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A developmental perspective on business model innovation: exploring sequences of change in high-performing IT firms — Source link

Edgar Brea

Published on: 12 Jan 2018

Topics: Business model, Entrepreneurship, Competitive advantage and Dimension (data warehouse)

THE UNIVERSITY OF QUEENSLAND

AUSTRALIA

A developmental perspective on business model innovation: Exploring sequences of change in high-performing IT firms

Edgar Brea

Bachelor of Systems Engineering, Master of Technology and Innovation Management

A thesis submitted for the degree of Doctor of Philosophy at

The University of Queensland in 2017

UQ Business School

Abstract

Altering and enhancing existing business models through business model innovation has emerged as a powerful competitive strategy that can provide advantage over extended periods of time. Business model innovation also presents a fundamental counterpart for technological, product and organisational innovations. Success stories of unconventional firms disrupting markets and sustaining financial rewards over competitors through business model innovation can be found in virtually any industry. A key success factor for long-term competitiveness lies in the implementation of multiple, rather than punctual, business model innovations over time, although achieving change through successive iterations is a challenge driven by market and technological dynamics and disruption. However, the lack of empirical investigation on the dynamics of business model change over extended periods of time limits our understanding of how established firms can mimic successful innovators and reconfigure their business models over time. This thesis responds to this gap by exploring the dynamic mechanisms enabling business model development in successful, high-performing firms. It defines and examines the distinctive properties of business model development to understand what determines success in extended business model change processes. The theoretical model and research design were developed to empirically investigate the sequences of change events in business models to find patterns characterising business model development in high-performing firms.

The theoretical framework deconstructs the structure of a business model using three well-accepted dimensions of value: value creation, value delivery and value capture. It treats the business model as a dynamic open system in which a firm's dynamic equilibrium behaviour and complementarity mechanisms are the drivers of change. Then, it employs principles from organisational theory, strategic management, innovation and entrepreneurship to explore the developmental trajectories of business models by examining: (a) the agents and nature of the actions driving business model changes; (b) the frequency of business model change events; (c) the magnitude of business model change events; and (d) the order of business model change events.

The exploratory, longitudinal and quantitative research design supporting this study is process-based, where business model development is formulated as a sequence of change events unfolding over time. A set of 12 financial ratios are used to examine fluctuations in a firm's operational, economic and product-market domains that are attributable to business model transformations for a sample of 1,651 listed firms in the IT sector worldwide. This sector was selected as the research setting because of its dynamism, global size and the pervasiveness of the technologies underpinning it.

Business model change events are identified through outlier detection and analysis of coordinated changes across the value creation, delivery and capture dimensions of the business models. Data were collected from a large financial database and transformed into individual sequences of change events. A validation procedure assessed the accuracy of the identification process for business model change events through qualitative data and in-depth analysis for four firms in the larger sample. Then, the individual sequences of change events were used as inputs for data mining methods of analyses, complemented by frequency domain analysis and statistical tests, which revealed the patterns of business model development in high-performing firms.

The results suggest a significant association between the timing and intensity at which firms change their business models and their average performance over time. The evidence also suggests that business model change is likely to culminate in events where the value delivery dimension is altered. In terms of the frequency and magnitude of changes, high-performing firms are more likely to develop their business models through frequent and incremental alterations over time, except for mature-large firms who, compared to young-small, young-large and mature-small firms, are more likely to implement radical, less frequent changes over time. Both environmental and internal forces influence the intensity at which high-performing firms typically alter their business models, although environmental factors are more significant than internal forces. Both unconscious and deliberated actions influence business model development in high-performing firms. Unconscious actions dictated by the firm's particular characteristics of age, size and sub-industry membership are a more significant influence than deliberated, emergent actions.

This research develops the new concept of business model development, and provides a contribution to theory by empirically examining a previously unexplored process. By adopting the process-based approach, this research contributes to new thinking and research in business model innovation centred on analysing the flow of events and patterns of business model development across multiple cases. Methodologically, this research developed a research design appropriate for large samples of firms, able to analyse multiple developmental trajectories of business models in a systematic and consistent manner. The research can assist practitioners and firms' leaders adjust established business models by providing guidance on the intensity, order and frequency of the changes required.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Publications during candidature

Conference proceedings:

BREA, E., HINE, D. & KASTELLE, T. 2016. Dynamics of business model innovation: a processual approach. Paper presented at the 10th ACERE Conference, Gold Coast, Australia, 2016.

BREA, E., HINE, D. & KASTELLE, T. 2016. Exploring trajectories of business model change. Paper presented at the 16th International Schumpeter Society Conference, Montreal, Canada, 2016.

Industrial reports:

KING, S., HINE, D., BREA, E. & COOK, H. 2014. Make for Asia: The emerging Asian middle class and opportunities for Australian manufacturing. CSIRO.

Publications included in this thesis

No publications included.

Contributions by others to the thesis

The advisory team of Associate Professor Damian Hine and Associate Professor Tim Kastelle contributed to the refinement of the ideas leading to the design of the project, provided direction on literature that inspired the study, and critically reviewed the thesis. The author conceived the research design and conducted the majority of the conceptual and design work. There were no significant contributions by others in non-routine technical activities, analysis and interpretation of research data.

Statement of parts of the thesis submitted to qualify for the award of another degree

None.

Acknowledgements

Firstly, I would like to thank the CSIRO's Data61 and Manufacturing business units for their financial support throughout this project in the form of a postgraduate scholarship and corresponding top-up, as well as the UQ Business School for providing funds to attend conferences and the resources for daily research activities.

I would like to express my sincere gratitude to my academic advisory team of Associate Professor Damian Hine and Associate Professor Tim Kastelle (UQ Business School) and to my industrial advisory team of Dr Alberto Elfes and Dr Peter Kambouris (CSIRO) for their invaluable professional and personal guidance, and for their trust, patience and support since the very first day of the project.

I have been fortunate to have both Tim Kastelle and Damian Hine as lecturers in my master's degree. They sparked my interest in corporate strategy and innovation management, which encouraged me to rethink and redirect my career. Years later, they did the same in my PhD. I thank them for keeping me motivated, for pushing my intellectual boundaries and expanding my capabilities, and for supporting me in every step of the research.

My sincere thanks to Associate Professor Marta Indulska and Associate Professor Martie-Louise Verreynne who acted as the Readers of Milestone Committee, and Dr Paul Brewer who acted as the Chair. I greatly appreciate their valuable comments, suggestions and constructive feedback.

I thank my family, my parents and sisters, for their emotional and moral support that kept me going. I owe them all my past achievements, and once again, they were there for me during this important time of my career.

Last but by no means least, I thank my wife Sandra for being the emotional and spiritual beacon that led the way through my PhD. I would not have gone this far without you, without your encouraging words, without your understanding during hard times, and without your bright advice when I needed it the most. And thanks to the biggest-little gift I have received during my PhD; my son Aaron, the biggest motivation of all.

Keywords

Business model innovation, business model change, business model development, business model evolution, business models, innovation, organisational change, firm performance, IT sector, data mining.

Australian and New Zealand Standard Research Classifications (ANZSRC)

ANZSRC code: 150307, Innovation and Technology Management, 75%

ANZSRC code: 150310, Organisation and Management Theory, 15%

ANZSRC code: 080109, Pattern Recognition and Data Mining, 10%

Fields of Research (FoR) Classification

FoR code: 1503, Business and Management, 90%

FoR code: 0801, Artificial Intelligence and Image Processing, 10%

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List of acronyms, abbreviations and symbols

Admin. – Administrative

ANOVA – Analysis of Variance

BM – Business Model

BMC – Business Model Change

BMI – Business Model Innovation

CEO – Chief Executive Officer

df – Degrees of freedom

DFT — Discrete Fourier Transform

DV – Dependent Variable

e-commerce – Electronic commerce

f – Frequency

F – F-statistics

FFT — Fast Fourier Transform

gen. – General

GICS – Global Industry Classification Standard

ICT – Information and Communication Technology

Inc. – Incorporated

IT – Information Technology

IV – Independent Variable

LOF – Local Outlier Factor

MAD – Median Absolute Deviation

MANOVA – Multivariate Analysis of Variance

Mdn – Median

NA – Not available

OM – Optimal Matching

OME – Optimal Matching Extended

p – Probability value

R&D – Research and Development

SD – Standard Deviation

SE – Standard Error

SME – Small and Medium Enterprises

t – Time

T – Period

χ^2 – Chi-square statistics

$\bar{x}$ – Sample mean

Chapter 1: Introduction

As the pace of technological progress and speed of developments in the global economy increases, corporate strategies based on conventional types of innovation are less and less likely to create sustained competitive advantage. Business model innovation has emerged as a powerful competitive strategy that provides advantage for longer periods of time (Afuah, 2014; Casadesus-Masanell & Ricart, 2010a), as well as a fundamental counterpart for technological, product and other forms of innovations (Chesbrough, 2007; Rayna & Striukova, 2014). The strength of a novel business model lies in its inimitability given the number and variety of organisational dimensions altered and the level of coordination required to implement such alterations (Foss & Saebi, 2015), which is also the reason why incumbents face considerable challenges when innovating their models (Lindgardt & Ayers, 2014). Despite the associated challenges, successful stories of unconventional firms disrupting markets and reaping financial benefits over their competitors through business model innovation are found in virtually all industries.

Recognising the value in investigating how successful firms innovate their business models, this research explores the dynamic mechanisms enabling business model development over time in successful, high-performing firms and others in defined industries. This study examines the distinctive properties of business model development, as well as the factors driving such development, to understand the characteristics determining success in business model innovation processes. The research responds to calls from academic scholars to expand knowledge on business model transformation processes (Demil & Lecocq, 2010; Zott & Amit, 2013).

1.1 Background

1.1.1 Definitions

Given the recent history of research on business models and business model innovation, as well as the wide variety of interpretations of what a business model represents, it is important to establish a base concept for the business model and business model change (Abdelkafi, Makhotin, & Posselt, 2013), so that the new concept of business model development can be framed early in the research process.

The business model is an abstract concept involving a set of business elements contributing to the generation of economic value for a business and its customers (Chesbrough & Rosenbloom, 2002; Johnson, Christensen, & Kagermann, 2008; Osterwalder, Pigneur, & Tucci, 2005; Teece, 2010; Zott & Amit, 2007). From this general view, a vast collection of more specific definitions have been proposed (Foss & Stieglitz, 2015), with the nature of the specificity depending on the author's field of study (Teece, 2010). One of these definitions is Zott and Amit's vision of the business models as

a system of interdependent firm-level activities enabling the creation and appropriation of value (Zott & Amit, 2010). This doctoral research builds on Zott and Amit's conceptualisation to define the *business model* as a system of firm activities and resources that are interconnected under the same goal to create customer value, to deliver the value created to the targeted customer and to capture a portion of value back to the firm and its partners (section 3.2.3.1 in Chapter 3 discusses this operational definition in detail).

Business model change has been defined by many authors under a variety of perspectives. The literature offers diverse definitions for concepts such as business model innovation, transformation and evolution (Saebi, 2015). Essentially, these are all examples of different forms of business model change, but a lack of explicit conceptualisation and the interchangeable nature in which these definitions are employed between and within studies make it difficult to categorise and differentiate them, so that they can be empirically studied. Table 1 seeks to clarify this variety of approaches by classifying some of the most relevant conceptualisations of business model change in the literature according to the implicit dimension driving each definition.

Definitional dimension	Magnitude	Concept	Definition	Author
Degree of change	Low	Business model adjustment	"changes of only one (or a minor number of) business model element(s), excluding the value proposition"	Schaltegger, Lüdeke-Freund and Hansen (2012)
	High	Business model transformation	"change in the perceived logic of how value is created by the corporation, when it comes to the value-creating links among the corporation's portfolio of businesses, from one point of time to another."	Aspara et al. (2013)
		Business model reconfiguration	"The phenomenon by which managers reconfigure organizational resources (and acquire new ones) to change an existing business model"	Massa and Tucci, (2014)
Degree of novelty	Low	Business model adoption	"changes that mainly focus on matching competitors' value propositions"	Schaltegger, Lüdeke-Freund and Hansen (2012)
		Business model replication	"repeated application of a specific business model"	Dunford, Palmer and Benveniste, (2010)
		Business model adaptation	"The process by which management actively aligns the internal and/or external system of activities and relations of the business model to a changing environment"	Saebi (2015)
	High	Business model innovation	"the discovery of a fundamentally different business model in an existing business"	Markides (2006)
			"reconfiguration of activities in the existing business model of a firm that is new to the product/service market in which the firm competes"	Santos, Spector and Van Der Heyden (2009)
Number of iterations over time	Single iteration	Business model lifecycle	"involving periods of specification, refinement, adaptation, revision, and reformulation"	Morris, Schindehutte and Allen (2005)
	Multiple iterations	Business model development	"an initial experiment followed by constant fine tuning based on trial-and-error learning"	Sosna, Trevinyo-Rodriguez and Velamuri (2010)
		Business model evolution	"Fine tuning process involving voluntary and emergent changes in and between permanently linked core components"	Demil and Lecocq (2010)

Table 1 - Distinctions between the different perspectives on business model change

Arguing that changing an existing business model requires a substantial alteration in the structure of the entire value generation logic (Demil & Lecocq, 2010), this study adopts a "high-magnitude degree of change" perspective to define *business model change* as any alteration in one or more of the activities and resources in a business model, resulting in a fundamentally different configuration.

While the definitions focused on degree of novelty articulate change as the transition from an existing model to a novel one, the concepts of business model development and evolution treat change as an ongoing process in which new business model configurations emerge over time. The latter view is compatible with the concept of organisational development, defined as a progression of changes unfolding from the formation of the entity to its termination (Van de Ven & Poole, 1995). Under this view*, business model development* is defined in this study as a series of business model changes implemented across the duration of a firm's existence (considering there is always at least one business model in place at each point through the life of the firm (Chesbrough, 2007)).

1.1.2 History of the business model: from static aspects to a dynamic view and beyond

The business model concept originated in the IT sector during the Internet boom in the mid to late 1990s, when practitioners were interested in exploring the success factors driving what they saw as a paradigm shift from traditional to Internet-based businesses activities (Osterwalder et al., 2005; Zott, Amit, & Massa, 2011). After the collapse of promising Internet-based firms, practitioners sought ways to explain why some firms failed and why others succeeded, and many suggested that the unsuccessful IT firms lacked solid revenue mechanisms to achieve profitability and long-term growth (Magretta, 2002).

During this period, the term "business model" was informally applied to the profit-making logic of a firm, while the term was more formally applied to explain the competitive strategies distinguishing Internet-based businesses from traditional businesses (Timmers, 1998). Scholars in the IT domain used the term in a more technical way to refer to the digitised model of a business (Heumann, 2001; Jacobson, Booch, Rumbaugh, Rumbaugh, & Booch, 1999), while scholars from business-related disciplines used the term as a unit of analysis to investigate strategy formulation at the corporate level (Afuah & Tucci, 2000; Winter & Szulanski, 2001). Discussions on the components of a business model, as well as a diverse variety of business model definitions, started to appear (Alt & Zimmermann, 2001), and soon attention turned to exploring the static aspect of the business model involving typologies (Chesbrough, 2007; Schweizer, 2005), characterisations (Morris, Schindehutte, & Allen, 2005), structural components (Osterwalder, 2004; Shafer, Smith, &

Linder, 2005) and design aspects of a business model (Bouwman, De Vos, & Haaker, 2008; Zott & Amit, 2007).

Building on earlier work linking business models with strategy and firm-level innovation in the early and mid 2000s (see Hamel (1998), innovation and entrepreneurship researchers became interested in the innovation processes leading to particular configurations, which led to more dynamic discussions on the change processes of business models (Aspara, Hietanen, & Tikkanen, 2010; Mason & Leek, 2008; Pateli & Giaglis, 2005). Since then, research on business model innovation has taken a more transformational approach to focus not only on the end product of particular business model configurations, but also on the process leading to the implementation of new configurations (El Sawy & Pereira, 2013).

Although interest in the dynamic aspects of business model innovation has been increasing, some researchers still identify a significant gap in our understanding of the dynamic processes driving business model development over time (Achtenhagen, Melin, & Naldi, 2013), which may involve not one, but multiple business model transitions. Sosna, Trevinyo-Rodriguez, and Velamuri (2010) and McGrath (2010) have suggested a developmental view of business model development as a constant trial-and-error learning process based on continuous experimentation, revision and adaptation of a model over time. Demil and Lecocq (2010), Doz and Kosonen (2010) and Bohnsack, Pinkse, and Kolk (2014) have also suggested an evolutionary view that transcends single transitions at a particular point in time, by theorising about the effects of a firm's strategic agility, path dependencies and evolution of resources and capabilities, on the development of business models.

Numerous aspects of business model development remain unanswered including the firm's circumstances that stimulate business model development (Morris et al., 2005; Zott & Amit, 2013), the actions and agents driving business model development, the set of actions and events leading to efficient business model transformation (De Reuver, Bouwman, & Haaker, 2013; Saebi, 2015) and the nature of the trajectories of business model development (Foss & Saebi, 2016). This thesis responds to this research gap, and recognises that there is a need for more empirical work on business model change and development to progress our theoretical understanding of the dynamics of business model development.

1.1.3 Differentiating business model development

Although research on business model innovation is sometimes classified within the broad class of business model research, there are differences in the analytical focus between business model research and business model change research (including business model innovation and

development) (Foss & Saebi, 2016). The former tends to focus on classifying existing business model configurations according to the effects on the firm, often requiring dedicated analysis of the structural components of the business model (Burkhart, Krumeich, Werth, & Loos, 2011). The latter focuses on exploring the process of transforming an existing business model into a novel configuration, and largely explores the antecedents and effects of the reconfiguration process on the organisation (Wirtz, Pistoia, Ullrich, & Göttel, 2016). Thus, research on business model change tends to explore the dynamic aspects of business models, and the interrelation with other dynamic aspects of the firm. This research contributes to the second stream of research by exploring the dynamic mechanisms leading to business model development over time.

1.2 The importance of business model innovation and development

Ongoing configuration of business models is essential in dynamic environments to achieve strategic resilience (Hamel & Valikangas, 2003), strengthening a firm's competitiveness in a sustained manner (Markides & Charitou, 2004). Increasing evidence supports the role of business model innovation as a source of sustained competitive advantage (Demil, Lecocq, Ricart, & Zott, 2015; Matzler, Bailom, Eichen, & Kohler, 2013; Schneider & Spieth, 2013) and as a driver of superior performance (Foss & Stieglitz, 2015; Zott & Amit, 2007, 2008). Some evidence suggests that the competitive edge offered by product and process innovations is not as durable as it used to be, thus, firms are forced to rethink their business models in their quest for longer-lasting improvement (Bjorkdahl & Holmen, 2013). Other evidence suggests that the novel combination of strategic and economic decisions in a business model can be difficult to replicate by competitors (Morris et al., 2005; Teece, 2010), enhancing the resource-based inimitability argument.

Driven by the accelerated pace of technological advances, volatility of consumer preferences and increased competition (Bouwman et al., 2008), the rate at which established business models are becoming obsolete is forcing firms to consider business model innovation not just as a proactive action, but also as a response strategy (Aspara et al., 2010). Business models are constantly reconfigured to take advantage of technological innovations (Teece, 2010), which also suggests that the isolated implementation of traditional forms of innovation does not confer the degree of advantage required to succeed (Chesbrough & Rosenbloom, 2002).

1.2.1 Relevance to practical research

The concept of business model innovation is appealing for practitioners because it provides an overview of the logic of a business in terms of economic value, facilitating identification of new

ways to generate profit through exploiting unmet customer needs and detecting new and alternative sources of value creation (Johnson et al., 2008). The concept is also attractive because it considers external actors as a key part of the value creation process, which responds to the corporate need for an instrument that reflects the networked nature of modern businesses (Allee, 2000). Practitioners also see business model innovation as a potential source of competitive advantage, with CEOs from a variety of industries recognising that business models are the real differentiating factor in their markets, as they are more difficult to replicate than products and services (Johnson et al., 2008).

Despite its relevance for practitioners, business model innovation has been regarded as an underused source of competitive advantage (Zott & Amit, 2009), with only one in every four firms worldwide actively pursuing it (Lindgardt & Ayers, 2014). As in every change process, the journey may be understood but the final destination remains difficult to predict. Furthermore, the business model-related tools available for practitioners, such as the highly successful Business Model Canvas (Osterwalder & Pigneur, 2010), are not designed to help firms understand the way particular changes affect each of the business model components and how a change may provoke successive changes over time. Insights on these dynamic factors could unarguably help managers keep their business models flexible and adaptable (De Reuver et al., 2013).

Inertia, path dependence and cognitive barrier to experimentation are all factors impeding the alteration of an existing business model (Cavalcante, Kesting, & Ulhoi, 2011; Chesbrough, 2007, 2010). Even if the management team manage to overcome these barriers and successfully change their business model, there are no guarantees that the associated competitive benefits will be sustained over time (Mitchell & Coles, 2003). Innovating a business model an ongoing activity rather than a one-off task, making it even more difficult to master. The complexity of the task at hand demands for frameworks to support practitioner in planning, implementing and monitoring the innovation process, as well as practical knowledge on the success factors associated with the reconfiguration of existing business models and the effects of particular business model innovation options on performance. Currently, this practical knowledge is scarce (Demil et al., 2015).

1.2.2 Relevance for academic research

The business model and business model innovation concepts have been evident in innovation management research for the last two and a half decades (Bucherer, Eisert, & Gassmann, 2012). Although the majority of the literature has been dominated by practitioner papers, the number of academic peer-reviewed articles on business model innovation has been increasing steadily since the late 1990s (Wirtz et al., 2016).

The business model and business model innovation can be traced back to seminal theories from business studies, such as the principles of architectural innovation Henderson and Clark (1990), disruptive innovation (Christensen, 1997), open innovation (Chesbrough, 2003), the exploitation-exploration trade-off in adaptive systems (March, 1991), and dynamic capabilities (Teece, Pisano, & Shuen, 1997) (refer to Chapter 2 for a thorough discussion of the relationship between these theories and business model innovation). Consequently, it is crucial not just for the business model field itself, but for others as well, to identify opportunities for further study of business models and business model innovation.

More recently, one of the key reasons driving research interest on the business model and business model innovation is that each allows scholars to explain why firms with relatively limited resources and relatively less advanced technologies and products are able to outperform better-positioned firms (Johnson et al., 2008). Much research has treated business models and business model innovation as independent, dependent and moderator variable to investigate value creation in firms, sources of competitive advantages, organisational response to environmental changes, sustainable business practices, among others (Foss & Saebi, 2017). Business models also offer a new unit of analysis to understand and explore other organisational phenomena (Gassmann, Frankenberger, & Sauer, 2016). A common denominator in most of these studies is that they treat the business model as a static construct, where the dynamic aspects governing change within the model are not necessarily the main focus of attention (Demil & Lecocq, 2010).

Despite the research efforts around the topic, the theory supporting further research is limited (Massa, Tucci, & Afuah, 2017). A number of scholars argue that, without empirical efforts on measuring the business model to understand how it behaves and changes over time, theory building and theory testing initiatives will remain scarce (Morris, Schindehutte, Richardson, & Allen, 2015). To develop a much-needed body of knowledge on business models and business model innovation, we must not only dedicate our research efforts on defining and classifying business models, but on assessing the mechanisms under which firms innovate their business models over time. This issue of a lack of theoretical grounding is amplified by the fact that the field is highly fragmented, and the knowledge created by past research is often not referenced by new research (Wirtz et al., 2016).

In conclusion, there is both an opportunity and a need to explore the transformational aspect of business models, where drivers and patterns of change, rather than simply structural components and typologies, are the main analytical focus of analysis (Zott & Amit, 2013). Bridging this gap is crucial not just for the advancement of the business model innovation field of study, but for other fields such as innovation management, business strategy and organisation theory.

1.3 Research problem

The previous section on the relevance of business model innovation for practitioners and academics introduces the main challenges faced by both groups. The main concern for the former is the challenges faced by managers and executives when conducting business model innovation. For the latter, the challenges centre on the lack of theory on the dynamic mechanisms explaining business model change, hindering the advancement of the field. These challenges are the direct result of four main issues, which represent the key research problems to be address by this research.

Firstly, there is a lack of methodological and theoretical tools designed to facilitate the examination of change in a business model over time (Schneider & Spieth, 2013). These tools are required to build dynamic models of business model change, and without them it remains difficult to produce actionable knowledge on the mechanisms driving business model change and development (Ginsberg, 1988). Most of the empirical studies on business model change either follow a case-based methodology that is typically difficult to replicate in other research contexts (Pettigrew, 1990) or not operationalised in a way that facilitates the systematic assessment of the dynamic interactions between the components of the business model (Demil & Lecocq, 2010).

Secondly, there has been a limited focus on the patterns of change as the main unit of analysis in business model development research. Assessing the dynamic patterns displayed by an entity as it changes over time allows to identify a variety of change types with different causal mechanisms, leading to richer explanations of why and how the entity changes (Van de Ven & Poole, 2005). Coupled with the lack of attention on patterns is the limited amount of empirical research studying business model innovation as a long-term developmental trajectory comprising multiple instances of change. This long-term view can potentially disclose new information on how firms implement change, and facilitate the emergence of meaningful patterns in the data on the mechanisms and actions driving firm-level change (Biemann & Datta, 2013). Additionally, considering that "each event arises out of, and is constituted through, its relations to other events" (Langley, Smallman, Tsoukas, & Van de Ven, 2013: 5), there is limited knowledge on how changes implemented in a business model in the past affect its future developmental trajectory, as well as the long-term performance effects and consequences from multiple and prolonged changes.

Some authors have proposed a set of linear stages to describe the process of business model change (Cavalcante et al., 2011; De Reuver et al., 2013; Morris et al., 2005). Although useful to characterise the process leading to a novel business model, the linear approach of these studies limits the exploration of additional, crucial concerns such as what happens to the model as it reaches the final stage of the process; whether one-time business model innovation is enough for

sustained performance (Zott & Amit, 2007); and, if an additional run of the innovation process is required later, what happens to the existing configuration in the meantime.

Thirdly, there are little clues as to when a firm should change their business model, the type of change required and the sequence in which the changes should be implemented. Timing is an important factor for the success of strategic renewal and organisational change (Amburgey, Kelly, & Barnett, 1990). However, timing has been neglected from business model research. Similarly, characterising the type of change in terms of the breadth and depth reduce uncertainty and provides actionable knowledge to managers and executives (Christensen, 1997). Regarding the sequence of change, observing the chain of activities leading to a change is as important as observing the characteristics of the change itself (Langley et al., 2013).

Lastly, there is little certainty on what drives a firm to change its business model at an ongoing basis. This is caused by a knowledge gap on two key aspects. The first one concerns the nature of the actions required for repeated business model change. Specifically, little is known on whether business model changes are the result of spontaneous actions or are the result of planned activities taken by the firm's leaders (Bjorkdahl & Holmen, 2013). The second knowledge gap concerns the role of the environment and the firm's internal conditions as driver of change (Bjorkdahl & Holmen, 2013), and whether the internal forces of the firm diminish or enhance the environmental forces inducing business model change (De Reuver et al., 2013).

1.4 Research questions and objectives

This study responds to the identified research gap and explores how business models are reconfigured over time in high-performing established firms, to generate a body of knowledge that will support theory building on the process of business model innovation. The process is compared with those other firms in industry sectors who are not sustaining their competitive performance to gauge whether distinct differences in patterns are evident. The results also have managerial implications for the implementation of business model innovation strategies in established firms. A developmental perspective is adopted, that considers the developmental trajectory of a business model over time rather than single transitions in time, to form a comprehensive understanding of the long-term dynamic interplay between an organisation and its business model.

The aim of this thesis is to conduct an exploratory investigation of the patterns of change driving business model development over time, which includes articulating a theoretical framework explaining business model innovation as a developmental process. This study explores configurations of variables using dynamic modelling to discover associations between key elements

of a business model and the influence of these elements in the change process that underpins business model development.

Building on the research problems and gaps identified in the previous section, this research specifically asks: (1) To what extent are there distinguishable patterns of change associated with business model development in established firms? (relates to the first and second research issue); (2) What are the characteristics of such patterns in terms of the magnitude, frequency and order of changes involved in the process? (relates to the third issue); (3) What is the nature of the actions and factors driving business model changes over time? (relates to the fourth issue).

A process stance is adopted to build a conceptual framework that helps observe the process by which high-performing firms innovate their business models over time. This research has been designed as a longitudinal, exploratory, quantitative investigation. Such design helps identify patterns of change in firms for which business model change has likely contributed to their financial performance, providing the existence of a relationship between business model change and firm performance (Zott & Amit, 2007). Likewise, the detection of commonalities and/or differences in the frequency, magnitude and order of business model change is also important for this study in order to contrast the business model change process in high performers against other firms in search of dynamic mechanisms that drive successful business model change.

The specific objectives of this study are:

a) To determine whether or not a distinction exists between patterns of business model change in high-performing outlier firms and other firms
b) To explore the magnitude, sequential order and frequency of the changes across the trajectories of business model development in high-performing firms, compared to other firms
c) To explore the source of the forces and nature of the actions driving business model development in high-performing firms.

The methodology measures change in business models at the firm level, complemented by a set of analytic methods to quantify and assess the events leading to business model development. This study also articulates a research design tailored to large samples of firms and a large amount of firm quantitative historical data, maximising the generalisation of research findings to support theory development.

1.5 Research design

The research is built on a series of principles from strategic management, systems theory, organisational change, innovation and entrepreneurships to conceptualise, dimensionalise and operationalise business model change, as well as to theorise on the dynamic characteristics that define business model trajectories in high-performing firms. The conceptualisation and dimensionalisation involves the concepts of product, customer and economic value, complementarities and regulatory mechanisms in open systems, while the explanation of the dynamics of business model development uses Van de Ven and Poole's models of organisational development (Van de Ven & Poole, 1995), rate of organisational change, innovation types and order in innovation processes, to generate propositions about the fundamental properties of business model development.

The study investigates the process of business model innovation not as a transitional event leading to a novel configuration, but as an ongoing developmental process in which different types of change are implemented over time as the firm seeks an optimal alignment between its business model and the environment (Porras & Silvers, 1991). Under this approach, business model development is considered a different process from business model innovation. Therefore, the study provides an incremental contribution towards theory building by examining the previously unexplored process of business model development, which, according to Colquitt and Zapata-Phelan (2007), offers significant potential for theoretical contributions to the field.

Some authors argue that the scarcity of empirical work on business model innovation is caused by difficulties in measuring business models (Morris et al., 2015). Given the lack of a measurement system for business model change, the research methodology develops and applies a procedure to measure business model change and quantify development over time. In addition, the research design incorporates up-to-date data analytic techniques to explore the propositions deriving from the framework. The analytic methods are based on data mining techniques complemented by statistical procedures and frequency domain analyses, integrated to allow assessment of the dynamics behind business model change processes.

Less than 5% of studies on business model innovation and change are multivariable and/or empirical in nature (Wirtz et al., 2016). The rest of the research is dominated by conceptual work and case studies with generally fewer than five cases. Quantitative-based studies involving large samples of established firms are rare in the literature (Demil et al., 2015). This thesis recognises the value of incorporating empirical tests on large datasets, to develop business model innovation as a research discipline (Morris et al., 2015). This means that, in the process of exploring the

phenomenon of business model development—which can potentially contribute to theory, the research design represents a novelty in itself, with potential for a methodological contribution.

The different research perspectives adopted in this study are illustrated in Table 2. The table describes the approach followed in each research task, which are categorised by the three key phases of the research process (exploration, research design and research execution), as proposed by Bhattacherjee (2012). There are two important observations to be highlighted from the table. Firstly, the inductive reasoning supporting explanations of business model development (second row) builds on observations from previous case studies in which the authors studied firms that have changed their business models in the past. Secondly, in terms of the key types of research purposes (exploration, description and explanation) this study follows an exploratory approach with elements of description (Rubin & Babbie, 2012) (see Section 4.2.2.4 for a detailed explanation of the research purposes and approaches adopted). While an exploratory approach guided many aspects of this thesis, with the theoretical framework development process being a clear example (fourth row), there were stages in which a scientific description was required. The descriptive approach supporting the data analyses and interpretation of results (last two rows) was enabled by the richness of the results facilitated by the data analyses, which allowed describing the events and trajectories of business model development through quantitative assessments.

Phase of research process	Thesis chapter	Task	Research approach
1. Exploration	Chapter 1	Articulate the research questions from the problems identified from a detailed review of literature	Process approach
	Chapter 3	Provide basic explanations on business model development to guide a more specific search for theories and principles	Inductive reasoning
	Chapter 3	Integrate and adapt a number of theories and principles from other research areas within the business studies	Deductive reasoning
	Chapter 3	Develop and articulate propositions from association between constructs	Exploratory approach
2. Research design	Chapter 4	Operationalise the business model change construct	Quantitative approach
	Chapter 4	Identify data source, sampling and data characterisation	Quantitative approach, longitudinal design
3. Research execution	Chapter 4	Data collection and manipulation	Quantitative approach, longitudinal design
	Chapter 5	Assess validity of the sequences of business model development quantitatively built	Qualitative approach, case study design
	Chapter 6	Establish the types of tests and analysis to be performed to the data	Descriptive, statistical approach, secondary data analysis
	Chapter 6 & 7	Analyse and interpret the results in relation to the research questions and propositions	Descriptive approach

Table 2 – The different research approaches employed in this study

1.6 Methodological considerations in a process approach

A process-based perspective is used to build a conceptual ground and propose a novel methodology to explicate business model development. Under the process approach, one of the two main methods for conceptualising organisational change (Mohr, 1982), growth and development are analysed as sequences of changes organised by time events. Pettigrew (1997) defines process as a sequence of actions and events unfolding over time in a contextual order. Similarly, business model innovation can be studied as a sequence of actions temporally ordered affecting multiple dimensions of an established model. This approach has the potential to deal with a change in a particular business model component that may affect the firm's capacity to change other components in the future. In addition, observation of change as a narration of successive events in a business model supports the examination of contextual effects and alternating causation—i.e. changing a firm's element induces changes either within the same firm or in others (Poole, Van de Ven, Dooley, & Holmes, 2000).

The second main method for studying organisational change is the variance approach. Under this approach, change and development over time is explained in terms of a deterministic causality of events, where independent variables cause changes in dependent variables (Van de Ven & Poole, 2005), with no account of the order of events in developmental processes (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Although the variance method has been the dominant approach in the fields of innovation and organisational change, a process view allows us to unravel new drivers and mechanisms that may not be evident at the beginning of the study (Van de Ven & Poole, 2005). To truly understand the developmental process for an entity, process research must be used to observe sequences of events to describe how the internal environment of the organisation changes over time (Van de Ven, 1992). Consequently, and inspired by past enquiries around sequential patterns in social science processes over time (Abbott & Tsay, 2000), business model innovation process in this study is articulated as a sequence of business model change events implemented over time, resulting in a new-to-the-firm or new-to-the-industry business model.

A central issue of business model innovation implementation is an organisation's lack of knowledge of when, why and how to transform their business models (De Reuver et al., 2013), as well as determining the sequence of business model change actions separating success from failure. To solve this, managers need a process theory that unveils the sequence of steps and organisational actions leading to novel business models (Demil & Lecocq, 2010; Van de Ven & Poole, 1990).

