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Commercialisation patterns of scientific knowledge in traditional low- and medium-tech industries

Paul J. Woodfield [a,*], Yat Ming Ooi [b], Kenneth Husted [b]

[a] International Business, Strategy, and Entrepreneurship department, Auckland University of Technology, 55 Wellesley Street East, Auckland 1010, New Zealand
[b] Department of Management and International Business, The University of Auckland Business School, 12 Grafton Road, Auckland 1010, New Zealand

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ABSTRACT

Research on technology commercialisation and science–industry interactions overlooks the specificity of connections between science and traditional low- and medium-technology (TLMT) industries. The few studies on science-based innovation in TLMT industries focus on barriers to investing, accessing, and creating value from science. This is problematic as TLMT industries exhibit different innovation patterns compared to high-tech and science-based industries. Therefore, we focus on the patterns arising from technology commercialisation processes utilised by TLMT firms to create value from scientific knowledge and technology. We used a qualitative multiple case study design and identified four types of commercialisation patterns in TLMT industries: *scientification*, *optimising nature*, *orchestration*, *and technification*. Our typology contributes to research in traditional industries and technology commercialisation by demonstrating firms' commercialisation patterns and the diverse ways in which they capture value within TLMT industries.

1. Introduction

Scientific knowledge plays an important role in various industries as a source of innovation. However, scientific knowledge alone is insufficient to spur innovation without the presence of complementary commercialisation strategies (Min et al., 2019; Stokes, 1997). Commercialisation brings scientific knowledge and technologies into the market through new and improved products and services (Kirchberger and Pohl, 2016). This commercialisation process often requires collaboration between research organisations and firms to leverage the technical and market knowledge within these organisations (Clayton et al., 2018). Understanding the interplay between science-industry collaboration, technology characteristics, different actors, and firm characteristics becomes the focus of commercialisation studies (Haessler et al., 2022; Maietta, 2015; Perkmann et al., 2021).

Despite the importance of the commercialisation process in successful exploitation of scientific knowledge, literature is mainly focused around high-technology industries (McKelvey and Ljungberg, 2017). High-technology industries are characterised by the volatile environments they operate in and their emphasis on fast-paced proliferation of technology, making them prime subjects of research (Chesbrough and Crowther, 2006; Teece et al., 1997; Qingzhi et al., 2018). While high-technology industries attract a lot of attention, traditional industries are often the backbone of economies in developed countries (Hirsch-Kreinsen, 2015a). However, these industries are largely neglected in academic studies of technology commercialisation and when setting public policies to stimulate innovation (McKelvey and Ljungberg, 2017). This study examines the technology commercialisation process in traditional low- and medium-technology (TLMT) industries to understand the commercialisation patterns arising from the transfer of technology from research organisations to commercial, TLMT firms.

We adopt a business model perspective (Foss and Saebi, 2018; Zott et al., 2011) to examine our research question. Specifically, we use this perspective to frame the value creation, delivery and capture mechanisms, and outcomes that occur in a firm's commercialisation of different technologies. TLMT firms' heavy reliance on innovation sources within their network increases the 'lock-in effect' and impacts their architecture of value creation and delivery (Kapoor and Teece, 2021; Sydow et al., 2009; Zott and Amit, 2010). The business model perspective links the creation and delivery activities within a firm, asserting that a firm would need to mobilise other related activities in its business model to appropriate value from the resulting innovation (Zott et al., 2011). Given the contextual differences between TLMT and high-tech firms (Hirsch-Kreinsen, 2015b), the business model used by TLMT firms to

* Corresponding author.
E-mail addresses: paul.woodfield@aut.ac.nz (P.J. Woodfield), y.ooi@auckland.ac.nz (Y.M. Ooi), k.husted@auckland.ac.nz (K. Husted).

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govern value creation and delivery is probably different from that in high-tech industries.

Commercialisation in TLMT firms is not a simple process and often leads to outcomes beyond patents, licencing, and spin-offs (Haessler et al., 2022; Min et al., 2019). Moreover, existing literature mostly covers high-technology industries (Hirsch-Kreinsen, 2015a; Robertson et al., 2009). Hence, this study contributes to the technology commercialisation literature (Haessler et al., 2022; Arora et al., 2016). We do this by combining commercialisation and business model perspectives to identify novel patterns for translating and transforming scientific knowledge into innovation outcomes for market applications in TLMT sectors. Doing so, we explain how TLMT firms organise and mobilise internal resources and capabilities to commercialise scientific knowledge (Zott et al., 2011). Furthermore, we also enrich the extant literature on innovation management, arguing that the determinants, methods, and processes of TLMT firms used to create and capture value are vastly different from those in high-technology firms (Heidenreich, 2009; Hervas-Oliver et al., 2011; Hervas-Oliver et al., 2012; Maietta, 2015).

2. Literature review

2.1. Background on traditional industries

Science has been a significant contributor of knowledge and innovation used in TLMT industries (Cohen et al., 2002; Hirsch-Kreinsen, 2015a; McKelvey and Ljungberg, 2017). Innovation activities and industry interactions with science are, on many dimensions, quite different depending on whether they are high- or low-technology industries (Heidenreich, 2009; Hervas-Oliver et al., 2011; Hervas-Oliver et al., 2012; Hirsch-Kreinsen, 2008; Maietta, 2015). High-technology industries' research and development (R&D) activities have long been linked to innovation performance (Castellani et al., 2019). However, the role of R&D is less prominent in low- and medium-technology sectors (Castellani et al., 2019; Zouaghi et al., 2018).

The TLMT industry is typically at the mature stage of the industry life cycle (Klepper, 1997; McKelvey and Ljungberg, 2017) and reflects a relatively low R&D intensity (Galindo-Rueda and Verger, 2016; Organisation for Economic Co-operation and Development (OECD), 2005). It typically engages in incremental innovation and adoption (Klepper, 1997; Trott and Simms, 2017; von Tunzelmann and Acha, 2006). The terms 'LMT' (low- and medium-technology) and 'traditional' industries are used interchangeably in innovation literature. For example, Molina-Morales and Expósito-Langa (2012) describe the Spanish textile industry as traditional with low-tech manufacturing and R&D, while Beerepoot (2008) refers to the Philippine furniture industry as 'traditional, low-technology'. Similarly, McKelvey and Ljungberg (2017) describe Sweden's food industry as a traditional industry characterised by low-technology research activities. Following Hirsch-Kreinsen (2008, 2015a), in this study, a traditional industry is defined as an industry within the scope of LMT classification according to the OECD, hereafter referred to as traditional LMT (TLMT) industries.

Thus, both in academic literature and policy, TLMT industries have often been side-lined, focusing mainly on the more fashionable high-technology industries (Heidenreich, 2009; Hirsch-Kreinsen, 2008; Robertson et al., 2009). Alongside economic impact, recent research has acknowledged growth, productivity, and employment from traditional industries (Hirsch-Kreinsen, 2008, 2015a). For example, across Europe, almost two-thirds of all employees in manufacturing are employed in the TLMT sector (Heidenreich, 2009; Hirsch-Kreinsen, 2008). However, business research tends to focus on the shortcomings of TLMT industries, including the lack of resources to engage in sophisticated and costly R&D initiatives (Hervas-Oliver et al., 2011; Hervas-Oliver et al., 2012; Santamaría et al., 2009), high dependency on accessing innovation outside the firm (Laforet, 2008; Spithoven et al., 2011), and the lack of sufficient absorptive capacity (Gassmann, 2006; Hervas-Oliver et al., 2012).

2.2. Defining (technology) commercialisation

Scientific knowledge contributes to key technological advancements in many industries (Cohen et al., 2002; Jensen et al., 2007). Scientific output development primarily occurs in industrial R&D laboratories and knowledge institutions such as universities and research institutes (Goduscheit and Knudsen, 2015; Jensen et al., 2007). According to Stokes (1997), basic scientific knowledge has no immediate application in the market. Thus, commercialisation or technology transfer studies aim to understand and prescribe processes, mechanisms, and methods for converting scientific knowledge into commercially viable IP (Perkmann et al., 2021; Teece, 2007). The concepts of commercialisation and technology transfer have a long, cross-disciplinary research history, often being used interchangeably in literature (Kirchberger and Pohl, 2016). Contemporary researchers are mostly in agreement that the concepts of commercialisation and technology transfer are describing the same process (Perkmann et al., 2013). Hence, in this paper, we will be using these two terms interchangeably.

