the first year is just enough to survive as a new firm -AV is hit by the 2008 recession. -AV continues to compete on price.	-AV steers strictly by the previous Chairman to outsource sales function.	
	Regulatory/ Societal push	-E-stack mixing ventilation system is claimed to have the potential to reduce heating bills as much as 50%.	-Provision of energy to buildings account for around 40% of the energy consumption in the developed world.		-The benefit of mixing ventilation is written into regulation-BB101 Guidelines on Ventilation, Thermal Comfort and Indoor Air Quality in School.	-Cleantech businesses are ushering in a green-energy revolution that may help lift Britain out of recession.	-The proposed changes to Part L and Part F of the Building Regulations in 2010 have been designed to support the Government's Building a Greener Future.

ALPHAVENT CHRONOLOGIC TIMELINE BASED ON CRITICAL EVENTS (JAN 2011-DEC 2016)

Events/year		Year 7 (2011)	Year 8 (2012)	Year 9 (2013)	Year 10 (2014)	Year 11 (2015)	Year 12 (2016)
IDEATION/ INCORPORATION	IP/ licensing		-AV is granted patent for passive stack system in Europe in 2012.		-AV's patent was infringed by a company that launched very similar product (they pulled their product from the market in the end).		
	Leadership /incorporation		-AV appointed its Business Development Manager.				-3 engineers from the AV venture to Edinburgh in search of Haggis, Kilts and the CIBSE Technical Symposium at Heriot Watt University.
PROTOTYPING / COMMERCIALISATION	Technology development	-AV launches an extension of design tool for office and schools. -AV co-develops (with a global ventilation company) a toolkit for mechanical engineers. -AV completes the first BREEAM 'Outstanding' Healthcare project. -AV makes its units available on Google Sketchup -AV establishes FAQs section.		-AV champions the benefits of PCM in the construction of a more sustainable built environment.	-AV releases second edition of new catalogue.	-AV tests the effectiveness of adding PCMs to a school built using lightweight construction -AV tests take place at Belvoir High School, Bottesford, Nottingham which featured R-Series e-stack through-the-roof ventilation units.	-AV ventilates the James Dyson Building and Centre at the University of Cambridge -Sir Robert Woodard Academy in West Sussex is handed over to the end client on the 22nd December.
	Strategy	-AV launches promotional material (a new educational brochure that explains school solution and Asda case study). -AV visits Canada and the US as part of a UKTI-led CleanTech mission. -AV sponsors an industry wide event for Healthcare, Retail and Sustainable urban planning and design. -AV showcases the collaboration between local organisations to the Secretary of State for Energy and Climate Change.	-AV outsources sales functions with US and Canadian companies to sell in their markets (using royalty based model) which ends after a year-does not work.	-AV creates a guidance paper to help contractors/engineers comply with the new criteria and cost targets. -AV updates Priority School Guide to reflect the changes in the Facilities Output Specification -AV creates a cold draught calculator (to help client ensure that the occupants of the buildings are comfortable)	-AV launches YouTube channel to discuss natural ventilation issues.		
	Financial		-AV receives £1M investment				-AV exceeds revenue forecast (2015/16 financial year) of more than 30% growth with average 3-year sales growth of 52.25% and recorded sales of GBP 7.8 million.