The design of this study is aligned with recent research that treats business model innovation as a process to form a clearer perspective on the dynamics leading to business model transformations. Zott and Amit (2015), for instance, recently urged more effort in process-based models to explain

the actions and steps that firms need to implement to innovate their business models. Recent business model innovation typologies such as work from Saebi (2015) build on business model innovation as a change process with varying degrees of radicalness. Similarly, Demil et al. (2015) stress the importance of discovering the organisational and decision making processes underlying business model innovation. Like these studies, this study embraces process thinking to elaborate on the mechanisms by which firms change their business models, however, the temporal scope is extended to include multiple episodes of change occurring to a business model, thereby focusing on developmental trajectories of change.

1.7 Thesis structure

The thesis has seven chapters. Chapter 2 depicts a literature assessment describing the business model innovation research conducted to date, as well as identifying the research gaps on the dynamics of business model innovation. Chapter 3 describes the conceptual framework designed to explore the different properties of business model development, and establishes the set of propositions guiding the rest of the research. Chapter 4 presents the research design and methodology implemented, with a discussion on the research orientation and attributes inspiring the design, and a description of the operationalisation and manipulation of business model change data. Chapter 5 explains the validation procedure of the business model change events identified in the previous chapter, using a qualitative research assessment of the four most successful and innovative firms in the IT sector. Chapter 6 on the analyses and results explains the five major analyses conducted in this study, and presents the results. Chapter 7 interprets and discusses the output from the research design and analyses, and concludes with implications and insights for future research on the dynamics of business model development.

Chapter 2: Literature Review

2.1 Introduction

Just as the business model construct serves as an unit of analysis to investigate firm-level value creation from a holistic perspective (Demil et al., 2015), the business model innovation phenomenon explains why firms with inferior technologies, limited resources or at a competitive disadvantage are sometimes able to dethrone leading players and disrupt entire markets (Christensen & Raynor, 2003). An investigation of the dynamics driving continuous business model innovation over time is crucial to understand the mechanisms under which established firms survive, succeed and evolve.

This chapter presents a critical analysis of the literature to explore the dynamics of business model development in high-performing firms. It not only describes the research gaps motivating this study, but also presents the theoretical antecedents that frame business model development as the research topic.

This literature review is divided into five categories: business models; business model change; business model innovation; business model development; and business model development and firm performance. It uses a funnel structure, where influential work relevant to the topic is grouped by commonality and discussed first, then moves to the analysis of literature that specifically addresses the objectives presented in Chapter 1. This structure is replicated for each of the five main categories. The chapter starts with an analysis of the theory base of seminal work considered the basis of the business studies discipline, which influences all five categories.

2.2 Theory base for business studies

The theoretical lineage of the dynamics of change between and within organisations in an economic system can be traced back to Joseph Schumpeter's work on the dynamics sustaining the development of the economic system as a whole. Schumpeter's creative destruction mechanism depicts innovation—the development of new combinations of ideas leading to the implementation of a new product, new process or the opening of a new market—as a revolutionary force interrupting a temporal state of equilibrium caused by routine behaviour (Schumpeter, 1934). Innovation, which is carried out by entrepreneurs in the form of entrepreneurial activities, is the dynamic mechanism driving economic development and evolution.

Coase (1937) elaborated on the entrepreneurial activities and investigated the mechanisms under which entrepreneurs organise their methods of production. He argued that Schumpeter's entrepreneurial activities are enacted by business organisations as an entrepreneur hires human

resources and forms a business to minimise the transaction costs associated with the acquisition of goods or services through the market (Coase, 1937).

Innovation was seen not only as the precursor of firm emergence; it was also a crucial mechanism enabling the continuity of a firm. Drucker (Drucker, 1954) argued that, because entrepreneurial activities are key for business development, they must be thoroughly managed. Building on the view of the firm as a dynamic, adaptive and evolving social entity, Drucker stressed entrepreneurial activities must be managed on a continuous basis, a perspective that led him to develop the term *systematic innovation* in successive works (Drucker, 1985).

Schumpeter's theory of innovation and its enactment through business firms also influenced the question of how these firms grow over time. Penrose (1959) addressed this question in her theory of the growth of the firm arguing that, while entrepreneurial actions drive firm growth, the capacity of existing administrative and productive resources limits the rate at which the firm can grow. Penrose (1960) maintained the focus on established firms, and argued that growth is enabled by a dynamic interaction between a firm's resources and market opportunities.

While elaborating on the dynamics driving organisational growth, Chandler (1962) incorporated two additional elements into the discussion: strategy and structure. Chandler argued that organisational growth begins with innovations occurring outside the organisation that stimulate changes in the firm's strategy, which are followed by changes in the structure of the organisation. Chandler also argued that the resulting changes in the strategy and structure of the organisation are an innovation in itself.

These seminal theories provided the theoretical grounds supporting successive work on a firm's value creation logic that led to the establishment of the business model concept, the dynamics driving change in business models and in the firm itself, the innovation and processes under which business models develop over time, and in the performance aspects of business model development.

2.3 The business model

Several researchers have stressed that the term business model "lacks theoretical grounding in economics or in business studies" (Teece, 2010: 175). However, there are traces of the influence of strategy, management, innovation, economics and organisational theories on the business model construct. This section firstly examines the depth and breadth of such influence, then discusses the aspects that have been studied to date, a structure maintained for every main category.

2.3.1 Foundational approaches to the business model

2.3.1.1 A value-based approach

A fundamental aspect of the business model concept is the generation of economic value. Under the transaction approach, a key source of value creation is the adoption of an appropriate governance structures supporting transaction efficiencies that reduce the associated costs (Williamson, 1981). Another influential perspective on sources of value generation is Porter's value chain framework, which centres on the activities performed by the firm and establishes that identifying key operational activities and determining a proper configuration and coordination of such activities increase the value adding capacity of the firm (Porter, 1985).

These two lines of enquiry on value generation influenced foundational business model studies such as Amit and Zott (2001), who presented a model for the sources of value in e-businesses and introduced the business model as an unit of analysis to study value creation. Another important study based on value creation was by Allee (2000), who expanded value chain thinking by proposing that modern companies adapt the more fluid structure of value network as it facilitates knowledge exchange between the actors.

This value creation perspective influenced many seminal business model studies in the early 2000s. As a result, the concept of economic value lies at the core of most business model definitions proposed and used to date. Some of these seminal studies have referenced the value network theory to justify the importance of the entire value creation network of suppliers, partners and customers in a firm's business model (Morris et al., 2005). Others, such as Chesbrough and Rosenbloom (2002), complemented value creation with value capture, arguing that a successful business model allows the realisation of economic value from technical potential. Similarly, Magretta (2002) complemented the business model construct with the capacity to deliver value, arguing that an appropriate business model explains the mechanisms under which a firm delivers value to their customers at a proper cost.

2.3.1.2 A resource-based approach

The resource-based view of the firm led to a new view of corporate strategy as the balance between exploitation of the resources available and development of new ones (Wernerfelt, 1984). Barney (1991) built on the resource-based view to propose that sustained competitive advantage is determined by the value, rareness, inimitability and substitutability of the firm's resources.

Researchers who recognised the importance of a firm's resources for competitive advantage, on the one hand, and the importance of the business model for a firm's competitiveness, on the other,

concluded that a firm's resource bundle is a fundamental element of the business model concept (Hedman & Kalling, 2003). Other authors, such as Weill and Vitale (2001), argued that not all the resources were equally relevant for successful business models, but only those core competencies separating the firm from the rest (Prahalad & Hamel, 1990).

The influence of the resource-based view of the firm is also visible in the influential business model studies by Hamel (2000) and Osterwalder (2004) who proposed a firm's resources and core competencies as major components in their business model definitions given that they allow firms to create value and serve their customers in ways that other firms cannot.

More recently, the resource-based view of the firm is still inspiring operational definitions of business models, such as Demil and Lecocq (2010), who stressed the importance of a firm's resources and competencies in the capacity to create and deliver value, presenting them as a key component in their business model framework. Additional studies have recognised the connection between the resource-based view and the business model construct by pointing out that the success factor in certain business models is determined by the unique combination of a firm's resources (DaSilva & Trkman, 2014).

2.3.1.3 Knowledge and information management

Several authors have traced the origins of the business model term to practice-oriented literature in the IT sector (Burkhart et al., 2011). Practitioners applied the term "business model" as a unit of comparison to describe differences between traditional businesses and new forms of organisations using digital platforms to run their businesses, which emerged during the Internet boom of the late 1990s (Magretta, 2002; Timmers, 1998). After the dotcom crash in 2000, the term started to be used by researchers to explain why some IT firms failed and why others survived or even succeeded (Seddon, Lewis, Freeman, & Shanks, 2004). The business model term was also originally applied in the technology domain as an instrument guiding the design and development of e-commerce systems in electronic businesses (Stahler, 2002), thus, it was also referred to as the e-business model (Afuah & Tucci, 2000).

Timmers (1998) provided an early definition of business models that was used to classify different instances of business models in e-commerce businesses. The article was motivated by a lack of a consistent use of the business model term, which is why it was one of the first efforts to develop a more formal definition of business models. This was the same goal motivating Gordijn, Akkermans, and Van Vliet (2000), a study that focuses on the e-commerce domain to argue that the term centres on the core concept of economic value. Lastly, Afuah and Tucci (2000) aimed to reconcile the strategic management and technology management perspectives to propose an integrative business

model framework that highlights the positive effect of business models on firm performance—building on the effect of the Internet on business performance. Similarly to the two previous studies, Afuah and Tucci (2000) aimed to explain business models in Internet-based firms almost exclusively.

2.3.2 Key aspects of the business model

Apart from proposing business model definitions, early discussions on business models concentrated on business model configuration(s) at the firm level and developed frameworks to facilitate exhaustive observations on three basic questions. Firstly, there is the question of what the business model concept represents, and how to differentiate the business model construct from other firm aspects such as the business strategy. Secondly, there is the question of how to define the structure of a business model, for which proposed frameworks deconstruct business models into a number of components representing different aspects of an organisation. Lastly, there is the question of the range of possible types of business models, which requires an analysis of multiple companies and industries. Importantly, these questions are centred in static observations of business models in particular points in time, and do not consider the mechanisms by which the models are altered by business owners and executives.

2.3.2.1 Definition of business model

Although the interest in the business model and business model innovation has been translated into an ever-growing body of literature, there is no generally accepted definition for the term business model (Wirtz et al., 2016). The reason for the lack of an established definition may be in a weak cross-reference of business model concepts amongst similar studies, but it is also a natural result of the way in which the topic has evolved, as business models have arisen as an individual topic of study within multiple disciplines in parallel (Teece, 2010). This situation is problematic, resulting in a plethora of definitions, none of which has become dominant, and a disaggregated and ambiguous body of literature (Schneider & Spieth, 2013).

Nevertheless, there are emerging themes encompassing similar perspectives on what a business model represents (Zott et al., 2011). The key emerging conceptual themes are presented and described in Table 3.

Among all these interpretations of what a business model means, two key themes appear to be gaining headway in the research field: business models as assumptions about customers and markets; and business models as systems of interdependent activities (Foss & Stieglitz, 2015). As mentioned earlier, the former has been the basis of managerial and strategic tools among

practitioners. Nevertheless, studies that transcend the observation of a particular business model configuration at one point in time to explore business model change through time are now adopting a systems-based perspective to study business models. This enables the implementation the more sophisticated analytical techniques used in systems theory. It also facilitates the exploration of the dynamic mechanisms driving change in a business model, as it operationalises change based on the interaction among the different parts of the system. This conceptual theme is used to explore the multiple developmental trajectories of business models over time.

Study	Theme	Description
Timmers (1998) Afuah and Tucci (2000)	Descriptive plan for value generation	A business model is a blueprint describing the business actors and roles, the potential benefits for the business actors, sources of revenue, and the architecture of the offering and information flows. It is also perceived as how a company plans to make money in the long term.
Zott and Amit (2007) Amit and Zott (2001)	Collection of transactions and information flows supporting value generation	The business model is defined as the content, structure and governance of boundary-spanning transactions enabling the exploitation of business opportunities.
Magretta (2002) Teece (2010) Osterwalder et al. (2005)	Conceptual logic implemented in a firm	The business model is the conceptual economic logic supporting the company's operation and allowing them to satisfy customers at an appropriate cost. It is a conceptual tool reflecting the business logic of a firm explaining the type of value and how value is created to customers.
Osterwalder and Pigneur (2010) (Ovans, 2015)	Managerial assumptions about what customers want	Business logics formed by a set of managerial hypotheses about customers' needs. Significant work has been built on the business model as a set of assumptions on what the customer wants and how the company can generate value by testing and fulfilling those assumptions. The Business Model Canvas is employed as a template on which companies can articulate such assumptions.
Seddon et al. (2004) Zott and Amit (2010)	System of interconnected activities and resources within a firm	A business model is an activity system employed by a firm to create and deliver value to customers. Such system comprises activities from the firm's partners, suppliers and customers, which are intrinsically interconnected with each other forming a unit.
Casadesus-Masanell and Ricart (2010a) Loïc, Lecocq, and Angot (2010) Demil and Lecocq (2010)	The consequences from a company's management decision	The business model is a set of managerial choices and corresponding set of consequences involving policies, assets and governance mechanisms for value creation and capture in a firm.
Casadesus-Masanell and Ricart (2010b) Richardson (2008)	Reflection of a firm's strategy	A business model is the result of the implementation of all or part of the firm's strategies, i.e. the reflection of the realised strategy. The business model also works as a monitoring tool to determine the extent to which a company is executing its strategy effectively.
Chesbrough and Rosenbloom (2002) Björkdahl (2009) Chesbrough (2007)	Interface between technological potential and economic success	The business model represents the firm's ability to realise economic value from its technical attributes, by articulating the way value is created and delivered to customers and ultimately captured. It also describes the means for which a company converts their technological resources into economic output. A technology coupled with a novel business model may provide a superior advantage than the technology alone.

Table 3 – Major themes of business model definitions proposed by key business model studies

2.3.2.2 Components

Studies on the structural elements and components of a business model dominated the literature particularly during the early 2000s. Afuah and Tucci (2000) is one of the earliest studies on the deconstruction of business models and a dedicated chapter of their book presents a series of strategic questions that should be answered by a successful business model. The questions are categorised into 10 groups referred to as business model "components", which include customer

value, revenue source and capabilities, among others. Chesbrough and Rosenbloom (2002) proposed a set of six main functions of a business model, all of which were derived from previous definitions of corporate strategy. One of the most influential contributions on the structure of business models corresponds to Osterwalder (2004) and Osterwalder et al. (2005), where the authors proposed a list of nine components obtained from literature reviews in a wide range of fields from entrepreneurship to information systems. This work formed the basis of the visual tool know as "Business Model Canvas", typically used for the design and analysis of business models by entrepreneurs, investors, managers, commercialisation teams and researchers (Osterwalder & Pigneur, 2010). There are many studies on the components, structure and conceptual frameworks of business models in the literature (Abdelkafi, Makhotin, & Posselt, 2013; Al-Debei & Avison, 2010; Johnson et al., 2008). Table 4 presents a detailed description of the business model components proposed by the authors discussed above.

Author and year	Component	Description
Afuah and Tucci (2000)	• Profit site	• Describe the firm's (dis)advantage compared to its suppliers, customers and rivals
	• Customer value	• Compare firm's customer offerings compared to competitor's offerings
	• Scope	• Describe target customers and range or products/services
	• Pricing	• The price of the customer value
	• Revenue source	• Describe who pays for what value and when, the margin in each market and its drivers
	• Connected activities	• Describe the activities the firm performs to offer customer value, and the way the activities are interconnected
	• Implementation	• Describe the organisational structure, resources, and environment needed by the firm to carry out these activities
	• Capabilities	• Describe the firm's capabilities and capabilities gaps needed to be filled, and the sources, distinctiveness and degree of inimitability of the capabilities
	• Sustainability	• Describe the firm's competitive advantage
	• Cost structure	• Explain the drivers of cost in each business model component
Chesbrough and Rosenbloom (2002)	• Value proposition	• Describe the value created for users by the technology-based offering
	• Market segment	• Describe the potential users of the technology, and the revenue mechanisms
	• Value chain structure	• Define the value chain structure and complementary assets needed to create and deliver the offerings
	• Cost structure and profit potential	• Describe the profit and cost structure of producing the offering
	• Positioning within the value network	• Describe the position within the value network comprising suppliers, customers, and identify potential partners and competitors
	• Competitive strategy	• Formulate the competitive strategy that will support sustained advantage over rivals
Osterwalder (2004)	• Value proposition	• Comprise the firm's bundle of products and services adding value to the customer
	• Target customer	• Describe the customer segment for whom the value is intended
	• Distribution channel	• Describe the mechanisms for which the value will be delivered to the customer
	• Relationship	• Describe the linkages between the customer and the firm
	• Value configuration	• Describe the activities and resources needed to create value to the customer
	• Capability	• Describe the periodic pattern of actions needed to create value to the customer
	• Partnership	• Describe the agreements between partners for the co-creation of customer value
	• Cost structure	• The monetary representation of the means employed in the business model
	• Revenue model	• Describe the sources and mechanisms for which the firm generates revenue
Johnson et al. (2008)	• Customer value proposition	• Comprise the target customer, the job to be done to fulfil customer's need and the offering that satisfies the need
	• Profit formula	• Describe the revenue model, cost structure, profit margin model and resource velocity
	• Key resources	• Comprise the resources needed to deliver the customer value proposition, including people, technology and equipment, information, channel, partners and brand
	• Key processes	• Describe the processes, metrics, rules and norms for a sustained and profitable delivery of the customer value proposition

Al-Debei and Avison (2010)	• Value proposition	• Describe the logic of creating value to customers through products/service offerings satisfying customer needs
	• Value architecture	• Technological architecture and organisational structure supporting the provision of products/service offerings
	• Value network	• Describe the mechanisms for coordination and collaboration among partners
	• Value finance	• Describe the costing and pricing to sustain and improve revenue generation
Abdelkafi et al. (2013)	• Value proposition	• Describe the customer offering addressing the job-to-be-done and satisfying the customer needs
	• Value creation	• Describe the resources, processes and key partners supporting the creation of value
	• Value communication	• Describe the communication channels and the story for communicating value to customers
	• Value capture	• Comprise the cost structure and revenue mechanisms allowing the capture of value
	• Value delivery	• Describe the customer segments, relationships and distribution channels needed for the delivery of value created

Table 4 – Components of the business model proposed by business model authors

2.3.2.3 Typologies

Classification of multiple business models has also been a constant focus of attention since the early days of the business model field of study. For instance, Timmers (1998) identified 11 generalised versions of business models implemented in the e-commerce industry, and then classified them according to the degree of innovativeness. In their book on e-business models, Weill and Vitale (2001) described eight "atomic" e-business models representing fundamentally different forms of doing business electronically. They then made a detailed comparison between the types across parameters such as sources of revenue, required IT infrastructure and required competencies (Weill & Vitale, 2001).

More recently, there has been a growing literature on business model typologies intended for practitioners and managers. Johnson (2010) and Osterwalder and Pigneur (2010) have identified commonalities within different business model configurations and presented a series of archetypes that resemble business analogies such as freemium, razor-and-blade, open and bundling business models, among others. Gassmann, Frankenberger, and Csik (2014), a recent publication on business model classification, reviewed a number of successful firms and identified 55 unique "patterns" of business models, with practical indications on how to adopt each of these models. Table 5 describes the business model typologies discussed previously.

Author and year	Business model types	Description
Timmers (1998)	(1) e-shop, (2) e-procurement, (3) e-auction, (4) e-mall, (5) third-party marketplace, (6) virtual communities, (7) value-chain service provider, (8) value-chain integrators, (9) collaboration platforms, (10) information brokerage, (11) trust and other services	The 11 types of business model configuration correspond to e-commerce businesses (business-to-business and business-to-consumer), which is why the types are referred to as Internet business models. A brief description for each type is presented as well as a classification by degree of innovation and functional integration.

Weill and Vitale (2001)	(1) content provider, (2) direct to customer, (3) full service provider, (4) intermediary, (5) shared infrastructure, (6) value net integrator, (7) virtual community, (8) whole-of-enterprise / Government	The 8 atomic business models are part of a framework to assist practitioners in implementing Internet/electronic business practices. The 8 types work as building blocks, and they can be combined in multiple ways to create new electronic business models.
Johnson (2010)	(1) auction, (2) alter the usual formula, (3) bricks + clicks, (4) bundle elements together, (5) create user communities, (6) cell phone, (7) develop unique partnerships, (8) dial down features, (9) do more to address the job, (10) disintermediation, (11) freemium, (12) lease instead of sell, (13) leverage new influencers, (14) low-touch approach, (15) multi-level marketing, (16) own the undesirable, (17) razors/blades, (18) reverse razors/blades, (19) servitisation of products, (20) subscription	The author presented 20 business model types obtained from an assessment of a range of industries from aerospace and retailing to pharmaceutical and computer manufacturing. The names of the types represent practical business analogies, e.g. razor-blades and cell phone. Case examples for each business model type were also presented.
Osterwalder and Pigneur (2010)	(1) unbundling, (2) the long tail, (3) multi-sided platforms, (4) free, (5) open	The topology is built on the 9 building blocks (i.e. components) framework proposed by the authors, and is presented to illustrate the interactions between the building blocks. The 5 types are referred to as "patterns" (i.e. recombination between them is allowed), and are applicable to any business regardless of their industry.
Gassmann et al. (2014)	(1) add-on, (2) affiliation, (3) aikido, (4) auction, (5) barter, (6) cash machine, (7) cross-selling; (8) crowdfunding, (9) crowdsourcing, (10) customer loyalty, (11) digitalisation, (12) direct selling, (13) e-commerce, (14) experience selling, (15) flatrate, (16) fractionalised ownership, (17) franchising, (18) freemium, (19) from push-to-pull, (20) guaranteed availability, (21) hidden revenue, (22) ingredient branding, (23), integrator, (24) layer player, (25) leverage customer, (26) license, (27) lock-in, (28) long tail, (29) make more of it, (30) mass customisation, (31) no frills, (32) open business model, (33) open source, (34) orchestrator, (35) pay per use, (36) pay what you want, (37) peer-to-peer, (38) performance-based contracting, (39) razor and blade, (40) rent instead of buy, (41) revenue sharing, (42) reverse engineering, (43) reverse innovation, (44) Robin Hood, (45) self-service, (46) shop-in-shop, (47) solution provider, (48) subscription, (49) supermarket, (50) target the poor, (51) trash to cash, (52) two-sided market, (53) ultimate luxury, (54) user designed, (55) white label	The typology consists of 55 repetitive patterns identified by the authors after an analysis of a wide range of businesses and industries. The authors claim that the majority of the existing business models can be represented by one or a combination of the business model types presented in the typology.

Table 5 – Business model typologies available in the literature

2.4 Business model change

2.4.1 Foundational approaches to business model change

2.4.1.1 Capability-based perspective

Motivated by the question of how firms and industries change over time, Nelson and Winter (1982) adapted the concept of natural selection to provide a model that explains the dynamics of competition among firms in the context of technological change and innovation. Teece et al. (1997)

built on the concept of adaptation from the evolutionary theory of economic change to develop the concept of dynamic capabilities. Dynamic capabilities, a framework also related to the resource-based view, has been associated with business models as the enabler of business model adaptation and change (Achtenhagen et al., 2013). Leih, Linden, and Teece (2014) argued that the firm's recognition of the need for a change in a business model is a fundamental step in the business model reconfiguration process, one that is hardly trivial and one that requires dynamic capabilities. In general, they argued that the success of a business model change is determined by the firm's dynamic capabilities, which in turn requires a flexible organisation and transformational leadership (Leih et al., 2014). Inspired by the concept of dynamic capability, Demil and Lecocq (2010) proposed the term *dynamic consistency* as the firm's capability enabling a firm to change its business model while also sustaining operational and financial performance.

2.4.1.2 Exploration-exploitation approach

The dynamics occurring within an organisation as it is changing can also be explicated from an organisational ambidexterity perspective. The concepts of exploration and exploitation argue that, to remain competitive, firms should embark on a constant search for a proper balance between the exploration of new alternatives and the exploitation of existing routines (March, 1991). Maintaining an optimal balance between both ensures long-term sustainability while securing short-term opportunities necessary for survival.

The exploration-exploitation approach helps explain why firms concentrate on keeping their existing resources and activities optimised while, at the same time, they are forced to explore novel mechanisms for value creation and capture. Winter and Szulanski (2001) suggested this duality is why and how business models are changed. They argued that a business model change process comprises an exploration phase in which the new business model is created and implemented, and an exploitation phase in which the business model is stabilised. Doz and Kosonen (2010) proposed the inverse argument to explain business model change arguing that a prolonged exploitation phase results in the business model becoming excessively rigid, limiting the firm's strategic agility, for which a business model transformation (i.e. an exploration phase) is required.

2.4.2 Key aspects of business model change

Compared to the static attributes of the business model explored in the previous section, the dynamic side of the business model literature has received less attention in both academic and practical domains (Demil & Lecocq, 2010). This stream of business model research focuses on the dynamics driving the reconfiguration of business models in a firm, as well as the emergence of new business models. It centres on exploring what happens to a business model through time and the

nature of the interactions between a changing business model and the firm which is also changing over time. Some researchers have argued that propositions on business model change, particularly in existing firms, are slowly emerging (El Sawy & Pereira, 2013; Heikkilä & Heikkilä, 2013). Others argue that there is still a lack of empirical evidence on business model change, and that a clear understanding of how novel business models emerge and are transformed over time is missing (Schneider & Spieth, 2013; Zott & Amit, 2013).

As one of the earliest attempts to explore the type of activities required to change a business model, Yip (2004) compared radical versus routine strategies and suggested that business model change requires radical strategies such as vertical integration, geographical expansion and redefining pricing structure, whereas change in market positioning requires incremental strategies. Brink and Holmén (2009) longitudinally explored the association between the evolution of the firm's set of capabilities and changes in their business models in the bioscience industry and concluded that the lack of certain technological capabilities is not an obstacle for firms to change and adopt a business model, rather the existence (or absence) of business-related capabilities hinders the change.

There have been efforts to develop methodologies to guide business model change. Pateli and Giaglis (2005) proposed a scenario-based framework for firms operating in technology-intensive environments to provide them with future directions for their current business models, consisting of six predefined steps in the form of a sequential procedure. Schweizer (2005) presented a business model typology that is then expanded by hypotheses on the factors affecting business model changes over time. Whether initiated by competitors or by micro or macro-economic factors, environmental evolutions, as Demil and Lecocq (2010) pointed out, have the power to influence changes in each of the internal components of a business model, which then triggers systemic change throughout the entire model.

The limited research focus on business model dynamics leading to business model change has persisted over the last 10 years, evidenced by the substantial number of scholars who have stressed the need for increased attention on the matter. Saebi (2015) argued that examination of the drivers of business model change is missing in the literature. Zott and Amit (2013) and Morris et al. (2005) emphasised the need to examine and understand the dynamics of business model emergence and evolution. Tikkanen, Lamberg, Parvinen, and Kallunki (2005) and George and Bock (2011) argued that the evolutionary mechanisms leading to successful business model change are missing in the existing literature.

Most of the literature on business model dynamics particularly focuses on investigating the process of innovation leading to an existing business model that is fundamentally new, rather than on any

type of business model change. The next two sections discuss the literature on business model innovation and business model development, as key elements of this study.

2.5 Business model innovation

This section considers the literature on the process in which a business model is reconfigured into a new-to-the-firm and/or new-to-the-industry business model, while the previous section considered studies on the dynamics involved in the reconfiguration of a business model, for which the resulting model is not necessarily novel.

2.5.1 Foundational approaches to business model innovation

2.5.1.1 Capabilities and innovation

Adopting a resource-based perspective, (Leonard-Barton, 1992) elaborated on the concept of core competencies to propose that effective competition is achieved by incremental adjustments in a firm's core capabilities. Early work on business model innovation, such as Malhotra (2000a) and Chesbrough and Schwartz (2007), suggested that, given a firm's capabilities are a fundamental business model component, innovating a business model is an effective strategy to renew the core capabilities, thus avoiding the formation of core rigidities hindering further innovation.

However, other authors took a different approach in linking capabilities with business model innovation. In one of the very first attempts at elaborating on the business model phenomenon, Hamel (1998) emphasised that shifting from product-centring innovation strategies to business model innovation initiatives is a key source of competitive advantage, but, to realise this shift, companies must build an ability to implement systemic innovation and integrate it into their core capabilities. Chesbrough (2010) similarly argued that developing the capability to innovate a business model requires successful change leadership and the capacity to embrace experimentation-effectuation processes.

2.5.1.2 Disruptive innovation

Another stream of thought influencing research on business model innovation originated from Clayton Christensen on disruptive innovation, which, in turn, was influenced by resource dependence theory. Pfeffer and Salancik (1978) introduced the concept of resource dependence to argue that organisations implement strategies to reduce environmental uncertainty and dependence by adjusting their own resources to market needs, but also by controlling resources from other organisations (Hillman, Withers, & Collins, 2009). In his theory of disruptive innovation,

Christensen (1997) argued that the reason why incumbents have difficulties addressing a disruption is that they tend to allocate most (if not all) of their resources to the changing needs of their most profitable customers, as the resource dependence theory suggests, while paying little attention to disruptive innovation from smaller players tackling an underserved customer base. Interestingly, Christensen's successive work (Christensen & Raynor, 2003) proposed innovation at the business model level as a solution for incumbents eager for strategies to combat (and embark on) disruption.

This line of thought has produced some of the seminal work on business model innovation. Johnson et al. (2008) investigated how successful firms have complemented their technological innovation with novel business models, allowing them to disrupt competition by reshaping the entire industry. Similarly, Markides (2006) emphasised the disruptive power of business model innovation, arguing that the source of such power comes from the difficulties in responding to novel business models, as most innovative business models do not make economic sense for established firms (Markides, 2006).

2.5.1.3 Organisational paths

Levinthal and March (1981) argued that organisational histories are dependent on a combination of events and subsequent strategic adaptations to those events, creating a trajectory of adaptation and development for the organisation, which Liebowitz and Margolis (1995) defined as path dependence. The influence of organisational paths has led to studies suggesting that path-dependent forces are crucial sources hampering the business model innovation process. This is the case for Chesbrough (2007), whose foundational work elaborated on the dilemma faced by managers when implementing business model innovation. While there is the need to innovate the business model, managers feel comfortable with the existing model, as they know its strengths, weaknesses and advantages (Chesbrough, 2007).

Schreyögg, Sydow, and Holtmann (2011) argued that failures in the process of innovating an established business model are due to self-reinforcing dynamics produced by strategic decisions taken in the past that formed the basis of the established business model such as cost structures and complementary assets. The novelties required to implement a novel business model diverge so much from past decisions that the models are either rejected or are relatively similar to the old ones (George & Bock, 2011). Authors have proposed ways to identify and address organisational path resistance hindering the innovation of the business model, such as Cavalcante et al. (2011) who provided a framework to identify path dependencies and resistance against the innovation process.

2.5.2 Key aspect of business model innovation

2.5.2.1 Conceptualisation of the business model innovation phenomenon

Business model innovation has been defined as the process of purposefully modifying the firm's core elements to alter its business logic (Bucherer et al., 2012; Trapp, 2014). For new firms, business model innovation corresponds to the design of novel business model configurations, whereas for existing firms it is a transformational process centred on resource rearrangement to implement novel business model configurations (Massa & Tucci, 2014; Zott & Amit, 2010). Other studies define business model innovation as a learning and experimentation process (McGrath, 2010; Morris et al., 2005; Sosna et al., 2010). Thus, there seems to be a general consensus that business model innovation is a renewal process which a business model goes through, rather than a fixed state or condition. In that sense, the analysis of business model change and innovation must focus on the motion and dynamism of the business model and the firm (Pettigrew, 1992).

The term business model "innovation" and business model "change" are sometimes used interchangeably, though acknowledging that change contains innovation proves to be a more practical approach. Crossan and Apaydin (2010) argued that not all business model change can be considered business model innovation, as the latter must result in a new-to-the-firm, new-to-the-customer and/or new-to-the-industry business model configuration. In that sense, business model innovation is perceived as a subset of business model change. Moreover, not all change in an organisation is considered a business model change; only changes affecting the core components of the model qualify as business model changes (Cavalcante et al., 2011). Thus, business model change is a subset of an even larger group representing organisational change.

2.5.2.2 Antecedents

Research on preconditions of business model innovation has analysed organisational elements such as structure, resources and competences (Comes & Berniker, 2008), capabilities (Saebi, 2015), managerial practices (Mezger, Bader, & Enkel, 2013; Trapp, 2014) and strategic ability (Doz & Kosonen, 2010) to implement novel business models within a firm.

Conversely, barriers of business model change include limited responsiveness due to path dependence (Chesbrough & Rosenbloom, 2002; McGrath, 2010), reduced mobility to achieve strategic flexibility (Bock, Opsahl, & George, 2010), ambidexterity (Smith, Binns, & Tushman, 2010), lack of commitment to experimentation (Chesbrough, 2010) and problems maintaining two or more business models in parallel (Casadesus-Masanell, Ricart, & Tarzijan, 2015; Christensen & Raynor, 2003).

On the motivations for business model change, some authors agree that most of the triggering factors are external to the firm, for instance, increased competition and economic recessions (Sosna et al., 2010). As for internal factors, there is evidence on the role of organisational emotional factors like encouragement, sense of freedom and playfulness in inducing business model innovation (Tankhiwale, 2009). Entrepreneurial orientation and opportunity recognition have also been recognised as key antecedents for business model innovation (Guo, Su, & Ahlstrom, 2015).

2.5.2.3 Internal dynamism

The concept of capabilities has set the grounds to study the process of business model innovation by observing the interactive dynamics amongst the business model components and amongst a firm's elements to understand change (Schneider and Spieth, 2013). From this viewpoint, reorganisation of a firm's capabilities is what drives business model innovation (George and Bock, 2011).

Petrovic, Kittl, and Teksten (2001) used elements of system dynamics to operationalise business models as dynamically complex systems to formulate business model change in terms of the internal dynamics within the model. Similarly, and using the concept of homeostasis, Batista, Ng, and Maull (2013) suggested that business models turn from disequilibrium to equilibrium states internally, and that a homeostatic behaviour drives changes towards the latter. Regev, Hayard, and Wegmann (2013) also used homeostasis to explain why certain firms seek to appropriate more value for themselves than for their customers when changing their business models.

2.5.2.4 Implications

Some work on the consequences of business model innovation has investigated the financial performance effects and organisational impact of business model innovation strategies in established firms (Aspara et al., 2010; Bock et al., 2010). Other studies have compared the advantages of business model innovation from product or technology innovations (IBM Business Consulting Services, 2006; Markides, 2006).

Apart from comparing the effects of business model innovation versus other innovation strategies, comparisons between the effects of different types of business model innovation have also been conducted. Hall and Wagner (2012) suggested that integrating strategic management and environmental issues positively affects performance, but the magnitude depends on the type of business model innovation pursued by the firm. Habtay (2012) investigated the various disruptive effects between different forms of business model innovations, such as technology-driven and market-driven business model innovation.