Research in commercialisation can be broadly categorised into two views: science- and technology-views. Studies taking the science-view focus on universities and public research institutes' process of bringing patentable scientific knowledge and technology to market (Perkmann et al., 2013). This process normally takes the form of licencing, patents and university spin-offs (Fini et al., 2018; Kolb and Wagner, 2018). On the other hand, studies taking the technology-view focus on the process of transferring and applying technology by a recipient organisation into market-ready products (Kirchberger and Pohl, 2016). The technology, rather than the developers of scientific knowledge, is the subject of interest for researchers taking the technology-view of commercialisation. Taking these two views into account, in this paper, we align our work with Kirchberger and Pohl's (2016) definition of *commercialisation as the process of transferring technology, and the knowledge embodied in it, from a university or research institute to an organisation that is converting the technology into marketable products*.

Technology commercialisation literature focuses on the technology characteristics, collaborative arrangements, and actors in the transfer process. In their review of technology commercialisation literature, Haessler et al. (2022) conclude that technological heterogeneity and application affect an organisation's commercialisation process. Scholars have also suggested that actors' (or firms') heterogeneity affects collaborative arrangements and commercialisation activities, including the value these activities create for the organisation (Chesbrough and Rosenbloom, 2002; Ankrah and Al-Tabbaa, 2015; Grimpe and Hussinger, 2013; Min et al., 2019). Relatedly, Clayton et al. (2018) show that organisations' ability to source scientific knowledge from knowledge institutions, including the role of intermediaries such as incubators and licencing offices, impacts successful technology commercialisation. Such commercialisation literature establishes conceptual and empirical links between commercialisation performance and three key factors – technology characteristics, firm heterogeneity, and collaboration among knowledge institutions and firms (Kirchberger and Pohl, 2016). Importantly, this study builds on earlier technology commercialisation literature by emphasising the patterns of value creation and capture from technology transfer within the TLMT context.

2.3. Technology commercialisation patterns in TLMT

Commercialisation scholars have established important relationships between technology characteristics, the contributions of different actors, specific firm characteristics, and science-industry collaboration with commercialisation success (Haessler et al., 2022; Kirchberger and Pohl, 2016). Despite these important links, there is still a lack of research that examines the receiving firms' patterns of converting scientific knowledge and technology into marketable products (Haessler et al., 2022). Importantly, most studies do not explicitly differentiate between industries with varying R&D intensities (Maietta, 2015). As Grimpe and

Sofka (2009) show, high-tech industries exhibit knowledge search patterns distinct from those of low- and medium-tech industries. They posit that TLMT industries search for knowledge from competitors and customers, rather than knowledge institutions such as universities, because of the familiarity of the former knowledge sources to TLMT firms. Similarly, Laursen and Salter (2004) find that R&D intensity affects a firm's search for knowledge among knowledge institutions. They argue that firms with low R&D intensity interact indirectly with knowledge institutions.

As Laursen and Salter (2004) and Grimpe and Sofka (2009) suggest, TLMT firms are least likely to search for knowledge from knowledge institutions due to their lack of absorptive capacity. However, this is not always true. Further work on the science–industry collaboration practices of TLMT industries shows that some of these industries work closely with knowledge institutions for innovation. Maietta (2015) shows that TLMT firms often collaborate directly with knowledge institutions to create process and product innovation. An explanation could be derived from McKelvey and Ljungberg (2017), where they posit that policymakers need more insight into commercialisation patterns to understand the role of public policy in stimulating innovation in TLMT industries. Further, they suggest that TLMT industries have been neglected in prior research owing to their different innovation patterns compared to high-technology- and science-based industries. Hence, if science–industry collaboration between TLMT industries and knowledge institutions is direct, we question whether novel commercialisation patterns for value creation and capture could emerge within these collaborative arrangements.

2.4. Value creation and capture from technology commercialisation

Technology characteristics not only affect the commercialisation activities of a firm but also the value that is being created. A firm engaging in commercialisation activities create value through utilising and applying a technology developed by knowledge institutions into a product for the market (Haessler et al., 2022). The different technologies that a firm accesses and implements determine the value that is being created (Kapoor and Teece, 2021). However, the commercialisation process is focused on more than just value creation. The ways in which firms are able to appropriate the created value are also important. Therefore, we use a business model lens to frame the value creation, delivery and capture mechanisms and outcomes that occur in a firm's commercialisation of different technologies. A firm's *business model* outlines the links between activities related to value creation, delivery, and appropriation (Foss and Saebi, 2018). This lens is useful here because it includes a myriad of value creation and capture activities such as segmenting the market, crafting a value proposition for the segments, designing and implementing appropriability regimes for value capture, and implementing isolating mechanisms (Teece, 2010).

We believe that *value creation* happens when a firm combines different knowledge components it holds to create outputs that customers find useful (Bowman and Ambrosini, 2000). This can take the form of new products, services, or processes (Chesbrough and Rosenbloom, 2002; Howells, 1996; Teece, 2010). However, within a commercialisation context, firms need to combine knowledge from external sources. The need to transfer external knowledge requires specific *value delivery* mechanisms, as value creation is more than just converting internal knowledge but comprises the activities of knowledge transfer and integration (Baden-Fuller and Haefliger, 2013). More often than not, value is created collaboratively with other firms and knowledge institutions, which forms the firm's value proposition (Ooi and Husted, 2021; Saebi and Foss, 2015). After value is successfully (co-) created and transferred (and integrated) by the focal firm and converted into outputs, the next step is the implementation of appropriability mechanisms for *value capture*. This is when the firm sells the output and gains revenues from it (Bowman and Ambrosini, 2000). For instance, introducing a new product into the market or patenting and licencing a new process (Chesbrough and Rosenbloom, 2002; Teece, 2010).

Collaboration is an important aspect of commercialisation within TLMT industries. We are interested in understanding the methods firms use for accessing scientific knowledge, the pathways used to create value from science, and the transfer mechanisms used to transfer research outputs. Therefore, we draw on the business model literature to frame a firm's commercialisation activities that enable it to create, deliver and capture value from scientific knowledge and technology (Chesbrough and Rosenbloom, 2002; Zott et al., 2011). Fig. 1 combines the key factors derived from the technology commercialisation and business model perspectives (Mayer and Sparrowe, 2013) into an analytical framework.

3. Methodology

This study aims to examine the technology commercialisation patterns arising from the transfer of technology from research organisations to commercial, TLMT firms. We implemented a qualitative, theory-building research design (Eisenhardt and Graebner, 2007; Gioia and Pitre, 1990; Miles and Huberman, 1994) to develop types (Doty and Glick, 1994) for commercialisation in TLMT industries. We developed multiple case studies consistent with recommended practice (Creswell, 2009; Eisenhardt, 1989) as it facilitates theory building (Creswell, 2009; Eisenhardt and Graebner, 2007; Yin, 2003), which can ultimately be presented through proposed categories (Doty and Glick, 1994). We use New Zealand TLMT industries as the context of our analysis. Although small on the world stage, many of New Zealand's TLMT industries are comparable in size and impact with those of other countries.

Primary data were collected through semi-structured interviews (Roulston, 2010). Organisations and interviewees needed to meet basic criteria (Miles and Huberman, 1994; Patton, 2002). First, the organisations had to be within a TLMT industry (as defined earlier) or a science or technology supplier to a TLMT industry. It could be a private or public company; however, it was not limited to these. For example, government organisations were also approached. Maintaining broad purposeful criteria for the sample was important in capturing views from science and technology providers, alongside data collected from science and technology users. Second, we interviewed decision-makers and those responsible for R&D. The range of organisations and individuals targeted helped enhance the generalisability of our findings.

Initially, a comprehensive list of TLMT industry organisations was created. Where possible, personal acquaintances were contacted to identify individuals who met the criteria (Patton, 2002). Six cases were

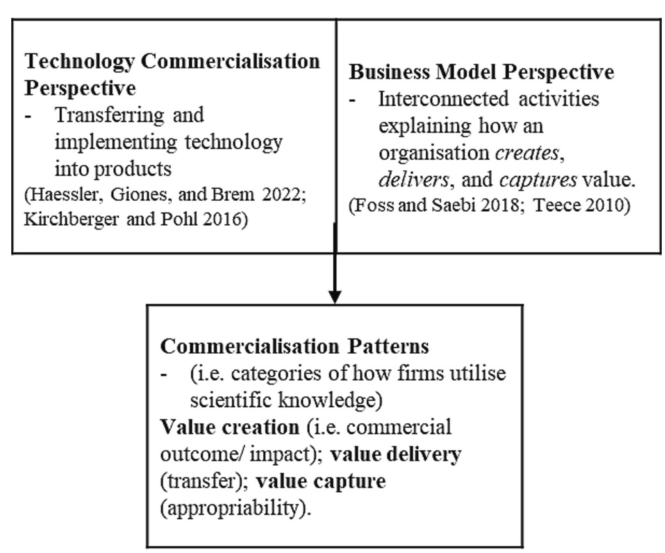

Fig. 1. Analytical model combining technology commercialisation and business model perspective.

formerly developed for the study; however, no rule was set for the number of cases (Eisenhardt, 1989). Additional cases assisted in confirming patterns, suggesting saturation (Orcher and Glendale, 2005), and were drawn from archival documentation. We completed a thick description of the cases (Patton, 2002) drawing on several data sources. Using multiple case studies, we built the confidence, validity, and stability of our findings across cases and contexts (Elsahn et al., 2020; Miles and Huberman, 1994). Table 1 presents data sources and descriptive details of the cases.