PROTOTYPING / COMMERCIALISATION	Partnerships	-AV enters partnership with Company N to develop a toolkit for mechanical engineers. -AV helps Willmott Dixon and NHS South of Tyne & Wear build the UK's first BREEAM 'outstanding' health facility. -AV completes Barnfield South Academy's project.	-AV enters partnership with the University of Cambridge to host Industry event (to discuss the challenges that the construction industry is facing) and CIBSE seminar on Low Energy Natural Ventilation. -AV enters partnership with Government to advise on the importance of ventilation in a educational space.		-AV sponsors prizes for 3 engineering students of Girton.	Arranges an Industry-Academia research event on Building the World of Tomorrow, in partnership with Prof Cam Middleton from the University of Cambridge.	-AV is acquired by a bigger firm (came to the market in 2014 and is best known for its ownership of the Vent-Axia brand of ventilation products).
	Market presence	-AV's CEO speaks at the Enterprise Tuesday Buildings which AV worked on received awards. -AV is featured in CAM Magazine 59- the culture and ethos of the company -AV's CEO speaks to H&V News about 'Greening' a buildings. - AV displays e stack at the Insite11 event at the BRE campus within Wilmott Dixon.	-AV's CEO was interviewed by H&V News about how he set up the UK's fastest growing natural ventilation. -AV survives during one of the longest economic downturns the construction industry has seen. -AV's CEO speaks about winning BREEAM (Houghton Primary Care Centre). -AV's CEO has been called upon by the Government to advise on the importance of ventilation in an educational space.	-AV's CEO speaks at Clean Tech Innovate 2013 -AV hosts a Breakfast event with CIBSE. -AV's CEO is interviewed by Radio 4's-the success of Ashmount Primary School and the BREEAM Outstanding award. -AV's CEO writes an article on avoiding cold draughts for the CIBSE -AV supports CIBSE Natural Ventilation event at UCL. -AV is invited by Modern Building Services to talk about challenges of cold draughts Hosts a Breakfast event with CIBSE.	-AV's CEO joins a panel of experts to discuss mixing ventilation online webinar CEO speaks at a CIBSE event at UCL -AV's CEO is interviewed by Naked Scientists Radio -AV's CEO presents 'Designing natural ventilation for thermal comfort in buildings' in International Energy Agency (IEA) Annex-62 Ventilative Cooling Seminar at Brunel University London.		-AV implements its technology in more than 300 buildings in the UK.
	Awards/ recognitions	-AV is shortlisted for the Cambridge Graduate Business of the Year Award. -AV is nominated for the BVCA Portfolio Awards 2011 -AV is listed in Business Weekly's new Killer50. -AV wins two major honours in quick-fire succession. -AV's CEO is awarded the 2011 Silver Medal for their contributions to driving unique engineering. -AV's CEO listed as one of Cambridge's brightest young entrepreneurs -AV's CEO gives MPs a masterclass on natural ventilation. -AV is named in Business Weekly's top 50 Killer companies in the East of England.	-AV is chosen as finalist by BREEAM for Sustainable Buildings 2011/12. -AV runs for Sustainia100, in Rio. -AV wins Berti Green Accelerator programme Awarded the BVCA awards for community and environmental action in the Midlands. -AV announces in the prestigious Global Cleantech 100.	-AV is shortlisted for the CIBSE Building Performance Awards 2014.	-AV is shortlisted in the Private Business Awards 2014.		

PROTOTYPING / COMMERCIALISATION	**Challenges**				-AV patent was infringed by a company that launched very similar product (they pulled their product from the market in the end). -AV loses 5 projects totalling about £30,000 to the infringer.		
	Regulatory/ societal push			-Many new school are suffering from overheating and energy bills because of problems with ventilation design. -New guidance from the EFA aims to address the issue- BB explains in April's CIBSE Journal -The NHS produces 18 million tonnes of CO_2 every year – AV's technology could be the solution.	-EFA announces new regulations governing ventilation in schools, signalling the end of BB101-the importance of the occupants' comfort and the importance of mitigating cold draughts. -EFA publishes new guidance on acoustics, lighting and ventilation in schools.		

Appendix B: Interview protocol

INTERVIEW PROTOCOL VER 0.1 (for pilot study)

- Introductory protocol
- SET 1: Generic information
- SET 2: Business model development

INTRODUCTORY PROTOCOL

Student/interviewer:	Zurina Moktar (Second year PhD student)
Affiliation:	Institute for Manufacturing, Engineering Department, University of Cambridge, UK
Research title:	Business models (BM) in commercialising university technology
Research questions:	RQ1-How does the design and development of BM assists in commercialising university technology? RQ2- How does a BM integrate internal and external factors in order to enable the commercilisation of university technology?

Introductory Protocol

Thank you for your agreeing to participate. To facilitate note-taking, I would like to audio record our conversations today. For your information, only myself as the researcher on the project will be privy to the recordings, which will be eventually destroyed after they are transcribed. In addition, you have to sign a form devised to meet the university human subject requirements. Essentially, this document states that:

1) all information will be held confidential;
2) your participation is voluntary and you may stop at any time if you feel uncomfortable;
3) I do not intend to inflict any harm.

You have been selected to be interviewed because you have been identified as someone who has a great deal to share about the USO. My research project as a whole focuses on BM in commercialising patented technology. I do not aim to evaluate your company performance. Rather, I am trying to learn more about how a BM can be used as a tool to commercialise patented technology and hopefully learn about the configuration of BM elements prior to product or service commercialisation stage.

I have planned this interview to last no longer than 60/90 minutes. During this time, I have several questions that I would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete the line of questioning.