The positive effect of business model innovation on a firm's competitiveness has also gained important attention. Authors such as Spieth, Schneckenberg, and Ricart (2014) and Casadesus-

Masanell and Ricart (2010a) argued that business model reinvention increases the chances of internationalisation and further innovation, which makes a firm more competitive. Christensen (Christensen, 2006; Christensen & Raynor, 2003) has also highlighted the importance of business model innovation in enhancing a firm's disruptive capacity. On the negative effects of business model innovation, Bock, Opsahl, George, and Gann (2012) investigated the interplay between business model innovation and a firm's reconfiguration, and how such interplay affects a firm's strategic flexibility. They concluded that the negative effects on a firm's strategic flexibility are greater when reconfiguration is caused by business model innovation, than when reconfiguration requires business model innovation.

2.5.2.5 Typologies

There have been two main approaches used to classify forms of business model innovation and change: (1) identifying different types of business model change processes; and (2) identifying different types of (possible) actions within the business model change process.

For the first approach, the case study-based work of Taran, Boer, and Lindgren (2015) offers four types of processes from the 10 companies analysed: open proactive, closed proactive, open reactive, and closed reactive. Koen, Bertels, and Elsum (2011) presented three types of business model innovation: financial hurdle business model innovations, new value network business model innovations targeting existing consumers, and new value network business model innovations targeting non-consumers. Recently, Saebi (2015) investigated the mechanisms behind business model innovation and proposed business model evolution, adaptation and innovation as the three basic forms of business model development, arguing that each one require particular organisational capabilities.

For the second approach, Santos, Spector, and Heyden (2009) argued that the reconfiguration activities involved in the process of innovating a business model can take four basic forms: relinking the connections between business units, repartitioning the boundaries of the business units, relocating the business units and reactivating the set of activities for each unit. Cavalcante et al. (2011) proposed four types of changes that can be implemented to a business model: creation, extension, revision and termination. Similarly, Zott and Amit (2015) presented five stages: observation, synthesis, generation, refining and implementation. A key difference between Zott and Amit's work and the rest is that they incorporated the ideation activities as part of the business model innovation process. Table 6 describes the elements of the typologies discussed previously.

Author and year	Focus of analysis	Typology	Description	Dimensions for classification
Taran et al. (2015)	Types of business model innovation	• Open proactive	• Radical, high reach changes made to the business model of a new firm (spin-off, joint venture), thus, the risk of failure is reduced.	Radicalness (high, low); reach (high, low); complexity (high, low); risk (high, low)
		• Closed proactive	• Radical changes in the existing business model. The risk of failure is high given the effects on the entire business if the model fails.	
		• Open reactive (A)	• Incremental business model changes with high reach and low complexity. Low risk due to the limited changes to the core business.	
		• Open reactive (B)	• Radical changes made to a business model from an acquired business. Low reach and high complexity. Moderate risks.	
		• (Partly) closed reactive	• Incremental business model changes, with low reach and high complexity (as they tackle the core business). Low-moderate risks.	
Koen et al. (2011)	Types of business model innovation	• Financial hurdle business model innovations	• Business model innovations based on any type of technology (i.e. incremental, architectural, radical) using a low-price approach, tackling a new value network.	Technology (incremental, architectural, radical); value network (existing, new to the incumbent with existing consumers who are not yet customers, new to the incumbent with new non-consumers); financial hurdle (existing, lower than expected)
		• New value network business model innovations (consumers)	• Business model innovations based on any type of technology (i.e. incremental, architectural, radical) tackling a new value network based on an existing consumer-base not tackled before, maintaining an existing financial hurdle rates.	
		• New value network business model innovations (non-consumers)	• Business model innovations based on any type of technology (i.e. incremental, architectural, radical) tackling a new value network based on a new consumer-base, maintaining an existing financial hurdle rates.	
Saebi (2015)	Types of business model innovation	• Business model evolution	• Changes have natural, minor and incremental adjustments, few business areas are affected, done in a continuous fashion, the resulting model has no degree of novelty.	Planned outcome (adjustment, alignment, disruption); scope of change (narrow, wide); degree of radicalness (incremental, radical); frequency of change (continuous, periodic, infrequent); degree of novelty (none, novel to the industry)
		• Business model adaptation	• Changes align with the environment through either incremental or radical alterations, some business areas are affected, done in a periodic fashion, the resulting model may not be novel.	
		• Business model innovation	• Changes seek to disrupt the market through radical alterations, many business areas are affected, done infrequently, the result is novel to the industry.	
Santos et al. (2009)	Types of changes involved in business model innovation	• Relinking	• Changing the linkages between units performing the activities.	Action (regoverning, resequencing, insourcing, outsourcing, off-shoring, in-shoring, augmenting, removing); elements changed (transaction governance, order of activities, executor of the activities, location of activities, number of activities)
		• Repartitioning	• Moving the activities in or out of the firm.	
		• Relocating	• Altering the location of the units performing the activities.	
		• Reactivating	• Changing the set of activities carried out by the firm.	
Cavalcante et al. (2011)	Types of changes involved in business model innovation	• Creation	• Creating a new process. Challenges: Lack of resources, knowledge and skills, uncertainty and ambiguity.	Choices to manage the core standard repeated processes in a business model (creating, extending, reviewing, terminating)
		• Extension	• Adding new processes. Challenges: Controlled risks, minor resource shortages.	
		• Revision	• Altering existing processes. Challenges: lack of knowledge and skills, path dependence, inertia, resistance, uncertainty and ambiguity.	
		• Termination	• Terminating existing processes. Challenges: resistance.	
Zott and Amit (2015)	Types of changes involved in business model innovation	• Observe	• Examination of how stakeholders play their roles in the existing business model.	Phases of design processes (observe, synthesise, generate, refine, implement)
		• Synthesise	• Make sense of the observations by identifying market gaps and issues with value proposition.	
		• Generate	• Generate ideas for new business model according to the insights from synthesis.	
		• Refine	• Experimenting with the new model on a small scale and narrow scope.	
		• Implement	• Implementing the elements envisioned in the business model design.	

Table 6 – Key typologies of business model change and innovation in the literature

2.6 Business model development

This chapter has analysed the literature on business models, how business models are changed and how business models are innovated. These are foundational aspects for the study, as they support the main research question on the characteristics of business model development over time in established firms. This section reviews literature that directly addresses the research question, which explores the process of business model change and innovation as a continuous trajectory of changes implemented over time.

2.6.1 Foundational approaches to business model development

2.6.1.1 Discovery-driven perspective

Most of the work on organisational learning has adopted a developmental perspective to explore knowledge acquisition, information distribution/interpretation and organisational memory (Huber, 1991). In one study, McGrath and MacMillan (1995) proposed the concept of discovery-driven planning as the counterpart of conventional planning, arguing that while the latter formulates project success in terms of how aligned the project outcomes are from a pre-established set of parameters, the former assumes that the parameters are in a constant change as new information is assimilated. McGrath and MacMillan (1995) argue that the discovery-driven approach involves a constant translation of assumptions into knowledge as information from experiments is gathered and interpreted.

Based on work on discovery-driven strategies, McGrath (2010) argued that the process of implementing a novel business model involves a prolonged experimentation where the firm discovers and learns the most effective business model via testing and validating initial assumptions about ways to create customer value. In another study similarly influenced by the discovery-driven approach, Sosna et al. (2010) suggested that a trial-and-error learning process drives business model development over time, where the business model development process is characterised by an exploration phase followed by an exploitation phase. These two studies sought to bridge the theoretical gap on the dynamics behind business model reinvention and used organisational learning to show business model innovation as a developmental process that continuously unfolds over the course of the firm's life.

2.6.1.2 Organisational change and development

Organisational development studies rely on a long-term, ongoing perspective to understand how individual behaviour interacts with dimensions such as an organisation's physical setting,

organising arrangements, and technological and social factors (Porras & Hoffer, 1986). The field has built on this approach to provide several models depicting development as an ongoing alternation between incremental changes aligning with the context of the organisation, on the one hand, and fundamental changes aligning with future conditions and opportunities, on the other hand. Porras and Silvers (1991) referred to these two types of change as *organisational development* and *organisational transformation*, while Tushman and Romanelli (1985) and Gersick (1991) combined both types in the concept of punctuated equilibrium, defined as periods of convergence and incremental changes punctuated by periods of radical divergence.

This stream of organisational research is influencing recent studies on business model change, innovation and development. In one of the few examples available, Saebi (2015) conducted a theoretical study linking organisational studies with business models to propose her typology of business model development (see previous sections for more detail on this study). This body of knowledge on organisational change and development could advance the field of business model innovation by providing conceptual tools and models to assess the factors impeding and/or driving business model transformation and development over time (discussed in detail in Chapter 3). The limited amount of research linking organisational development with business model innovation has been a fundamental motivation for the theoretical framework and the longitudinal, process-based research design used in the study.

2.6.2 Key aspects of business model development

2.6.2.1 Process-based stages and types of development

Table 7 compares studies that have offered process-based solutions to the business model change question, adopting a development perspective inspired by work on organisational development (Poole et al., 2000). The table also indicates the type of classification, as well as the form of development adopted in each theory, following Van de Ven and Poole's categorisation of types of organisational change: lifecycle, dialectic, teleology and evolution (Van de Ven & Poole, 1995).

Author	Type of classification	Model of development	Stages / phases / types	Critique
Winter and Szulanski (2001)	Stages	Dialectic	• Exploration • Exploitation	Degree of change not considered, i.e. amount of experimentation versus exploitation
Morris et al. (2005)	Stages	Lifecycle	• Specification • Refinement • Adaptation • Revision • Reformulation	Fixed set of stages might not reflect nature of business model change

MacInnes (2005)	Stages	Lifecycle	• Overcoming technical issues • Overcoming environmental factors • Incorporating traditional business model factors • Incorporating strategic business factors	The model excludes non-technological cases
Chesbrough (2007)	Stages	Evolution/ lifecycle	• No differentiation • Some differentiation • Segmented • Externally aware • Integrative • Adaptive	More flexible than pure lifecycle view, but amount of change that leads to each phase is unknown
Sosna et al. (2010)	Stages	Dialectic	• Experimentation/exploration phase • High-growth exploitation phase	Magnitude of change not considered, i.e. amount of experimentation versus exploitation
De Reuver et al. (2013)	Stages	Lifecycle	• Development/R&D • Implementation/roll-out • Commercialisation	Fixed set of stages might not reflect nature of business model change
Schneider and Spieth (2013)	Types	n/a	• Development (continuous improvements) • Innovation (responses to environmental changes)	Does not consider sequence of changes that leads from one type to another
Batista et al. (2013)	Stages	Teleology	• Radical changes • Homeostatic (incremental) adaptations	Magnitude and sequence are considered but frequency and pace of change are unknown
Massa and Tucci (2014)	Types	n/a	• Design (creating a new business model) • Reconfiguration (altering an existing business model)	Subdivision is too general and static (design for start-ups and reconfiguration for existing firms)
Casadesus-Masanell et al. (2015)	Types	n/a	• Evolution (incremental) • Adaptation (various degrees) • Innovation (radical)	Magnitude and frequency of change are considered, but sequences of change that lead from one type to another are not

Table 7 – Existing frameworks of business model innovation using a developmental approach

There has been a recent trend in proposing typologies of business model change actions which focuses on listing the possible types or "moves" a firm can execute once the need for change arises. These studies do not answer the question of how a firm can recognise the particular moment in which change is required. Studies based on stages are more equipped to unveil the question of timing, as they tend to consider the sequence of events leading from one change event to another, and how this influences future events, while undertaking longitudinal analyses on rate and frequencies.

2.6.2.2 Selection of developmental models

In terms of model of development, the use of lifecycle models to explain change across time has prevailed, as shown in Table 7. There are two key characteristics of the lifecycle model: the predictable nature of the stages, and the irreversibility of the one-way progression of development (Miller & Friesen, 1984). Although this linear perspective might explain the events seen in late stages of product and technological innovation, there seem to be incompatibilities with the nature of business model innovation. Further longitudinal studies have shown that, while the late stages of

innovation show linearity, the early stages are governed by randomness and chaos (Bucherer et al., 2012) which occurs as decisions are taken and experimentations are made. As business models evolve through regular experimentation (Demil & Lecocq, 2010; McGrath, 2010), there is no reason to consider linear progression through stages as the most accurate (or the only) approach to explain the process of business model innovation.

In addition, lifecycle studies use a temporal window of observation that ends when the business model is successfully implemented. Process models that expand this analytical window to include multiple instances of a firm's business model are particularly rare. Given that extended periods of observation increase our understanding of how innovations emerge and develop across time (Kemerer & Slaughter, 1999), evidence from lifecycle-based studies can be complemented by using models that consider a series of iterations of a firm's business model; models that are capable of examining business model innovation as a permanent process continually unfolding across time.

Chapter 3 discusses in detail the assessment and integration of suitable models of organisational development into a framework to explore business model development.

2.7 Business model development and firm performance

This section discusses the literature on the relationship between business strategy, innovation processes and firm performance, and how such relationship has influenced subsequent research on the performance effects of business model development. This body of literature plays an important role in the design of research on innovation and change phenomena at the organisational level, given that: (1) the inclusion of a performance construct allows the identification of strategy content and process issues; and (2) studying business model development from a performance perspective allows discerning successful strategies from unsuccessful ones, given that business performance is the ultimate test of the effectiveness of any firm-level strategy (Venkatraman & Ramanujam, 1986).

2.7.1 Foundational approaches to business model development and firm performance

2.7.1.1 Transaction-based perspective

Transaction cost economics help explain how the adoption of organisational configurations that reduce the cost of internal transactions leads to increased performance, as pointed out by Milgrom and Roberts (1992). On the other hand, transaction costs explain how the development of novel transaction mechanisms and/or the implementation of existing transactions to link participants that

were previously unconnected represent new sources of value creation, which in turn leads to superior performance (Brandenburger & Stuart, 1996; Jarillo, 1988).

These two perspectives of how transaction costs economics explain business performance have influenced Zott and Amit (2007) on business model design and performance. The authors empirically tested the effects of business models configurations designed to maximise transaction efficiency and configurations designed to implement novel transactions on financial performance, particularly in entrepreneurial organisations.

2.7.1.2 Entrepreneurial orientation

An important stream of thought across business strategy, innovation and entrepreneurship proposes that an entrepreneurial approach is crucial for business success, particularly in dynamic, fast-paced environments (Dess, Lumpkin, & Covin, 1997). Embedded in this stream is the concept of entrepreneurial orientation, proposed by Lumpkin and Dess (1996), which captures the Schumpeterian view of entrepreneurial activity as the key mechanism of economic growth, and argues that a firm's entrepreneurial characteristics such as competitive aggressiveness, proactiveness, autonomy, innovativeness and risk taking are all contributors to business performance.

Aspara et al. (2010) built on the conception that an entrepreneurial orientation, such as exploiting new opportunities and experimenting with new ideas, leads to increased performance returns to explore the performance effects of business model innovation. They compared firms with a tendency towards innovating their business models to firms that tend to replicate previous successful versions of business models in other contexts, by measuring the financial performance gains once the business model strategy was implemented. They concluded that innovation leads to higher performance in small firms, while replication leads to higher performance in large firms.

2.7.2 Key aspects of business model development and firm performance

In one of the few empirical quantitative studies on business models available, Zott and Amit (2007) asked how the choice of a business model design affects a firm's performance, and found that designs centred on novelty, rather than efficiency, have a positive impact on performance. Zott and Amit (2008) also found that complementing such novelty-centred business model designs with product market strategies such as cost leadership also has a positive effect on performance.

In another study, the type of business model implemented was proposed as a mediator between management team composition and organisational performance, concluding that business models centred on the provision of therapeutics amplify the positive effect of an experienced top

management team in the performance of biotechnology organisations (Patzelt, Knyphausen-Aufseb, & Nikol, 2008). The relationship between the business model configuration chosen by a firm and its financial performance was also discussed by Chesbrough and Rosenbloom (2002), who found that four of their seven case study spin-offs achieved superior performance due to the selection of business models tailored to the particular offering of the spin-offs rather than the offering of the parent company.

Recently, Cucculelli and Bettinelli (2015) studied the effects of business model innovation on performance for a cohort of manufacturing SMEs. They found evidence of positive financial performance effects in business model innovators. Although some data was collected longitudinally, performance effects of multiple instances of changes over time, and effects of the particular dynamic characteristic of the change, such as tempo and depth of change, were not considered in this study.

2.8 Conclusions

The business model concept has emerged through contributions from supporters from a wide range of research and industry fields. The emergence of the business model innovation field of research has followed a similar path to many other fields in science, where descriptions, taxonomical categorisations, comparison with other constructs, structural elements and typologies dominated the research agenda in the early years. But once the limit of the value of static categorisation had been reached, then the functional aspects of business models, in terms of design and dynamics, were explored. Research interest in the dynamic aspects of business models has been growing, however, an understanding of the role of *change* as the enabler of business model innovation and development requires an increased number of empirical studies to answer dynamic-based research questions such as how and why novel business models emerge over time.

The literature on both static and transformational aspects of the business model is the basis for exploring business model innovation. Although the field of business model innovation research is still in a nascent stage, it is rapidly growing in size and relevance, and new contributions from a variety of research fields are constantly appearing. As the question of how the process of business model innovation is enacted by the organisation remains unanswered, research is now including detailed examination of the transition between an existing business model and a renewed version representing a fundamentally new model. Such examinations have, in most cases, used in-depth case studies to capture the interaction between the old and the new organisational arrangements resulting from the innovation process.

Nevertheless, the dynamism characterising modern business is forcing firms to innovate their business models on an ongoing basis to remain competitive. The challenges associated with a constant search for novelty are complemented by organisational complexities (Damanpour, 1996). Under this scenario, the mechanisms driving continuous business model innovation might not be revealed in a single business model transition. Thus, longitudinal observations in established organisations are fundamental to understand the interplay between the organisation's developmental mechanisms and business model innovation processes as the organisation develops over time.

While inspired by foundational business theories, the theory of business model development research is still fragmented and immature, which has delayed the advent of conceptual frameworks to study the dynamics of business model innovation in a longitudinal way (Demil et al., 2015). Some authors are revisiting the original linkages between business model innovation and organisational change and development, with the premise that theories of organisational transformation may help understand why and how business models develop over time. The use of longitudinal research designs to empirically test and propose models of business model development in existing firms will support the maturity of business model innovation as a research field.

Lastly, the literature review indicates that studies on the performance effects of business model development are scarce. There have been few studies presenting theoretical and/or empirical evidence of the positive effect of business model transformation on firm performance and competitive positioning. However, the role of the trajectories of business model development over time on a firm's success has remained unexplored. Incorporating a business performance construct into business model development not only helps determine the business model innovation strategies that lead to long-term organisational effectiveness (Murphy, Trailer, & Hill, 1996), but it also supports the contextualisation of findings on successful business model development processes in the practical domain, leading to the development of advice for managers (Venkatraman & Ramanujam, 1986).

Chapter 3: Theoretical Framework

3.1 Introduction

The theoretical framework presented in this chapter builds a conceptual platform that supports the systematic study of business model changes over time and provides guidance for the research design by developing propositions on the characteristics of the trajectories of business model development and providing direction on the type of questions addressed by the research methods.

The first section addresses the issue of conceptualising and dimensionalising business model change to facilitate longitudinal observation of the trajectories of development by defining the key dimensions of the business model construct. Building on systems theory and other mathematical principles, two organisational dynamic mechanisms that drive business model change over time are proposed.

The second section advances the conceptualisation of business model change established previously and explains how business models are developed over time. It integrates a series of concepts from the fields of business strategy, entrepreneurship, organisation studies and innovation to characterise the trajectories of business model change over time in four aspects: the agents and actions driving business model development, and the frequency, magnitude, and order of changes in the trajectories of business model development.

Moreover, a key output of the theoretical framework was the articulation of five propositions that guide the empirical component of this study. The propositions have been designed as single statements representing potentially testable components of the body of theories underpinning this investigation (Lynch, 2013). They are derived from the analysis and selection of theories, as the relationships between the different concepts from the theories were established. Whereas under the hypothetico-deductive approach hypotheses seek to statistically test relationships among variables, the propositions articulated in this study are extensions of the research questions, and they do not necessarily comprise formal variables. Given that the field of business model innovation does not own its own theoretical ground, the purpose of establishing a set of propositions is to link concepts taken from other fields within the business studies, to assist in establishing that theoretical ground. These propositions drove the methodologies and analyses of this study, which provided clues on whether the propositions were fully supported, partially supported or not supported. It is expected that these propositions and their assessment would stimulate future research, thereby evolving into hypotheses at later stages of empirical verification (Pawar, 2009).

3.2 Conceptualising and dimensionalising business model change

Developing an operational definition for a business model and business model change is a foundational step to examine the way business models are developed over time (Schneider & Spieth, 2013). The definition needs to be sufficiently generalisable so it can be implemented across a large sample of companies, fulfilling the research objectives in Chapter 1, but with a high degree of specificity to capture a firm's dynamics attributable to business model change and innovation while excluding other firm-related phenomena. The first of the two main elements in the theoretical framework describes a dynamic view of business model change that facilitates longitudinal analysis, by building on principles from corporate strategy, management, innovation, organisational change and systems theory.

3.2.1 The role of value in the business model concept

3.2.1.1 Business value

The concept of business models has been linked to economic value since its inception, in that business models reflect how value is generated and diffused among a network of suppliers and customers (Gordijn et al., 2000). The majority of business model definitions and conceptual themes are directly related to economic value (Abdelkafi et al., 2013).

In its pure economic sense, the value of a business is defined as the difference between the *benefits* of carrying out a business opportunity represented by the outcomes shared among the employees, shareholders, suppliers and customers, and the *costs* incurred while carrying out the business opportunity represented by the inputs required to produce outputs (Davies & Davies, 2011). As business value is distributed across the business stakeholders, the definition of value is stakeholder-dependent and means different things for different stakeholders. The business literature has largely concentrated on studying value generated for the shareholders and business owners (a predominant view within finance and accounting) and value generated for customers (particularly relevant across marketing, strategy and innovation). For instance, customer value is the difference between the perceived value of the product or service and the amount that the customer is prepared to pay (Bowman & Ambrosini, 2000), while shareholder value is the difference between earnings resulting from business activities and the cost of investment (Dial & Murphy, 1995).

Although both customer and shareholder value are crucially relevant for modern organisations, they are different. The business model concept is appealing because it considers both views of value as relevant and attempts to combine them into a single framework. Several marketing and corporate strategy studies have recognised the importance of the interplay between these kinds of value for

firm performance (Mizik & Jacobson, 2003). The business model concept implies the existence of a symbiotic relationship (not an "either-or" relationship or a parasitic one) between customer value generation, known as value creation in the business model literature, and shareholder value generation, known as value capture.

3.2.1.2 Relationship with value chain and value network

A connection with Porter's value chain principle has also been drawn by many authors, suggesting that the business model represents a more dynamic way of observing value creation among different actors (Jetter, Satzger, & Neus, 2009), as well as an extension of the value chain framework that incorporates a firm's revenue generation mechanisms. This suggests that the value chain concept is closely aligned with business models (Chesbrough & Rosenbloom, 2002; Markides & Charitou, 2004).

Porter's work on the value chain (Porter, 1985) showcased the importance of value creation for firms' performance. It portrays the way firms create value through a description of the chain of activities adding value to the product as it transitions from input to output stages. This perspective of value creation is compatible with business models. However, it visualises value generation as one-way, with no consideration of the transactional dynamics among value creating actors (Allee, 2000; Amit & Zott, 2001). The value creation logic for service firms might not be the same as for manufacturing as the activities and resources involved are different. Thus, value chain (initially ideated to suit manufacturing firms) does not fully explain value creation in all firms (Afuah & Tucci, 2000). The essence of the business model concept suggests a broader perspective of how firms create and deliver value for customers, as well as how capturing some of that value creates further value. Thus, the business model works as a value-generating system.

In terms of networks, the concept of value network presents a more dynamic perspective on value creation than value chain, as it considers the complex interactions between an arrangement of firms via connections that are reciprocal rather than sequential (Santos et al., 2009). Value networks have also been directly associated with business models, recognising that value creation is not solely encapsulated in a single firm, as a network of partners is required to create and deliver customer value (Richardson, 2008). Thus, the business model considers the ecosystem of actors around a firm as fundamental to the generation and appropriation of value. Not only is the selection of value network participants key, but the firm's positioning within its network is an essential component of the business model framework (Chesbrough & Rosenbloom, 2002; Shafer et al., 2005; Voelpel, Leibold, & Tekie, 2004).

3.2.2 Towards a tridimensional framework of business model change

If a system is defined as a set of components connected in such a way that acts as an entire entity, unit or whole (Becht, 1974), then, as in any system, a business model follows a holistic order facilitating achievement of value-related goals while enabling interactions among its elements. This order is established through three main dimensions, a view compatible with the business model definition suggested by Morris et al. (2005): an economic dimension covers the way the firm monetises its activities; an operational dimension covers routine activities, resources and partnerships needed to generate products and services; and a strategic dimension embodies decisions on which customer or market to focus on and how to serve them. In the case of the former, the term "strategic" might not be adequate to this study, as it implies that the routines and activities comprised in this dimension are a subset of the corporate strategy domain of the firm, which is not the case. The concept of product-market domain proposed by Miles, Snow, Meyer, and Coleman (1978) is a more suitable alternative, as it refers to the resources and activities supporting the definition of the market and the firm's orientation towards it (Miles et al., 1978), converging to what Morris et al. defined as strategic dimension.

There is a direct relationship between these dimensions and the business model as a value system. In the economic dimension, the objective is to capture and monetise value on the firm's side, while in the operational dimension the goal is to repeatedly create value for consumers. Finally, the product-market dimension seeks to connect the value produced to the right customer ensuring effective value delivery.

Author	No. elements and type	Elements associated with each dimension		
		Operational	Product-market	Economic
Timmers (1998)	4 conceptual elements	• Description of the various business actors and their roles	• Description of the potential benefits for the business actors • Architecture for the product, service and information flows	• Description of the sources of revenues
Hamel (2000)	5 components	• Strategic resources • Value network	• Core strategy • Customer interface	• Wealth potential
Stahler (2002)	4 conceptual elements	• Value architecture (agents involved in the value creation and their roles)	• Value proposition • Product/service	• Revenue model
Chesbrough and Rosenbloom (2002)	6 functions	• Define the structure of the value chain • Describe the position of the firm within the value network	• Articulate the value created for users by the offering • Identify the market segment • Formulate firm's competitive strategy	• Estimate the cost structure

Afuah and Tucci (2000)	8 components	• Connected activities • Implementation • Capabilities	• Customer value • Sustainability (competitive) • Scope • Pricing	• Revenue source
Osterwalder (2004)	9 building blocks	• Relationship • Value configuration • Capability • Partnership	• Value proposition • Target customer • Distribution channel	• Cost structure • Revenue model
Johnson et al. (2008)	4 elements	• Key resources • Key processes	• Customer value proposition	• Profit formula
Demil and Lecocq (2010)	3 components	• Resources and competences • Organisational structure	• Value propositions	• Revenues and costs (included as sub-elements of value propositions and organisational structure)
Al-Debei and Avison (2010)	4 dimensions	• Value architecture • Value network	• Value proposition	• Value finance
Teece (2010)	7 questions	• How should the product be presented as a solution to customer's problem, and not merely a novel item?	• How is the product a solution to customer's problem? • Do competitive offerings exist? • Is there a dominant design? • How large is the target segment?	• What might customers be enticed to 'pay' for value delivered? • What will it cost to deliver value to the customer?
Abdelkafi et al. (2013)	5 dimensions	• Value creation	• Value proposition • Value communication • Value delivery	• Value capture

Table 8 – Relationship between elements in influential business model definitions and proposed dimensions

Table 8 summarises relevant business model definitions, along with their elements and their relation with the business model innovation framework proposed in the study. Importantly, regardless of the research field in which the literature sits, or the level of analysis used in selecting the conceptual elements, the three dimensions in the business model definitions remain constant. This shows the key role of each of the three dimensions in the business model construct. Some authors have explicitly mentioned value delivery as a key dimension in business model frameworks. Others, including Chesbrough and Rosenbloom (2002), Osterwalder (2004) and Al-Debei and Avison (2010) omitted value delivery as a separate dimension; however, they included organisational aspects that support the interaction with customers and with markets (either physical or information-based interaction), so that the value created can be transferred, accessed and/or communicated to the customer.

3.2.2.1 Value creation

Value creation represents the operational dimension of the firm and refers to the firm's capacity to acquire resources, such as raw material, land, capital and labour, and transform them into products

and services. From a product perspective, this is a vertical process involving multiple players where the value created from one firm is the input for the value creation process of the next firm, and starts from the very basic raw materials and ends when the product reaches the final user (Brandenburger & Stuart, 1996). From a firm's perspective, value creation is less a vertical chain and more a set of repeated activities that the firm executes on a regular basis, conforming to a process that starts from the firm's acquisition of the raw material and ends when the product reaches the firm's customer. This collection of repeated activities is, then, part of the organisational routines (Becker, Lazaric, Nelson, & Winter, 2005). Thus, value creation is considered a dimension of a business model from this perspective. This does not mean, however, that the value creation dimension does not recognise the contribution of multiple players. In fact, the network of partners supporting the firm in the value creation process is a key component of any business model (Osterwalder et al., 2005). On delimiting the boundaries between the firm and the network of partners, Amit and Zott (2001) recognised that the business model construct spans firm boundaries, and suggested that, when it comes to value creation, the unit of analysis should not necessarily be the firm, but the set of transactions between the network of firms intended to create value to satisfy customer needs (Zott & Amit, 2007).

Two components of customer value have been widely identified in the business model innovation literature: perceived use value (product usefulness perceived by the customer), and exchange value (the amount that the customer is willing to pay for the use value) (Bowman & Ambrosini, 2000). From the customer perspective, value creation is achieved by either increasing the use value or decreasing the exchange value, as both alternatives increase consumer surplus. From the firm's perspective, increased value creation could potentially result in increased value captured by the firms and its partners (Priem, 2007).

The resource-based view and dynamic capability perspective help deconstruct the firm in terms of the bundle of resources and combination of capabilities comprising it (Teece et al., 1997). There are two distinctive classes of a firm's components within the value creation dimension: the *resources* employed and the *activities* carried out. Resources include employees, equipment, network of partners, competencies, and all those elements that are used (as a tool or raw material) to create the intended value. The activities include the operational routines, procedures, production processes, service delivering, and all those actions carried out by the firm to create the intended value (Afuah & Tucci, 2000; Demil & Lecocq, 2010; Johnson et al., 2008).

Importantly, there is a strict difference between the definition of value creation within accounting and finance and the definition within the business model innovation field, as well as the majority of the corporate strategy, management innovation and entrepreneurship literature. In accounting and

finance, value creation in commonly defined in terms of the value created to the shareholder, whereas the latter focuses on the value created for the consumer.

3.2.2.2 Value delivery

Value delivery represents the product-market dimension of the firm and refers to the transfer of the value created by the firm, and its partners, to the intended consumers, clients and/or end users, ensuring that the products and/or services created are physically or digitally distributed, accessible and successfully consumed (Demil & Lecocq, 2010; Teece, 2010).

From a marketing perspective, value delivery is also conceptualised as a competitive strategy that goes beyond the traditional objective of securing a sale, and concentrates on establishing a customer relationship in which the sale is only the starting point. Selecting and targeting the right customer is also a key action that must be included in a firm's value delivery strategy (Webster Jr, 1994).

For some business model innovation researchers, the value delivery dimension is implicit within the value creation dimension. However, according to Teece (2010), Matzler et al. (2013) and Rayna and Striukova (2014), value delivery involves a different set of firm-level elements and routines than those involved in value creation and value capture, thus, it must be studied and analysed as a separate dimension.

This distinction has become more evident recently as modern digitisation has enabled switching from physical to digital delivery of a firm's offerings, disrupting entire industries such as news media and music in the process (Smith et al., 2010; Vaccaro & Cohn, 2004). In addition, superior customer value delivery is emerging as a powerful competitive strategy and as a relevant managerial practice for modern businesses, which emphasises the importance of the value delivery dimension for business model innovation (Woodruff, 1997).

Webster Jr (1992) argued that the management of strategic partnerships, alliances and relationships between vendors and customers is vital to ensure a superior value delivery to customers. Under this view, the traditional marketing activities involving market-based transactions and the distribution of value are complemented with engagement activities and relationships with the customer. These sets of routine activities are embedded into a construct referred to as value *distribution,* and it is the first of two components of the value delivery dimension. The objective of these activities is to realise the economic transaction between the customer and the firm so that the transfer of the value from the provider (the firm) to the end user can be achieved. These routine activities and procedures involving the distribution of value and ongoing relationships with customers have also been considered as business model components by several authors using different terminologies such as

customer interface (Hamel, 2000), the pricing component (Afuah & Tucci, 2000) and distribution channels (Osterwalder, 2004).

Before the value is distributed to the customer and ongoing relationships with them are established, the firm must target the right customer (Afuah & Tucci, 2000), understand their needs (Shin, Kraemer, & Dedrick, 2012) and communicate the value that is being created to them (Abernathy & Clark, 1985), so that the right customer is enticed by offering them the goods or services that they demand (Teece, 2010). Allee (2000) argued that the knowledge exchange and communication channels are vital for value provision to customers, as it allows personalised offerings based on user preferences. In addition, the concept of value proposition, considered a key business model component by several authors, converges with this set of routine activities that the firm engages in as part of the value delivery dimension, as value proposition involves an articulation of the value being created in the form of a clear statement of how the firm fulfils customer demands (Chesbrough & Rosenbloom, 2002). In light of this, these routine activities to target market segments, and propose and communicate customer value form the second component of the value delivery dimension, referred to as value *selling.* These activities have been implemented in other business model frameworks under different names such as procedures for the identification of market segments (Chesbrough & Rosenbloom, 2002) and their quantification (Teece, 2010), value proposition (Demil & Lecocq, 2010; Johnson et al., 2008; Osterwalder, 2004) and value communication (Abdelkafi et al., 2013).

3.2.2.3 Value capture

Value capture represents the economic dimension of the firm and refers to the firm's ability to appropriate and monetise a portion of the value that has been created for and delivered to the customer, to generate profit to the shareholder and provide financial support for subsequent value creation and delivery (Mizik & Jacobson, 2003). To capture value, the firm must be able to simultaneously: (1) receive payments from consumers; (2) neutralise competitors' efforts to seize those payments; and (3) maximise the proportion of revenue directed to the firm before it is diffused across other members in the value system such as suppliers and resellers (Priem, 2007).