Semi-structured interviews were designed for capturing insights related to innovation and technology commercialisation activities in the TLMT industries. Interviews were carried out between 2013 and 2016 under ethics approval. Questions centred on understanding each organisation's background, competition and competitive advantage, knowledge generation and diffusion, collaboration, barriers, and policy implications. Prior to commencing interviews, written consent was obtained and confidentiality of data collected was assured. Although anonymity was not guaranteed, care was taken to maintain anonymity where possible.

Table 1
Description of primary cases.

Cases	Descriptive details	Industry	Data sources
Comvita	Honey-based products	Apiculture	Interview, newspaper articles, media releases, company website
Gallagher	Animal management equipment, security, fuel systems	General farming	Interview, newspaper articles, media releases, company website, factory and R&D department tour
Abodo	Wood products	Construction	Interview, company advertising materials, company website, factory tour
AgriSea	Seaweed products	Aquaculture	Interview, newspaper articles, media releases, company website, factory tour
Pastoral Robotics	Farming robotics	Robotics	Interview, newspaper articles, media releases, and company website
Compac Sorting Equipment	Fruit and vegetable sorting equipment	Engineering and manufacturing	Interviews, presentation, newspaper articles, media releases, company website, factory and R&D department tour
Tru-Test Corporation	Animal management equipment, weighing scales	General farming	Interviews, confidential company documents, company website
SPATnz	Green-lip mussels	Aquaculture	Reports, newspaper articles, media releases, company/ government websites
New Zealand Dairy Research Institute* (Cheddarmaster)	Cheese processing	Dairy	Articles, media releases, websites, historical documents *Now part of Fonterra Co-operative Group Ltd
ClimbMAX	Timber harvester	Forestry	Articles, media releases, company/ government website

Real-time observations—for example, visiting trade shows, presentations, and factory tours—were recorded in our field notes. These observations provided contextual information on certain industries and organisations. Secondary data sources provided a background understanding and context of each organisation's structure and history and included annual reports, books, general media, and websites.

We conducted a within-case analysis to examine each case's dynamics before cross-examining other cases (Miles and Huberman, 1994). This allowed us to compare scenarios, identify patterns, and, where necessary, relabel the types through an iterative procedure. Cross-case analysis included pattern matching to recognise the internal validity of each case and replication logic to identify external validity (Eisenhardt and Graebner, 2007; Yin, 2009). Through this procedure, we could synthesise types representing how science and technology research is embodied in various TLMT industry sectors and organisations. In doing so, we identified examples for each type, the origin of research for each, who set the research agenda, and the mechanism for transferring research.

To begin, we developed a conceptual matrix supporting an iterative procedure. At least three iterations of the matrix were independently conducted in isolation by two researchers. This was interspersed with collegial discussions to maintain a robust and unambiguous typology. Moreover, through this iterative procedure, we initially arrived at seven commercialisation pattern types. With further iterations, we eventually agreed on four types and their labels before populating the matrix with descriptions based on the within- and across-case findings (Table 2). As part of this iterative procedure, we requested a third researcher to further validate the labels for the typology. Ultimately, convergent concepts, patterns, differences, and similarities were identified (Miles and Huberman, 1994).

4. Results

In this section, first, we present an overview of each case, which draws attention to the industry/sector, the activity and innovation related to each case, and the science engaged with. We then elucidate the commercialisation pattern types derived from these cases.

4.1. Cases

4.1.1. Gallagher

Gallagher has led the way in animal management since the 1920s. It has an approximately NZ$250 million turnover and over 1000 employees. Known to have invented the electric fence, it became a world leader with its accessory fencing products, including portable posts, connectors, and reels. The business evolved into producing traceability products, weighing scales, and electronic identification and security systems. More recently, it has shifted towards more design-driven value creation extending beyond the functional product design, by engaging with design thinking practices (Johansson-Sköldberg et al., 2013) encouraged by a social-science-informed program, Better by Design—an initiative through New Zealand Trade and Enterprise (Better by Design, 2015; DesignCo, 2017; New Zealand Government, 2015). Gallagher revised its design process by listening to customers, understanding competitors, and gathering insights informing their ideation process. One activity informed by this knowledge was redesigning its standard ring-top/pigtail posts used to guide temporary electric fences. The output was a well-designed alternative providing better handling, lighter safety, and more durability. This incremental innovation has led Gallagher to redesign other products to minimise waste and redundancy. Gallagher's R&D team is also cognisant of the need to protect its design through patents and the licencing of technologies to capture value.

Table 2
Firms' commercialisation pattern types.

Commercialisation patterns	Description	Source of problem and innovation	Typology attributes		
			Value creation (commercial outcome/impact)	Value delivery (transfer)	Value capture (appropriability)
Scientification	• The properties of an existing product/resource are subjected to scientific analysis. • Efficacy is sought for products with known properties that have not been systematically tested and legitimised.	• Widespread practices (based on trial-and-error knowledge and/or cultural knowledge). • Scientific curiosity. • Indigenous knowledge (e.g. AgriSea, Comvita).	• Scientific knowledge provides new opportunity sets. This includes testing, which leads to products fit for medicinal purposes or for consumption. • Value-add in final product. • New application and purposes for the product. • Revitalisation of complete industries leading to a burst of innovation activity. • Competitive advantage.	• Push of scientific knowledge and IP.	• Some research outcomes would be considered pre-competitive research. • Patents/exclusive licencing of technologies/research outcomes from universities and Crown Research Institutes.
Optimising nature	• Improving critical parts of a natural process to better fit commercial needs by using scientific methods. • Balancing ongoing raw-material supply and/or environmental concerns with an industry's need to be economical and productive.	• Problem addressed by science. • Typically, well-known bottle-neck problems in the industry (e.g. SPATnz, New Zealand Dairy Research Institute ['Cheddarmaster']).	• Can lead to a competitive advantage for the organisation or wider industry initiating optimisation. • Scalability. • Better quality end product. • Predictability. • Cost savings.	• Embodied in raw material, plants, animals, bacteria, fish, and organisms.	• End user will typically only have a non-exclusive right to use with purchase.
Orchestration	• Research that either increases the use of waste products or shifts use into high value areas. • A focus on design leads towards aesthetic and functional and aesthetically research-based products.	• Redesigning in a way that minimises waste or redundancy (anatomic or aesthetic design) (e.g. Gallagher, Abodo, Tru-Test Corporation).	• Well-designed products underpinned by robust science and technology can lead to an organisation's competitive advantage.	• Embodied in technology and solutions.	• Patents/exclusive licencing of technologies orchestrated by an innovator.
Technification	• Science for TLMT industries mediated by technology provider. • Use science and technology to create innovative opportunities for user organisations. • Science embodied in production/process technologies.	• User organisations and migration of solutions from other industries and/or technology push (e.g. Compac Sorting Equipment, Pastoral Robotics, ClimbMAX).	• Increased awareness of ways science and/or technology can lead to higher productivity through better equipment, systems, and processes. • Activities of this type benefit both the specialised supplier who will consolidate their knowledge base and acquire a validated specialised set of competencies that can be used to go internal with the technology and/or diversify into related markets. • The user organisation will gain innovation benefits either in the form of improved process or ability to extend the feature of the existing product range. • Competitive advantage.	• Embodied in technology and solutions. • Science/technology was supplied to the industry. Scion (a Crown Research Institute) provides a service and consultancy to industry.	• User organisations will typically only have a non-exclusive right to use with purchase. • Lead-time advantages.