SET 1: GENERIC INFORMATION

Objective:	To gather generic information about the USO
Target:	USO founder/CEO
Duration:	No longer than 60 minutes
Mode:	Semi structured interview (6 sections, 26 questions)
Prerequisite:	Study all the information about the USO available on the company website

A. USO generic info

1. Name of the company
2. Date incorporated (establishment was led by IP or otherwise)
3. Founding team (e.g. 4 professors + 2 team members)
   - Name, age, background and past experience of founding team members
4. Stage of the company (Nascent Entrepreneur, New Business or Established Business)
5. Activity description
6. Number of employees

B. Opportunity identification and development

1. Approximate date of initial idea
2. Context of initial idea (e.g. stumbled into an opportunity)
3. Stage when marketing issues get considered
4. Approximate date of incorporation
5. Original research and which department
6. Type of technology exploited, list of patents (and other protected IP)
7. Type of industry explored
8. Specific domain (e.g. virtual marketplace)
9. Most critical resource for initial opportunity development (e.g. one professor's industry experience)
10. Source of basic technology and competence (e.g. university research and industry experience)

C. Technology and market development

1. Major performer of technology development (e.g. founders)
2. Other performers of technology development (e.g. industrial partners)
3. Major roles in market development (e.g. founding team)

D. Funding

1. Has the USO received any type of external funding?
2. Initial funding (e.g. self-funded)
3. Major source of funding (e.g. public grants)
4. Additional funding sources (e.g. industry)

E. Company performance

1. Estimated time-to-market
2. Date of first sale
3. Estimated date of first sale (if no sales)
4. Date of first customer order
5. Estimated date of first customer order (if no orders)

F. Additional info/documentation to request

Business plan, presentations, annual report/other reports, notes, videos, audio, website, press releases and other.

SET 2: BUSINESS MODEL DEVELOPMENT

Objective:	To gather information about the USO's BM, how it is developed and changed over time
Target:	All board members, by levels
Duration:	No longer than 90 minutes
Mode:	Semi structured interview (4 sections, 24 questions)
Prerequisite:	Study information gathered from the first-round interview.

A. VALUE PROPOSITION

[What the USO aimed and has delivered to its customer, why the customers were willing to pay for it and the USO's basic approach to competitive advantage].

1. *Could you please briefly describe the stage when the idea about this USO was first fleshed out?

2. When the idea was first fleshed out, what were the benefits you aim to offer to the targeted customers? **A1. Value/benefits**

3. What were the top goals at this early stage? **A2. Goals**

4. *Could you please briefly describe what happen next after the ideation stage? How was the USO established and how did the USO discover the first functional technology?

5. Did the initial benefits you aim to offer to the targeted customers and company goals change when you came out with the first functional technology? **A3. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

6. *Could you please briefly describe about the stage when the product/service/technology was ready to enter the market?

7. Did the benefits you aim to offer to the targeted customers and your goals change when technology/product/service is ready to be introduced into the market? **A4. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

B.VALUE CREATION (AND DELIVERY SYSTEM)

[How did the USO create and deliver its value to its customer and the source of its competitive advantage].

1. When the idea was first fleshed out, what were the key resources needed to make your business model work? **B3. Key resources**

2. What were the sources of funding available during that time? **B2. Funding**

3. What were the key activities that you aim to include at this planning stage? How did the value chain look like at the ideation stage? **B3. Key activities/value chain**

4. When the idea was realised and you came out with the first functional technology, did any of the key resources, funding and key activities/value chain change from the previous plan? **B5. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

5. Prior to the introduction into the market, did any of the key resources, funding and key activities/value chain change? **B6. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?

C. VALUE CAPTURE
[How did the USO generate revenue and profits].

1. When the idea was first fleshed out, what were the most important costs considered in your business? **C1. Cost structure**

2. What and how you thought your customer could pay for the product/service/technology this USO provide? **C2. Value capture/Revenue stream**

3. When the idea was realised and you came out with the first functional technology, did the important costs in your business and the way your customer will pay for the product/service/technology change?**C3. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

4. When the technology/product/service was ready to be introduced into the market, did the important costs in your business and the way your customer will pay for the product/service/technology change? **C4. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

D. VALUE NETWORK
[Who are the people involved and what are their roles]

1. When the idea was first fleshed out, what did your customer segments/types/groups of customers look like? **D1. Customer segment**

2. What was the type of relationship you wished to establish and maintain with each of your customer segments? **D2. Customer relationship**

3. Who did you think would be the key partners in your business network? **D3. Key partners**

4. Did the customer segments, customer relationships and key partners change when you come out with the first functional technology? **D4. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

5. Did the customer segments, customer relationships and key partners change when technology/product/service is ready to be introduced into the market? **D5. Change**
    - What has been changing?
    - When did the change occur?
    - Why did it change?
    - Who initiate the change, how did the decision made?