The nature of the routine activities that support value capturing varies; some activities support reducing costs, while others focus on increasing revenue (Foss & Stieglitz, 2015). This duality has its roots in the strategy literature, arguing that a firm has two basic choices to achieve competitive advantage: incur lower costs than rivals, or provide differentiated offerings at premium prices (Porter, 1991). The two different categories of a firm's elements in the value capture dimension are: *cost* management and *revenue* management. The former includes all those routines used to assign costs to products and services, as well as those supporting the control and monitoring of the cost

structures around the value that has been created (Hansen, Mowen, & Guan, 2007) such as cost control systems, cost related data, selection of suppliers and raw material based on costs, and operational procedures to reduce expenses (Chesbrough & Rosenbloom, 2002; Osterwalder, 2004). The latter is more demand-driven, and involves the routines and actions supporting the control of old and development of new revenue mechanisms to increase the monetisation of the value created for the customer (Talluri & Van Ryzin, 2006) such as digital and physical systems to collect revenues, arrangements with third parties such as sellers and retailers to increase revenue, activities to add extra offerings to the product and/or services being created, and marketing intelligence data to monitor demand trends (Afuah & Tucci, 2000; Johnson et al., 2008).

Apart from the potentially virtuous relationship with a firm's value creation and delivery capacity (the more value is created and delivered, the bigger the opportunity to appropriate more value), the ability to capture value is also conditioned by the context in which the firm operates. The concept of value slippage suggests that the value created by one firm can also be captured by third parties, diluting value captured by the firm and disseminating the amount of appropriable value among partners, stakeholders, competition and ultimately customers (Lepak, Smith, & Taylor, 2007). This occurs when the collection of valuable, rare, inimitable and non-substitutable resources allowing a firm to create value in unique ways is replicated and/or surpassed by competition (Barney, 1991). At the extreme, this situation benefits consumers, when the increased competition drives prices down and/or increases the amount of value generated for the same price (Peteraf, 1993; Srivastava, Fahey, & Christensen, 2001).

The concept of value capture from the business model perspective is more aligned with the concept of value creation typically used in accounting and finance. The underlying idea in both views is that the firm, and its partners, appropriates a portion of the value generated for the customer and transferred to the market; it is essentially value created for the firm and its shareholders.

3.2.2.4 The framework

As seen in Table 8, the three value dimensions of the business model are a constant in each of the key business model definitions in the literature. This section has presented a detailed description and interdisciplinary analysis of the value creation, delivery and capture dimensions, as well as their roles in the business model and the aspects of the firm comprising each dimension. In summary, this study conceptualises business model change as alterations in the value creation, delivery and capture dimensions constituting a business model. Figure 1 shows a representation of business model change as a function of changes in the value creation, delivery and capture dimensions, as well as the corresponding components of each dimension. The next section builds on

this framework to elaborate on the change mechanisms of each individual dimension and dynamic interactions among them.

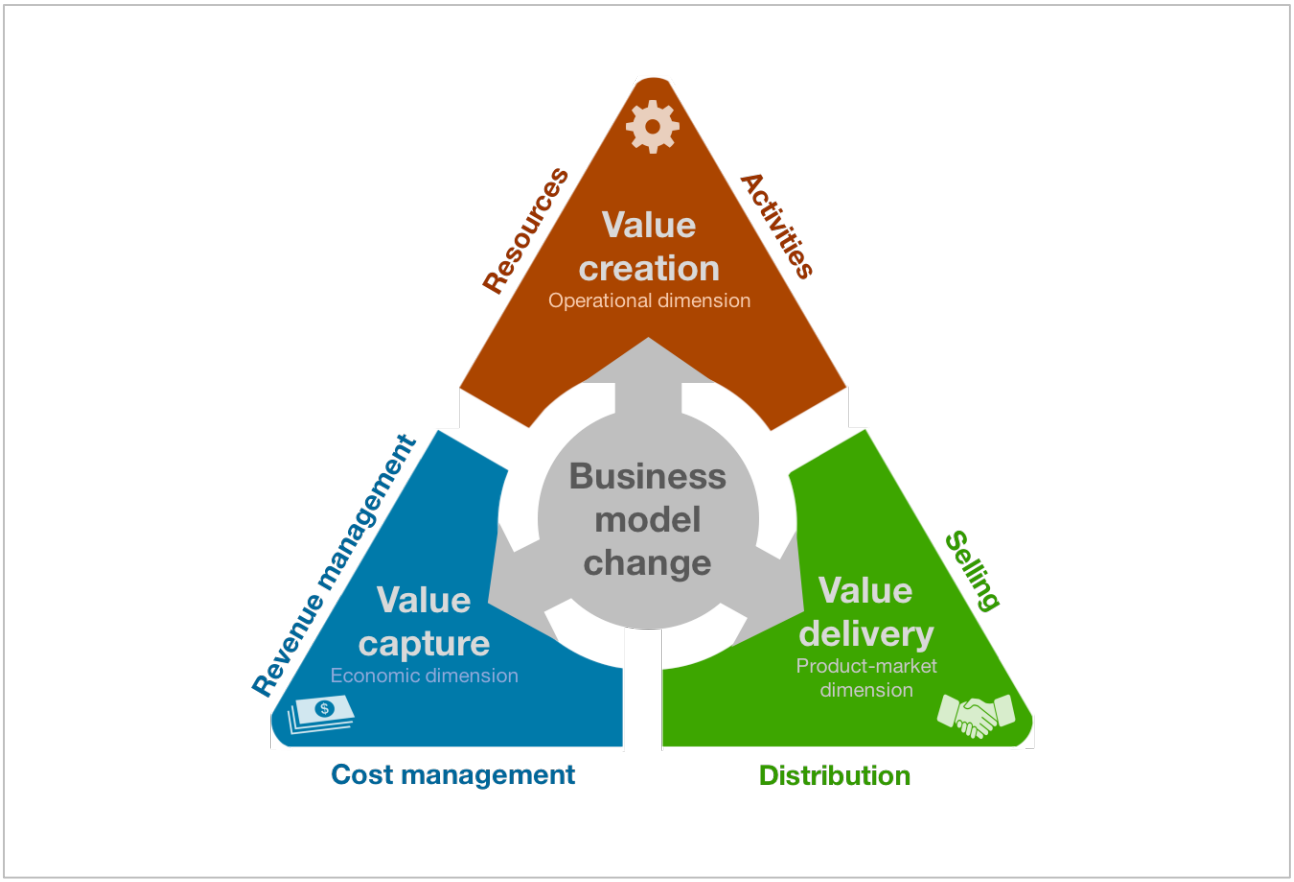


Figure 1 – Dimensionalisation of business model change based on three value-based dimensions and corresponding firm aspects

3.2.3 Dynamics of business model change

This section builds on the three dimensions of the business model to elaborate on the interaction between them and how the dynamics of this interaction enable business model change over time. The main argument in this section is that each value dimension affects and is affected by the other dimensions. The amount of customer value created by the firm conditions the amount of value that can be delivered, which in turn constrains the extent of value that can be captured by the value creators. Likewise, failure to optimise value captured by the firm affects its capacity to create and deliver value on an ongoing basis. Investigating these internal dynamics between the business model dimensions will enhance our understanding of the mechanisms driving business model development, given the role that internal dynamics caused by changes in routines play in driving continuous organisational change and development (Feldman, 2000).

This section explores two key perspectives to explicate the dynamics underpinning the business model change process to support the conceptualisation of business model change. The first perspective reviews principles from systems theory to explore the internal dynamics of the business

model as it is an open system, to explain action-reaction mechanisms at the whole-system level. The second perspective focuses on the mathematical concept of complementarity to explain the interdependent forces between the internal components of the system (i.e. the three dimensions), arguing that the patterns of coordinated changes among the three dimensions help distinguish business model changes from the rest of the change process within the firm.

3.2.3.1 A system-based perspective on business model change

An emerging perspective of the business model in the business model innovation field is the conceptualisation of business models as open and dynamic systems. Among all the interpretations of business models in the literature (see Chapter 2), a key theme appears to be gaining a slight notoriety: business models as systems of interconnected activities (Foss & Saebi, 2015). Studies that transcend the observation of a particular business model configuration at a point in time to explore business model change through time are now adopting the systems-based concept of business models. This concept is built on the Zott and Amit (2010) definition of a business model as a value-creation system of a firm's activities sharing strong interdependencies between each other. A study sharing this system-based perspective is Santos et al. (2009), who argued that business models are systems of activities connected with a system of relationships, and that examining the dynamics in such systems is the only way to understand how and why business model innovation occurs. In another example, Berglund and Sandstrom (2013) adopted a view of business models as open systems to propose that the interdependencies with the contextual network of partners is a key variable when exploring the mechanisms by which business models are innovated over time.

The conceptualisation of business models as open systems enables the implementation of methodologies used in systems theory, allowing sophisticated analysis on the dynamics of change. The interconnectedness between the elements of the business model denotes a complex and dynamic scenario caused by the interdependence among the dimensions, which cannot be analysed using traditional reductionist methods (Bak, 1996). The search for appropriate methods points towards systems theory, as it offers tools for exploring non-linear behaviours to model complex systems (Khalil, 1996), methods extended from thermodynamics that are useful for exploring emergent properties in ecosystems (Jorgensen & Svirezhev, 2004), and tools to examine change in entities operating under non-equilibrium conditions (Nicolis & Prigogine, 1977).

This study conceptualises business models as a system of firm activities and resources that are interconnected under the same goal (Zott & Amit, 2010) to create value in the form of products, services and other customer-related offerings (the value creation dimension in the framework); to deliver the value created to the targeted customer (the value delivery dimension); and to capture a portion of economic value back to the firm and its partners (the value capture dimension). Under

this concept, the interdependencies between the parts of the firm comprising the business model are what determines the real boundaries of the business model as a system (Geels, 2004) . Each business model varies in the complexity and consistency of the interconnections among the organisational elements of the model (Demil & Lecocq, 2010).

A key attribute of open systems is the principle of dynamic equilibrium. It refers to the regulatory mechanism enabling a system to deal with the tension produced by the search for internal stability needed to perform its functions, and the search for flexibility needed for environmental adaption, renewal and growth (Beerel, 2009; Dekkers, 2015). Reaching an optimal balance between both forces is crucial for the survival of the system (Bertalanffy, 1968).

Dynamic equilibrium is a familiar concept in management science, and it has been employed by organisation theorist to provide theoretical support to their empirical assessments of change in organisations (Johnson, Kast, & Rosenzweig, 1964). A recent example is Smith and Lewis (2011), who employed the principle of dynamic equilibrium to develop an equilibrium model for organisational theorising that proposes that simultaneous management of paradoxical forces (such as exploitation versus exploration, or efficiency versus flexibility) drives organisational sustainability over time (Smith & Lewis, 2011).

Far from reflecting an absence of change, dynamic equilibrium denotes a perennial search for stability to ensure survival of the system, through constant changes to the internal components of the system (Skyttner, 2005). Using the principle of dynamic equilibrium, change in a system is explained as a constant tension between negative feedback forces driving stability in the system and positive feedback forces driving variability and flexibility. Each of these forces induce change in the components of the system over time.

Under this perspective, and employing the principle of dynamic equilibrium to explicate change in the business model, the interplay between stability and variability forces provokes changes across the three dimensions comprising the business model (previously presented in this chapter). In the value creation dimension, the dynamic equilibrium mechanism produces changes in the amount or intensity of value being created. In the value delivery dimension, it produces changes in the capacity to deliver the value being created. Lastly, in the value capture dimension, it produces changes in the ability to monetise part of the delivered value back to the firm and its network.

Specifically, the set of activities, resources and business elements under each dimension are the targets for self-regulation and change. Each dimension influences the other. For instance, an increase in the amount of value being created from a business model alteration may force a firm to increase the amount of value delivered to the customer, which in turn enables an increase in the amount of value that can be captured. This converges with the fact that successful business models

have consistency among components (Demil & Lecocq, 2010; Morris et al., 2005; Saebi, 2015), as well as internal stability and coherence (Doz & Kosonen, 2010).

3.2.3.2 Complementarity theory and business model change

As discussed previously, business models can be seen as systems of complex interdependencies and interactions among a firm's elements. These types of systems are likely to manifest complementarities among their components (Ennen & Richter, 2010). The concept of complementarity states that a group of activities are complementary to each other if carrying out any one of them increases the return to carrying out the others; thus, the size of the effect of a system of complementary activities is greater than the sum of its parts (Choi, Poon, & Davis, 2008).

The mathematics behind the principle of complementarity have been used in accounting and economics to explain diverse phenomena such as the fit between an organisation's strategy, structure, resources and managerial processes (Cassiman & Veugelers, 2006; Dyer & Singh, 1998; Mohnen & Röller, 2005), where the use of complementarity theory has concluded that individual alterations in each element drive the entire system away from optimal levels and that coordinated changes in all of them increase performance (Milgrom & Roberts, 1995). In strategic management research, resource complementarity has been recognised as the main cause of success in strategic alliances and acquisitions as the synergistic forces between a firm's resources have a greater performance effect than the degree of similarity among the resources acquired (Harrison, Hitt, Hoskisson, & Ireland, 2001). Similarly, complementary assets are fundamental for the monetisation of innovative rents (Stieglitz & Heine, 2007). The complementarity framework has also been used to provide explanations on change management, competitive strategies, organisational choices, and leadership and culture (Brynjolfsson & Milgrom, 2013).

Complementarity can explicate the logic behind the actions implemented by firms who have successfully innovated their business models (Casadesus-Masanell & Ricart, 2007; Foss & Stieglitz, 2015; Mezger et al., 2013; Scupola, 1999). Foss and Stieglitz (2015) provide an example of the applicability of the complementarity framework to business model innovation. The authors presented a case of a firm that decided to reconfigure its business model amid performance issues and leadership crises. The first step by the firm was to decrease the number of product offerings, a part of the value creation dimension, which, in turn, achieved economies of scale in purchasing (the value capture dimension) by concentrating on a reduced number of suppliers. Concentration on product offerings, suppliers and purchases also led to cost reductions as the company relied less on offshoring and outsourcing (particularly from the product lines that were no longer part of the firm's offerings), action that ‚moved financial resources to digitisation activities in which the firm

achieved superior customer engagement through cooperating in design activities and service provisioning (the value delivery dimension) (Foss & Stieglitz, 2015).

A similar dynamic is found in case studies by Demil and Lecocq (2010), Sosna et al. (2010), Matzler et al. (2013) and (Pedersen & Sornn-Friese, 2015), where variations in a particular value dimension reinforced previous variations in other value dimensions, resulting in a synergistic configuration where each element reinforces the other. In Demil and Lecocq (2010), this reinforcing effect comes from the fact that certain elements of the firm constituting core components of the business model are permanently linked, such as resources and competencies and value proposition, thus the reinforcement between them is not just a mechanism for the creation of additional value, it is a must to ensure the consistency of the model. The case studies by Matzler et al. (2013) and Sosna et al. (2010) suggest that, although all the business model components are tightly coupled together, interdependence is particularly stronger for certain combinations of elements such as marketing strategy and revenue logic.

A strong complementarity among the components of a system comes at a price. Implementing changes without a coordinated order is a challenge as every individual alteration might negatively impact the performance levels of the entire system if not fully coordinated with the rest of the components (Simatupang, Wright, & Sridharan, 2002), which also requires a high degree of leadership and managerial direction (Stieglitz & Heine, 2007). Thus, major changes in a system require the involvement of all the complementary dimensions.

That value creation is influenced by and influences value capture (Priem, 2007) is another indication of the complementarities between the elements of the value system. Any change in a firm's activities responsible for value creation has an impact and is impacted by any change in both value capture and value delivery aspects. Thus, every element of a business model is systematically interconnected and complemented with the rest (Zott & Amit, 2010).

Evidence on the importance of complementarities among a firm's innovation activities for the performance of the innovation process (Cassiman & Veugelers, 2006) also provides clues on the existence of complementarities between the business model dimensions and the importance of coordinated changes in each one of them for the success of the business model innovation process.

In conclusion, from a complementarity approach, business model innovation is implemented in a way that involves a series of coordinated alterations on each of the value creation, value delivery and value capture dimensions of the existing business model, considering the complementarities and interdependences between them.

3.3 Explaining business model development

The second main aspect of the conceptual framework analyses the concepts available to explicate business model innovation from a developmental perspective, and integrates such concepts to build a conceptual platform supporting the study. It assesses how relevant principles from other fields are to business models, business model innovation and business model development.

Key to this study is considering business model change and innovation from a developmental point of view. Consequently, the adoption of theoretical and methodological tools that treat change as an ongoing process over time is crucial. Before describing the second part of the theoretical framework, it is important to review the differences in terms of the focus of analysis between research on business models, business model innovation and business model development, which is illustrated in Figure 2.

As discussed in Chapter 2, a large portion of the literature examining the business model has considered the static attributes of the concept. Such studies focus on establishing the boundaries between a business model and the remaining aspects of the organisation, as well as exploring the relationships between both. This foundational literature has adopted a cross-sectional view to explore the business model, mainly because a longitudinal approach does not add value as it deviates from the focus of analysis.

The remaining portion of the business model literature has adopted a more dynamic approach, compelled by the need to explicate how business models are changed. As a result, there is now a growing body of literature exploring business model evolution, emergence and innovation. The main focus of analysis of these studies is the process of transforming a business model from its current state to a fundamentally different model. This is illustrated in Figure 2 under the name of business model innovation.

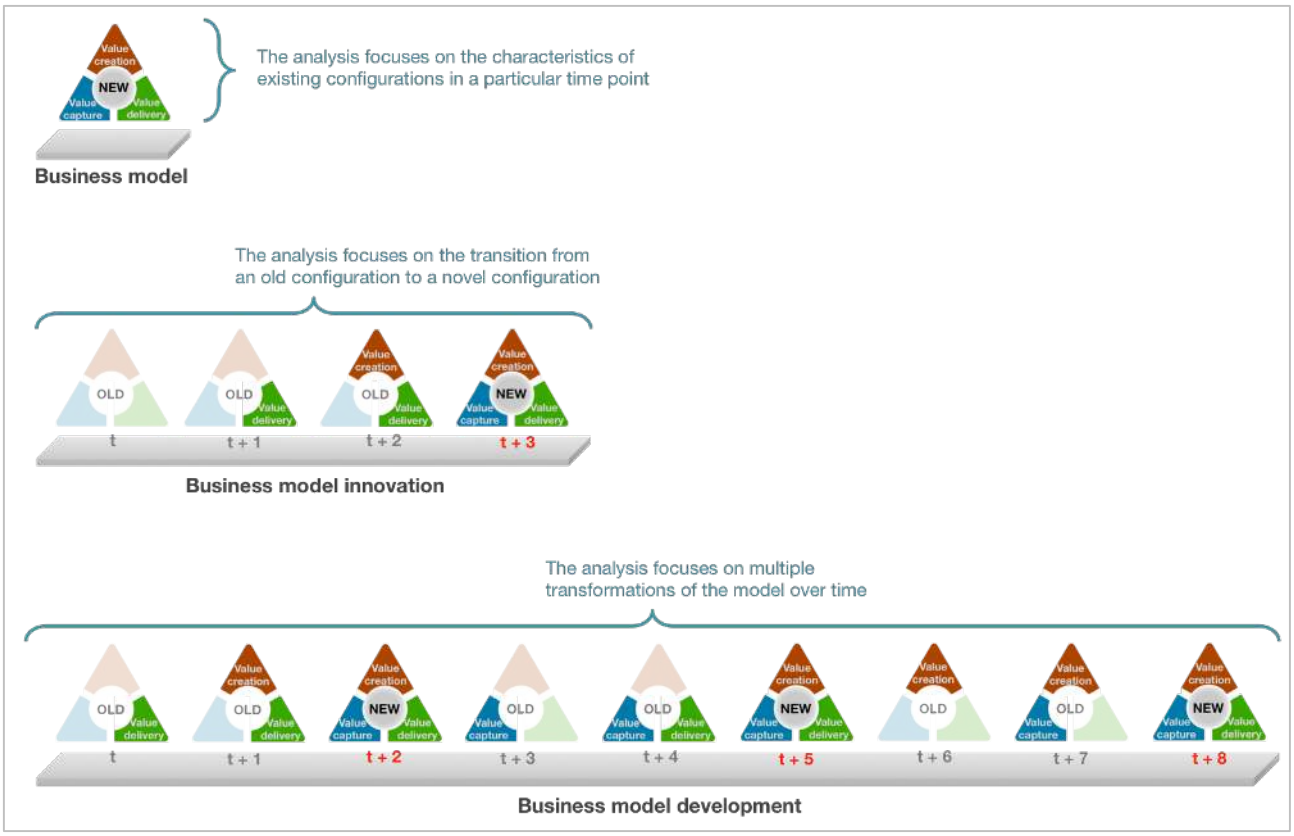


Figure 2 – Research perspectives on business model, innovation and development

Explaining the factors involved in the transition from one business model to another has never been easy given the many factors involved from the firm's capacity to anticipate the need for innovation (Cavalcante et al., 2011), the capabilities and resources required in the process (Bock et al., 2012), to the impact on the organisation and the network of partners involved in the process (Kastalli & Van Looy, 2013). Despite the complexity of the task, researchers have not had the need to examine events occurring after (or before) the transition to the novel model. As the main focus of analysis is on the transition, there has not been an apparent need to assess whether a firm becomes more efficient in changing their models over time through continuous learning (Pettigrew, 1990), or how each instance of business model change incrementally shapes the structure of the firm (Kieser, 1994), or how the occurrence of particular events throughout the life of the firm affects their capacity to implement future business model innovations (Kimberly & Bouchikhi, 1995).

It remains important to examine the "big picture" of a developmental trajectory across time to fully comprehend the true drivers behind a changing entity (Salthe, 1993). Empirical explorations of change as continuous processes rather than mere transitions from one state to another are a prerequisite for a holistic understanding of change in organisations (Weick & Quinn, 1999). The trajectories of historical events help search for patterns reflecting the time cycles and rhythms of an organisation, patterns that shape the emerging future of the organisation (Pettigrew, Woodman, & Cameron, 2001). When the entire collection of micro-level changes implemented over time is

accounted for, new organisational patterns emerge. A tendency towards stability, standardisation and bureaucracy in the short term might turn out to be over-written by a long-term tendency towards flexibility, improvisation, self-organisation and learning (Orlikowski, 1996). The lower level in Figure 2 illustrates this perspective, referred to as business model development.

To disclose the patterns of development of business models, it seems rational to look at how the phenomenon is investigated in the field of organisational development, considering the symbiotic relationship between organisations and their business models (Foss & Saebi, 2015). Van de Ven and Poole (1995) studied several models used in a variety of disciplines, from management and psychology to geography and biology, to explain growth and development, resulting in four basic types of models present in all the disciplines studied. Van de Ven and Poole (1995) argued that any theory explaining organisational development and change can be deconstructed into the four models: evolution (development of a population of firms through variation-selection-retention mechanisms), lifecycle (development of an individual firm through predefined stages of growth), dialectic (population development through mechanisms based on opposing forces and conflict resolution) and teleology (individual development through purposeful envisioning and achievement of goals). These four models of organisational development represent a theoretically appropriate starting point to discuss why and how business models develop over time.

The rest of this section explicates *why* business models change over time by applying each of Van de Ven and Poole's four types of organisational change, followed by a description of *how* business models change by assessing the following properties of the business model change process: frequency, magnitude and order.

3.3.1 Drivers of change in business model development

A key driver of business model change is the interplay of unintended versus deliberate actions (Lumpkin & Dess, 1996; Mintzberg & Waters, 1985). Alterations in a business model naturally emerge as internal consistency is achieved between the organisational structure and its business model (Demil & Lecocq, 2010). On the other hand, reinventing the business model allows a firm to proactively break free of the internal rigidity and to gain agility after years of accommodating its structure to the business model in place (Doz & Kosonen, 2010).

Similarly, the interplay between internal and population-level factors is also a key driver of business model change in established firms (Kimberly & Bouchikhi, 1995; Tushman & Romanelli, 1985). Given that the external conditions of a firm, such as customer needs, market regulations, technology and competitors' offerings, are constantly changing (Brown & Eisenhardt, 1997), renewing a business model is a necessary phenomenon, as it enables adaptation to the external environment

(Morris et al., 2005). On the other hand, purposive changes enable a firm to reconfigure its business model (and corresponding elements) into novel configurations with the capacity to disrupt and rewrite the rules of how business is done in an industry (Johnson et al., 2008).

Models that explain the drivers of business model development must consider both the proactive versus emergent actions, and individual versus population mechanisms as key dimensions of change. The four models proposed by Van de Ven and Poole (1995) were constructed by articulating change across these two dimensions, as shown in Figure 3. One dimension discerns the *agents* driving change (Baum & Singh, 1994): the collective, driving change through interactions between a group of firms; and the individual, driving change through the interactions between its internal constituents. The second dimension encompasses the *action mechanisms* driving change (Watzlawick, Weakland, & Fisch, 1974), and discerns the involuntary actions, implying that the steps taken in the change process are conditioned by a prescribed order for which the agent has little control, and voluntary actions, implying that the flow of change emerges from the agent and that there are no conditions on the nature of the steps. These two dimensions form a powerful framework to answer the "why?" question of business model change and innovation.

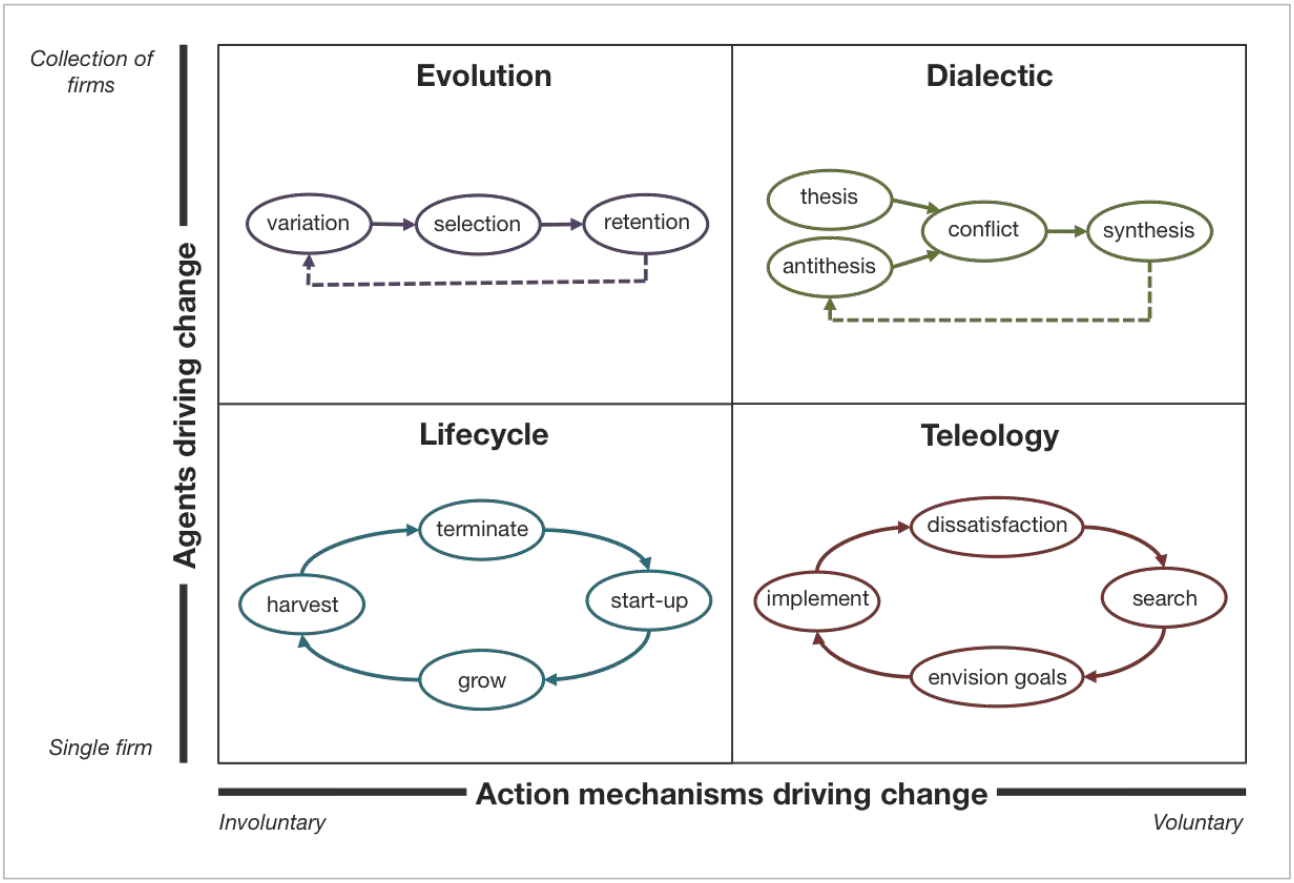


Figure 3 – Four basic models of development, adapted from Van de Ven and Poole (1995)

Importantly, Van de Ven and Poole recognised that a theory of organisational change could be built on the combination of any of these four basic models (Langley, 1999). Punctuated equilibrium (Gersick, 1991; Romanelli & Tushman, 1994) is an example of a model formed by the evolution and teleological motors of change, each one acting at the collective and individual level. The dimensionalisation of organisational change and development presented by Van de Ven and Pool has supported further discussions on change and development processes in a variety of research topics including innovation clusters (Pouder & John, 1996), strategic alliances (De Rond & Bouchikhi, 2004) and organisational change communication (Frahm & Brown, 2005). In business model development, there is no reason to discard the fundamental role that both type of agents (collective and individual) and both types of action mechanisms (involuntary and voluntary) play in influencing business model evolution and emergence over time.

3.3.1.1 Evolution: Involuntary actions in the collective level

This model of growth argues that events occurring at the firm's population level condition the developmental circumstances of each individual firm, which means that the innovation and change processes of one firm potentially affect the entire population of firms within the same industry or market.

Variation-selection mechanisms have been proposed as the means by which dominant business model configurations emerge at the industry level. Competition among firms and their business models drives *variations* until the market and customers *select* the right configuration that offers the maximum value for them (Nelson & Winter, 1977), which is *retained* as the dominant business model until new variations emerge (Bohnsack et al., 2014; Teece, 2010). There is a relevant body of literature suggesting the evolutionary nature of innovation process at the systemic level, which stems from the foundational concept of creative destruction (Schumpeter, 1942) and evolutionary theories of economic change (Nelson & Winter, 1982). This work suggests that mechanisms of retention, generation and selection of change drive the development of innovation systems (McKelvey, 1997).

The crucial aspect of the evolutionary model is the reason why firms decide to alter or vary their business models in the first place. Several external factors have been proposed as the sources of business model change in firms (Huber, 1991). For instance, Osterwalder et al. (2005) proposed customer opinion and the legal environment, De Reuver et al. (2013) proposed socio-economic trends and Sosna et al. (2010) proposed competitive intensity. In the business model literature, Chesbrough and Rosenbloom (2002) were among the first to recognise that technological changes in an industry, such as advances, new platforms and standards, are directly connected with business model reconfigurations, a perspective derived from the evolutionary economics literature where

technological innovation is seen as the dynamic catalyst of economic development (Etzkowitz & Leydesdorff, 2000). As evidenced by these factors, an everchanging external environment triggers new forms of business models that better adapt to the new conditions (Aspara, Lamberg, Laukia, & Tikkanen, 2011; Saebi, 2015; Tikkanen et al., 2005).

Importantly, in the evolutionary model, customers play a fundamental role in deciding the fittest business model, together with the survival capacity of the firms. The containerisation of the shipping industry is an example of business model development through evolutionary forces, where multiple business models such as port-port delivery, door-door delivery and provision of independent services competed in the same industry, and where the domination of the winning business model based on containerised shipping was gradual and adaptive rather than explosive and unpredictable (Pedersen & Sornn-Friese, 2015).

3.3.1.2 Lifecycle: Involuntary actions in the individual level

Although the evolutionary perspective might explain the mechanisms by which a successful business model emerges in an industry, it does not fully explain why some individual firms find it easier to innovate their business model than others. A single level perspective might be required to explore change at the individual level.

Under the lifecycle approach from Van de Ven and Poole's framework, the factors driving change operate at the individual level, meaning that it is not competition between firms that is responsible for change, but a prescribed process occurring within each one of them. In the lifecycle model, development is achieved in a series of determined steps of growth (Van de Ven & Poole, 2005).

Descriptions of the business model innovation process from a lifecycle perspective represent the dominant school of thought among business model authors. This preference seems to be inherited from the field of innovation management, where several authors had conceptualised innovation as a process with differentiated steps of growth (Rogers, 1962; Rothwell, 1994). In the lifecycle philosophy, business model innovation typically involves early phases of conceptualisation and design, and late phases of execution and/or implementation (Cavalcante et al., 2011; Frankenberger, Weiblen, Csik, & Gassmann, 2013; Zott & Amit, 2015). The idea of business models developing through predictable stages is still suggested in recent material on business model innovation (Joyce & Paquin, 2016; Muzellec, Ronteau, & Lambkin, 2015).

In some cases, the emergence of disruptive business models follows an organic trajectory, starting from the introduction of a differentiated configuration, developed as the firm grows in scale, maturing as the customer mass switches towards the model, and declining as the model is not able to satisfy new customer demands (Foss & Stieglitz, 2015; Malhotra, 2000b; Zott & Amit, 2008).

In other cases, however, alterations in business models are uncertain, unpredictable and constructive in nature, rather than constrained to a prescribed set of stages (Andries, Debackere, & Looy, 2013). In addition, lifecycle assumes that the right type of development for a firm is to grow, which sometimes proves to be wrong (Levie and Lichtenstein, 2008).

3.3.1.3 Teleology: Voluntary actions in the individual level

The teleology model, the third of Van de Ven and Poole's four basic models of organisational change, suggests a more flexible and constructive set of actions as drivers of change, arguing that the fundamental cause of organisational change is the sense of purpose and goal accomplishment (Van de Ven & Poole, 1995). The principle of equifinality, an end state that can be reached via multiple trajectories (Kast & Rosenzweig, 1972; Katz & Kahn, 1978), is implicit in this model, suggesting there is not just one single possibility to achieve successful business model configurations (Foss & Saebi, 2015).

Under the teleological approach, the entity itself takes actions needed to reach the final goal while monitoring its progress at the same time. This behaviour correlates highly with real-life practices of business model innovation in firms, which includes recognising the need for a change, searching for the right business model elements to change, testing and implementing the changes based on trial-and-error (Magretta, 2002; McGrath, 2010; Sosna et al., 2010). Two main factors motivate the voluntary search for a novel business model. On the one hand, firms engaging in major organisational transformations or technology adoption may realise that the current business model is incompatible, as it either requires a different set of resources and/or capabilities that will be discarded after the transformation, or the current business model is not aligned with the new goals of the firm, as experienced by many firms during the emergence of the Internet (Afuah & Tucci, 2000). On the other hand, the need for a model change arises as a strategic move to increase competitiveness by implementing an innovative, inimitable or more efficient business model, as has been the case for big players in computer and electronics manufacturing (Johnson et al., 2008) and finance services (Magretta, 2002).

As in lifecycle, factors driving change operate at the individual level, and the firm's internal situation does not condition the developmental circumstances at the population level. However, failing to acknowledge the influential effect of competition leaves out several business model change cases where the friction between two (or more) firms is the main cause of the emergence of novel business models. For this reason, the teleology model explains cases where constructive goal-seeking actions drive changes from the inside, but does not explicate cases where interaction between firms drives business model innovation. The latter cases are better explained by the dialectical model, the fourth type of organisational change in Van de Ven and Poole's framework.