4.1.2. Abodo

Abodo focuses on providing healthy, durable, and renewable timber products. Established in 2001, the company has a NZ$50 million turnover. Abodo began as a pure commodity trading business originally specialising in trading framing lumber from New Zealand to the Pacific Islands and later evolved into producing solid timber and panel products. More recently, Abodo has shifted towards using different types of preservatives and preservation techniques. With the growing demand for lower toxicity treatments in preserved wood, it has developed its own treatments. With continued growth, Abodo has redirected its value creation through designing products by engaging with the Better by Design programme, allowing it to gain access to education and mentoring (Better by Design, 2015). This refocus has led Abodo to restructure its business model towards a design-led innovation programme, developing a strategy focused on natural wood exteriors. It has outsourced the R&D required to support its patents, while maintaining control over the ideas and patent process. Its patented products have provided Abodo with a competitive advantage that has had an impact on end users.

4.1.3. Comvita

Established in 1974, Comvita concentrated on the production of natural honey-based products traditionally used in indigenous remedies and makes over NZ$170 million. With significant growth through the

1990s and more interest in honey's medicinal properties, the company began formalising its processes and systems to achieve ISO 9002 certification, which would align it with the requirements imposed on mainstream pharmaceutical manufacturing. Comvita Health Products utilised externally supplied science and its own R&D to create value for its products. The need to provide evidence of the medicinal properties and efficacy of its honey led it to collaborate with the University of Waikato that found higher levels of antibacterial activity in manuka than regular honey (i.e. what came to be known as 'Unique Manuka Factor' or UMF). This allowed Comvita to capture value through translating this science output into commercial outcomes, wherein manuka honey was deemed appropriate for medicinal use. A further affirmation that strengthened its competitive advantage originated from Comvita's participation in randomised controlled trials conducted by the University of Auckland, which found that manuka honey compared favourably against other products as an application for burns, ulcers, and infections (Comvita, 2013; Karlson et al., 2013). Some Comvita products have been legitimised by receiving the UK CE mark, enabling products to be marketed directly to hospitals.

4.1.4. AgriSea

AgriSea New Zealand is at the forefront of seaweed collection and production in New Zealand with a NZ$3 million turnover. Founded by educators who learnt about the properties of seaweed after spending time on organic farms, AgriSea's evolution gained momentum from farmers and orchardists who demanded its liquid seaweed concentrates for turf, pasture, soil, and foliar for horticulture and viticulture, together with animal health concentrates for agriculture, including dairy and equine. Seaweed has been used as a raw material for many years; however, AgriSea has led the way in creating value through conducting efficacy testing to legitimise seaweed as a mainstream product. AgriSea needed science to reinforce seaweed qualities, nutrients, and purposes beyond horticultural and animal products, towards approval for human consumption. AgriSea initially investigated seaweed supply from the ocean bed, which is of better quality than the seaweed harvested from the shoreline. In doing so, AgriSea collaborated with a marine ecologist to undertake a rigorous experimental process assessing the amount of seaweed stock available, the speed at which it grows, and the time it takes to regrow after each harvest. AgriSea also collaborated with a private research company, Cognosco, to establish long-term results supporting the efficacy of its products and developing its own competencies and competitive advantage. Its rigorous research is motivated by the need to compete against the chemical sector and change people's perceptions of its products.

4.1.5. Pastoral Robotics

As a start-up, Pastoral Robotics Ltd. (PRL) has established its presence in the emerging farm robotics sector. PRL identified that in the dairy industry, farmers sprayed entire paddocks to neutralise nitrates and minimise nitrate leaching. This is unnecessary and expensive as farmers only need to spray urine patches, which are significantly smaller. Recognizing this problem, PRL conducted trials at Massey University with a six-metre wide 'Spikey' unit detecting urine patches and administering additives for neutralising them. PRL works closely with an expert in agricultural additives, including urine-patch spray treatments formulated to be applied by Spikey (Bates et al., 2015; Pastoral Robotics, 2020; Quin et al., 2016). A robotic system has been developed that detects urine patches precisely and applies products that control nitrate levels. This system offers significant savings for farmers, contributing to farming productivity with a robotised vehicle systematically covering entire paddocks and returning to the docking station where it can be charged without human intervention. PRL's research into developing sensory detection systems, robotics, and spray applications has led to a more productive farming system that can transform farming in the future.

4.1.6. Compac Sorting Equipment

Compac is a leader in manufacturing high-speed packhouse technology for the production industry. Established in 1984, its revenue before being purchased by Tomra in 2016 (TOMRA Systems ASA, 2016) was close to NZ$100 million. Originally, the founder recognised the need to produce machines that would sort kiwifruit, and subsequently other fruits, efficiently and cost-effectively. The company evolved by engaging heavily in the R&D of its automated equipment and software, including detection technology (New Zealand Herald, 2013). R&D in Compac focuses on determining the most efficient way to sort fruits through a machine combining mechanical, electrical, and optical technologies. It works closely with a New Zealand Crown Research Institute—Plant and Food Research—to develop technology that detects bruises on apples and establishes the firmness of fruit without any contact. Compac manufactures equipment that sorts round fruits and vegetables, engaging heavily in the R&D of its automated equipment and software, including detection technology. Utilising its InVision System, Compac focused on speed and accuracy of sorting while also developing important advances in detection technology (Compac Tomra, 2015). This system efficiently detects numerous attributes, such as weight, size, shape, density, and colour, which are graded through 3-D modeling at speed. The development of the core sorting equipment product has led to other technological solutions, including robotics, feeding, bagging and packing, and data and analytics.

4.1.7. New Zealand Dairy Research Institute (Cheddarmaster)

The New Zealand Dairy Research Institute (now part of Fonterra Co-operative Group Ltd) Dairy Factory Mechanisation Committee developed and patented the Cheddarmaster to increase efficiency, reduce costs, and produce consistent cheeses. The Cheddarmaster initiative contributed to driving the industry towards automation by providing a continuous process consisting of a conveyor belt that allowed the drainage of curd and whey through to the salting, mellowing, and cutting stages of the cheese (Te Ara, 2021). In the 1970s, the cheese process was further optimised with Vatmaster designed and developed in New Zealand to handle larger milk volumes. The vat was fitted with mechanical knives and paddles for cutting and stirring (Johnston et al., 2010), and along with the Cheddarmaster system and other modifications, it reportedly reduced labour in one plant from 100 to 25 employees (Johnston et al., 2010; McGillivray, 1978). This exemplifies an industry body being proactive in optimising a natural process and simultaneously supporting its industry's competitive advantage through automation and mechanisation tailored to the industry's needs.

4.1.8. SPATnz

SPATnz is an aquaculture joint venture between the government and Sandford Industries under the auspices of a seven-year Primary Growth Partnership (PGP; Ministry of Primary Industries, 2015). This partnership developed a research facility to reduce the time from spawning to reaching harvest size by approximately 12 months (Manning, 2012), resulting in a controlled and sustainable future for mussel harvesting and supporting the industry's need to be economical and productive. The innovative means of sourcing raw materials contributes towards balanced efficiency and sustainability and addresses a concern on fish stocks introduced through the Quota Management System, which manages more than 50 seafood species (Jeffs and Liyanage, 2005). This case exemplifies the significant impact a company can have on the wider industry in partnership with the government.

4.1.9. ClimbMAX

ClimbMAX International originated from a forestry joint venture between Future Forests Research Ltd. (now Forest Growers Research) and the government (Ministry of Primary Industries, 2020). From the partnership, steep country tree harvesting was identified as an opportunity for increasing forestry worker safety and profitability. Kelly Logging Ltd. and Trinder Engineering Ltd. were engaged in designing and building the harvesting system. Using ClimbMAX, workers using chainsaws were removed from the hill face and replaced with a one machine operator. ClimbMAX can bunch felled trees for extraction (ClimbMAX Equipment Ltd, 2015). Alongside the engineering of ClimbMAX is the development of remote-controlled machinery, advanced hauler vision, grapple control, and innovative yarding technology. The ultimate aim is to develop teleoperated felling machines operating on slopes independently without exposing workers to potential risks, transforming forestry in the future (Ministry of Primary Industries, 2020; van Rossen and Brown, 2014).

4.1.10. Tru-Test Corporation

Tru-Test is a New Zealand-based farming equipment manufacturer. It began in 1964 when John Hartstone incorporated Tru-Test to commercialise the milk meter he had invented a year earlier (Lomas, 2011). Its line of farming equipment products includes animal weighing scales, electronic identification (EID) readers, milk meters, electric fences, and farm automation. At the time of data collection in 2014, Tru-Test had a NZ$130 million turnover. In September 2018, Tru-Test sold its milk meters and retail solutions business units to Datamars, a Switzerland-based farm management solutions firm, for NZ$147.9 million (BusinessDesk, 2018). To compete globally with farm management competitors, Tru-Test focuses on an innovative portfolio of products, customer-centric strategy, and lean manufacturing capabilities. When developing a newer version of its portable EID reader, Tru-Test employed a user-driven approach to product development. A market research company was commissioned to survey farm operators in domestic and international markets. The product development team also developed tools for engaging users during product conceptualisation and development, such as user personas. These user-centric activities aimed to design an EID reader that meets the functional and aesthetic needs of its customers.