6. Anything else you find interesting about the journey of your USO from the ideation stage to the commercial deployment not covered abov

INTERVIEW PROTOCOL VER.04 (after pilot study and iterations)

- SET 1: Protocol for the internal stakeholders (Academic Founder/Board of Director)
- SET 2: Protocol for the external stakeholders (TTO/partner/competitor/others)

SET 1: INTERVIEW PROTOCOL FOR THE INTERNAL STAKEHOLDERS

Date, Time, Venue	xx, xx, xx
RQ	How does a USO develop BM in commercialising university technology?
Interviewee's name	xx
Position	xx
Background	xx
Objectives	1. To access information about the USO and its formation 2. To understand how business model is developed in commercialising the technology 3. To identify the enablers and barriers to a successful university technology commercialisation

1. USO FORMATION, GOVERNANCE, STRUCTURE AND BUSINESS MODEL	
1	What does the USO do? When was the USO established? Where: which lab/which research?
2	Who was and still is involved? Organisation chart?
3	Who are the 1) inventors 2) case managers in the TTO and 3) board of directors 4) key partners?
4	How does the USO currently operate? The stage it is currently at?
5	What is the USO's current business model? How did it differ from the initial idea?

2. BUSINESS MODELS DEVELOPMENT IN COMMERCIALISING UNIVERSITY TECHNOLOGY	
1	The story from ideation stage (when the technology is just an idea) to current state?
2	Patents involved?
3	How did the USO create and deliver value to its customer? What is the source of its competitive advantage?
4	How did the USO encase the technology into a proposition?
5	Did market resistance affect business model development process? How and why? Solution?
6	How did the USO generate revenue and profits? How did the USO entice payments from the customers?
7	What type of financial pressure faced? Why? Solution?
8	Who are the USO's major stakeholders (from the academic network and commercial network)?
9	Did the USO face any conflicting value, culture and motives? How and why? Solution?
10	What were the overall major challenges in developing a business model? Solution?

3. KEY ENABLERS/BARRIERS FOR A SUCCESSFUL UNIVERSITY TECHNOLOGY COMMERCIALISATION	
1	Based on your experience, what are the INTERNAL key enablers for a successful university technology commercialisation? What could be better?
2	What are the EXTERNAL key enablers for a successful university technology commercialisation? What could be better?

Info/logistics needed from the USO:

1. Consent to disclose annual IP commercialisation report
2. Related transactions/documents
3. Referral to the key partners/stakeholders
4. Follow up interview (if needed)

SET 2: INTERVIEW PROTOCOL FOR THE EXTERNAL STAKEHOLDERS

Date, Time, Venue	xx, xx, xx
RQ	How does s USO develop BM in commercialising university technology?
Interviewee's name	xx
Position	xx
Background	xx
Objectives	1. To understand the remit of X 2. To understand the general role of X in facilitating USO technology comemrcilisation 3. To identify the enablers and barriers to a successful university technology commercialisation

1. INFORMATION ABOUT X	
1	What is the remit of x and whose interest does it represent?
2	What is x relationship with the USO? How did it first establish? When and why?

2. X INVOLVEMENT IN THE BUSINESS MODEL DEVELOPMENT TO COMMERCIALISE UNIVERSITY TECHNOLOGY	
1	Whether it is direct or indirect, to what extend did x facilitate the commercialisation of technology in the USO?
2	How did x facilitate the USO to create and deliver value to its customer?
3	Do you think market resistance affect business model development process? How and why?
4	How did x facilitate USO to generate revenue and profits?
5	Do you think financial pressure affect business model development process? How and why?
6	How did x facilitate USO to expand its network?
7	Do you face any conflicting value, culture and motives with the USO? How and why? Solution?
8	What is your view about the USO journey in comemrcilisaing its technology?

3. KEY ENABLERS/BARRIERS FOR A SUCCESSFUL UNIVERSITY TECHNOLOGY COMMERCIALISATION	
1	Based on your experience, what are the INTERNAL key enablers for a successful university technology commercialisation? What could be better?
2	What are the EXTERNAL key enablers for a successful university technology commercialisation? What could be better?