3.3.1.4 Dialectics: Voluntary actions in the collective level

As in teleology, the dialectic model suggests a constructive view, though the driving mechanisms operate at the population level. It explains change as the result of opposing viewpoints between two or more firms competing against each other until a synthesised viewpoint emerges (Van de Ven & Poole, 1995). Examples of viewpoints include ways of satisfying customer needs, types of product improvements, and mechanisms for cost control. The dialectics principle is analogous to dominant design, the population-level mechanism by which technologies evolve in an industry and a crucial factor for a firm's survival (Suarez & Utterback, 1995). Authors have suggested that, similar to technology, business models evolve through the emergence of dominant designs (Teece, 2010), which implies that a dialectic model of change influences business model development.

There are examples of novel business models emerging through a process where opposing firms try to establish the status quo, engaging in a purposeful competition of successive reconfigurations in their business models until the appropriate configuration is achieved. For instance, in the IT services sector, the status quo has been the provision of IT infrastructure through selling and leasing, while service provision is an ongoing revenue source. Today, a cloud-based model where the infrastructure resides on the provider's side is becoming the new model but, importantly, this model is being refined by old players implementing their versions of the cloud-based business model (Desyllas & Sako, 2013; Ojala & Tyrvainen, 2011). Initially, the optimum model is not apparent; rather, the industry's "established" business model appears later on after multiple business model configurations compete against, learn from and influence each other (Teece, 2010), particularly when a new firm enters the market with a new business model that forces established players to adapt their business models (Markides, 2006).

Similar to evolution, the dialectic model builds on the view that factors operating at the population level condition the development of each individual firm, meaning that a single firm has the potential to affect the developmental processes of the entire population of firms within the same industry or market. Nevertheless, what guides the selection of the winning business model in an industry is not always the interaction between competing firms, as dialectic implies, but selection and retention mechanisms from the market side (Aspara et al., 2011). Just like the other models, the explanatory power of the dialectic form of change is amplified when combined with the other models.

3.3.1.5 Propositions for business model development

As indicated in the previous analysis, all of the four models of organisational development (Van de Ven & Poole, 1995) are applicable to business model development, and help explain change under different situations. Evolution explains business model development as a series of unconscious

alterations driven by environmental selection of the fittest business model among the firms in an industry. When the unconscious alterations are driven by an inherent organic growth of the firm, rather than population-level selection dynamics, lifecycle is the most adequate model to explain business model development. Teleology explains business model development as the result of deliberate and intentional actions towards change, driven by an internal search for individual (firm level) goals and efforts towards achieving them. When the deliberate actions toward change are driven by the competitive dynamics between business models from different firms within an industry or market, the dialectic model of change provides the most appropriate explanation of the drivers behind business model development.

Rather than classifying firms across these four models, firms' positioning across the two main dimensions implicit in the four models, the agents of change and the action mechanisms driving change, vary considerably across time given cyclic dynamism fuelled by creative and destructive forces (Schumpeter, 1934). Therefore, a conceptual framework explaining the drivers of business model innovation must include all of the four models of organisational change. The consideration of these two dimensions fully explains the mechanisms under which business models are developed across the various conditions a firm faces over time.

The dimension of the agents driving change can also be thought of as a measure of the factors influencing change. At one end, the dynamics created by the collection of firms within the industry interacting (i.e. competing, cooperating) with each other affect the way business models are developed over time. At the other end, the internal dynamics caused by the interactions between the organisational components within the individual firm are the key factor influencing business model development. Miller (1992) found evidence suggesting that firms that concentrate on achieving internal consistencies among organisational components for certain periods, while disrupting the internal harmony to adjust to changes in the environment, experience superior performance. Similarly, Kimberly and Bouchikhi (1995) argued that the trajectories of organisational development are equally shaped by both external and internal forces and Siggelkow (2002) indicated that, while pursuing organisational configurations offering an optimal fit among the internal components is associated with superior performance, ensuring effective transition from one optimal configuration to the next one to achieve external fit is equally crucial for firm performance. Therefore, it is proposed:

Proposition 1: For high-performing firms, both environmental and internal dynamics are likely to influence business model development at proportionate levels.

For the dimension corresponding to actions driving change, Crossan, Lane, and White (1999) argued that experts rely on unconscious recollection of previous knowledge to take action, whereas entrepreneurs are always engaging in a conscious search for new ideas and novel connections that support their actions; unconscious expert actions support exploitation, while conscious entrepreneurial actions support exploration (Crossan et al., 1999; March, 1991). Barrett (1998) suggested that the type of organisational creativity that drives success comes from a combination of deliberate and automatic cognition processes. Consequently, it is proposed:

Proposition 2: For high-performing firms, both deliberate and unconscious actions are likely to drive business model development at proportionate levels.

3.3.2 Frequency of change events

Investigating the timing of business model innovation is core to understanding the dynamics of business model development over time. The pace and rhythm of corporate change has been a central topic in several business-related disciplines, as the managerial repercussions of acknowledging the appropriate timing for strategic change are significant (Klarner & Raisch, 2012). Examining the rate at which business models change over time helps describe the overall trajectory of business model development (Pettigrew et al., 2001).

As is usual in social sciences, where a phenomenon remains unexplained, we look for analogies in the physical and life sciences. This also opens opportunities to leverage methodologies, techniques and algorithms developed for the sciences. This offers the rigour of the scientific methods as well as highlighting a pathway that can be followed.

Describing the trajectory of business model development as a visual representation similar to wave-like patterns caused by natural phenomena, such as sound, light and electromagnetic radiation, helps deconstruct business model change trajectories into distinctive parameters that can be quantified and analysed individually, just as signal processing techniques deconstruct a wave into distinct wave parameters: frequency, amplitude, velocity and wavelength (Narayanan & Saha, 2015). This study uses two of those parameters to describe the process of business model change: frequency and amplitude (the latter is discussed in Section 3.3.3). The frequency of business model innovation is the number of change events a business model experiences throughout the life of the firm or over a given period of observation. Knowing the number of changes in a specific window of time is equivalent to knowing the rate at which business models are developed.

The rate of organisational change and innovation has been explored in the literature by assessing the balance between instances of change and instances where no change is observed[1]. At one end of the change rate continuum, change unfolds in disconnected episodes across time, separated by long periods of equilibrium; at the other end, change occurs continuously across time, with only minor (or no) episodes of equilibrium (Weick & Quinn, 1999). Given there is theoretical and empirical evidence supporting both sides of the argument, investigations on the factors conditioning a firm's innovation processes towards one or the other side of the continuum remain highly relevant (Pettigrew et al., 2001). Likewise, the business model innovation literature does not clearly define where on the continuum the phenomenon sits, a situation that needs empirical investigation.

3.3.2.1 Episodic change in organisations

At the heart of the concept of episodic change is a close relationship with stasis, momentum and convergence, proposing that a firm's natural resistance to change, tendency towards maintaining previous strategic stances and the need for refining existing reorientations is what makes organisations develop through infrequent change events (Miller, 1993). Episodic change also implies that renewal activities occurring within an organisation are infrequent, and occur when the firm agrees to move away from equilibrium as an environmental and/or organisational misalignment increases in time (Pettigrew et al., 2001). An additional antecedent of episodic change is the firm's ability to maintain impulse, suggesting the change agents run out of energy to sustain change process for long periods of time (Pettigrew et al., 2001).

On the other hand, condensed periods of fundamental reorientations become a necessity, as the implementation of new strategies and structure erases the excesses, problems and deficiencies incurred during long periods of inertia (Miller, 1982). A different perspective suggests that reorientations after pervasive inactivity are the adaptive vehicle by which a firm can realign its strategy and structure to realise environmental and technological changes (Tushman & Anderson, 1986).

Most of the authors who have found evidence of episodic changes have referred to the term "punctuated equilibrium" to describe the way entities develop through a series of sporadic alterations that disrupt the equilibrium. Gersick (1988) studied the development of corporate work teams and found that the project's guidelines and frameworks remain untouched for most the project duration, and that progress is achieved by sudden changes made to the frameworks at particular points in time. The punctuated equilibrium theory establishes that organisations evolve

[1] The change-stability dualism to examine organisational change and innovation derives from the Schumpeterian perspective on entrepreneurial acts as disruptors of economic equilibrium, but also from the work of Lachmann (1956), who postulated the instability of market systems and a tendency towards disequilibrium.

"through convergent periods punctuated by reorientations which demark and set bearing for the next convergent period" (Tushman & Romanelli, 1985: 173). Several other models explaining technological development and innovation are derived from the punctuated equilibrium model. For instance, Utterback and Suarez (1993), despite recognising the significance of the punctuated equilibrium model in organisation studies, pointed out that the model might not explicate organisational change in general, which is why they limited their study on technological change and firm survival to the manufacturing industry. To assess the significance of the model, Romanelli and Tushman (1994) found empirical evidence on punctuated equilibrium-type of change in most of their sampled minicomputer producers. Specifically, the authors argued that the punctuated equilibrium model explained the patterns of change seen in organisational activities as they were altered over time. Importantly, recalling the conceptualisation of business models as a system of firm's activities to generate value, the punctuated equilibrium model, which is a special case of episodic change, is a prospect to explain business model change and development.

Evidence suggests that the factors driving organisational development by means of episodic change are relevant to business model innovation. Studies suggest that, once a business model configuration is altered, the organisation enters a period of convergence and inertia where the new business model is aligned with the organisation's structure, routines, procedures and control mechanisms (Demil & Lecocq, 2010). Achieving this internal fit which is crucial for the sustainability of the business, is a lengthy process as it may require subsequent adjustments until optimal levels of operational efficiency are reached (Doz & Kosonen, 2010). Additional business model transformations implemented within this period of convergence seem counterproductive for the stability of the business model and the firm (Morris et al., 2005). Although the firm might recognise the need for new transformations further on, the episodic view suggests that the amount of time the firm spends on actual business model transformations throughout the life of the firm is substantially less than the time spent at equilibrium. Johnson et al. (2008) recognised the infrequent nature of business model change, stating that, although business model innovation seems a necessity these days, the low proportion of successful cases of business model innovation makes it a rare phenomenon.

Radical environmental shifts, such as technological breakthroughs, regulatory changes, political events and economic crises, have the potential to affect several organisational elements at once, including those resources and activities destined to create, deliver and capture value. Thus, sudden environmental shifts are also drivers of infrequent business model reconfigurations that punctuate the periods of equilibrium (Saebi, 2015).

Despite evidence that business models develop through episodic change events, there are also reasons to assert the contrary. The view of equilibrium as the ultimate state of development and disequilibrium as an occasional phenomenon has been criticised by supporters of Lachmann's disequilibrium philosophy (Chiles, Bluedorn, & Gupta, 2007; Lachmann, 1956). In that sense, there is a slight incompatibility with business model innovation trends in modern economic circumstances; recent technological advances, the rampant rate of globalisation, and increased competition from developing nations are all contributing to a never-before-seen level of complexity. The pace of emergence of new business models is increasing (SustainAbility Inc, 2014), while new technology is forcing business model reconfiguration at an exceptional rate (SAP Center for Business insights, 2013). Disequilibrium is now seen as the permanent state of business models (Demil & Lecocq, 2010).

3.3.2.2 Continuous change in organisations

Several authors have criticised the accuracy of the punctuated equilibrium model in describing the realistic behaviour of firms operating under fluctuating environments. Brown and Eisenhardt (1997) argued there are firms that are much more dynamic than predicted under equilibrium-based models of development, and that such behaviours are better explained by models emphasising continuous change as the main competitive force. In contrast to episodic change, continuous organisational change is cumulative, evolving and ongoing (Pettigrew et al., 2001).

One of the most important drivers of continuous improvements is environmental adaptability. Under this perspective, ongoing variability augments the firm's capacity to adapt to changes in the environment, such as technological advances, increased competition and volatile demand, as the conditions in many industries are becoming more unpredictable (Leana & Barry, 2000). This is because the more dynamic an industry is, the bigger the need for continuous change for the firms operating in that industry (Brown & Eisenhardt, 1997).

From a product innovation perspective, the firm's ability to undertake more product adjustments in less time is crucial to product quality and project success, particularly when the firm operates in technology-intensive and dynamic settings (Kessler & Chakrabarti, 1996). In the presence of market and technical uncertainty, improvisation based on iterative and constant adjustments and product testing improves the performance of the entire innovation process (Brown & Eisenhardt, 1995). New product development is also recognised as a key driving force supporting continuous corporate change and the most efficient way to turn change into an ongoing and consistent process (Verona & Ravasi, 2003).

In business model innovation, one-off business model renewal is less and less a guarantee for established firms to develop a sustained advantage over time (Foss & Saebi, 2015). Research suggests that continuous business model adaptation is now becoming a necessity (Achtenhagen et al., 2013; Mitchell & Bruckner Coles, 2004), suggesting that business models develop by introducing ongoing alterations on each of the value creation, delivery and capture dimensions. Mitchell and Coles (2003) investigated business model change in a group of 100 fast-growing public companies, and found that most of them were fundamentally altering several components in their business models on a frequent basis. The authors also found that, no matter how novel a business model is, an excessive search for efficiency (and absence of change) leads to an increased inertia around the existing model, making it more difficult for the firm to innovate their business model in the future. This is aligned with other studies with similar findings and propositions (Doz & Kosonen, 2010).

Eisenhardt and Tabrizi (1995) emphasised that a continuous renewal of product offerings, the core of a firm's value creation dimension, is a key dynamic mechanism driving business model evolution, citing examples of top players in the IT sector who implemented novel business models configurations by constant adjustments to several components of their business models such as the nature of the products (e.g. electronic instruments versus computers), value propositions and customer segments targeted.

The strength of the continuous form of business model development lies in the firm's capacity to alter the course of their developmental trajectory, just like episodic change, through constant actions, as repetition amplifies the power of the incremental adjustments made to business model components over time, accumulating to the point that creates fundamental change (Mitchell & Coles, 2003; Weick & Quinn, 1999). However, not all organisations are fit for continuous business model change and innovation due to the need for non-trivial capabilities (Leih et al., 2014), ambidextrous traits (Chesbrough, 2010) and strategic agility (Doz & Kosonen, 2010). Excessive frequent change could also disrupt the stability and internal consistency required for business models to remain sustainable over time (Morris et al., 2015), thus, some firms have a voluntary resistance to change their business models as a mechanism for maintaining internal balance (Regev et al., 2013). Ultimately, there is a limit in the frequency and the speed at which firms grow, as there are dynamic restraints such as the acquisition of additional resources which constrain the pace of development (Penrose, 1995).

3.3.2.3 Propositions for business model development

Dean, Carlisle, and Baden-Fuller (1999) argued that both punctuated alterations and continuous change perspectives are equally effective in achieving sustained competitive performance. They

found evidence of positive effects on firms implementing both types of developmental trajectories, and even argued that most firms adopt both strategies: they adopt the punctuation approach only when continuous changes fail for them (Dean et al., 1999). This is true for business model development, as there is evidence of the episodic nature of business model innovation given the time it takes to achieve the desired configuration, and there is also evidence suggesting the disruptive power of business model innovation lies in multiple and serialised adjustments over time ensuring that a novel configuration is always in place.

These opposing views indicate that the rate, pace or speed of change is variable. In some instances, the number of changes in a period of time is greater than that of other periods. Sastry (1997) argued that, while turbulent environmental conditions impose a need for accelerated changes, successful transformation depends on the firm's capacity to regulate the pace of change to a level at which the corresponding strategic reorientations are appropriately implemented. An inability to maintain a balance between fast-paced, frequent change on the one hand, and slow, infrequent change on the other is also associated with organisational failure (Hambrick & D'Aveni, 1988).

From an organisational learning perspective, transformations involving different parts of the organisation occur at varying timing and speeds depending on the learning behaviour of each of the parts. Dodgson (1993) argued that learning capabilities in complex, established organisations are not necessarily uniform, meaning that different learning processes occur at different speeds. Thus, the capacity to manage the different learning processes with different attributes and speeds occurring within the organisation is key to success (Levitt & March, 1988).

In conclusion, as contextual and internal mechanisms forcing change occur at different rates (continuous in some circumstances, intermittent in others), a firm's success depends on its capacity to transform its business models and organisational elements at varying frequencies of change. Thus, it is proposed:

Proposition 3: High-performing firms are more likely to develop their business models at a variable (rather than constant) rate of change than other firms.

3.3.3 Magnitude of change events

As discussed in the previous section, investigating the amplitude of the trajectories of business model development is a fundamental step in describing how business models are innovated over time. In addition, classifying innovations according to the magnitude of novelty (i.e. incremental and radical) is useful to understand innovation adoption and development at the firm level (McKelvey, 2014)

In the physical sciences, amplitude is commonly known as the maximum displacement of a wave pattern or particle from its equilibrium position (Narayanan & Saha, 2015). The concept of amplitude is the magnitude of a business model change event compared to the equilibrium position, which is the absence of change. In other words, the magnitude of a business model change event represents the radicalness of such event.

Under this perspective, and assuming business model reconfiguration is a process involving different degrees of radicalness (Massa & Tucci, 2014), the disruptiveness of a business model change must be a function of the business model dimensions (see Section 3.2.2); a change is more radical as more of a firm's elements are involved in the change process, as well as the shorter the time window in which the entire change process is completed.

The following section examines the evidence of business model innovation and change as both radical and incremental innovation process. The reconciliation of the two is vital to build a framework that defines business model innovation and change over time as the alternation between the two magnitudes of change.

3.3.3.1 Radical innovation and change

Radical innovation is at the extreme of the innovation effect scale. It is a type of innovation that disrupts and destroys firm competencies, in contrast to the enhancing nature of incremental innovations (Tushman & Anderson, 1986), through the introduction of new knowledge that makes the existing knowledge obsolete (Abernathy & Clark, 1985).

Radical change is the vehicle by which firms explore new business alternatives, as well as a proactive mechanism to take advantage of new elements emerging within an industry, from technical elements to the recognition of an unserved customer segment (Benner & Tushman, 2003; Stoddard & Jarvenpaa, 1995). For this reason, radical change and innovation usually come from new entrants trying to disrupt an established set of competitors by providing fundamentally new offerings or exploiting new ways of creating value (Utterback & Suarez, 1993).

Radical organisational transformations do not always emerge as the organisation seeks to undertake new business avenues and seize opportunities. Firms often find themselves bound to radical reconfigurations when competitive advantage cannot be sustained by following the old ways of doing business and business viability is compromised (Francis, Bessant, & Hobday, 2003). Changes in technological paradigms force radical organisational restructuring (Greenwood & Hinings, 1996), as many firms depend on certain technological platforms to create, deliver and/or capture value (Francis et al., 2003).

In terms of the breadth of the changes a business model can be subject to, the framework proposed in this study suggests that disruptive transformations are and will always be present in business models, as they allow a firm to alter a market's "rules of game" in their favour. Christensen (Christensen, 1997), the promoter of the idea that disruptive innovation is key to business success, argued that business models are central elements of disruption, as any technology-related problem will always have a market counterpart seeking to set the correct value logic to match technology to the right market. (Christensen & Raynor, 2003) suggested that the real disruption in business model innovation comes from the exploitation of sources of value generation that diverge from the business model a firm has in place, and the bigger the departure a change represents from an existing business model, the bigger the potential disruption.

Many argue that business model innovation is a radical process, given the systemic nature of the changes implemented (Teece, 1996; Voelpel et al., 2004). While other types of innovation and organisational changes, such as redefining a market positioning, require routine strategies, business model innovation requires radical or transformational strategies, as evidenced by the number of organisational aspects that need re-evaluation when switching to new model configurations, as well as the risks associated with altering core business components (Yip, 2004).

Adding to the risks associated with radical business model change are the difficulties in managing the restructuring of a firm's activities and resources given the complex interdependencies between the various organisational elements, a problem that is usually modelled with complex systems techniques such as the NK model (Levinthal & Warglien, 1999). These factors create challenging conditions that ultimately force firms to avoid major restructuring in their business models (Cavalcante et al., 2011), especially when the logic of the new model requires new resources, activities and/or partners. Radical change becomes more demanding for established firms, given that it is easier for start-ups and young organisations to alter their structure to accommodate new, different business models. Despite the barriers, there are numerous cases of established firms overcoming the difficulties and implementing major restructuring of their existing models (Chesbrough, 2010). Thus, business model development through radical alterations may not be the standard for all types of organisations, but it certainly describes business model developmental trajectories seen in certain existing firms.

3.3.3.2 Incremental innovation and change

In contrast to radical transformations, incremental change represents a competence enhancing type of development (Tushman & Anderson, 1986) that relies on a firm's existing capabilities, history and knowledge learned from the past (Kim, 1998). Incremental growth focuses on gradual improvements of existing technologies and products, thus, it is considered a market-stimulated

growth strategy (Ettlie, Bridges, & O'keefe, 1984). In some circumstances, firms are particularly attracted towards incremental alterations, as more radical departures from the status quo usually require more time (Kessler & Chakrabarti, 1996). In other cases, firms embark on incremental innovation to secure and strengthen their competitive positioning, which is why incumbents are more likely to implement incremental change than start-ups (Afuah & Tucci, 2000).

One of the benefits of incremental change is that organisational change demands time and resources, hence, it is more efficient and manageable to introduce small additions at a time (Stoddard & Jarvenpaa, 1995). In environments characterised by cost-reduction pressures and incremental technological progress, such as certain manufacturing industries, organisational development by means of incremental change is a commonly used growth strategy as the focus is on improving efficiency (Benner & Tushman, 2002).

Incremental change leads to efficiency gains, increased performance, decreased costs of technological and product innovations, and accelerated commercialisation of innovations (Benner & Tushman, 2002), which, in turn, strengthen customer relationships and market linkages (Abernathy & Clark, 1985). Once a dominant product or technology design emerges, further development and progress is achieved through incremental alterations (Tushman & Anderson, 1986).

Some authors agree that the success of novel business models is the incremental manner in which they are reconfigured and/or implemented. When the dominant business model configuration is established in an industry, firms typically adopt the configuration, but then introduce incremental adjustments to gain a competitive edge and reduce the chance of imitation (Afuah & Tucci, 2000). Evidence suggests that a combination of incremental change and high breadth, that is, minor adjustments in all or most of the components of a business model, reduce the firm's probability of failure (Taran et al., 2015). These types of incremental, broad business model changes normally require more close involvement from top management leadership (Foss & Stieglitz, 2015). Nevertheless, as this approach represents a less risky alternative than transformational business model alterations, it becomes appealing for established, particularly complex firms.

Advocates of the experimental, trial-and-error nature of business model innovation recognise that incremental alterations made over time are key to successful business model renewal (Sosna et al., 2010). Given the optimal business model configuration is not achieved instantly, the introduction of successive incremental adjustments is crucial for the development of a business model as it allows the firm to experiment with recalibrations of a business model's elements and rapidly incorporate the lessons learned once the resulting model configuration has been tested in the market (Dunford, Palmer, & Benveniste, 2010; McGrath, 2010; Winter & Szulanski, 2001).

Incremental adjustments are also an important form of business model change as they allow the business model to naturally adapt to ever-evolving external environments through a refinement and extension of the configurations in place (Chakravarthy, 1982; Henderson & Clark, 1990; Saebi, 2015). Adaptive business model changes also have a positive effect on organisational learning processes, as they provide time to better comprehend history and to encode experiences into routines through repeated behaviour (Levitt & March, 1988; Lumpkin & Lichtenstein, 2005)

Regarding the disadvantages, development through incremental change might be too slow and fragmented for the pace of change outside the firm, resulting in the firm being trapped between the old and the targeted configuration (Miller, 1982). Although the introduction of small changes requires less effort and is time efficient, a potential risk in relying too much on incrementalism is that major business model changes with long-term profit might be discarded and/or overlooked (Rothwell, 1994). Incremental adjustments may also strengthen the dominance of the current business model configuration, hampering the firm's ability to anticipate and recognise circumstances that require fundamental business model transformations (Chesbrough, 2010).

3.3.3.3 Propositions for business model development

Rather than a dichotomous classification, determining the magnitude of a business model change requires a continuum scale ranging from radical alterations to incremental adjustments (Green, Gavin, & Aiman-Smith, 1995). However, like technological innovations, the distinction between radical and incremental business model change events is easier to intuit than to measure, thus, it is more common to evaluate the two extremes as discrete classes (Dewar & Dutton, 1986)[2].

Tushman and Anderson (1986) noted that technological change affecting the environmental conditions surrounding a firm occurs both incrementally and radically. When the technological change is radical, established firms must introduce fundamental transformations, as the competences employed for value creation are not relevant any more. When the technological changes are incremental, established firms must improve the competences they use to create value, which results in incremental organisational adjustments (Tushman & Anderson, 1986). This also means that firms' ability to align with external technological changes depends on their capacity to dynamically deal with change at different levels of radicalness, which, in turn, requires the development of the right type of capability according to the environmental conditions (Hine, Parker,

[2] Henderson and Clark (1990) on architectural innovations provide fundamental leads on the type of changes in the middle of that continuum, but identifying *architectural* type of change in business models has proved to be difficult for the research design. This incompatibility is because the concept originates from product and technological innovations. While identifying architectural and modular changes in a product or technology is generally straightforward, determining whether a business model change involves a change in the way the dimensions are linked rather than in the dimension per-se is more complex.

Pregelj, & Verreynne, 2014). This suggests that firms that successfully adapt to both radical and incremental technological changes, and with the right set of capabilities to accommodate the required type of change, are able to reconfigure their business models in both an incremental and radical fashion over time (Dunford et al., 2010). Specifically, it is proposed:

Proposition 4: High-performing firms are more likely to develop their business models through a similar number of radical and incremental changes than other firms.

3.3.4 Order of change events

The fourth feature of business model innovation proposed and explored in the study is the ordering of the events and actions in the trajectories of business model development. To fully characterise successful business model innovation processes, the questions of how *frequent/infrequent* and how *radical/incremental* business model changes are must be complemented with a question on how *ordered/unordered* the succession of events is leading to business model innovations (Amis, Slack, & Hinings, 2004).

From a developmental perspective, exploring the sequence of events in change processes is recurrently present in process-based studies from organisational science and social science, and its importance is in the potential theoretical and managerial implications of identifying particular sequences of actions associated with preferable outcomes (Abbott, 1990). McKelvey and Lassen (2013) argued about the importance of resolving tensions between creativity and structural order for knowledge intensive businesses, implying that both sides of the equation (ordered change versus unstructured change) are usually manifested across the innovation processes. Recognising the importance of exploring the ordered (or unordered) nature of innovation activities within an organisation, the next section assesses whether business model change is the result of a structured sequence of actions, or a collection of random actions.

3.3.4.1 Innovation and change processes as ordered sets of actions

Evidence suggests that the steps in organisational change and innovation processes at the firm level are taken in a certain sequential and linear order, and that the order influences the success of the change strategy (Pettigrew et al., 2001). For instance, it has been suggested that a sequential type of change, where the central, high-impact elements of the organisation are altered early in the process, is favoured by many firms as it sets the ground for further changes (Amis et al., 2004). In another example, Greiner's model of development suggests that creative activities tend to occur in the early phases of development, while late phases are centred on efficiency and control (Greiner, 1972).

Organisational change, innovation, strategy and entrepreneurship studies suggest that the order in which sequential events unfold matters for firms' performance and innovation outcomes. When an organisation finds a path of actions that proves successful for a particular task, such as implementation of novel ideas, shifts in strategy or organisational adaptation, it tends to revive such paths in further opportunities, even in the absence of the original event that caused the identification of the path in the first place (Buttriss & Wilkinson, 2006). This behaviour has been found in several studies, arguing that the organisation "remembers" particular orders of actions that have proven to be successful in the past (Glynn, Lant, & Milliken, 1994).

Evidence of ordered progressions of actions has also been found in technological innovation processes. Sabherwal and Robey (1993) assessed the events in the development of information systems and developed a taxonomy of six sequences of events observed in their sampled firms. While the study concluded that there is not a single predetermined path of actions, it also suggested there are strong similarities among the paths observed, which were similar enough for the authors to group. There is some degree of order in these developmental processes, thus, the mechanisms driving the whole developmental trajectory are not entirely random and chaotic.

There is evidence that business models develop through ordered and sequential events. Cule and Robey (2004) proposed a developmental model for business models with three types of sequential transitions: creation, in which the need for a new business model is recognised and actions are taken; destruction, in which the initial actions towards changing the model are discarded due to conflict and experimentation with different components, and alterations take place; and unification, in which the best experiments are selected and a unified model is established. Similar frameworks focus on explaining the mechanisms of business model development by establishing a linear trajectory of actions. According to those, business model innovation starts with the firm's recognition of issues with current models and ideation of a new model, and ends with implementation and monitoring (Zott & Amit, 2015).

3.3.4.2 Innovation and change processes as unordered sets of actions

Opposing the orderly progression of events is that changes in organisations and in innovation processes are non-linear, chaotic and unordered, implying that the complexity of such processes results in parallel and overlapping actions. There is evidence suggesting that, no matter how radical a reorientation is for an organisation, it is likely that reversals, oscillations, delays and related difficulties will appear as the change process unfolds (Amis et al., 2004).

In a study on organisational change processes in the government sector, Stevenson and Greenberg (1998) found that decision making processes in government institutions are characterised by

unorderly progressions of steps and actions, concluding that policy development is achieved by a series of non-linear progression of events where multiple actions are taken in parallel. The authors argued this is an indication that change actions are not always directed by well coordinated and rational plans (Stevenson & Greenberg, 1998).

Cheng and Van de Ven (1996) reported empirical evidence suggesting that innovation processes are characterised by the presence of chaotic progression of events with no apparent order. Specifically, the authors found that chaotic patterns are mostly seen in early phases of innovation development, where discovery and experimentation prevail, whereas the later phases comprised more linear and ordered sequences of events where learning and refinement take place (Cheng & Van de Ven, 1996).

Whether change events occur in a temporal ordering or not also depends on the way discovery and learning processes are conducted in an organisation. Given that many innovation processes involve a constant search for solutions to either technical problems or unsolved market needs, not all firms experience a sequential ordering of actions during the search for appropriate solutions (Leonardi, 2011).

The informal nature of activities in the early phases of business model development (Sabatier, Mangematin, & Rousselle, 2010) suggests that, just like the early chaotic phases in other forms of innovation, the business model innovation process is built from an unordered progression of events in which a preliminary version of the model configuration is sketched. An additional indication of the unordered and non-linear nature of business model development is the influence from multiple partners and suppliers, on top of the influence from multiple actors within the firm. This situation causes an intricate and complex flow of influences that questions the existence of a linear and ordered progression of actions driving business model change (Mason & Spring, 2011).

3.3.4.3 Propositions for business model development

As discussed previously, there is sufficient evidence that business model development is either achieved by particular linear sequences of events, or by an unordered and chaotic arrangement of actions unfolding over time. The firm's capacity to reap financial benefits from business model innovation to achieve success depends on the ability to learn from previous restructuring actions that have proven to be successful so that the actions can be repeated over time, but also depends on the firm's ability to experiment with emerging restructuring actions when past actions were unsuccessful (Cyert & March, 1963; Greve, 1998). For this reason, it is proposed:

Proposition 5: High-performing firms are more likely to develop their business models through a similar number of temporally ordered changes and unordered changes than other firms.

3.4 Summary

The theoretical framework supporting the research concentrates on two key aspects of business model innovation: (1) building an operational definition of a business model that facilitates longitudinal observations of change; and (2) providing explanations on how business models are developed across time.

On the first aspect, given the fundamental role of business value to the business model concept, it is appropriate to deconstruct the internal structure of a business model to three dimensions of value: value creation, value delivery and value capture. The best way to explicate the dynamics within a business model as it is being changed is to treat the model as a dynamic open system in which self-regulation behaviour and complementarity mechanisms are the drivers of change.

Once the operational definition of business model change was described, the next step was to build a framework that guides the exploration of the nature of the developmental trajectories a business model goes through. Principles and theories from organisational theory, strategy, management, innovation and entrepreneurship were used to build a series of propositions to explore: (a) the number of agents driving business model changes; (b) the nature of the actions involved in business model changes; (c) the frequency of business model change events; (d) the magnitude of business model change events; and (e) the order of business model change events. Figure 4 illustrates the relationship between the five propositions stemming from the theoretical framework and the research objectives.

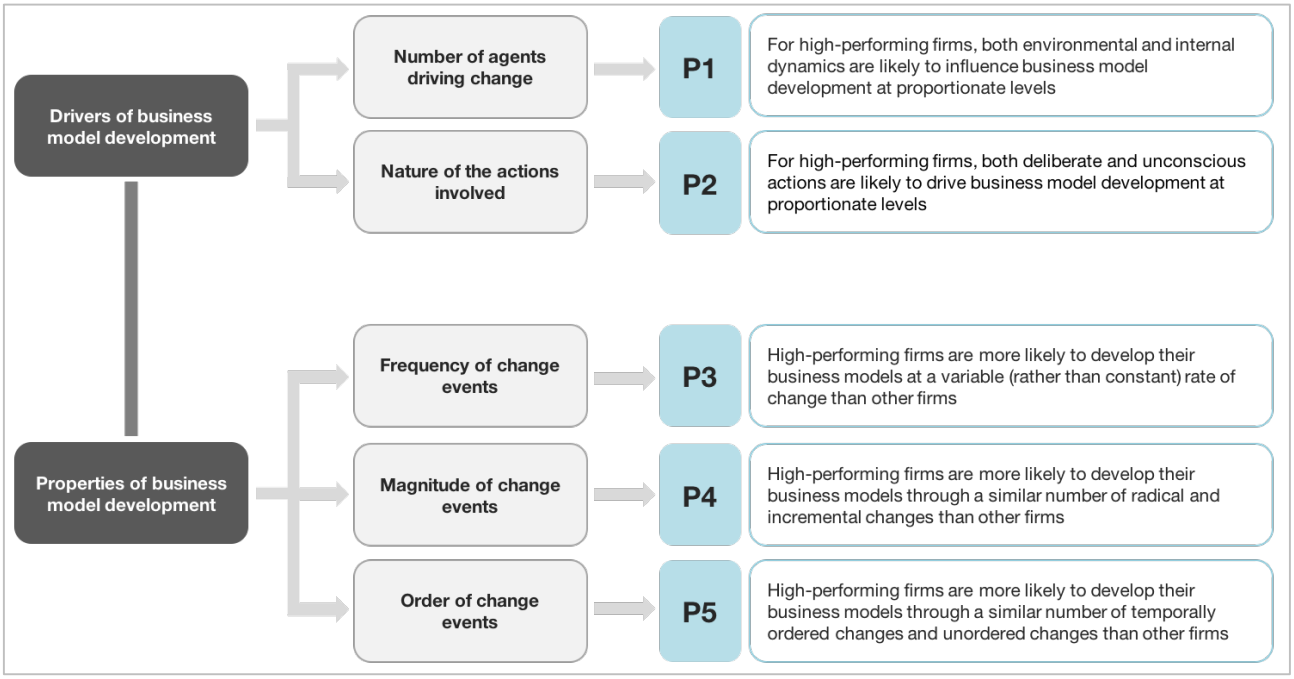


Figure 4 – Relationship between the research objectives, theoretical framework and propositions

Chapter 4: Research Design

4.1 Introduction

This chapter explains the attributes of the research designed to address the questions, research gaps and assess the propositions developed in previous chapters. The first of the three sections comprising this chapter discusses the exploratory, quantitative and longitudinal research design, as well as explicating the process and sequence-based approach used. It also explains the reasons behind the choice of financial history as the main source of empirical data and selection of financial ratios to parameterise business model development. The second section explains the research process including the characteristics of the data used, computational and information management systems developed, sample design, data collection, storage and transformation. The final section concludes with a summary of the analytic methods used.