4.2. Commercialisation pattern types

As mentioned earlier, we followed an iterative procedure to identify commercialisation patterns within and across the cases. Through this procedure, we merged convergent concepts, patterns, differences, and similarities and ultimately agreed on the four commercialisation pattern types. Thus, from our within- and across-case analysis, we categorised TLMT industries' commercialisation patterns into four types: *scientification*, *optimising nature*, *orchestration*, and *technification*. These types provide an overview of the specific features related to research within TLMT industries and envisage how research is embodied in these industries. Table 2 presents a summary conceptual matrix of this typology.

4.2.1. Scientification

Scientification is sought when a raw material (e.g. seaweed or honey) has known properties; however, it has not been systematically tested and legitimised. This is aimed to bring traditional raw materials, sometimes with medicinal properties, into the mainstream market (World Health Organization, 2013). These raw materials may not be regulated or may lack legal frameworks governing their use and access (Bodeker and Kronenberg, 2002). Engaging in scientification does not necessarily mean a product is changed through testing. Instead, products need to be tested to legitimise them alongside mainstream products. Organisations engaging in scientification often lead producers to use raw material in untested products. Testing these products can lead to value creation through them being used for medicinal purposes or legitimised as fit for consumption. Firms engaging in scientification create value through the potential that their research could result in creating standards or influencing, revitalising, or refining current regulations. Scientific outputs for firms engaging in scientification are normally provided by universities. From our cases, Comvita and AgriSea best demonstrate scientification by seeking legitimacy and efficacy for their products by engaging with universities to conduct research where value is delivered and captured to this end.

4.2.2. Optimising nature

Optimising nature engagement focuses on business sustainability through science for the long term. This can potentially set standards to influence the industry (Miller et al., 2014). The main motivation for engaging in optimising nature is balancing the ongoing raw-material supply and/or environmental concerns with an industry's need to be economical and productive. Typically, this pattern results in the process innovation of a radical nature, albeit mostly incremental changes to products. In our cases, SPATnz and Cheddarmaster (with its various modifications) demonstrated vastly different processes culminating in value creation through optimising nature. While SPATnz established a mussel hatchery and lab facility to reduce time from spawning to reaching harvest size (Manning, 2012), the Dairy New Zealand Research Institute automated the traditional labour-intensive cheesemaking process. Both examples provide insight into how raw materials can be processed with increased efficiency and reduced cost through scientific discovery or technology and where value delivery and value capture can thrive.

4.2.3. Orchestration

Orchestration engagement is where firms use scientific output focused on designing products that are appealing and functional for the market. Although research may be a fundamental part of an organisation's product development, a focus on design leads to functional and aesthetically pleasing research-based products (Hoegg et al., 2010; Noble, 2011). Well-designed products underpinned by robust science and technology can lead to an organisation's competitive advantage (Goffin and Micheli, 2010). Firms engaging in orchestration lean towards social-science-informed programmes, such as design-driven practices underpinned by research. In our cases, Gallagher, Abodo, and Tru-Test demonstrated how social science can inform scientific and technological advancement with attention to a user-driven approach influencing the function, design, and aesthetics of their products. With the end user in mind and matched with science and technology inputs, their products are high performing, durable, cost-effective, and deliver a competitive advantage, which may have never been realised through in-house R&D.

4.2.4. Technification

Firms following *technification* engagement are motivated to streamline systems and processes that support productivity and lead to innovation activity (Wakeman and Le, 2015). Such organisations have an increased awareness of how science and/or technology can lead to higher productivity through better equipment, systems, and processes. Firms engaging in technification seek to minimise labour-intensive practices in TLMT industries by sourcing technology from their suppliers (von Tunzelmann and Acha, 2006). Productivity can be increased by requiring less human input, creating better information flows, or even by minimising health and safety incidents, giving firms a further competitive advantage. Pastoral Robotics, Compac, and ClimbMAX embodied technification by engaging with science and technology partners to yield products that increase productivity, systems, and processes through better equipment. The equipment they produce not only minimises labour-intensive practices but also accounts for health and safety, provided that, through automation, human input is reduced. With technification, precision is often built to reduce the likelihood of human error.

4.3. Synergy and overlaps

Overlaps occur across the types; however, these distinctive types possess different overarching attributes. For example, the mechanisation of cheese making could be determined to be technification. However, the attribute driving the Cheddarmaster case is that the equipment optimises a natural process in contrast to, for example, Compac, where the driving attribute increases productivity through sorting produce (i.e. not optimising a natural process). Elements of scientification through orchestration may be found. A relevant example would be Abodo lowering toxicity treatments in preserved wood as part of the orchestration process through science. However, the social science approach (in this case design-led and user-driven approach) ultimately influences the function, design, and aesthetics of their product.

5. Discussion

Our typology of commercialisation patterns contributes to research in TLMT industries and technology commercialisation. We demonstrate the commercialisation patterns and diverse ways that firms apply to utilise and implement scientific knowledge and technology. We respond to the recent calls by technology commercialisation researchers to provide insight into alternative patterns of commercialisation success beyond patenting, licencing, and spin-offs (Arora et al., 2016; Haessler et al., 2022; Min et al., 2019). Specifically, we build on the work of Kirchberger and Pohl (2016) and McKelvey and Ljungberg (2017) by empirically categorising the technology commercialisation patterns we observed in our cases to offer TLMT firms ways to inject scientific knowledge and technology into new processes and products with economic and societal impacts. In contrast to McKelvey and Ljungberg (2017), our focus is on the commercialisation patterns of TLMT industries to create value rather than showing how public policy stimulates innovation in these industries by connecting universities and firms through collaboration.

Our research shows that TLMT firms might not systematically develop high-tech solutions by themselves, but they often use advanced knowledge and technologies developed elsewhere and utilise them for commercial purposes (Chamberlin and Doutriaux, 2010; Hirsch-Kreinsen, 2015a; McKelvey and Ljungberg, 2017; Robertson et al., 2009). Our findings show that firms in TLMT industries apply four commercialisation patterns to create value when commercialising scientific knowledge: *scientification*, *optimising nature*, *orchestration*, and *technification*. The commercialisation patterns are categorised based on shared attributes related to technology commercialisation and business model perspectives (Mayer and Sparrowe, 2013). From our findings, the attributes of these technology commercialisation patterns show glimpses of activities firms use to create and capture value from transferring scientific knowledge and technology.

Our empirical evidence suggests that TLMT firms use not only suppliers as their source of innovation, but also universities (Castellani et al., 2019; Zouaghi et al., 2018). Furthermore, evidence shows that they have different innovation patterns compared to high-tech industries. We offer an alternative framing of the technology commercialisation success through commercialisation patterns for creating and capturing value. For example, in the technification commercialisation pattern, Kelly Logging appropriates the value created by the ClimbMAX product through patents and spin-offs of the collaborative project into a separate entity. This arrangement ensures that the created value is protected and collaborative partners can capture value without the constraints of transferring the technology into Kelly Logging, which could result in complications of drawing up IP protection guidelines for all partners (Fini et al., 2018; Kolb and Wagner, 2018). In this case, the ClimbMAX product created value for the collaboration partners, and given its government funding through a Primary Growth Partnership (PGP), was destined to create value for the wider logging industry. Therefore, aspects of the value created for the logging industry, which aimed to increase worker safety, could be transferable to other industries.

A somewhat common conundrum facing case firms is the tension between collaboration and IP protection. Our analysis shows that these firms collaborate to compensate for the lack of R&D capabilities, putting themselves at risk of compromising their IP. Our findings show that TLMT firms create value collaboratively with other firms and universities. Through our four commercialisation pattern types, we further show that firms create value very differently from the scientific knowledge and technology created internally or externally depending on the firm's value proposition. The value proposition is the guiding principle in a firm's business model (Ooi and Husted, 2021; Teece, 2010). For example, Abodo aimed to provide healthy, durable, and renewable timber products using various preservatives and develop their own treatments. The scientific outputs utilised from an external source were social-science-informed design, which influenced their focus on natural products and aesthetics.