Info/logistics needed from the firm:

1. Related transactions/documents
2. Referral to the key partners/stakeholders
3. Follow up interview (if needed)

Appendix C: Example of the signed CDA form

CONFIDENTIALITY AGREEMENT FOR A STUDENT PROJECT IN THE DEPARTMENT OF ENGINEERING

THIS AGREEMENT is between:

(1) **The Chancellor, Masters and Scholars of the University of Cambridge** ("University"), whose registered address is at The Old Schools, Trinity Lane, Cambridge CB2 1TN, UK; and

(2) **Zurina Moktar** ("Student"), whose office address is The Institute for Manufacturing, 17 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom ; and

(3) [redacted]

RECITAL

A. The Student is studying for a Degree (as defined below) at the University.

B. [redacted] willing to disclose to the Student Information (as defined below) which belongs to [redacted] and which it regards as confidential. Student may use this Information to produce the Assignment (as defined below), as part fulfilment of the Degree.

C. [redacted] willing to allow the Information to be disclosed to the University in order to facilitate the assessment of the Degree, and the parties have agreed to enter into this Agreement to set out the basis upon which [redacted] prepared to disclose the Information to the University and the Student.

IT IS AGREED as follows:-

1. In this Agreement, the following words shall have the following meanings:

Assignment	Business Models in Commercialising University Intellectual Property
Degree	shall mean the [PhD in Engineering from the University of Cambridge]
Disclosing Party	shall mean the party to this Agreement that discloses information, directly or indirectly to the Receiving Party under this Agreement.
Effective Date	shall mean 1 February 2015
Information	shall mean all information provided directly or indirectly by the Disclosing Party to the Receiving Party whether written oral or otherwise including without limitation know-how, drawings, data software or other technical matter and relating to the Purpose.

Purpose	shall mean the preparation of the Assignment by the Student, and the subsequent review by the University of the Assignment for the purpose of assessment of the Degree.
Receiving Party	shall mean the party to this Agreement that receives information, directly or indirectly from the Disclosing Party under this Agreement.

2. All Information will be regarded as, and kept confidential and no part of it will be divulged by the Receiving Party to any third party at any time and in any form whatsoever except as provided in clauses 6, 7 and 8.

3. Information shall be used by the Receiving Party only for the Purpose.

4. For the avoidance of doubt ownership of Information shall remain the property of the Disclosing Party. No licence is granted hereunder to the Receiving Party and no licence shall be deemed to have arisen.

5. No warranty or representation express or implied is given as to the accuracy, efficacy, completeness, capabilities or safety of any Information.

6. Information may be revealed to employees of the Receiving Party but only to the extent that this is necessary for the Purpose. The Receiving Party will bind such employees to keep such Information confidential both during and after their current employment and will take appropriate steps to enforce the obligations of such employees in relation thereto.

7. The Student may disclose the Information to the University but only to the extent that this is necessary for the Purpose.

8. This Agreement shall not apply to any Information which:

   (1) at the date of this Agreement is in the public domain or subsequently comes into the public domain through no fault of the Receiving Party and not in breach of this Agreement; or

   (2) was already known to the Receiving Party on the date of disclosure, provided that such prior knowledge can be substantiated and proved by documentation; or

   (3) properly and lawfully becomes available to the Receiving Party from sources independent of the Disclosing Party; or

   (4) is independently developed by any student, employee or officer of the Receiving Party who had no access to the Information received by the Receiving Party and where the independent development can be proven by contemporaneous written documentation; or

   (5) the Receiving Party is required to disclose by a court of competent jurisdiction or statute.

9. The Receiving Party shall at any time and if so requested by the Disclosing Party return to the Disclosing Party (or if the Disclosing Party so requests destroy or erase) all Information.

10. This Agreement shall come into effect on the Effective Date and shall have a term of three (3) years; provided however that the obligations of confidentiality and non-use as set forth in clauses 2 and 3 shall remain in effect for a period of five (5) years from the Effective Date.

11. (1) If any dispute arises out of or in connection with this Agreement the parties will attempt in good faith to settle it by negotiation.

(2) If the parties are unable to settle any dispute by negotiation within twenty-eight (28) days the parties will attempt to settle it by mediation in accordance with the Centre for Effective Dispute Resolution (CEDR) Model Mediation Procedure.

(3) To initiate a mediation a party must give notice in writing to the other party requesting a mediation in accordance with clause 11(2).

11. This Agreement and all questions of construction, validity and performance under this Agreement shall be governed by English law and (without prejudice to clauses 11(1), 11(2) and 11(3)) shall be subject to the exclusive jurisdiction of the English courts to which the parties hereby submit except that a party may seek an injunction in any court of competent jurisdiction.