4.2 Research attributes

This section presents the methodological motivation supporting the research design, and explains and justifies the key characteristics of the study including the selection of sequential, quantitative process-based research to meet the research aim and objectives. The aspects discussed in this section are summarised in Table 2 in the Introduction Chapter, where the different research perspectives adopted in this study are illustrated.

4.2.1 Research orientation and type

This research emerges from the need to characterise business model innovation as a dynamic and developmental process unfolding over time. Questions on the frequency and radicalness of business model change (Brink & Holmén, 2009), factors driving the evolution of successful business models (George & Bock, 2011) and the nature of the dynamic forces shaping business models over time (Zott & Amit, 2013) are motivations for an exploratory, quantitative and longitudinal view of a process that has been historically approached from a static stance (Demil & Lecocq, 2010).

Firstly, the research is exploratory in nature, contributing to a new research stream on business model development. According to Stebbins (2001), exploratory social science research is a way of conducting the scientific process where the aim is discovering generalisations to explicate and describe an area of social sciences where previous scientific knowledge is limited. Schneider and Spieth (2013) claimed that business model innovation is a field in which there is little scientific knowledge on the mechanisms driving innovation and change. This creates the need to address those flaws through exploratory research. Unlike confirmation-based research, exploration requires open-mindedness on where to find the data and where to look for insights, and flexibility on the

methods used to examine the data (Stebbins, 2001). Such flexibility and open-mindedness is reflected in the research design and analytic techniques, choices that diverge from more traditional confirmatory research on innovation and strategy.

Exploratory research enables the generation of ideas leading to the development of theoretical explanations that are later assessed by confirmatory research, thus, "finding the question is often more important than finding the answer" (Tukey, 1980: 24). Exploring possible relationships rather than confirming existing ones represents a key goal in the study, not only because there is a lack of relationships proposed in the literature that explain the process in which business models are continuously reconfigured over time, but because the topic requires new ideas and questions to stimulate further theory development.

Secondly, a quantitative approach is adopted. The research objectives on characterising the sequences of business model development require quantification of the frequency, magnitude and the order of business model change events, to examine multiple patterns of development. The value of designing quantitative research is the potential to produce generalisable findings, as it facilitates systemic measurements across large samples (Modell, 2005). Conducting research that is oriented towards generalisation has been consistently pointed out as a necessary step for the progress of business model innovation as a research field (Bucherer et al., 2012; Zott & Amit, 2015).

Although the qualitative approach dominates in many exploratory social science investigations, quantitative explorations are not uncommon, and are normally used to further explore basic qualitative observations (Stebbins, 2001). The propositions, conceptualisation and operationalisation of the business model construct in this study have emerged from previous business model innovation studies that are, almost entirely, qualitative. Thus, the selection of a quantitative-exploratory combination complements previous examinations on the dynamics of business model change through the design and implementation of a novel research methodology and generalisable findings.

Thirdly, the research is longitudinal in nature because it provides the appropriate temporal scope to capture the dynamic processes creating long-term development (Pettigrew, 1992). Studies on the static attributes of the business model have largely been cross-sectional, as the research questions centre on inter-firm comparison. In business model innovation, many studies have explored how innovation works by observing change from an episodic perspective, with the size of the episode being long enough to cover the transition from the old to the new model. However, research on business model development must be designed to allow thorough monitoring of all relevant variables and constructs driving change over extended periods of time (Dawson, 1997).

In the longitudinal (or panel) method, the researcher selects an individual or a panel of entities and collects repeated measures of a particular event at multiple points in time, allowing the observation of similar (or dissimilar) characteristics across the selected panel (Appannaiah, Reddy, & Ramanath, 2010). This is the method of choice in studies on organisational change and innovation (Huber & Van de Ven, 1995), as the variations between intervals provide clues on the factors inducing and/or inhibiting the change, the behaviour and response of the entities as they are changed, as well as the effects of other variables on change and innovation processes. In addition, a longitudinal analysis captures the temporal interconnectedness of the events driving change, as past events shape subsequent circumstances in a firm, as well as conditioning the firm's ability to change in the future (Pettigrew, 1990).

Panel studies in the business model and business model innovation field are scarce (Wirtz et al., 2016), with some notable exceptions—see Achtenhagen et al. (2013); Andries et al. (2013); Mason and Leek (2008). In fact, studies on the implications of business model innovation have recognised the lack of longitudinal data as a key limitation (Aspara et al., 2010; Brettel, Strese, & Flatten, 2012), and the need for more longitudinal approaches to advance understanding on how business model structures change over time (George & Bock, 2011; Mason & Spring, 2011; Mezger et al., 2013).

The exploratory, quantitative and longitudinal nature of the research requires research methods focused on defining and explaining phenomena as a progression of events, actions or states occurring over time. There is, then, a strong compatibility with the process-based research approach.

4.2.2 Research philosophy

As described in the previous chapter, the business model is dimensionalised with three value creation, delivery and capture dimensions, each one a collection of a firm's elements. Then, business model change occurs when each of the dimensions is altered in a coordinated and synchronised way. Building on this view, business model development is a *process* comprising a *sequence* of change events resulting from concurrent alterations in each of the three value dimensions of the business model. Such characterisation facilitates investigation with an exploratory, quantitative and longitudinal orientation. This section explains the reasons behind and advantages of using a *processual* and *sequential* approach to business model innovation.

4.2.2.1 Adopting a process-based approach

The implementation of the process approach as a method of investigation can be traced back to seminal studies within sociology. Historically, actions and events have been central in sociological theories, and the use of explanatory narratives to describe processes has influenced areas from comparative religion to economics (Abbott, 1992). In an influential work on process theory, Mohr (1982) introduced process research to organisational behaviour, and established a new dialectic between two different forms of empirical research: one based on the analysis of the variables causing a phenomenon, the variance approach, and the other based on temporal observations of the actions leading to the phenomenon, the process approach (Langley, 1999). Since then, authors in fields from information systems to entrepreneurship have stressed the value of developing the process-side of research to determine the true dynamics of change.

The field of strategic management also has two distinctive study design branches: the content approach, on the identification of strategic postures leading to optimal performance; and the process approach, on "how" a firm's decision processes influence strategic positioning (Chakravarthy & Doz, 1992). In this field, process research has focused on explaining recurrent patterns in processes such as decision making, competitiveness and market creation (Pettigrew, 1992). This line of inquiry has contributed to the field by identifying organisational structures associated with superior performance, as well as discovering new types of firms and processes.

Similar to the field of strategic management, the variance and the process approaches used in the field of organisational change represent opposing ways of observing a phenomenon: one focusing on the causal relationships of external and internal factors in organisational change; the other observing the actions leading to organisational change across time (Van de Ven & Poole, 1995). Studies adopting the process approach have positively influenced the development and assessment of theories explaining organisational design, change and innovation (Van de Ven & Huber, 1990). They have also helped explore theoretical propositions of organisation theory such as the linearity of the corporate change phenomenon comprising a logical sequence of steps, and the idea that organisational development is always driven by the search for constant improvement (Dawson, 1997). In summary, the influence of process research on theoretical development in corporate behaviour, strategic management and organisational change makes it an interesting alternative for studies seeking to contribute to theory building on business model innovation.

4.2.2.2 Processes as sequences of events

Entrenched within the process-based approach is the concept of sequence. Some authors argue that every process theory involves assumptions about distinctive patterns in the sequence of events, as well as speculation about the effects of such patterns on other organisational factors (Abbott, 1990).

The concept of sequence has encouraged the exploration of significant questions about innovation in organisations, leading to alternative research designs and methods. For instance, an individual innovation process can be articulated as a sequence of activities and then compared to other innovations to explore similarities and differences in developmental paths, which can be explored using optimal matching methods (Van de Ven & Huber, 1990). Another example is investigating similarities in the implementation processes of different technological innovations to build a taxonomy of technological change and evolution (Sabherwal & Robey, 1993). Scholars in corporate strategy have applied sequential thinking to study competitive actions in firms, market entry strategies, transformational processes and acquisition and alliance initiatives (Shi & Prescott, 2011). As shown in these examples, the representation of innovation processes as a chain of events facilitates the detection of unique patterns when chains from multiple firms or from multiple processes within a firm are studied together.

This research formulates business model innovation as a temporal process comprising a sequence of business model reconfiguration events occurring in a successive order across time, assembling a novel business model that is new to the firm, new to the industry, or both. This approach provides a more integrative and comprehensive view to study the order, timing and magnitude of change events in the business model development process.

4.2.2.3 Sequential approach from a quantitative perspective

As process research requires extensive resources for data collection and analysis, collecting in-depth qualitative information for each change event in a firm would have added considerable complexity to the research. To set a balance between accuracy and achievability, and to exploit the benefits of a quantitative research design, a quantification-processual strategy is used. This strategy, proposed by Langley (1999), sits in the domain of process research, but differs from others such as narrative strategy as it aims to reduce data complexity in preparation for statistical-based analysis at later stages. The quantification strategy involves streamlining of qualitative information about change incidents by systemically coding it into quantitative data, which facilitates subsequent analysis of incidents or events to identify high-level patterns in the sequence of events. With this method, "explicit process theories can be tested rigorously" (Langley, 1999: 697).

There are notable examples of studies implementing quantification strategies that have set the tone for further process-based research on organisational change and innovation. These examples, described below, served as methodological signposts supporting and guiding the research design for this study.

Firstly, Romanelli and Tushman (1994) empirically tested the punctuated-equilibrium model of development by assessing change in computer manufacturers from the United States. The authors used quantitative measures across three organisational domains, including indicators such as the number of products in existing markets, the ratio between research expenditure and total expenditure, and the ratio between the number of research position titles and the total position titles in the organisation. They used a dummy coding system to classify years where year-on-year variations in the quantitative measures were considerably high as "1", while the remainder were coded as "0", to finally classify "revolutionary transformations" to points in time with variations on each of the three organisational domains.

Secondly, Van de Ven and Poole (1990) studied innovation development in research programs to identify developmental paths leading to success for different forms of innovation. The authors quantified change events from different types of qualitative incidents reported throughout the innovation development process, using a dichotomous coding system similar to that used by Romanelli and Tushman (1994) where "1" represents change and "0" the absence of change. They analysed the resulting trajectories of events (sequences of 0's and 1's) using time series analysis to disclose temporal relationships and developmental patterns.

In conclusion, just as the quantification of change event sequences has been proposed as a novel methodology to capture the dynamics driving technological innovation processes (Hekkert et al., 2007), a methodology in which sequences of change events are constructed from quantitative measures is a suitable alternative to use a process-based perspective to explain how successful business models emerge and develop over time.

4.2.2.4 Quantitative-exploratory studies for complex phenomena

Given its flexibility, the exploratory approach allows researchers to design empirical studies around topics that are new or understudied, as well as to develop and refine new methodologies to be employed on subsequent explanatory research around the topic (Rubin & Babbie, 2012). As discussed in Chapter 1, this thesis acknowledges the lack of a solid theoretical background on business model innovation, thus, it adopts an exploratory stance that provides the flexibility required to find and build relationships between concepts from other fields that can add clarity to the discussion on the mechanisms of business model development. However, the study also follows

a description approach to some degree, which supports the scientific description of events, actions and situations that have not been previously described in search for characteristics that can be quantified (Rubin & Babbie, 2012). The second and third research questions in Chapter 1 relate to this approach.

Although exploratory research is predominantly built on qualitative data, the proportion and importance of quantitative-exploratory research in the social sciences is increasing (Stebbins, 2001). A key advantage of quantitative explorations over qualitative explorations is that they accelerate subsequent explanatory research leading to theory building and theory testing, given that they not only solve the why and how questions, but tend to identify potential variables of interests and provides preliminary clues on the relationships between them (Leonard & Marquardt, 2010). In light of this, and to achieve consistency in the methodology, the core analytic techniques chosen for this thesis are two statistically-based techniques typically employed in exploratory data analyses, namely cluster analysis and data mining, as they are specifically designed to discover meaningful information from large datasets (Aggarwal, 2015).

A quantitative-exploratory approach also enables exploration of common patterns. As explained in the introductory chapter, examining patterns of business model change is part of the core objectives and questions driving this study. Patterns emerge in the form of common features seen in multiple observations of the phenomenon. Research designs focused on observing repeated patterns are the ideal context for quantitative analysis approaches, as they summarise the data in a way that enables detection of common features (Rapkin & Luke, 1993). When the observations represent complex phenomena with a large amount of qualitative data associated, quantitative methods are better equipped to isolate the confounding factors potentially associated to the phenomenon that otherwise may distort the qualitative findings (Abeyasekera, 2005). Given that business model innovation has been described as a chaotic process given the complex interrelationships across business elements from a variety of organisational dimensions (Mason & Spring, 2011), quantitative analyses are particularly helpful in sorting out patterns associated with business model change from patterns generated by other organisational phenomena.

4.2.3 Operationalisation of business model change

This section operationalises the business model change construct in way that is valid and suitable for the research question, given that an appropriate operationalisation is key to any systematic investigation (Hambrick, 1980). Recent studies have stressed the importance of operationalising the business model and business model innovation for the advancement of the field, as it enables theory building through the development and testing of empirical hypotheses (Foss & Saebi, 2017).

Operationalisation is defined as the process of "defining an exact research procedure (operations) for measuring a non-physical property based on a concept for that property" (Melcher, 2014). Given that operationalisation is the next step after a construct is operationally defined, this section builds on the conceptualisation of business model change from the previous chapter to propose an operationalisation based on firm-level financial information to measure business model changes over time.

4.2.3.1 Examining change from a firm's financial history

Once a sequential perspective of business model change had been justified and incorporated in the research design, the next step towards measuring change was identifying the aspects of the firm that could serve as inputs to assemble the sequences of business model change events. Just as a business model can be mapped in a way that discloses the organisation's evolutionary paths (Morris et al., 2005), developmental paths in an organisation can be mapped to disclose business model evolution. The main idea of this section is that trajectories of organisational change and development, which, in turn, reflect business model development, can be constructed from information on the financial history of the organisation. Thus, business model changes are measured in relation to the effects that the changes imprint on the organisation's structure and financial circumstances.

The explanatory power of historical data has been shown in many organisational change, economics and innovation studies. Greenwood and Hinings (1996) argued the analysis of historical data from multiple firms leads to the identification of significant insights on the mechanics of intra-organisational dynamics. In discussing his disruptive theory, Christensen (2006) stressed the importance of historical data for theory building as it is the source of the inductive reasoning behind many theories. Historical data also contains information about underlying processes of structural development that are not always explicitly visible (Foster & Wild, 1999). Conducting a retrospective study also presents advantages such as time and cost efficiency, as the researcher does not have to wait for the events to actually occur, and data can be obtained in a single or few collection phases (Mayer, 2007).

Among the different types of firm-level historical data available, financial and accounting information has withstood the scientific rigour in multiple disciplines, and has been considered a fundamental source of general business data (Edum-Fotwe, Price, & Thorpe, 1996). In corporate strategy, financial data is considered the only objective piece of information available that discloses the realised strategy of a firm (Mintzberg & Waters, 1985). In management, financial data constitutes a verifiable source of managerial behaviour (George, 2005). The benefits of using

financial data are the accuracy, transparency and objectivity of the information (Cheng, Lin, Hsiao, & Lin, 2010), as well as its availability and ease of access (Magnusson et al., 2005).

4.2.3.2 Financial ratios as constructs

The important role of financial ratios (known as the quotient of two numbers representing financial statement items) in financial and accounting analysis has been widely recognised, as shown by their ability to predict fundamental organisational events such as failure and financial distress (Beaver, 1966), an objective indicator of firm performance (Bromiley, 1991), capacity to facilitate the modelling of complex financial relationships (Fuller-Love, Rhys, & Tippett, 1995), and usefulness as a management evaluation tool (Edum-Fotwe et al., 1996). Given fluctuations in financial ratios are an indicator of fluctuations in firm strategy (Mizik & Jacobson, 2003), a substantial change in financial ratios signals the presence of transformational events occurring within the organisation such as a full reconfiguration of the business model (Foss & Saebi, 2015; Romanelli & Tushman, 1994).

The importance of financial ratios comes from the mathematical logic behind them. As they represent the numeric relationship between two key financial items, financial ratios allow the cross-sectional comparison of multiple companies within an industry, as well as longitudinal year-on-year comparisons within an individual company (Castro & Chousa, 2006). Because a ratio measures the magnitude of one financial item in relation to the other, it can be used to determine the dominance of certain organisational activities, actions or elements over others, while controlling for the presence of trends affecting the entire organisation or industry as a whole such as organic growth, crises and business cycles (Altman, 1968; Castro & Chousa, 2006; Van Peursem, Prat, & Lawrence, 1995).

For these reasons, and given that financial ratios are echoes of managerial actions that quantitatively show the impact of strategic decisions on the firm's financial position after their implementation (George, 2005), this study observes variations in financial ratios to detect business model changes across the developmental trajectory of a business model. As a change event represents a significant alteration in the three business model dimensions, the procedure to detect such alterations is a structured analysis of the firm's financial historical information annually from the earliest year in which data is available, until the latest available year. A set of 12 financial ratios was designed to reflect alterations on each of the value creation, value delivery and value capture dimensions, resulting in four ratios per dimension.

Table 9 shows the list of financial ratios used as parameters for business model change detection, along with the corresponding supporting references. The ratios were identified by a detailed

analysis of: (1) the 55 cases studies presented in Gassmann et al. (2014); (2) description of the nine components of the business model canvas (Osterwalder & Pigneur, 2010); (3) quantitative (Zott and Amit (2007) and qualitative (Sosna et al. (2010) case studies of business models; and (4) the supporting references presented in Table 9.

Dimension	Sub-dimension	Ratio/construct	Codename	Description	References
Value creation	Resources	$\frac{\textit{Tangible fixed assets}}{\textit{Intangible fixed assets}}$	ta-ia	Measures the proportion of physical resources to non-physical resources within the firm's total assets. It indicates variations in the type of the resources employed to create value (e.g. an increased amount of intangible assets might indicate an emphasis on patent generation/acquisition leading to value creation in the form of new products)	• Intangibles: Accounting value of goodwill, and possibly patents and brands, obtained via takeovers (Greenhalgh & Rogers, 2006) • Intangible and tangible assets are the "raw material" of value creation to customers (Allee, 2008) • Novel business models require efficient combinations between intangible and tangible assets (Boulton, Libert, & Samek, 2000)
Value creation	Resources	$\frac{\textit{Number of employees}}{\textit{Net current assets}}$	em-ca	Measures the proportion of labour force employed in relation to the amount of capital resources possessed by the firm. A significant variation in this ratio indicates a change in the resources employed to create value (e.g. an increased number of employees might suggest a refocus towards service provisioning)	• Capital employed by a firm, as well as the total number of employees are key factors for the calculation of value created by the firm (Lieberman & Balasubramanian, 2007)
Value creation	Activities	$\frac{\textit{R\&D expenses}}{\textit{Other operating items}}$	rd-ot	Compares the intensity of research and development activities with the relevance of other operating activities by assessing their corresponding expenses. A substantial variation in this ratio indicates a shift in the activities carried out for the production of value (e.g. a decrease in R&D expenses might reflect a shift away from new product development and towards improvements of existing offerings)	• A firm's technology capabilities driven by R&D expenditures have been linked to value creation (Mizik & Jacobson, 2003)
Value creation	Activities	$\frac{\textit{Depreciation}}{\textit{Operating revenue}}$	de-op	An estimation of the degree of utilisation of capital assets such as property, machinery and equipment to generate revenue. A significant variation on the reliance on depreciating assets to generate value suggests a potential change on the type of offerings produced (e.g. a decreased use of machinery might indicate an outsourcing of manufacturing activities)	• Asset utilisation is a key metric to determine a firm's balance between governance for profitability and governance for revenue growth and innovation (Weill & Ross, 2005)

Dimension	Sub-dimension	Ratio/construct	Codename	Description	References
				(continued)	
Value delivery	Selling	$\frac{Selling,\ gen.\ and\ admin.\ expenses}{Cost\ of\ goods\ sold}$	se-co	Compares the efforts on sales-related activities over the efforts on other activities involved in the production process, by measuring the operating costs associated with each item. A substantial variation reflects changes in the way the product is delivered to the market (e.g. increased selling expenses might indicate a restructuring in the sales and distribution channels employed)	• A firm's ability to differentiate offering through advertising has been linked to value distribution and appropriation (Mizik & Jacobson, 2003) • Advertising expenditures are linked to a firm's value creation as it increases new product development adoption, given that the consumer learns more quickly about the existence of the product (Wyatt, 2008)
Value delivery	Selling	$\frac{Sales}{Total\ assets}$	sa-ta	Provides a measure for sales performance in relation to the assets owned by the firm. A significant fluctuation in this ratio suggests internal restructuring limiting or enhancing the firm's ability to deliver the value created (e.g. increased sales in relation to assets might indicate a redefinition of the value proposition, which attracts more customers)	• Dividing sales by total assets provides a measure for sales performance. It is also representative of a firm's efficiency in generating revenue from its total assets (Lo, Yeung, & Cheng, 2012)
Value delivery	Distribution	$\frac{Other\ operating\ items}{Number\ of\ employees}$	ot-em	Quantifies the efforts in distributing, selling and marketing the product/service offerings in relation to the size of the firm (in terms of the number of employees). A significant alteration in this ratio suggests a change in the way the firm distributes the value into the target market (e.g. increased operating items and equal size might indicate the use of a more efficient marketing strategy based on digital channels)	• The shift between the physical distribution towards distribution of information affects a firm's value capture logic (Sharma, Krishnan, & Grewal, 2001)
Value delivery	Distribution	$\frac{Operating\ revenue}{Stocks}$	st-tu	Also known as stock turnover, this ratio estimates the firm's capacity to distribute the produced goods and/or service to the target market by measuring the time it takes the firm to sell the goods in inventory. A substantial fluctuation in stock turnover indicates reconfigurations of the value distribution activities (e.g. a decreased stock turnover might be the result of the adoption of improved distribution channels)	• Inventory turnover is an indicator of speed of sales and, hence, an indicator of the efficiency of the order winning and delivery strategy (Edum-Fotwe et al., 1996)

Dimension	Sub-dimension	Ratio/construct	Codename	Description	References
				(continued)	
Value capture	Revenue management	$\frac{Financial\ revenue}{Operating\ revenue}$	fr-op	Measures the proportion of non-sales revenues in relation to sales-related revenues. Significant fluctuations in this ratio indicate changes in the sources of revenues implemented by the firm (e.g. increased financial revenue over operating revenue might suggest the implementation of additional revenue mechanism based on investments made by the firm)	• Other revenue such as investment income represents alternative sources of revenue (Callen, 1994)
Value capture	Revenue management	$\frac{Debtors}{Operating\ revenue} * 360$	co-pe	Also known as collection periods, it measures the time it takes a firm to receive and collect payments from its customers and clients. Considerable fluctuations in this ratio suggest a change in the firm's ability to capture value back from its customers (e.g. decreased collection period might reveal the implementation of a new financial information system, reflecting a period in which the firm adjusts to the change)	• Firm's managerial capacity to capture value could be affected by reducing inventories and the number of days for which their accounts are outstanding (Gill, Biger, & Mathur, 2010)
Value capture	Cost management	$\frac{Cost\ of\ goods\ sold}{Operating\ revenue}$	cg-op	Measures firm's operational cost management efficiency as a function of revenue. When this ratio fluctuates substantially, it indicates the presence of firm-wide alterations affecting the firm's capacity to control their costs (e.g. decreased cost of goods sold over operating revenue might reflect scale economy efficiencies achieved by the implementation of new arrangements with suppliers)	• The cost of goods sold to revenues ratio is used as an indicator of a firm's costs reductions/increases achieved by the implementation of innovations such as the adoption of new IT systems (Poston & Grabski, 2001)
Value capture	Cost management	$\frac{Financial\ expenses}{Other\ operating\ items}$	fi-ot	Compares the costs from financial items (e.g. cost of making financial investments) over the costs from other operating items (non-operational costs). Significant fluctuations in this ratio suggest reorientations in the way the firm balances non-operative costs (e.g. decreased financial expenses might indicate additional costs of marketing activities where the focus has changed from cost-efficient to value-driven)	• Profitability can be measured in terms of financial expenses to sales and to debt ratio (Chen & Cheng, 2010)

Table 9 – Financial ratios used in this study to parameterise business model change, organised by value dimension, and supporting references

4.3 Research process

4.3.1 Type and source of data

The financial ratios are obtained from Osiris, a repository of company data owned and maintained by Bureau Van Dijk. Osiris is a large financial database with information collected from income statements and annual reports, as well as other company and market-related sources, for approximately 80,000 publicly-listed firms around the world (Bureau Van Dijk, 2015). The database is used not only in finance and accounting research where it has supported cross-sectional analyses of shareholding patterns in large corporations (Li, Moshirian, Pham, & Zein, 2006), and assessments of the capital structure in multinational and domestic companies (Akhtar, 2005), but also in operations research where it has supported the analysis of performance effects of servitisation in manufacturing firms (Neely, 2008), and in corporate strategy research on the effect of certain strategies (e.g. diversification) on firm performance (Chakrabarti, Singh, & Mahmood, 2007).

The strength of Osiris over other financial databases is the availability of large amounts of longitudinal data (up to 30 years of data for hundreds of items) and cross-sectional data (approximately 80,000 worldwide firms) in formats that are easy to export, facilitating large-scale studies.

With the exception of stock turnover and collection period, none of the ratios employed in the study were readily available in Osiris as built-in variables. The ratios were manually added as "user defined variables" using the corresponding functionalities in the Osiris web application, a process involving the individual selection of the ratio components. For instance, to create the *ta-ia* ratio, tangible fixed assets and intangible fixed assets were selected from the pool of available items. As a result, 10 financial ratios were created as user defined variables in the Osiris web application.

In addition to the financial ratios, supportive financial information and meta-data were collected from Osiris. This data includes operational and profitability indicators, such as profit margin, return on assets and operating revenue, dates of incorporation, industry codes and number of employees for each firm. This additional data supported manipulation and arrangement of the sampling, as well as firm profiling by financial performance (which is explained in the rest of this chapter). Table 10 shows the additional data extracted from the Osiris database that complements the 12 financial ratios described in the previous section.

Parameter	Class	Type	Format	Function
Company name	Identifier	Cross-sectional	Text	Identify individual firms
Global Industry Classification Standard (GICS) code	Identifier	Cross-sectional	Numeric	Identify firms by industry of operation
Country code	Identifier	Cross-sectional	Text	Identify firms by country of incorporation
Number of employees	Identifier	Cross-sectional	Numeric	Identify firms by number of employees
Date of incorporation	Variable	Cross-sectional	Date-time	Stratify sample by firm's age
Operating revenue	Variable	Longitudinal	Numeric	Calculate revenue growth to estimate firm's performance, and stratify sample by firm's size
Profit margin	Variable	Longitudinal	Numeric	Estimate firm's performance

Table 10 – Additional parameters extracted from Osiris, with corresponding description

4.3.2 Statistical software and coding environment

The choice of the source and type of data led to the selection of the computer programs and statistical software supporting the data collection, manipulation and analysis. During the early stages of the research design, it became clear that the collected financial data would require transformation and manipulation to build the sequences of business model change. This task required a flexible statistical software package but also a programming environment to allow the development of automatic programs to perform the transformations.

The software selected for this study is R, a software environment for statistical computing and graphics, which also allows the development of customised programs, or *scripts*. The coding process was done in RStudio, an open-source software interface that facilitates the visualisation, development and management of the computer scripts. R has become the statistical tool of choice for researchers in various fields ranging from biology and medical sciences to finance and marketing (Smith, 2014). Three main reasons justify the use of R in this study: (1) it enables combination of custom code with statistical functions available in R in a single environment (see Lundberg et al. (2012) and Wu et al. (2014) for examples); (2) it offers a large collection of data mining algorithms specifically designed for the analysis of time series and sequential data

(Shumway & Stoffer, 2010); (3) the set of tools for data visualisation and presentation in R is one of the most advanced, powerful and robust available (Paradis, Claude, & Strimmer, 2004).

A detailed list of the 18 scripts designed and developed in R for the data import, storage, computation of values such as firm performance, identification of change events, computation of sequences of change events and data analysis procedures, with corresponding descriptions, is presented in Appendix 1. Scripts are discussed in Sections 4.3.4, 4.3.5, 4.3.6 and 4.4 .

4.3.3 Sample design

4.3.3.1 The Information Technology sector

After the selection of the potential research data and data source, the next step was selecting a single sector for the study. Firms operating under the same regulatory environment, affected by the same technological developments and customer demands, are more likely to form an homogeneous sample, enabling a detailed observation of the phenomenon under investigation (Teddlie & Yu, 2007). In contrast, a selection of firms from multiple sectors would have compromised the level of homogeneity required, as the pace of business model innovation varies considerably across industries given the external forces shaping business models are dissimilar (Morris et al., 2005). A sector with a collection of industries offers the degree of diversity and variation required to identify central patterns of business model development that cut through a variety of firms tackling different markets in the same sector. (Ritchie, Lewis, & Elam, 2003). Thus, a sector-level sample of firm business models with an optimal balance of homogeneity and heterogeneity has increased the accuracy of the analyses and facilitated the identification of commonalities in business model change patterns of multiple firms, which has also maximised the explanatory power of the different tests performed (Kozberg, 2001).

As the methodology is built on exploring business model innovation by observing change events, it was appropriate to contextualise this study in a dynamic environment as seen in technology intensive sectors, to maximise the likelihood of observing multiple change events over time, considering the dual relationship between technological change and business model change. Technological innovation has a double-sided effect in business models as a promoter of change; it enables implementation of completely new and potentially disruptive business model configurations (Afuah & Tucci, 2000; Timmers, 1998), but it also forces firms to reconfigure their business models as an adjustment mechanism when they adopt technologies requiring a whole new set of capabilities, resources and structure (Chesbrough & Rosenbloom, 2002; Schweizer, 2005).

The Information Technology (IT) sector is appealing to researchers exploring organisational change, as the accelerated rate of environmental changes driven by technological progress stimulate firms to modify their activities, resources and strategies more frequently than firms operating in less technology intensive industries (Brown & Eisenhardt, 1997). Several studies on corporate strategy, innovation and organisational change have been contextualised in either an individual industry within the larger IT sector, such as computer producers (Romanelli & Tushman, 1994), semiconductor industry (Christensen, 2006) and software industry (Rajala & Westerlund, 2008), or have considered the entire set of firms within the sector (Liberman-Yaconi, Hooper, & Hutchings, 2010).

Under the Global Industry Classification Standard (GICS) code (S&P Capital IQ & MSCI, 2015), the IT sector contains firms operating in the following 14 sub-industries: Internet software and services; IT consulting and other services; data processing and outsourced services; application software; systems software; home entertainment software; communications equipment; technology hardware, storage and peripherals; electronic equipment and instruments; electronic components; electronic manufacturing services; technology distributors; semiconductor equipment; and semiconductors. Figure 5 shows the industry groups, industries and sub-industries comprising the IT sector, according to the GICS. Including all of these sub-industries instead of selecting only one of them ensured a degree of heterogeneity in the sample and a sample of appropriate size. Different samples containing individual industries as well as a collection of industries were tested, however none of these selections gave samples of suitable size, with all less than 500 firms.

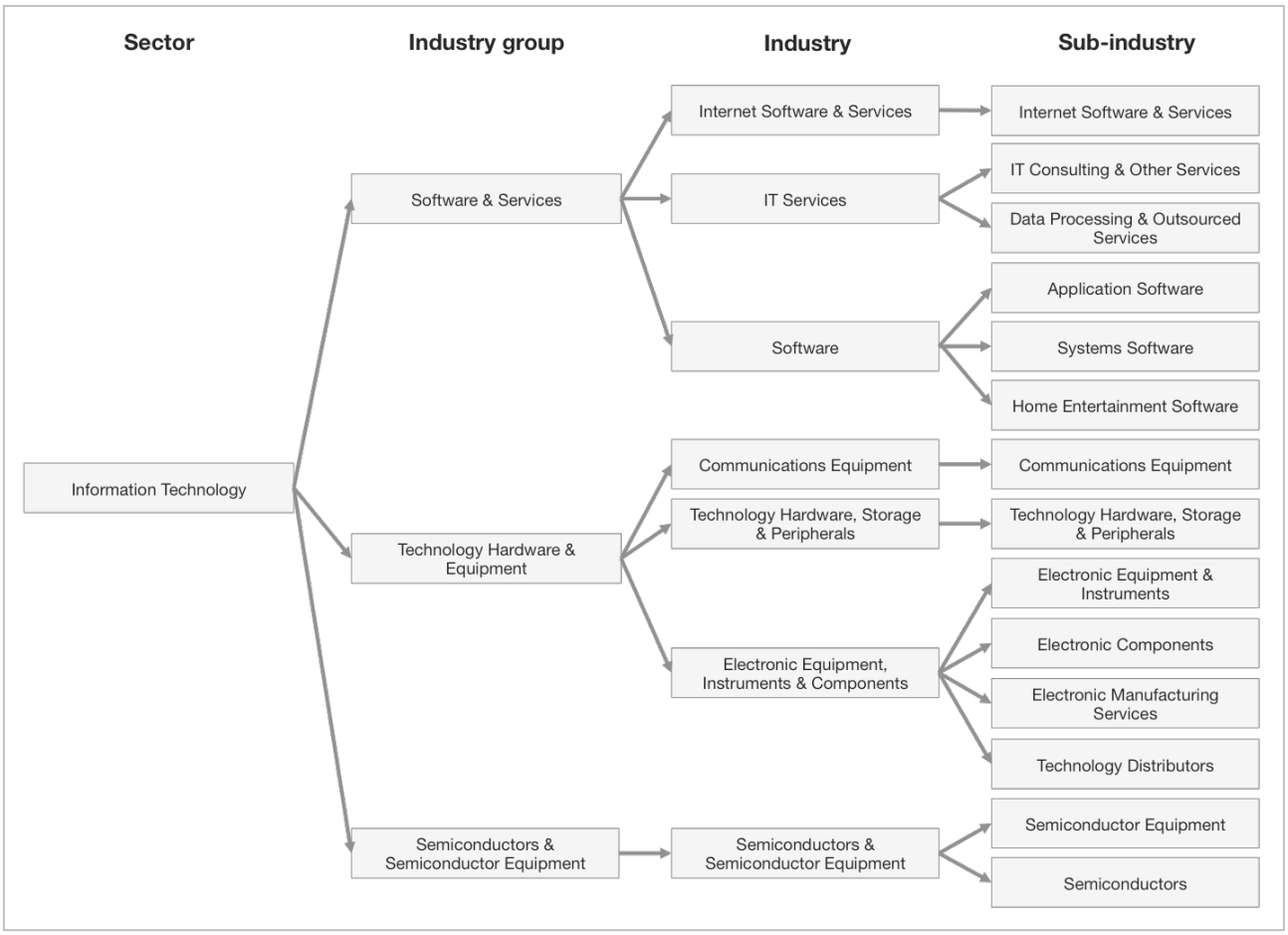


Figure 5 – GICS structure of the IT sector

4.3.3.2 Characteristics of the firms

The first characteristic of the firms considered in this study is their ownership status. The sample consists of publicly listed firms classified as active at least until 2015, a decision based on the necessity for historical data from a large cohort of firms. In addition, listed firms tend to report financial information more consistently given their public obligation to disclose financial data, which facilitates observation and analysis of business model design and change (Zott & Amit, 2007).