Furthermore, Comvita’s value proposition provides science-based manuka honey products. Comvita’s use of the UMF standards results in significant value being created through medicinal manuka honey products. Another example is SPATnz and its government-linked joint venture, wherein value proposition focuses on providing a sustainable supply of green-lipped mussels by optimising the breeding, harvesting, and delivery of mussels. As demonstrated, having a targeted value proposition is the first step in guiding the value-creation element of the business model (Zott and Amit, 2010). The proposed technology commercialisation patterns were delineated based on this.

Moreover, value creation and capture are crucial in innovation management (Teece, 2010). For each of the proposed technology commercialisation patterns, an appropriate business model architecture is evaluated on a case-by-case basis. For example, the value a firm wants to create would also impact external sources, wherein technology and knowledge are sought to generate the necessary innovative outcomes (Howells, 1996). The business model architecture is required to accommodate the needs of stakeholders while satisfying the firm's needs. In some instances, the solution could be that value propositions align with existing interventions—government led or otherwise (e.g. the ClimbMAX case)—or delivering value to customers through strategic partnerships, such as university–industry joint ventures (e.g. the Comvita case).

Unsurprisingly, competitive advantage features across the types of commercialisation patterns, confirming that the configuration of a firm's commercialisation activities can strengthen their competitive advantage (Kapoor and Teece, 2021; Zott et al., 2011). Moreover, radical innovation can occur focused on creating and capturing value from internal R&D and external research outputs in industries typically known for their lack of absorptive capacity (Gassmann, 2006; Hervas-Oliver et al., 2012). Through our examples, we observed a move towards increased inbound innovation by engaging in research patterns generated through various publicly and privately funded science providers (Spithoven et al., 2011). Particularly, we found that universities are significant science providers, reflecting the shift from being ‘knowledge accumulators’ to being an active intermediary and ‘knowledge hub’ (Perkmann et al., 2013).

Combined, the four commercialisation patterns and their attributes largely reflect the value architecture (i.e. business model) applied by firms in TLMT industries to create, deliver, and capture value from scientific outputs. Generating innovative outcomes from scientific knowledge and technology requires firms to design this architecture relative to their resources and stakeholders, technology transfer mechanisms, and the appropriability regime for capturing value (Chamberlin and Doutriaux, 2010; Saebi and Foss, 2015; Teece, 2010). The four commercialisation pattern types show that commercialising scientific outputs requires access and usage of resources held by various stakeholders. In some cases, value co-creation occurs when the firm works collaboratively with universities and suppliers of resources to innovate or to implement social science, as in the Gallagher and Abodo cases where they engaged in design thinking practices facilitated by a government-led design initiative (Better by Design, 2015; DesignCo, 2017).

This study is based on a limited number of cases functioning in the same country. As this is a single-country study, an effect on the generalisability of the findings is possible. Further cases from other countries and regions are needed to support the proposed technology commercialisation patterns and business model architecture. Moreover, as with this study, future research could pursue diverse TLMT industry sectors that may be emerging or are close to mainstream examples. Despite these limitations, this study may help academics and practitioners better understand technology commercialisation patterns for firms operating in TLMT industries, providing insights into the firm's technology transfer, value creation, and appropriation activities.

6. Conclusion

Overall, our findings support ways wherein TLMT industries conduct technology commercialisation activities. This study contributes to the technology commercialisation literature significantly by providing an alternative framing of commercialisation success. Combining technology commercialisation and the business model perspective, we demonstrate that firms in TLMT industries apply four commercialisation patterns for accessing and (co-)creating innovations using resources held by various stakeholders. Most significantly, we also contribute to the innovation management literature by proposing that these commercialisation patterns form part of a firm's value architecture. Implications for practice are that TLMT firms should adopt scientification, optimising nature, orchestration, and technification during commercialisation. Scientification is particularly relevant when seeking to legitimise products by creating standards or influencing, revitalising, or refining current regulations to promote efficacy. Optimising nature is appropriate when a natural process is inefficient or uneconomical, and scientific discovery or technology can assist in productivity. Orchestration is useful when addressing user concerns by gathering insights to address products' functionality, design, and aesthetics through science and technology inputs. Technification is used when streamlining systems and processes to support productivity with science and/or technology, such as equipment, to minimise human input, create better information flows, or even limit health and safety incidents. These distinctive commercialisation patterns are not limited to incremental or processual innovation. However, these can drive radical innovation. Ultimately, the commercialisation pattern types serve to create, deliver, and capture values supporting an organisation's competitive advantage.

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CRediT authorship contribution statement

Paul J. Woodfield: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Yat Ming Ooi:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Kenneth Husted:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Data availability

The data that has been used is confidential.

References

Ankrah, S., Al-Tabbaa, O., 2015. Universities–Industry collaboration: a systematic review. Scand. J. Manag. 31 (3), 387–408. https://doi.org/10.1016/j.scaman.2015.02.003.

Arora, A., Cohen, W.M., Walsh, J.P., 2016. The acquisition and commercialization of invention in American manufacturing: incidence and impact. Res. Policy 45 (6), 1113–1128. https://doi.org/10.1016/j.respol.2016.02.005.

Baden-Fuller, C., Haefliger, S., 2013. Business models and technological innovation. Long Range Plan. 46 (6), 419–426. https://doi.org/10.1016/j.lrp.2013.08.023.

Bates, G., Quin, B., Bishop, P., 2015. Low-cost detection and treatment of fresh cow urine patches. In: Currie, L.D., Burkitt, L.L. (Eds.), Moving Farm Systems to Improved Attenuation, 28. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand, p. 12.

Beerepoot, N., 2008. Diffusion of knowledge and skills through labour markets: evidence from the furniture cluster in Metro Cebu (the Philippines). Entrep. Reg. Dev. 20 (1), 67–88. https://doi.org/10.1080/08985620701631522.

Better by Design, 2015. Design programme. https://www.betterbydesign.org.nz/.

Bodeker, G., Kronenberg, F., 2002. A public health agenda for traditional, complementary, and alternative medicine. Am. J. Public Health 92 (10), 1582–1591.

Bowman, C., Ambrosini, V., 2000. Value creation versus value capture: towards a coherent definition of value in strategy. Br. J. Manag. 11 (1), 1–15. https://doi.org/10.1111/1467-8551.00147.

BusinessDesk, 2018. Tru-Test to sell businesses to Datamars for $147.9 million. SCOOP Independent News, August 16. https://www.scoop.co.nz/stories/BU1808/S00540/tru-test-to-sell-businesses-to-datamars-for-1479-million.htm.

Castellani, D., Piva, M., Schubert, T., Vivarelli, M., 2019. R&D and productivity in the US and the EU: sectoral specificities and differences in the crisis. Technol. Forecast. Soc. Chang. 138, 279–291. https://doi.org/10.1016/j.techfore.2018.10.001.

Chamberlin, T., Doutriaux, J., 2010. Sourcing knowledge and innovation in a low-technology industry. Ind. Innov. 17 (5), 487–510. https://doi.org/10.1080/13662711003633413.

Chesbrough, H., Crowther, A.K., 2006. Beyond high tech: early adopters of open innovation in other industries. R&D Manag. 36 (3), 229–236. https://doi.org/10.1111/j.1467-9310.2006.00428.x.

Chesbrough, H., Rosenbloom, R.S., 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Ind. Corp. Chang. 11 (3), 529–555. https://doi.org/10.1093/icc/11.3.529.

Clayton, P., Feldman, M., Lowe, N., 2018. Behind the scenes: intermediary organizations that facilitate science commercialization through entrepreneurship. Acad. Manag. Perspect. 32 (1), 104–124. https://doi.org/10.5465/amp.2016.0133.

ClimbMAX Equipment Ltd, 2015. ClimbMAX Steep Slope Harvester. Accessed 27 May 2021. http://www.climbmax.co.nz/.

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2002. Links and impacts: the influence of public research on industrial R&D. Manag. Sci. 48 (1), 1–23.

Compac Tomra, 2015. InVision 5.0 advances fruit defect detection and sorting. http://www.compacsort.com/en/invision/.

Comvita, 2013. Share Nature Share Life: Comvita Annual Report 2013. Comvita Ltd., Paengaroa, New Zealand.

Creswell, J.W., 2009. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 3rd ed. Sage, Thousand Oaks, CA.

DesignCo, 2017. The Value of Design to New Zealand: A Study Highlighting the Benefits and Contribution of Design to the Economy of New Zealand. http://designco.org.nz/value-of-design/the-value-of-design-to-new-zealand/.

Doty, D.H., Glick, W.H., 1994. Typologies as a unique form of theory building: toward improved understanding and modeling. Acad. Manag. Rev. 19 (2), 230–251. https://doi.org/10.5465/AMR.1994.9410210748.

Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14 (4), 532–550.

Eisenhardt, K.M., Graebner, M.E., 2007. Theory building from cases: opportunities and challenges. Acad. Manag. J. 50 (1), 25–32.

Elsahn, Z., Callagher, L., Husted, K., Korber, S., Siedlok, F., 2020. Are rigor and transparency enough? Review and future directions for case studies in technology and innovation management. R&D Manag. 50 (3), 309–328. https://doi.org/10.1111/radm.12412.

Fini, R., Rasmussen, E., Siegel, D., Wiklund, J., 2018. Rethinking the commercialization of public science: from entrepreneurial outcomes to societal impacts. Acad. Manag. Perspect. 32 (1), 4–20. https://doi.org/10.5465/amp.2017.0206.

Foss, N.J., Saebi, T., 2018. Business models and business model innovation: between wicked and paradigmatic problems. Long Range Plan. 51 (1), 9–21. https://doi.org/10.1016/j.lrp.2017.07.006.

Galindo-Rueda, F., Verger, F., 2016. OECD taxonomy of economic activities based on R&D intensity. In: OECD Science, Technology and Industry Working Papers (Vol. 2016/04). OECD Publishing, Paris, France.

Gassmann, O., 2006. Opening up the innovation process: towards an agenda. R&D Manag. 36 (3), 223–228. https://doi.org/10.1111/j.1467-9310.2006.00437.x.

Gioia, D.A., Pitre, E., 1990. Multiparadigm perspectives on theory building. Acad. Manag. Rev. 15 (4), 584–602. https://doi.org/10.2307/258683.

Goduscheit, R.C., Knudsen, M.P., 2015. How barriers to collaboration prevent progress in demand for knowledge: a dyadic study of small and medium-sized firms, research and technology organizations and universities. Creat. Innov. Manag. 24 (1), 29–54. https://doi.org/10.1111/caim.12101.

Goffin, K., Micheli, P., 2010. Maximising the value of industrial design in new product development. Res. Technol. Manag. 53 (5), 29–37.

Grimpe, C., Hussinger, K., 2013. Formal and informal knowledge and technology transfer from academia to industry: complementarity effects and innovation performance. Ind. Innov. 20 (8), 683–700. https://doi.org/10.1080/13662716.2013.856620.

Grimpe, C., Sofka, W., 2009. Search patterns and absorptive capacity: low- and high-technology sectors in European Countries. Res. Policy 38 (3), 495–506. https://doi.org/10.1016/j.respol.2008.10.006.