12. This Agreement does not create any right enforceable by any person who is not a party to it under the Contracts (Rights of Third Parties) Act 1999 but this clause does not affect any right or remedy of a third party which exists or is available apart from that Act.

For and on behalf of
The University of Cambridge
Department of Engineering

Signed _____

Name Philip Guildford

Position Director of Research & Finance

Date 2/6/2016

Signed _____

Zurina Moktar

Date 2/6/16

For and on behalf of [redacted]

Signed [redacted]

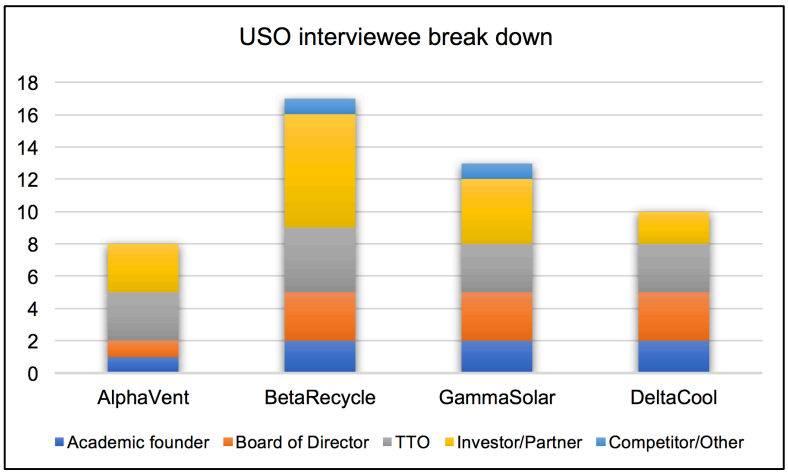
Name [redacted]

Position Chairman

Date 2/6/2016

Appendix D: List of interviewees

No	Code	Position	Firm
1	A_A01	Academic founder (A)	AlphaVent
2	A_B01	Board of Director (B)	
3	A_T01	TTO (T)	
4	A_T02		
5	A_T03		
6	A_P01	Partner/Investor (P)	
7	A_P02		
8	A_P03		
9	B_A01	Academic founder (A)	BetaRecycle
10	B_A02		
11	B_B01	Board of Director (B)	
12	B_B02		
13	B_B03		
14	B_T01	TTO (T)	
15	B_T02		
16	B_T03		
17	B_T04		
18	B_P01	Partner/Investor (P)	
19	B_P02		
20	B_P03		
21	B_P04		
22	B_P05		
23	B_P06		
24	B_P07		
25	B_C01	Competitor/Other (C)	
26	G_A1	Academic founder (A)	GammaSolar
27	G_A2		
28	G_B01	Board of Director (B)	
29	G_B02		
30	G_B03		
31	G_T01	TTO (T)	
32	G_T02		
33	G_T03		
34	G_P01	Partner/Investor (P)	
35	G_P02		
36	G_P03		
37	G_P04		
38	G_C01	Competitor/Other (C)	
39	D_A01	Academic founder (A)	DeltaCool
40	D_A02		
41	D_B01	Board of Director (B)	
42	D_B02		
43	D_B03		
44	D_T01	TTO (T)	
45	D_T02		
46	D_T03		
47	D_P01	Partner/Investor (P)	
48	D_P02		
49	E_01	Former Deputy Director	Cambridge Enterprise, UK
50	E_02	Deputy Director	Cambridge Enterprise, UK
51	E_03	Technology Manager	Cambridge Enterprise, UK
52	E_04	Technology Associate	Cambridge Enterprise, UK
53	E_05	Head of Consultancy Service	Cambridge Enterprise, UK
54	E_06	Head of Marketing	Cambridge Enterprise, UK
55	E_07	CEO	Cambridge Carbon Capture, UK
56	E_08	CEO	Biobeat, UK
57	E_09	CEO	Inotec AMD, UK
58	E_10	Director	IdeaSpace, UK
59	E_11	Director of Research	Industrial Sustainability, Institute for Manufacturing, UK
60	E_12	Former Director	Institute for Sustainability Leadership, UK



Informant / USO	AlphaVent	BetaRecycle	GammaSolar	DeltaCool	Total
Academic founder	1	2	2	2	**7**
Board of director	1	3	3	3	**7**
TTO	3	4	3	3	**13**
Investor/Partner	3	7	4	2	**16**
Competitor/Other	0	1	1	0	**2**
Total	**8**	**17**	**13**	**10**	**48**