The second feature of the sampled firms is their longevity. All firms with at least five years of accounts on Osiris are included, that is firms that have been in operation a minimum of five years. Exclusive consideration of firms with more than five years of recorded data increases the probability of capturing of at least one business model change cycle, according to Mitchell and Coles (2003) study suggesting that successful firms change several elements of their business models at once every two to four years. An exception to this constraint are firms with more than five years in operation that have reorganised their legal structure (such as Google Inc., now Alphabet Inc.), thus, the date of incorporations for these firms can be as recent as 2015, though technically they have been in operation for more than five years.

The third aspect considered when designing the firm sample is their geographical location. The sample of firms is not restricted to any particular country (country of incorporation) because the supply chain and value networks in the IT sector are globally distributed due to lowered geographic barriers and offshoring trends (Arora & Gambardella, 2004), which means that the value creation, value delivery and value capture processes involve suppliers and partners from multiple geographic locations (Kagermann, Osterle, & Jordan, 2010). This is evidenced by internationalisation trends seen in IT firms such as an increasing tendency towards cross-border modularised production (Chen, 2004), the adoption of internationalisation practices at earlier stages of growth (Paul & Gupta, 2014), and a tendency towards geographic decentralisation caused by IT (Garicano & Rossi-Hansberg, 2012). In addition to the trend towards geographically dispersed business models in IT firms, the inclusion of firms from multiple countries contributes to the heterogeneity of the sample, which leads to observations of a wider set of patterns of development (Garcia-Castro, Aguilera, & Ariño, 2013)

The fourth and last feature considered in the sampling design is the size of the firm. Initially, a sample of established firms with more than 1,000 employees was tested, given differences in the attitude towards organisational change and innovation between firms with more than and firms with less than 1,000 employees (Link & Rees, 1990). However, the sample excluded an important number of firms with multiple business model changes over time that would have contributed to the research questions on the dynamics of business model development. Given the recent examples seen in IT industries such as software and Internet services where young firms have growth without necessarily expanding their workforce or physical assets (Valsamis, Coen, & Vanoeteren, 2016), the sample design was modified to any number of employees (Florin, Lubatkin, & Schulze, 2003). This decision generated larger and more diverse groups of firms when stratifying the sample by size, as described in Section 4.3.3.4.

4.3.3.3 Sampling size and data availability

The total number of IT firms satisfying the conditions presented above was 5,531. A key consideration in the sampling design process was minimising the number of firms with missing values, and maximising the reliability of the trajectories of business model change observed. Even though the sample considered firms with five or more years of accounts in Osiris, that did not exclude the possibility of missing values for the set of financial ratios used in the temporal window under analysis (discussed in Section 4.3.4.1).

A filtering step similar to Minton and Schrand (1999) selecting firms with at least one non-missing, non-zero value for each of the financial ratios analysed generated a sample of 2,162 firms from the initial sample of 5,531 firms. In addition, firms with non-missing, non-zero values for the *operating*

revenue and *profit margin* parameters for 2015 were selected, as well as firms with non-missing values for the *date of incorporation*. These parameters were needed to classify firms by performance and for the sample stratification by firm age (see next section). As a result, the final sample contained 1,651 firms.

4.3.3.4 Stratified sampling

Post-stratification sampling, also known as after-sampling stratification, was used as a control mechanism for firm-specific variables that are known to have an effect on organisational change. This method categorises cases across different levels once the sample has been obtained (Levy & Lemeshow, 2013), and is typically applied when the researcher is interested in holding certain variables constant within a group or stratum to explain the effects of the variable of interest.

Stratified sampling was used to compare trajectories of change events across firms with similar causal mechanisms of organisational change, to control for the change events that are caused by the contextual situation of the firm, facilitating the observation of change caused by business model reconfiguration. Controlling for both the external and internal causes of organisational change helps observe outlying change events that are not attributable to either major environmental events or the particular characteristics of the firm (i.e. phase of growth and/or size). This approach increases the ability to capture events reflecting business model transformations, providing that the phenomenon is properly parameterised by the observed variables (see Chapter 3: Theoretical Framework for the conceptualisation and dimensionalisation of business model change and Section 4.2.3.2 for the definition of parameters to observe change events). The design of the sample controls for external causes, whereas the stratification procedure controls for the internal causes of change.

Among internal reasons driving change, the age of the firm has been recognised as a key driver of organisational transformation. As a firm progresses through different developmental phases, the challenges requiring internal restructuring differ (Greiner, 1972). A start-up IT firm entering a market might experience a series of restructuring moves that differ from those of a firm already established in the market (Almeida & Kogut, 1997; Eisenhardt & Schoonhoven, 1990)

The size of the firm is another key factor influencing differences in patterns of organisational change and innovation (DeTienne & Koberg, 2002). A large firm with several departments or business units might experience mergers and divisions between departments in the search for efficient operational structures, whereas transformations in smaller firms might be searching for proper structures to grow, rather than searching for efficiency (Covin & Slevin, 1989)

Consequently, age (calculated from the firm's incorporation date) and size (the median of the firm's operating revenue across all the available years) were used as the variables for sample stratification.

Young firms are those incorporated in or after 1992 (the median of the sample), whereas large firms are those with median annual operating revenue of all years of operation greater than or equal to US $106.9 million (the median of the sample). This procedure resulted in four age-size groups formed by the combination of the size and age dimensions: young-small, young-large, mature-small and mature-large (see Figure 6).

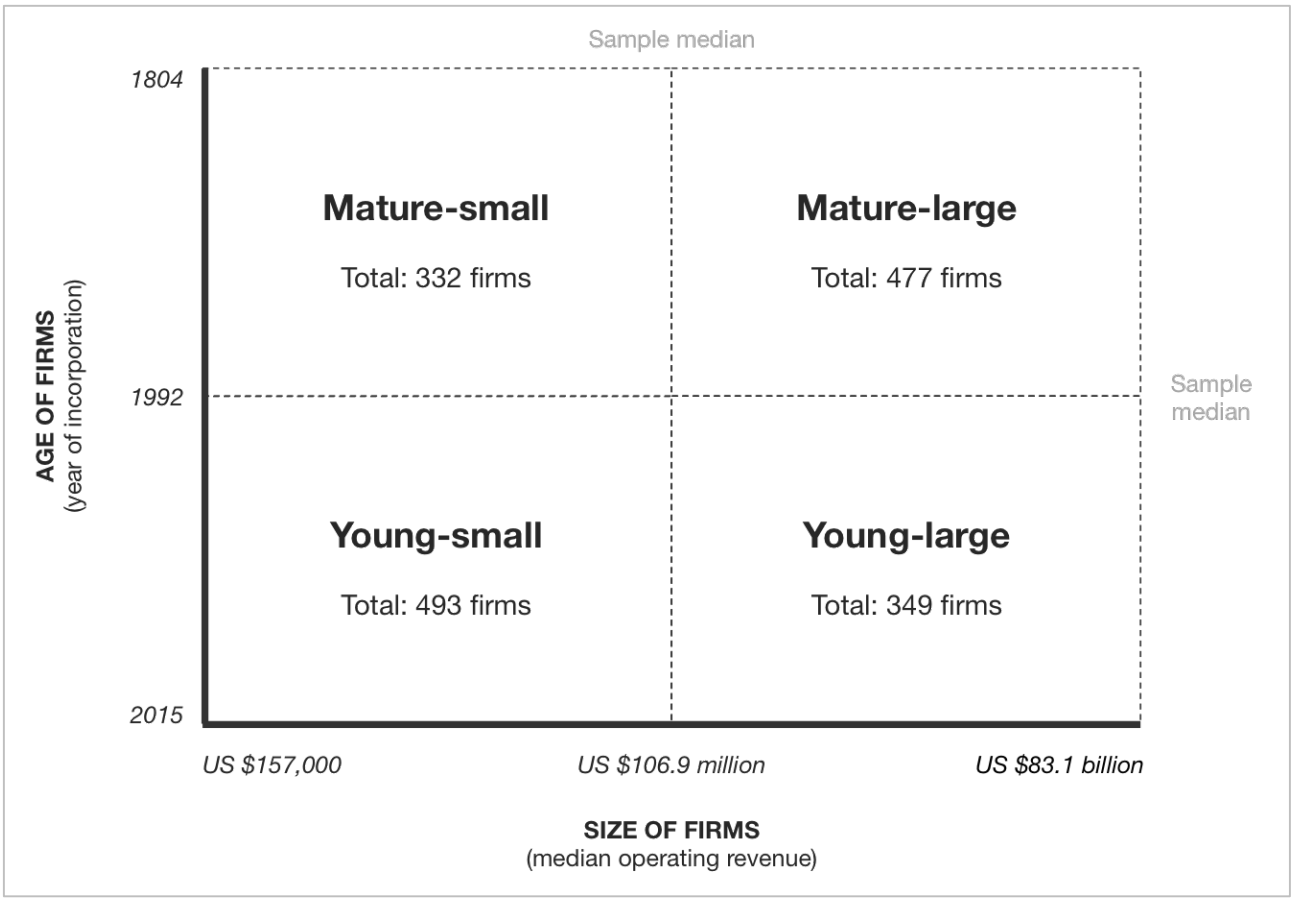


Figure 6 – The four age-size groups of firms from sample post-stratification

4.3.4 Data collection

The data collection process included the temporal range for which the firm-level data is collected for each ratio and parameter. The next section explains how the selected data points were exported from Osiris and prepared for import to the project's database.

4.3.4.1 Frequency and number of data points

The financial data for each firm is compiled from the earliest point in time available in Osiris to 2015. As Osiris does not provide access to information prior to 1987, the maximum number of years of data for any firm is 29 years. This means that the number of temporal data point varies from firms with only five yearly values to firms with 29 yearly values.

Most of the data is also available monthly and quarterly in Osiris, however, there may not be sufficient variability occurring within monthly or quarterly periods, which is shown by several case studies on business model innovation in which the process was finalised years after the initial recognition of change (Desyllas & Sako, 2013; Sosna et al., 2010; Wu, Guo, & Shi, 2013). The fundamental and revolutionary nature of the strategic changes made to a firm's key activity domains as part of business model innovation requires years, rather than weeks or months, for full implementation and diffusion (Foss, Stone, & Ekinci, 2008; Foss & Stieglitz, 2015; Romanelli & Tushman, 1994; Van den Bulte, 2000). Thus, monthly or quarterly data points would have resulted in numerous data points with no interesting fluctuations, adding little value to the analysis of patterns of development. In addition, a detailed review of the Osiris data for a few test cases revealed that firms tend to be more consistent when reporting their financial information yearly, rather than on a monthly or quarterly basis.

4.3.4.2 Collection process

The financial ratios (Table 9) and parameters (Table 10) for each sampled firm across the selected data points were exported as MS Excel comma-separated files using the export functionality in Osiris. The export process was done in four output files, as the Osiris web application limits the number of exports in a single file. The four Excel files contained all the sampled firms as rows and their corresponding records as columns.

The data on each file was inspected to ensure consistency and integrity (Xu & Quaddus, 2013). During this process, a search and replace was executed for any symbol that could potentially cause errors in the R scripts (e.g. #, @, ') as well as letters not included in the English alphabet such as Ü or É. In addition, the numeric values were formatted to have five decimal places to preserve the precision for values that are close to 0.

Lastly, the reviewed Excel files were combined into a single file, which was automatically read one record at a time and stored for its subsequent analysis, using an R script (Munzert, Rubba, Meibner, & Nyhuis, 2014). There was no treatment for missing values at this stage.

4.3.5 Data storage

Although the R environment stores data and variables in temporal data objects, the study used relational databases as the main storage structure, in line with studies on software evolution (Kemerer & Slaughter, 1999), financial valuation of research and development and intellectual property activities (Greenhalgh & Rogers, 2006) and technological innovation (Benner & Tushman, 2002).

Relational databases are particularly capable of dealing with large datasets as they are structured to maintain relation and order between data, a key attribute when searching through large sets of data (Whitehorn & Marklyn, 2007), and they allow calculations and analysis with subsets of data rather than the entire dataset, leading to a more efficient use of memory and processing power. Fewer resources are allocated for data access and more for the analysis (Hine, 2006; Whitehorn & Marklyn, 2007). Relational databases also offer a reliable, centralised and secure environment for scientific data (Hine, 2006), as well as the flexibility required to manipulate and manage longitudinal data (Johnston & Weis, 2010).

SQLite was chosen as the relational database software for the study based on the ease of access, portability, cost and resource consumption, while also ensuring the integrity and security of the data (Allen & Owens, 2010). SQLite not only offers integrated functionalities and direct connectivity with the R software, it can also be installed on the same computer where R is installed, simplifying data management tasks.

A suitable database configuration was then developed. An appropriate and careful design of the database structure is a fundamental step in research involving large and complex datasets, as it can save time and resources when querying, searching and analysing the data (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990). Nine independent data tables, each one storing different information from the sampled firms, were designed to enable interconnectedness among the data, facilitating searches across multiple tables at the same time. Table 11 shows the structure and types of data stored on each data table.

Table name	Description	Columns	No. records
Companies_table	Contains information about the firms in the raw initial sample of firms drawn from Osiris (before applying the filtering step)	ID_company, name, gics_code, country, incorp_date, perf_score	5,531
Ratios_table	Contains the yearly values of the financial ratios in parameters_table, for each of the firms in companies_table	ID_company, parameter, timepoint, value, delta_value, is_event	1,924,788
Financials_table	Contains the yearly values of the financial parameters that are additional to the financial ratios, for each of the firms in companies_table	ID_company, parameter, timepoint, value, delta_value	1,122,793
Parameters_table	Contains a static set of the 12 financial ratios used in the study, together with the lower and upper bounds used for the estimation of change events	ID_parameter, dimension, description, lower_bound, upper_bound, weight	12
Events_x_dim_table	Contains the change events identified with the corresponding value dimension, for each firm in companies_table after the filtering step	ID_company, timepoint , dimension, category	78,207

Events_x_bm_table	Contains the change events resulting from the calculation of coordinated changes in the value dimension in events_x_dim_table, for each firm in companies_table after the filtering step	ID_company, timepoint, intensity, duration, magnitude	26,069
Bmc_magnitude_table	Contains a static set of the 30 possible intensities of business model change, and corresponding combination of duration and magnitude	Intensity, duration, magnitude	30
Revenue_growth_table	Contains the calculated values of year-on-on-year revenue growth for each firm in companies_table after the filtering step	ID_company, timepoint, growth	25,072
Tmp_clusters_table	Contains the cluster memberships and group memberships for each of the firms in companies_table after the filtering step	ID_company, name, ID_cluster, group_name, date	1,651

Table 11 – Description of the nine data tables in the database designed and implemented for the study

4.3.6 Data manipulation

This stage of the research process identified business model change events, represented by outlying data points in the firms' financial ratios, as well as the construction of the sequences of business model development. It is the temporal sequence of such events over time that creates a particular "events history" for each firm, describing the underlying patterns of transition by each of them (Kelly & Amburgey, 1991; Langley et al., 2013).

A variation of the methodology designed by Van de Ven and Poole (1990) and Romanelli and Tushman (1994), in which they used a binary nomenclature to identify meaningful change events in several organisational dimensions, was implemented. They relied on manual codification to code the time points where events were observed, and then aggregated the events by organisational dimension. This research design incorporates computational programs to code change events automatically, to then aggregate them by value dimension to build sequences of business model change events (Spector, 2008). The automation of the coding process allows transforming financial data to sequences of events for each of the 1,651 firms in the sample in a consistent and standardised manner, thus minimising error rates due to human coding (O'Brien & Marakas, 2006; Smith & Offodile, 2002).

This phase of the research transformed the data from continuous time series obtained from financial ratios into discrete sequence data representing business model change events. This was done following a three-stage procedure: (1) using outlier detection to estimate outlying time points for each series of financial ratios; (2) coding events using a categorical (i.e. binary) system and aggregation by dimension; and (3) constructing sequences of change events (see Figure 7).

As illustrated in Figure 7, the data manipulation process began with the detection of business model change events using the outlier detection method (discussed next) to estimate the degree of

"outlierness" for each data point. The second step involved the codification of events based on the degree of outlierness estimated in the previous step for each financial ratio, as well as the aggregation of change events for each value dimension. In the third step, the change events for each value dimension were aggregated into individual events of business model change per time point where the appropriate intensity, duration and magnitude were assigned, which were combined into firm-level sequences of business model change events ordered by time point.

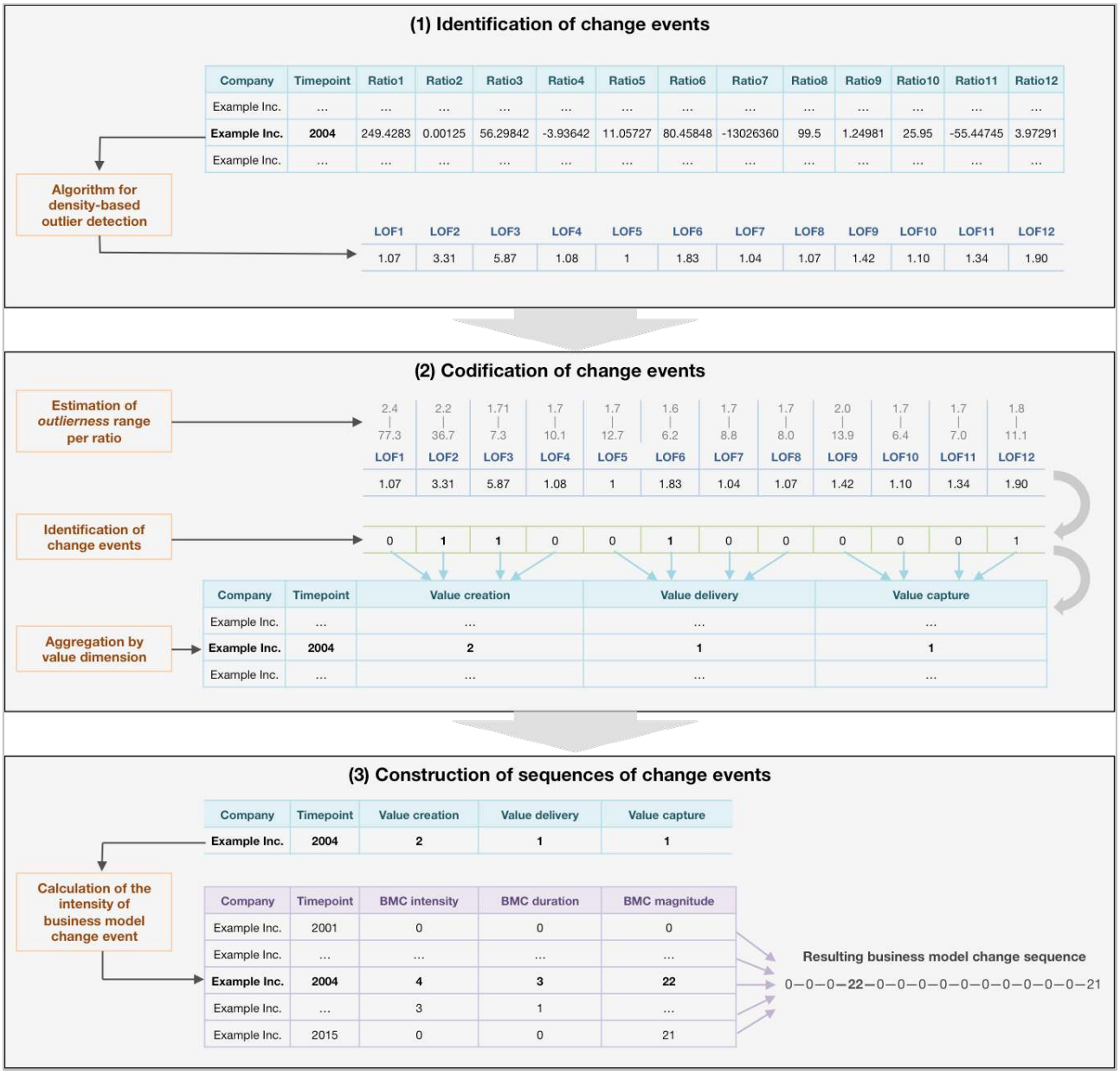


Figure 7 – Data manipulation process with assessment of financial ratios, codification of change events based on outlier detection, and construction of the sequences of change events

4.3.6.1 Outlier detection for the identification of change events

A key step in the data manipulation process was the detection of points in time where the value of the financial ratio deviates from the rest of the values from different time points, indicating

fundamental alterations in the firm that could be attributable to business model changes (see previous chapter). This task is equivalent to what it is known as outlier detection, an approach used when there is a need to identify erroneous data objects to then remove them, as they are considered noisy data objects that do not comply with the general data model (Schwertman, Owens, & Adnan, 2004).

Outlier detection is also used when there is research value in isolating and further exploring anomalous data objects that do not come from the same statistical distribution as the rest of the data, an approach that considers outliers as interesting events, such as detection of credit card fraud, intrusion detection and medical care (Han, Kamber, & Pei, 2011). The relevance of this technique for the study is supported by the second approach, as the outlying data points in firms' financial data reflect fundamental change in the activities, resources and structure of the firm (Romanelli & Tushman, 1994); events that may reflect reconfigurations in the business model and that are central to the study.

An outlier is defined as a data point that deviates substantially from the rest of the data to the extent that suggests it was generated by a different mechanism (Aggarwal, 2015). An outlier in a financial ratio might indicate that, at the particular point in time, the firm went through a reconfiguration that deviates from the normal behaviour of adjustments over time. Outlier detection captures unusual behaviour that leads to the discovery of meaningful events providing useful insight on firm-level processes (Liu, Bhattacharyya, Sclove, Chen, & Lattyak, 2001).

Generally, outliers are detected using three different approaches: (1) using statistical tests including Bayesian methods, parametric and probabilistic models, where the distribution of the data is known (Tsay, 1988); (2) computing the distance among data points and considering remote points as outliers (Gupta & Han, 2012); and (3) using density-based techniques that identify outliers in groups of contingent data points (Han et al., 2011). The outlier detection method in this study is based on the latter approach and builds on the principle of local density, as this approach accounts for the behaviour of the time points immediately preceding and succeeding the data point under analysis, rather than accounting for the behaviour of the entire set of data points in the time series, regardless of how distant they are from the data point being analysed (He, Xu, & Deng, 2003)

Known as the LOF (Local outlier factor) method, it consists of calculating a factor for each data point indicating how likely the data point is to be an outlier. The calculation is based on comparing the density of a particular point (the distances with adjacent points), and the densities of their neighbours. If the density of the former is considerably less than the latter, the data point is considered an outlier (Breunig, Kriegel, Ng, & Sander, 2000; Han et al., 2011). The two main advantages of this method are that it identifies outliers based on local groups of neighbouring data

points, rather than on the entire set of data points, and it provides a continuous estimation of the *outlierness* of a data point, rather than a categorical "yes" or "no" estimation. This perspective incorporates outlying points that are otherwise not detectable using other methods such as boxplot, MAD (median absolute deviation) or probability-based outlier detection methods (Leys, Ley, Klein, Bernard, & Licata, 2013). In this study, unusual variations must be determined according to the recent behaviour of the firm, given that different periods may mean different organisational structures and behaviours resulting from the natural development of the firm.

Other outlier detection methods such as time series outlier detection were also used. In particular, time series outlier detection works well with stationary data, as it accommodates an autoregressive model to the time series to detect points where the model cannot explain the variations, then, such points are labelled as outliers (Tsay, 1988). Apart from being a global, not local, outlier estimation method, the main disadvantage of time series outlier detection is that it depends on the stationarity and normality of the data. Most of the data from the ratios used in this study contain missing values, have unexpected presence of zeroes which may indicate erroneous data and, in many cases, are non-normal and non-stationary. Such variability in the data makes it difficult to implement time series outlier detection.

Based on Breunig et al. (2000) and Han et al. (2011), LOF algorithm from the "DMwR" package in R, designed and presented by Torgo (2010), was implemented adjusting the parameter for the number of neighbours to 4 (representing four years), meaning that the *outlierness* of a data point is calculated in relation to the local time window of five years (the two previous years and two subsequent years of the time point under study). The time window reflects that the sample design includes firms with a minimum of five years of data. This process calculated the LOF for each data point, for each financial ratio by firm, which were stored in the data table ratios_table. Part 1 of Figure 7 illustrates this process of detection of change events.

4.3.6.2 Detection and codification of change events

Once the LOF of each data point was computed, the next step was to identify the data points with a LOF value that deviates significantly from what is considered an average outlierness. Following suggestions from Breunig et al. (2000) on determining a range with upper and lower bounds so that significantly high LOFs can be identified, a range for the entire collection of ratios at once was computed, however, this led to asymmetries in the number of change events across the financial ratios and across value dimensions. To remedy this, the range for each financial ratio was calculated individually, a decision that led to a more balanced count of events per business model dimension, thus increasing robustness of the systematic analysis across the three dimensions.

The lower bound of the range was set at percentile 85 and the upper bound at percentile 99 of the entire distribution of LOFs per financial ratio. This meant that the outlying points representing change events are those sitting between the top 15% and top 1% of the LOFs (where 100% is the minimum LOF, thus, 100% to 15% is considered an average value for a LOF). The inclusion of an upper bound ruled out disproportionately high outliers that might represent errors in the data (top 1%).

Next, an R script searched for all the data points falling inside the 15% to 1% range for the corresponding ratio and labelled them as a change event (category "1", while the rest are "0"). Then, the same R script aggregated the categories of the four financial ratios per value dimension at each time point, and stored the results in events_x_dim_table. This means that: (1) each time point (i.e. year) has a category for the value creation dimension, a category for value delivery, and a category for value capture; (2) each value creation, delivery and capture category represents the sum of all the individual categories of the four ratios corresponding to the dimension, meaning that the possible values range from "0" (no ratio with a change event for the time point) to "4" (all of the ratios with change events for the time point). Part 2 of Figure 7 illustrates this coding process.

4.3.6.3 Construction of sequences of change

The detection of change events at the value dimension level led to the estimation of the time points where a business model change event occurred, and then the concatenation of these events across time to build the trajectories, or sequences, of business model development.

For this, an R script searched through all the value dimension change events in the database, and detected time points with a value of "1" or above in each of the three dimensions, complying with the conceptualisation of business model change as coordinated, complementary changes across the three business model value dimensions (see Chapter 3: Theoretical Framework). Importantly, this procedure also considers contiguous change events spanning across two or three years, in line with the evidence that business model reconfiguration is fully achieved in periods of years rather than months (Foss & Stieglitz, 2015; Sosna et al., 2010). Mitchell and Coles (2003) found that the successful firms in their study involving 100 public firms worldwide were implementing business model transformations every three years on average. This implies that, according to the authors, a single transformation could take up to three years before a new one is carried out. Although this period strictly depends on the circumstances of the firm, its business model and the change itself, for empirical purposes a time window of three years was used. Thus, the following combinations were classified as business model change:

- A change event (category >=1) in the value creation, delivery and capture dimension manifested in the same year.
- A change event in two value dimensions manifested in the first year, and a change event in the remaining value dimension in the following year. Alternatively, one change event from one dimension manifested in the first year, and change events in the remaining two dimensions in the following year.
- A change event in one value dimension manifested in the first year, a change event in a second dimension in the second year, and a change event in the remaining value dimension in the third year.

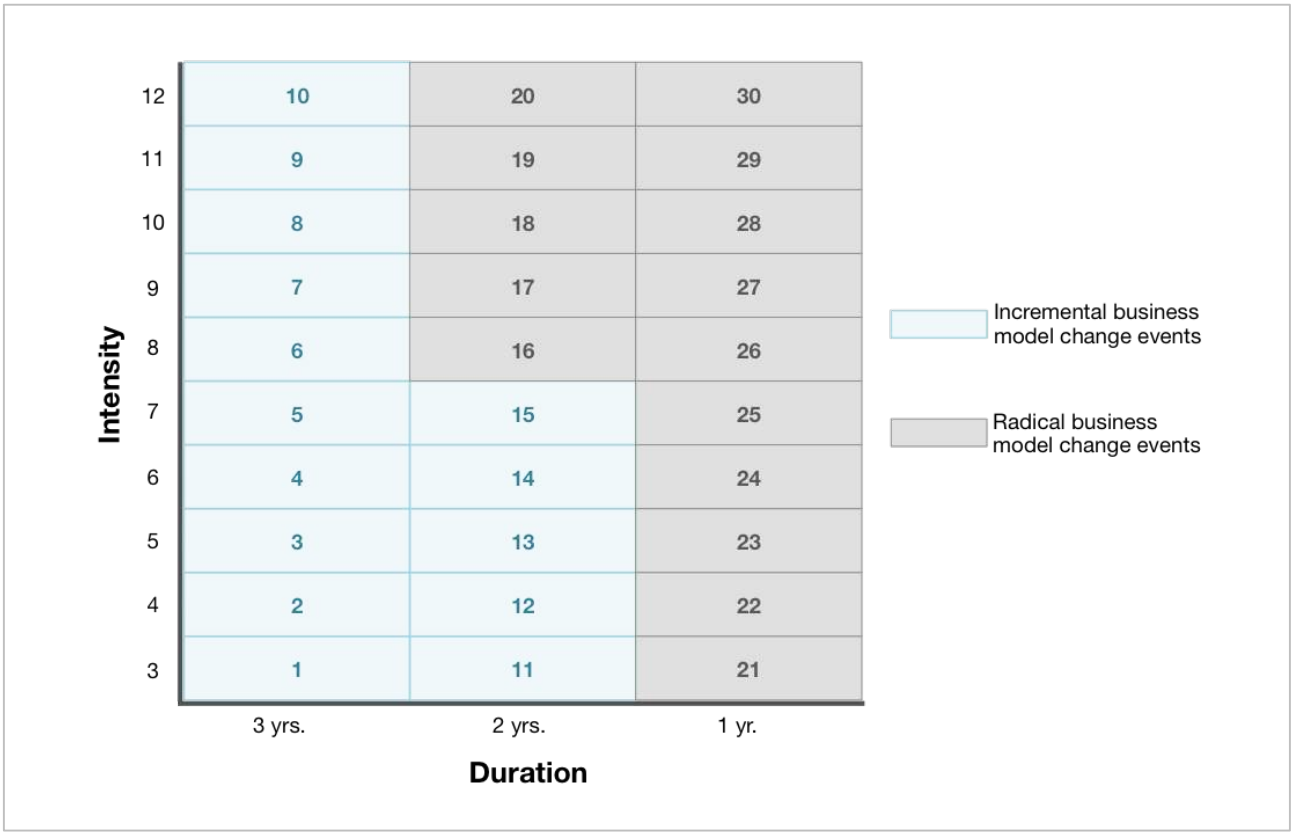


Figure 8 – Classification scheme to determine the magnitude of a business model change

As the study not only investigates the timing of the business model changes, but also the magnitude of the changes implemented, the magnitude of the change is characterised as a function of the intensity and the frequency of change. Figure 8 illustrates the scheme used to estimate the magnitude of a business model change for a point (or points) in time.

The duration of the change is determined by the time it takes to fully implement the business model change, starting from the year in which a change in one dimension starts and ending where the rest of the three dimensions are changed. The duration takes the following values: “1” where the three dimensions are changed in a single year; “2” where one dimension is changed in one year and the

remaining dimensions in the following or previous year; "3" where each dimension is changed in separate years. The intensity of the change is determined by the sum of the categories for each value dimension. As previously described, a business model change is identified when all three dimensions have a category of at least "1", thus, the minimum value for the intensity of a change is "3", while the maximum is 12 as there are up to four ratios per dimension contributing to the dimension's category.

As shown in Figure 8, the two main types of business model change are *radical* and *incremental* (see Chapter 3: Theoretical Framework for a discussion on the magnitude of business model change). Incremental business model changes are characterised by having low intensity and/or tending to occur slowly in time. On the other hand, radical business model changes are characterised by a high degree of intensity and/or tending to occur quickly in time.

The computation of the magnitude of change events was followed by the construction of the sequences of change, which is illustrated in Part 3 of Figure 7. The computed magnitudes were stored in database (events_x_bm_table), by inserting the magnitude in the corresponding time point. For business model changes occurring across two and three years, the magnitude of the change was inserted in the time point when the change was finalised. For instance, if company X has a category "1" value creation in the year 2002, category "1" value delivery in 2003 and category "1" value capture in 2004, the R script inserts a business model change magnitude "1" in the year 2004, while 2002 and 2003 remain at "0". Storing the magnitudes of the business model changes at each time point enabled the construction of sequences of business model change by concatenating the entire set of time points by firm, resulting in a string of magnitudes such as the following example: "*0—0—0—22—0—11—0—21—0*". This concatenation process worked as the input for the majority of the analyses performed in this study (see Section 4.4).

4.3.6.4 Validity and reliability

A key reason for using multiple ratios to measure firm-level alterations is to observe change from multiple perspectives, as organisational change takes multiple forms and is expressed differently across firms' financial data. In this perspective, it is crucial to design a set of multiple measures that are independent from each other, so that the constructs represented by the measures are not overweighted (i.e. two or more ratios capturing the same phenomenon) and the constructs are not empirically redundant (Shaffer, DeGeest, & Li, 2016).

Cross-correlation analysis was used to examine discriminant validity among constructs and explore multicollinearity among the set of ratios (Ketchen & Shook, 1996). (Chase, 2013) suggested using the cross-correlation function to assess the extent to which a time series Y_t is related to past lags of

a time series X_t, while Campbell and Fiske (1959) suggested that a low correlation between constructs that are supposed to measure different things is a solid case to accept discriminant validity. Therefore, cross-correlation between pairs of financial ratios was calculated, which are essentially time series, to assess the independence of each ratio in measuring different operational, strategic and economic aspects of the firm.