Haessler, P., Giones, F., Brem, A., 2022. The who and how of commercializing emerging technologies: a technology-focused review. Technovation 102637. https://doi.org/10.1016/j.technovation.2022.102637.
Heidenreich, M., 2009. Innovation patterns and location of European low- and medium-technology industries. Res. Policy 38 (3), 483–494. https://doi.org/10.1016/j.respol.2008.10.005.
Hervas-Oliver, J.-L., Albors Garrigos, J., Gil-Pechuan, I., 2011. Making sense of innovation by R&D and non-R&D innovators in low technology contexts: a forgotten lesson for policymakers. Technovation 31 (9), 427–446. https://doi.org/10.1016/j.technovation.2011.06.006.
Hervas-Oliver, J.-L., Albors-Garrigos, J., de-Miguel, B., Hidalgo, A., 2012. The role of a firm's absorptive capacity and the technology transfer process in clusters: how effective are technology centres in low-tech clusters? Entrepreneurship & Regional Development 24 (7-8), 523–559. https://doi.org/10.1080/08985626.2012.710256.
Hirsch-Kreinsen, H., 2008. 'Low-tech' innovations. Ind. Innov. 15 (1), 19–43. https://doi.org/10.1080/13662710701850691.
Hirsch-Kreinsen, H., 2015a. Innovation in Low-tech Industries: Current Conditions and Future Prospects. In: Som, Oliver, Kirner, Eva (Eds.), Low-tech Innovation. Springer International Publishing, Switzerland, pp. 17–32.
Hirsch-Kreinsen, H., 2015b. Patterns of knowledge use in 'low-tech' industries. Prometheus 33 (1), 67–82. https://doi.org/10.1080/08109028.2015.1062237.
Hoegg, J., Alba, J.W., Dahl, D.W., 2010. The good, the bad, and the ugly: influence of aesthetics on product feature judgments. J. Consum. Psychol. 20 (4), 419–430. https://doi.org/10.1016/j.jcps.2010.07.002.
Howells, J., 1996. Tacit knowledge, innovation and technology transfer. Tech. Anal. Strat. Manag. 8 (2), 91–106.
Jeffs, A., Liyanage, S., 2005. Raw Material Access and Sustainability as a Principal Driver for Innovation in the New Zealand Seafood Industry. Int. J. Learn. Chang. 1 (1), 80–95. https://doi.org/10.1504/IJLC.2005.007999.
Jensen, M.B., Johnson, B., Lorenz, E., Lundvall, B.A., 2007. Forms of knowledge and modes of innovation. Res. Policy 36 (5), 680–693. https://doi.org/10.1016/j.respol.2007.01.006.
Johansson-Sköldberg, U., Woodilla, J., Çetinkaya, M., 2013. Design thinking: past, present and possible futures. Creat. Innov. Manag. 22 (2), 121–146. https://doi.org/10.1111/caim.12023.
Johnston, K.A., Barclay, A.B., Honoré, C.G., 2010. A Brief History of Innovation in New Zealand Cheesemaking. Aust. J. Dairy Technol. 65 (3), 122–127.
Kapoor, R., Teece, D.J., 2021. Three faces of technology's value creation: emerging, enabling, embedding. Strateg. Sci. 6 (1), 1–4. https://doi.org/10.1287/stsc.2021.0124.
Karlson, B., Krull, E., France, N., 2013. Comvita: Bee-coming an International Natural Health Company. The University of Auckland, Auckland, New Zealand.
Kirchberger, M.A., Pohl, L., 2016. Technology commercialization: a literature review of success factors and antecedents across different contexts. J. Technol. Transfer. 41 (5), 1077–1112. https://doi.org/10.1007/s10961-016-9486-3.
Klepper, S., 1997. Industry life cycles. Ind. Corp. Chang. 6 (1), 145–181. https://doi.org/10.1093/icc/6.1.145.
Kolb, C., Wagner, M., 2018. How university spin-offs differ in composition and interaction: a qualitative approach. J. Technol. Transf. 43 (3), 734–759. https://doi.org/10.1007/s10961-017-9629-1.
Laforet, S., 2008. Size, strategic, and market orientation affects on innovation. J. Bus. Res. 61 (7), 753–764. https://doi.org/10.1016/j.jbusres.2007.08.002.
Laursen, K., Salter, A., 2004. Searching high and low: what types of firms use universities as a source of innovation? Res. Policy 33, 1201–1215. https://doi.org/10.1016/j.respol.2004.07.004.
Lomas, D., 2011. John Hartstone's Revolutionary Dairy Invention: A Little-Known New Zealand Invention Has Revolutionised Dairy Farming Here and Around the World. New Zealand Listener (No. 3711).
Maietta, O.W., 2015. Determinants of university-firm R&D collaboration and its impact on innovation: a perspective from a low-tech industry. Res. Policy 44 (7), 1341–1359. https://doi.org/10.1016/j.respol.2015.03.006.
Manning, B., 2012. Selective Breeding for Greenshell Mussels Unveiled. New Zealand Herald. http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11426515.
Mayer, K.J., Sparrowe, R.T., 2013. Integrating theories in AMJ articles. Acad. Manag. J. 56 (4), 917–922. https://doi.org/10.5465/amj.2013.4004.
McGillivray, W.A., 1978. "Cheese and Cheesemaking". In New Zealand Dairy Research Institute: A History of the First Fifty Years 1927–1977. New Zealand Dairy Research Institute, Palmerston North.
McKelvey, M., Ljungberg, D., 2017. How public policy can stimulate the capabilities of firms to innovate in a traditional industry through academic engagement: the case of the swedish food industry. R&D Manag. 47 (4), 534–544. https://doi.org/10.1111/radm.12224.
Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis. Sage, Thousand Oaks, CA.
Miller, T., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., Loorbach, D., 2014. The future of sustainability science: a solutions-oriented research agenda. Sustain. Sci. 9 (2), 239–246. https://doi.org/10.1007/s11625-013-0224-6.
Min, J.-W., Vonortas, N.S., Kim, Y., 2019. Commercialization of transferred public technologies. Technol. Forecast. Soc. Chang. 138, 10–20. https://doi.org/10.1016/j.techfore.2018.10.003.
Ministry of Primary Industries, 2015. SPATnz. http://www.mpi.govt.nz/funding-and-programmes/primary-growth-partnership/primary-growth-partnership-programmes/spatnz/.
Ministry of Primary Industries, 2020. Steepland Harvesting. https://www.mpi.govt.nz/funding-and-programmes/sustainable-food-and-fibre-futures/primary-growth-partnership/completed-pgp-programmes/steepland-harvesting/.
Molina-Morales, F.X., Expósito-Langa, M., 2012. The impact of cluster connectedness on firm innovation: R&D effort and outcomes in the textile industry. Entrep. Region. Dev. 24 (7–8), 685–704. https://doi.org/10.1080/08985626.2012.710260.
New Zealand Government, 2015. Design Thinking. https://www.beehive.govt.nz/release/better-design-celebrates-10-years.
New Zealand Herald, 2013. Technology's Top Names: Compac Sorting Equipment. New Zealand Herald. https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11145772.
Noble, C.H., 2011. On elevating strategic design research. J. Prod. Innov. Manag. 28 (3), 389–393. https://doi.org/10.1111/j.1540-5885.2011.00808.x.
Ooi, Y.M., Husted, K., 2021. Framing multi-stakeholder value propositions: a wicked problem lens. Technol. Innov. Manag. Rev. 11 (4), 26–37. https://doi.org/10.22215/timreview/1434.
Orcher, L., Glendale, C.A., 2005. Conducting Research: Social and Behavioral Science Methods. Pyrczak Pub, Glendale, CA.
Organisation for Economic Co-operation and Development (OECD), 2005. Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed. OECD Publishing, Paris, France.
Pastoral Robotics, 2020. Spikey. http://www.pastoralrobotics.co.nz/spikeyreg.html.
Patton, M.Q., 2002. Qualitative Research and Evaluation Methods. CA Sage, Thousand Oaks.
Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Brostrom, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., Sobrero, M., 2013. Academic engagement and commercialisation: a review of the literature on university-industry relations. Res. Policy 42 (2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007.
Perkmann, M., Salandra, R., Tartari, V., McKelvey, M., Hughes, A., 2021. Academic engagement: a review of the literature 2011–2019. Res. Policy 50 (1), 104114. https://doi.org/10.1016/j.respol.2020.104114.
Qingzhi, Z., Yacheng, Y., Yaoyuan, Q., Jiasu, L., 2018. Science-based innovation in China: a case study of artemisinin from laboratory to the market. J. Ind. Integr. Manag. 3 (02), 1850011.
Quin, Bert, Bates, G., Bishop, P., 2016. Locating and treating fresh cow urine patches with Spikey®: the platform for practical and cost-effective reduction in environmental losses and increased pasture production. In: Currie, L.D., Singh, R. (Eds.), Integrated Nutrient and Water Management for Sustainable Farming: Occasional Report No.29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand, pp. 1–8.
Robertson, P.L., Smith, K.H., von Tunzelmann, N., 2009. Innovation in low- and medium-technology industries. Res. Policy 38 (3), 441–446. https://doi.org/10.1016/j.respol.2008.10.019.
Roulston, K., 2010. Considering quality in qualitative interviewing. Qual. Res. 10 (2), 199–228. https://doi.org/10.1177/1468794109356739.
Saebi, T., Foss, N.J., 2015. Business models for open innovation: matching heterogeneous open innovation strategies with business model dimensions. Eur. Manag. J. 33 (3), 201–213. https://doi.org/10.1016/j.emj.2014.11.002.
Santamaría, L., Nieto, M.J., Barge-Gil, A., 2009. Beyond formal R&D: taking advantage of other sources of innovation in low- and medium-technology industries. Res. Policy 38 (3), 507–517. https://doi.org/10.1016/j.respol.2008.10.004.
Spithoven, A., Bart, C., Knockaert, M., 2011. Building absorptive capacity to organise inbound open innovation in traditional industries. Technovation 30 (2), 130–141. https://doi.org/10.1016/j.technovation.2010.10.003.
Stokes, D.E., 1997. Pasteur's Quadrant: Basic Science and Technological Innovation. Brookings Institution Press, Washington, D.C.
Sydow, J., Schreyögg, G., Koch, J., 2009. Organizational path dependence: opening the black box. Acad. Manag. Rev. 34 (4), 689–709. https://doi.org/10.5465/AMR.2009.44885978.
Te Ara, 2021. Agricultural and horticultural research: The Cheddarmaster. Accessed 27 May 2021. https://teara.govt.nz/en/photograph/19638/the-cheddarmaster.
Teece, D.J., 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. Strateg. Manag. J. 28, 1319–1350. https://doi.org/10.1002/smj.640.
Teece, D.J., 2010. Business models, business strategy and innovation. Long Range Plan. 43 (2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003.
Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strateg. Manag. J. 18 (7), 509–533.
TOMRA Systems ASA, 2016. TOMRA Acquires NZ Sorting Machine Manufacturer Compac. October 12. SCOOP Independant News. https://www.scoop.co.nz/stories/BU1610/S00354/tomra-acquires-nz-sorting-machine-manufacturer-compac.htm.
Trott, P., Simms, C., 2017. An examination of product innovation in low- and medium-technology industries: cases from the UK packaged food sector. Res. Policy 46 (3), 605–623. https://doi.org/10.1016/j.respol.2017.01.007.
van Rossen, R., Brown, M., 2014. Progress Review of Primary Growth Partnership Steep Land Harvesting Programme: Summary Report. Ministry of Primary Industries, Wellington, New Zealand.
von Tunzelmann, N., Acha, V., 2006. Innovation in 'low-tech' Industries. In: Fagerberg, Jan, Mowery, David C. (Eds.), The Oxford Handbook of Innovation. Oxford University Press, Oxford, England, pp. 407–432.
Wakeman, S., Le, T., 2015. Measuring the Innovative Activity of New Zealand Firms, (June 2015 ed). Productivity Commission, Wellington, New Zealand (Working Paper 2015/2).
World Health Organization, 2013. WHO Traditional Medicine Strategy 2014–2023. World Health Organization, Geneva, Switzerland.
Yin, R.K., 2003. Applications of Case Study Research, 2nd ed. Sage, Thousand Oaks.
Yin, R.K., 2009. Case Study Research: Design and Methods, 4th ed. Sage, Los Angeles, CA.

Zott, C., Amit, R., 2010. Business model design: an activity system perspective. Long Range Plan. 43 (2–3), 216–226. https://doi.org/10.1016/j.lrp.2009.07.004.
Zott, C., Amit, R., Massa, L., 2011. The business model: recent developments and future research. J. Manag. 37 (4), 1019–1042. https://doi.org/10.1177/0149206311406265.
Zouaghi, F., Sánchez, M., Martínez, M.G., 2018. Did the global financial crisis impact firms' innovation performance? The role of internal and external knowledge capabilities in high and low tech industries. Technol. Forecast. Soc. Chang. 132, 92–104. https://doi.org/10.1016/j.techfore.2018.01.011.

Paul Woodfield is a Senior Lecturer in the International Business, Strategy, and Entrepreneurship department at Auckland University of Technology (AUT), New Zealand. He has a PhD from the University of Auckland, New Zealand. His research focuses on innovation in low-tech industries, knowledge management (knowledge sharing, knowledge creation), innovation/knowledge management in family businesses. Paul's current research projects examine interdisciplinarity in science and technology; trust with stakeholders; entrepreneurship in science teams; and innovative methodologies. He also has an appointment as a longitudinal researcher for the "*Building New Zealand's Innovation Capacity*" spearhead for the National Science Challenge: Science for Technological Innovation.

Yat Ming Ooi is Lecturer at the Department of Management and International Business, University of Auckland Business School. His research focuses on collaborative forms of innovation activities, digital transformation, circular economy, business model innovation, emerging technologies and technology commercialization. Yat Ming has published articles in the *Research-Technology Management* and *International Journal of Production Economics*. He is also a board of editors member for *Research-Technology Management* and editorial review board member for the *Technology Innovation Management Review*.

Kenneth Husted is a Professor of Innovation and Research Management at The University of Auckland Business School, New Zealand. He has been the Head of Department, Management and International Business since 2018. His research covers R&D collaboration, innovation in low-tech industries Knowledge Management (knowledge sharing, knowledge protection, knowledge governance). Kenneth's current research projects focus on Industry 4.0 and innovation, firm level innovation in the circular economy, AI and innovation. Kenneth is the Regional Editor for the *Journal of Knowledge Management* and Associate Editor of *Technology Innovation Management Review*.