Table 12 shows the resulting coefficients from the cross-correlation analysis of the 12 financial ratios used in this study. The analysis was conducted for each individual firm, and then the resulting values were averaged by ratio to obtain the overall coefficients. The cross-correlation was calculated using a lag value of 0, which means it considers whether values from one ratio and another at a particular time point are correlated, not whether the variations in one affect the other in successive points in time. There are no cross-correlation coefficients greater than 0.36, therefore, each financial ratio indeed represents an independent construct measuring different aspects of the firm.

	ta.ia	**em.ca**	**rd.ot**	**de.op**	**se.co**	**sa.ta**	**ot.em**	**st.tu**	**fr.op**	**co.pe**	**cg.op**	**fi.ot**
ta.ia	1											
em.ca	0.011	1										
rd.ot	-0.034	0.000	1									
de.op	-0.039	-0.081	-0.071	1								
se.co	-0.013	0.045	-0.105	-0.242	1							
sa.ta	0.045	0.105	-0.082	0.317	-0.246	1						
ot.em	0.032	0.284	0.188	-0.035	-0.173	-0.059	1					
st.tu	0.002	-0.034	-0.025	0.158	-0.088	0.276	-0.086	1				
fr.op	0.069	-0.058	-0.008	-0.119	0.108	-0.263	0.005	-0.036	1			
co.pe	-0.001	0.022	0.008	-0.065	0.048	-0.255	0.133	-0.144	0.040	1		
cg.op	-0.022	-0.032	0.006	-0.037	0.363	-0.109	-0.052	0.089	0.037	-0.023	1	
fi.ot	0.032	0.074	-0.086	-0.084	-0.065	-0.074	0.048	-0.057	0.066	0.029	-0.102	1

Table 12 – Cross-correlation of the 12 financial ratios, with lag = 0 (see Table 9 for full names of the ratios)

To ensure reliability of the measurements, a conditional treatment of missing values was also conducted. Although Osiris returns an 'NA' character where there are no values available regardless of the cause of unavailability, this study recognises that there are two types of NAs: (1) those where the firm was not in operation (the firm did not exist for the time point in observation); and (2) those caused by the firm's failure to report them. A case of missing value corresponded to

the second situation if there was at least one non-missing value across the entire set of ratios for the time point under analysis.

Throughout the data manipulation process, cases from the first situation were kept as NA, as years of no-operations had to be considered as such, and not as a zero value or any other numeric value that may distort further analyses. This meant that the sequences of business model change have different lengths across firms, conditional on the years of operation.

For cases in the second situation, the missing values were omitted from the calculation of LOFs, as well as for the identification of change events. For the time points corresponding to the missing values, an empty space was coded instead of "0" or "1". Then, during the aggregation of change events by dimension, the said time points were omitted from the sum of the change event categories. Importantly, if there were empty spaces in all four ratios of a dimension, the category of the change event for that dimension was recorded as "0", as the lack of data prevented identifying change events of category "1" or above.

4.4 Analytic methods

The selection of analytical methods has been completely influenced by the theoretical framework and research motivations supporting this study. There is a closed-loop relationship from the research motivations to processual philosophy, the sequence-based approach and analytic methods (which points back to the research motivations). The adoption of a processual perspective responds to a need to understand how business models develop over time by focusing on the progression of change events, rather than the cause and/or effects of change (Van de Ven, 1992). Key to this perspective is acknowledging business model innovation as a sequence of change events temporally connected, a definition that enables the application of sequence-based analytic techniques with the capacity to unveil pattern similarities and dissimilarities across various cases (Abbott, 1990). Lastly, among the vast collection of techniques proposed for the ever-increasing studies of sequential data (Aisenbrey & Fasang, 2010), the family of methods known as data mining is emerging as a versatile and effective alternative for studies with large datasets of temporal data (Gupta & Han, 2012). Data mining algorithms enable the discovery of temporal dependencies in longitudinal data to explicate the mechanisms by which things change over time (Aggarwal, 2015), which is the key question motivating this study.

Table 13 shows the selection of analytic methods, as well as the role each one plays in the methodology. Data mining methods, represented by hierarchical cluster analysis and sequential pattern mining, are an important part of the analysis phase. Nevertheless, these methods are

complemented by others such as multivariate analysis of variance and frequency domain analysis. The rest of this section describes each method in detail.

Feature of BMI studied	Method of analysis	Level of analysis	How are research questions answered?
Assess the existence of distinctive patterns of business model change	Cluster analysis, MANOVA and descriptive statistics	Separate analysis for each of the four age-size groups	By finding statistically significant differences in performance means between clusters of firms with different change patterns. Identifying performance levels associated with sequences of business model change support the existence of business model innovation patterns
Order of events in business model development	Sequential pattern mining and descriptive statistics	Separate analysis for each of the four age-size groups and, on each group, firms are segmented in performance deciles	By comparing frequent sub-sequences of change seen in high-performing firms, compared to the rest. Orderings of change events at each of the three value dimensions are analysed
Frequency of events in business model development	Frequency domain analysis and descriptive statistics	Separate analysis for each of the four age-size groups and, on each group, firms are segmented in performance deciles	By comparing average frequencies of change seen in high-performing firms, compared to the rest. High frequencies imply business model innovation is continuous in nature; low frequencies imply business model innovation is episodic in nature
Magnitude of events in business model development	Sequential pattern mining and descriptive statistics	Separate analysis for each of the four age-size groups and, on each group, firms are segmented in performance deciles	By comparing average magnitudes of change, as well as frequent sub-sequences of change, seen in high-performing firms, compared to the rest. High magnitudes imply business model innovation is radical in nature; low magnitudes imply business model innovation is incremental in nature
Mechanisms driving business model development	Sequential pattern mining, Pearson's Chi-square test and ANOVA	*1st phase of analysis*: high-performing firms within a chosen IT industry and, on that industry, firms are segmented by the four age-size groups *2nd phase of analysis:* high-performing firms within a chosen age-size group and, on that group, firms are segmented by the seven IT industries	By assessing similarities and differences between frequent sub-sequences of change among high-performers from (1) a chosen industry but across the four age-size groups; (2) a chosen age-size group but across the seven industries. Controlling either the external or the internal conditions allows discerning whether changes are driven by individual/collective forces and by voluntary/involuntary actions

Table 13 – Methods of analyses in this study, with reasons for their use and corresponding description

4.4.1.1 Hierarchical cluster analysis

Hierarchical clustering is a data mining method in which a set of data points are partitioned into groups based on similarity by estimating distances between them, forming a taxonomy of clusters in the process (Aggarwal, 2015). The advantage of building a hierarchy of cases is that it allows assessing not just the cases that are similar to each other, but the degree of similarity between the remaining cases in the sample. It is also particularly useful when there are no prior assumptions

about the number and composition of clusters, facilitating the identification of the optimal number of clusters based on the desired level of granularity (Provost & Fawcett, 2013).

Cluster analysis has been applied in social sciences to explore and describe diversity in samples ranging from life trajectories (Rapkin & Luke, 1993) to customer segments (Punj & Stewart, 1983). In strategic management, cluster analysis is usually used to explain differences in organisational performance by forming groups of similar firms.

In computational science terms, hierarchical clustering follows an unsupervised learning approach, where there are no predetermined inferences about the relationships among the data; data points are classified by their statistical properties only, rather than by their predicted value generated by a known model, as in supervised learning (Provost & Fawcett, 2013). Thus, it is a suitable analytical tool where there is no prior knowledge on the relationship among data points. For this reason, hierarchical clustering is an appropriate alternative for this study, as there are no previously known inferences on the nature of business model change events under analysis, and also, the focus is on discovering recurrences among their patterns of change rather than on constructing a predictive model.

The sequences of business model change events, which were generated in the data transformation phase, are used as the sole firm feature to form different clusters of firms, thus, the firms sharing similarities in their trajectories of business model change are clustered together. The clusters were built by calculating the distance between the sequences using a variation of the optimal matching algorithm, a technique initially proposed and promoted by social theorist Andrew Abbott (Abbott, 1990; Abbott & Tsay, 2000).

In a detailed study on the use and misuse of clustering analysis in strategic management, Ketchen and Shook (1996) stressed the need to combine clustering analysis with other statistical techniques to enable more robust and powerful theoretical models. The authors stressed that cluster analysis should be used to provide a context in which to investigate the similarities and/or differences between organisational characteristics and performance constructs (Frankenberger et al., 2013). Following this suggestion, cluster analysis is complemented with multivariate analysis of variance (described next in this section), and the firm's performance is included as a variable to assess the extent to which there are similar patterns in the sequences of business model change of high-performing firms. This question on the existence of typical sequence patterns converges with what Abbott (1990) proposed as one of the key motivations when theorising on sequences of social events.

4.4.1.2 Analysis of variance

As part of the data analysis procedures, univariate analysis of variance (ANOVA) was used to test for group differences in dynamic patterns across similar firms, and multivariate analysis of variance (MANOVA) to test for performance differences across firms clustered by dynamic pattern similarities.

ANOVA is a linear model in which a dependent variable is formulated in relation to the influence of an independent source with the main purpose of asserting the existence of group differences, an approach that is highly suitable to test for variable effects resulting from a particular treatment (Huberty & Morris, 1989). MANOVA is an extension of the more traditional ANOVA in that it also tests the significance of group differences between two or more groups of individuals (such as patients, employees and firms), but it is applied when there are two or more dependent variables where correlation among them needs to be controlled (Haase & Ellis, 1987).

MANOVA has also proved to be an effective analytic method in combination with classification methods such as cluster analysis. In such cases, cluster assignment (or membership) is used as the independent variable to: (1) assess the variance of the dependent variable across clusters (Ketchen & Shook, 1996); (2) validate the implementation of the clustering process (Turk & Rudy, 1988); and (3) estimate the optimal number of clusters that maximise variability across cases (Rapkin & Luke, 1993). The method has been extensively used together with clustering analysis in life sciences to study the effects of certain treatments among different groups of patients (Turk & Rudy, 1988).

Building on the results from the cluster analysis, one-way MANOVA was implemented to test the significance of the financial performance differences between the firms across the various clusters. This analysis assessed whether the pattern in which a firm changes its business model across time has an effect on its average performance. Considering that successful business model implementation affects a firm's competitiveness and, ultimately, its performance (Zott & Amit, 2008), validating the existence of significant differences in firm performance across different clusters is an indication that the sequences under analysis are not a reflection of merely random events, but orchestrated moves involving the firm's value creation, delivery and capture dimensions. The firm's cluster membership was taken as the independent variable, and firm's average revenue growth and average profit margin, both indicators of performance (Bettis & Mahajan, 1985), as the dependent variables. A subsequent test indeed validated the existence of a significant correlation between revenue growth and profit margin variables, which is a prerequisite to employ MANOVA tests.

One-way ANOVA was implemented to statistically assess the extent to which pattern differences among similar firms (i.e. identical age, size and industry affiliation) were more significant than differences among dissimilar firms. For this, firm similarity was transformed into a variable named *class* and used as the independent variable for the ANOVA test, whereas overall magnitude of changes implemented were used as the independent variable. Various ANOVA tests were conducted using multiple combinations of firm class configurations as independent variables and either intensity or duration of change as dependent variables. Then, F-statistic values from the different ANOVAs were examined to assess the circumstances under which between-group variability was greater than within-group variability, which enabled insights on how constrained a firm is when reconfiguring its business model over time.

4.4.1.3 Pearson's Chi-square test

The Pearson's Chi-square test of independence is one of the most frequently used statistical tests in social science when the research question involves assessing the degree of independence of one nominal (or categorical) variable from another categorical variable (Lewis-Beck, Bryman, & Liao, 2003).

Examples of using the Chi-square test to assess the relationship among variables representing business-related phenomena include testing the independence between individual-level characteristics of gender, age, income and educational level with the adoption of Internet banking practices (Foon & Fah, 2011), assessing the dependence of survey responses from CEOs and board members on corporate social responsibility (O'Neill, Saunders, & McCarthy, 1989), and assessing whether the judgement of accounting auditors is independent of their past experiences and expertise (Frederick & Libby, 1986). In addition, a Chi-square test can test the appropriateness of a statistical model and how well the model represents the observed data, as demonstrated by Tsai and Ghoshal (1998) who conducted Chi-square tests to measure the appropriateness of their proposed model of social capital and value creation.

Chi-square tests were used to assess the independence of the following categorical variables: (1) the type of the most frequent pattern of business model change for each firm; and (2) the firm's characteristics of age-size and industry of operation. Multiple tests were conducted with different combinations between firms' characteristics of age-size and industry affiliation on the one hand, and types of sub-sequences formed by either the dimensions changed, intensity or duration of change on the other hand. The statistical significance of the relationship between the two categorical variables used tested the extent to which the age-size characteristics and/or industry of operation drive the patterns of business model change observed.

4.4.1.4 Descriptive statistics

Statistical analyses in social sciences have two main aspects: statistical description and statistical inference. The former provides support for the later, as it describes and summarises the characteristics of the sample in a visual form, guiding the design and development of inference tests (Rosenthal, 2012).

In the field of strategic management, descriptive statistics is generally used in empirical studies for a variety of reasons, from describing and comparing themes from interviews on the use of different corporate strategies (Dess & Davis, 1984) and managerial behaviours (Wageman, 2001), to summarising variables from models explaining transferability of organisational capabilities (Zander & Kogut, 1995), business model design (Zott & Amit, 2007) and firm information sharing across its suppliers (Dyer & Chu, 2003).

Descriptive statistics are used to analyse the characteristics of the change events comprising the trajectories of business model development such as frequency (i.e. number of occurrences) by value dimension and magnitude, as well as proportion of business model change events per firm. Such characteristics are contrasted by firm performance to identify differences between high-performing firms and the rest of the sample. The intention behind the application of descriptive statistics is to complement the insights from the dedicated analyses on the order, magnitude and frequency of change events.

Specifically, measures of central tendency (e.g. median, mean) and measures of variability or dispersion (e.g. standard deviation, variance) are considered. Assessing central tendency provides clues about what is considered an average business model change behaviour while assessing dispersion allows estimation of how variable the business model change trajectories are from one another. Measures are provided for the entire sample, as well as for both high-performing firms and the rest of the firms as separate groups.

4.4.1.5 Sequential pattern mining

Abbott (1990) argued that the two main questions driving social theory development by means of analysing sequences of social events are: assessing the existence of distinctive sequence patterns; and assessing the existence of common sub-sequences, that is "whether a certain portion of the development process repeats in every one of a set of innovations" (Abbott, 1990: 390). Cluster analysis addresses the first question and sequential pattern mining addresses the second question.

When these patterns are present across all cases, the data mining task of discovering such recurrence is known as frequent pattern mining (Aggarwal, 2015). One of the objectives of frequent pattern mining is to find associations between data items that tend to occur simultaneously. Finding

this association has proved an efficient analytic method for market basket analysis in consumer behaviour research, the analysis of items that are usually bought together. Questions on this aspect are, for instance, the probability of finding <*milk*> and <*bread*> together in the same transaction.

When the data represents sequences of temporally ordered events, frequent pattern mining algorithms aim to find frequent sequences (or portions of a sequence, known as a sub-sequence). This task is known as frequent (sub)sequential pattern mining (Han et al., 2011), and is a special case of the frequent pattern mining technique. It solves questions such as the probability that a transaction including the items <*butter, milk*> made in one day is followed by a transaction with the items <*bread, butter, cheese*> made the next day. Although most of the frequent pattern mining algorithms are applicable to sequential mining, the latter represents a more complex problem (Aggarwal, 2015).

The discovery of frequent sequential patterns through data mining is a fundamental tool for data analysis in many disciplines. In bioinformatics, sequential pattern mining is generally employed to identify meaningful strings of DNA or protein sequences that occur frequently to predict gene expression and detect particular medical diagnoses (Gupta & Han, 2012). In engineering and computer sciences, frequent sub-sequences of events are mined to predict the behaviour of entire sequences, a procedure that allows the detection of potential failures in web-based information systems (Mannila, Toivonen, & Verkamo, 1997), prediction of peaks in traffic across telecommunication networks (Gupta & Han, 2012) and detection of intrusion, misuse and attacks across computer networks (Lee, Stolfo, & Mok, 1999).

Inspired by technical advances in sequence mining algorithms in biomedical sciences, social science researchers have been incorporating sequential pattern mining as an analytic method in a variety of research topics including life course research, where the discovery of common sub-sequences shared by many individuals has led to the identification of converging and diverging life course trends, historical evolution of political institutions, and assessment of employment patterns (Blanchard, Bühlmann, & Gauthier, 2014).

In implementing frequent subsequent pattern mining in the business model change sequence data, the goal was to: (1) identify periodic sub-sequences of change events that are frequently present in a set of firms grouped by performance (comparing the results among groups); and (2) determine the probability of occurrence for each frequent sub-sequence identified. Identifying frequent sub-sequences of change events and estimating probability of occurrence support the characterisation of business model development in high-performing firms.

Sequential pattern mining is implemented in three ways. Firstly, sequences of business model change events are considered at the level of the three value dimensions to assess the order of events

in business model trajectories, such as sequences in the form of <2vcre—1vcap—1vdel>, which indicate a change of category "2" in the value creation dimension, followed by a category "1" change in the value capture dimension, followed by a category "1" change in the value delivery dimension. Secondly, sequences of business model change are considered at the aggregated level to assess the magnitude of events in business model trajectories, such as sequences in the form of <21—1>, which indicate a radical event of business model change with magnitude "21", followed by an incremental event of business model change with magnitude "1". Thirdly, sequences of business model change events are considered both at the level of the value dimensions and aggregate level, while controlling for the industry first, and then for the age-size group, to assess the mechanisms driving business model trajectories in high-performing firms.

4.4.1.6 Frequency domain analysis

The distinction between time and frequency domains emerged from engineering and electronics fields as two opposing ways of representing and analysing signals: in the time domain, the amplitude of data points is expressed in terms of time of occurrence (this is the traditional approach in time series analysis); in the frequency domain, the amplitude of data points is expressed in terms of their frequencies. Broughton and Bryan (2008) argued that every object existing in a time domain has a corresponding representation in the frequency domain, and that the key reason for transforming data from time domain to frequency domain is because mathematical operations in the latter are easier to implement.

The main goal of the analytic methods for the frequency domain is to detect periodicities in data to either remove them from the entire time series, or isolate them for further examination. Both tasks are particularly valuable in topics such as signal and image processing (Broughton & Bryan, 2008). This is generally achieved by constructing a frequency domain representation for time domain data, such as the business model change sequences in this study, to estimate the most dominant frequencies according to their *spectral densities* or intensity of business model change events so that periodicities in the temporal data can be determined (Shumway & Stoffer, 2010).

Fourier analysis, also know as harmonic analysis, is one of the most used set of methods for frequency domain analysis. It consists of deconstructing a time series or sequence into a sum of sinusoidal components, and it is generally used to refer to any analytic tool that assesses fluctuations in time series by comparing them with sinusoids (Bloomfield, 2000). Its reliance on trigonometric functions makes it a fit-for-purpose method to study periodicities in data, thus, it is commonly used to identify periodic oscillations in data representing phenomena in fields as diverse as astrophysics, economics and environmental sciences (Bloomfield, 2000).

Recently, data mining authors have suggested the method of discrete Fourier transform (DFT), a member of the Fourier analysis family of methods, for data feature extraction by transforming a sequence of discrete data objects from the time domain to a corresponding representation in the frequency domain (Antunes & Oliveira, 2001; Shumway & Stoffer, 2010). The resulting frequency information is then assessed to identify periods in time where the original time series is more likely to change in amplitude, the frequency in which the sequence fluctuates over time.

Following this approach, DFT is used by applying an algorithm known as fast discrete Fourier transform (Shumway & Stoffer, 2010) to represent the sequential data in the frequency domain to explore the frequencies of business model change events across the sampled firms. DFT is used because the sequences of business model change manipulated in the study are composed of discrete data points, while, in comparison, DFT algorithms are less computationally intensive than other Fourier analyses such as Fourier series, given the reduced mathematical complexity of manipulating discrete rather than continuous values (Smith, 2007). This analysis first segmented the firms by performance, and then aggregated all of the business model change sequences from all of the firms on each segment, then applied the fast discrete Fourier transform algorithm to the aggregated sequence. The resulting frequencies (i.e. the number of business model changes per year) and periods (i.e. how often in years does a business model change occur) were then compared across segments to assess the timing of business model change in high performers compared to the rest of the sample.

4.5 Summary and conclusions

The main motivation for this research design was the exploration of the mechanisms driving business model development in a way that captures the dynamics behind the change processes in business models, leading to theory development on business model innovation in established firms. The research design is exploratory, longitudinal and quantitative in nature, driven by a process-based approach in which business model development is seen as a sequence of change events over time.

Given the novelty of these research attributes compared to the rest of business model innovation studies, the identification of proper data sources was crucial. Building on the operational definition of business model change described in previous chapters, a set of 12 financial ratios was proposed as the most suitable form of parameterisation to examine fluctuations in a firm's operational, economic and strategic domains that are attributable to business model transformations.

The second step of the research process centred on designing the sample, resulting in 1,651 listed firms operating in the IT sector and located worldwide. The data was then collected from Bureau Van Dijk's Osiris database on a yearly basis for a period of up to 29 years. A transformation procedure, based on outlier detection, was performed on the financial data to generate discrete sequences of business model change events per firm.

Data were collected, transformed, and analysed using a digital platform with a relational database and a series of scripts in R (statistical package), which were purposefully designed for this study.

Lastly, data mining methods of analyses were complemented by discrete Fourier transforms and more static techniques such as multivariate analysis of variance and descriptive statistics to disclose particular characteristics of business model development in high-performing firms. The characteristics explored were: existence of patterns of business model change (using cluster analysis and multivariate analysis of variance); population-based and action-based mechanisms driving business model change (using sequential pattern mining and descriptive statistics); order and magnitude of change events (sequential pattern mining and descriptive statistics); and frequency of business model changes (discrete Fourier transforms and descriptive statistics).

The next chapter presents the validation process conducted to the business model change sequences generated by the procedure explained in section 4.3.6 in this chapter, using qualitative data collected and analysed for four cases of firms.

Chapter 5: Qualitative Validation

5.1 Introduction

This chapter discusses the validation procedure conducted on the business model change events resulting from the quantitative-based event detection procedure presented in Section 4.3.6. The confirmation of the business model change events represents an important step in the research design, as the events are the input data for subsequent analyses and assessment of the research propositions presented in Chapter 3. This chapter has two main sections: the first section explains the methodology supporting the validation process, while the second section discusses the results for the four cases under examination.

5.2 Validation process

5.2.1 Increasing validity through qualitative research

According to Creswell, Plano Clark, Gutmann, and Hanson (2003), a suitable method to validate statistical findings in social science studies in which certain degree of exploratory analysis is present involves the mutual validation with qualitative techniques. Qualitative analysis, for example case studies, offers data richness and a deeper interrogation of the high-level data gathered through the quantitative component of the study.

One key benefit of complementing a quantitatively-dominant study with qualitative approaches is that it allows validation of statistical values such as measurements and indexes by in-depth qualitative data (Johnson, Onwuegbuzie, & Turner, 2007). Multiple examples are found in public health research, where researchers typically use qualitative research to validate quantitative data (Petticrew et al., 2005). In corporate finance, financial analysts commonly assess qualitative factors on managerial activities and strategic plans at the firm level to validate quantitative financial variables (Chugh & Meador, 1984).

A key motivation for the use of qualitative data is the potential value in implementing two independent research methods and datasets to assess a theoretical proposition (Caracelli & Greene, 1993). The use of both quantitative and qualitative frameworks to test a hypothesis increases validity, as the effects of potential biases of each method are reduced (Blaikie, 1991).

This research study has also included qualitative data and methods as a mechanism for minimising threats to construct validity. The purpose is to corroborate the accuracy of the firms' sequences of business model change generated by the constructs which are themselves based on the financial ratios, and to assess the extent to which these sequences represent changes at the business model level, rather than changes at other levels and dimensions of the firm. The procedure is similar to the

triangulation method promoted by Onwuegbuzie and Leech (2004) where the goal is to seek convergence of quantitative results by using qualitative methods, or any other method distinct from the methods producing the results to be validated. Such an approach leads to construct validity. Sandelowski (2000) argued that, for instance, further qualitative assessments conducted on the respondents of a quantitative instrument help test the effectiveness and accuracy of the constructs used in the instrument.

5.2.2 Case selection

Cases in this qualitative phase were chosen by identifying firms that have achieved financial success by undertaking a variety of innovation activities to outperform their competitors and establish themselves as key players in their industries. These firms are more likely to follow a systematic approach to innovation, as well as having identifiable strategies, processes and capabilities in place allowing them to innovate on an ongoing basis (Aragón-Correa & Sharma, 2003). Concentrating on firms with these characteristics helps reconstruct the events that have led to innovations in the past, a key task for this qualitative validation. Additionally, key industry innovators are more likely to attract particular attention from scholars and practitioners as they are used as exemplars, thereby increasing the availability of secondary data required for qualitative investigations (Neubaum & Zahra, 2006).

Four different company rankings were used to identify firms with a consistent reputation as innovators in the IT sector over the five years from 2012 to 2016 including MIT's Technology Review 50 Smartest Companies (MIT Technology Review, 2017), The Most Innovative Companies list developed by The Boston Consulting Group (BCG, 2017), PwC's The Global Innovation 1000: The Top Innovators and Spenders (PwC, 2017) and the Top 100 Global Innovators list developed by Clarivate Analytics, formerly Thomson Reuters Intellectual Property and Science Business (Clarivate Analytics, 2017). As shown in Table 14, the selection process counted the number of times a firm was included in the 2012, 2013, 2014, 2015 and 2016 versions of the lists. The following four firms were selected as they clearly stand out from the remaining firms with at least 18 mentions out of a possible 20: Alphabet Inc., Apple Inc., International Business Machines Corp. and Microsoft Corp.

Firm	MIT Tech Review – Top 50					BCG – Top 50					PwC – Top 10					Clarivate Analytics – Top 100					Count
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	
3D Systems Corp.				✓																	1
Advanced Micro Devices Inc.																✓	✓	✓	✓	✓	5
Alcatel-Lucent S.A.	✓															✓	✓	✓			4
Alphabet Inc.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	20
Analog Devices Inc.																✓	✓		✓	✓	4
Apple Inc.	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18
ARM Holdings	✓	✓																			2
Broadcom Limited																✓	✓	✓	✓	✓	5
Brother Industries																✓	✓	✓			3
Canon Inc.																✓	✓	✓	✓	✓	5
Cisco Systems Inc.							✓	✓	✓	✓											4
Corning Inc.																✓	✓	✓		✓	4
Fireeye Inc.					✓																1
Fujifilm Holdings Corp.																✓	✓	✓	✓	✓	5
Fujitsu Limited																✓	✓	✓	✓	✓	5
HP Inc.						✓	✓	✓	✓	✓						✓	✓	✓			8
HTC Corp.						✓															1
IBM Corp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			18
Intel Corp.	✓	✓			✓	✓	✓	✓		✓						✓	✓	✓	✓	✓	12
Interdigital Inc.																			✓	✓	2
Lenovo Group						✓	✓	✓	✓												4
Mediatek Inc.																		✓	✓	✓	3
Micron Technology																	✓	✓	✓	✓	4
Microsoft Corp.		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	18
Motorola Solutions																✓					1
NEC Corp.									✓							✓	✓	✓	✓	✓	6
Nokia Oyj							✓													✓	2
NTT Data Corp.																✓	✓	✓	✓	✓	5
Nuance Comms.		✓																			1
Nvidia Corp.				✓	✓																2
Omron Corp.																				✓	1
Oracle Corp								✓									✓		✓	✓	4
Qualcomm Inc.	✓		✓													✓	✓	✓	✓	✓	7
Seagate Technology																✓	✓	✓	✓	✓	5
STMicroelectronics																✓	✓	✓			3
Symantec Corp.																✓	✓	✓	✓	✓	5
TE Connectivity																✓	✓	✓	✓	✓	5
Tencent Holdings		✓	✓	✓	✓		✓	✓	✓												7
Texas Instruments Inc.																✓	✓	✓			3
Toshiba Tec Corp.																✓	✓	✓	✓	✓	5

Table 14 – Result of case selection for qualitative phase

5.2.3 Event structure analysis

In qualitative research, event structure analysis equates to sequence analysis in quantitative research (Abbott, 1995). A form of formal qualitative analysis, event structure analysis is traditionally used to study complex historical narratives based on its ability to explain change processes as a chronological sequence of events unfolding over time (Stevenson & Greenberg, 1998). It emerged from sociology and was influenced by rational choice theory and by developments in cognitive anthropology in the late 1990s (Griffin, 1993). It was originally proposed by Heise (Heise, 1989) as a narrative-based tool to model event structures to explain popular realities explicitly and objectively.

A key reason for implementing event structure analysis in this thesis is that it supports the creation of a model of causality of events to identify main story lines and key patterns of causal relations between events, as well as enabling the identification of those events most influential in the entire sequence (Griffin, 1993). These aspects are particularly relevant to the study, as business model changes are a collection of events co-occurring across a period of three years, involving different dimensions of the firm. Therefore, understanding the sequential order and association between the events is crucial to validate business model changes.

Event structure analysis is used to identify associations between collections of firm-level events representing changes in particular domains of the firm, associations that may have led to changes in a firm's business model. The initial step in the validation process was compiling change events across three main organisational domains, discussed below, while the second step was identifying relationships between key events, and their effect on each value dimension and interpretation as a business model change event.

5.2.4 Domains of organisational activity

In their work on the discontinuous nature of organisational transformations, Romanelli and Tushman (1994) recognised that organisations change virtually every day, and that, investigating transformational processes and distinguishing them from routine improvements and replacements must concentrate on changes that significantly affect the way organisations carry out their business activities. Romanelli and Tushman (1994) identified three key domains of organisational activity that, if altered, can potentially affect a firm's survival and growth: strategy, structure and power distribution. These three domains were also selected for their appropriateness and applicability in longitudinal assessments using secondary data, which is an advantage over other organisational

domain classifications in the literature. For instance, the four domains proposed by Hannan and Freeman (1984) include stated goals, a characteristic for which temporal variations are difficult to track using secondary data, unless a firm explicitly informs via press releases or public reports that a change in goals has been implemented.

Changes in the strategy, structure and power distribution domains can be used as both measures of organisational transformation and measures of changes in a firm's existing business model. This is supported by the evidence that business model reconfiguration involves fundamental organisational transformations (Foss & Saebi, 2015), and also by cases where correlations between business model changes and corporate strategy changes (Aspara et al., 2011), structural changes (Foss & Stieglitz, 2015) and changes in leadership (Foss & Stieglitz, 2015) have been identified.

The strategy, structure and power distribution domains are used to discriminate, select and classify the events from the qualitative data sources. For instance, change events associated with strategy may involve the introduction of new products and/or introduction of existing products in new markets; events associated with structure may include acquisitions that expand the firm's capabilities; events corresponding to power distribution may involve CEO replacements and/or changes in key management personnel. Then, in the interpretation step, the events classified by organisational domain are re-assessed in terms of their relationship with the business model change events from the quantitative phase. This is done by matching each qualitative event to each value dimension event in the business model changes. This matching process allows confirmation of the occurrence of each quantitative business model change event; and understanding of the history of each business model change event by recreating the sequence of qualitative events leading to the change.

The next section illustrates the results of the above process for the four selected cases. For each case, a table with the full list of qualitative events is presented, with a figure illustrating the value dimension events and business model change events resulting from the quantitative phase (the value dimension events associated with a business model change are marked with a black circle). These figures also show the key qualitative events superimposed on the corresponding points in time.

5.3 Results of case studies of four innovative IT firms

5.3.1 Alphabet Inc. (formerly Google Inc.)

Alphabet Inc. was founded in 1998 under the name of Google Inc. in California, United States. After a corporate restructuring implemented in late 2015, Alphabet Inc. emerged as a conglomerate of subsidiaries that includes Google Inc., Google X, Calico and nine others (Hern, 2015). As the data collected in this study corresponds to the years prior to 2015, the trajectory of business model development for Alphabet Inc. reflects, in reality, the history of Google Inc., and does not include the history of the other subsidiaries. For this reason, this section makes explicit reference to Google rather than Alphabet.

Google currently offers online advertising services and Internet products, as well as technical infrastructure and hardware products, and distributes and sells digital content through online stores (Bloomberg, 2017a). In 2015, Google Inc. had revenues of US $75 billion, total assets of US $148 billion and 61,814 full-time employees (Alphabet Inc. and Google Inc., 2016). A total of 28 events were identified from a range of sources including case studies (in books, journal articles and reports), press releases and news articles, as shown in Table 15.

Year	Event	Domain of organisational activity affected	Reference
1999	Initial AdWords is developed using cost-per-impression model	Product/service strategy	(Karp, 2008)
2000	Partnership with Yahoo is launched	Product/service strategy	(Finkle, 2012)
2000	AdWords is officially launched	Product/service strategy	(Finkle, 2012)
2001	Eric Schmidt replaces Larry Page as CEO	Power distribution	(Google Inc., 2001)
2002	AdWords switches to pay-per-click model	Product/service strategy	(Karp, 2008)
2002	Google Labs is launched	Firm structure	(Mello, 2011)
2002	Google Search Appliance (company's first hardware) is launched	Product/service strategy	(Finkle, 2012)
2003	AdSense is included in company's portfolio of offerings	Product/service strategy	(Voigt, Buliga, & Michl, 2017)
2003	The company moves into GooglePlex	Firm structure	(Silicon Valley Business Journal, 2003)
2003	The company's first engineering office opens	Firm structure	(Wordpress, 2012)
2003	Applied Semantics and Pyra Labs are acquired	Firm structure	(CB Insights, 2016)
2004	Gmail is launched	Product/service strategy	(Mello, 2011)
2004	Dave Girouard is hired to run the enterprise search business unit	Power distribution	(Finkle, 2012)
2004	Initial public offering (IPO) takes place	Firm structure	(McFadden, 2017)
2004	A series of products (Froogle, Blogger, Picasa, calendar, translator) are developed and launched	Product/service strategy	(Deighton & Kornfeld, 2013)
2005	The rule of spending 20% of time on personal projects applies to all employees	Firm structure	(Steiber, 2014)
2005	A series of mobile products (Maps, Earth, Talk, blogger mobile) and Google Analytics are launched	Product/service strategy	(McFadden, 2017)
2005	An R&D centre in China opens	Firm structure	(Finkle, 2012)
2005	Android is purchased	Firm structure	(Arthur, 2012)
2006	YouTube is acquired	Firm structure	(Voigt et al., 2017)

2007	Partnership with Salesforce.com is launched	Product/service strategy	(Finkle, 2012)
2008	Google Chrome and Android Market Store are launched	Product/service strategy	(McFadden, 2017)
2009	Android Market Store adds support for paid apps in the US and UK	Product/service strategy	(Callaham, 2017)
2009	First revenue decline in consecutive quarters since IPO is posted	Firm structure	(Vascellaro, 2009)
2011	Larry Page replaces Eric Schmidt as CEO	Power distribution	(Reuters, 2011)
2012	Motorola is acquired (one of the biggest acquisitions in the industry)	Firm structure	(Rowe, 2016)
2012	Drive and DoubleClick platform are launched	Product/service strategy	(Voigt et al., 2017)
2013	Project loon joins the list of projects that also includes driverless cars	Product/service strategy	(McFadden, 2017)

Table 15 – Qualitative change events by organisational domain for Alphabet Inc.

The second step of the qualitative analysis for Google is summarised in Figure 9. According to the quantitative-based event detection process, the first of two business model change events identified for Google occurred in 2003, less than a year after it launched the version of Adwords, Google's main product offering, that enabled the development of a multi-billion dollar business (Marvin, 2015). As shown in Figure 9, the process was initiated when Eric Schmidt was hired as CEO in 2001. He actioned changes to create long-term product development plans and establish new partnerships (McCann, 2015), actions particularly relevant to the value creation dimension.

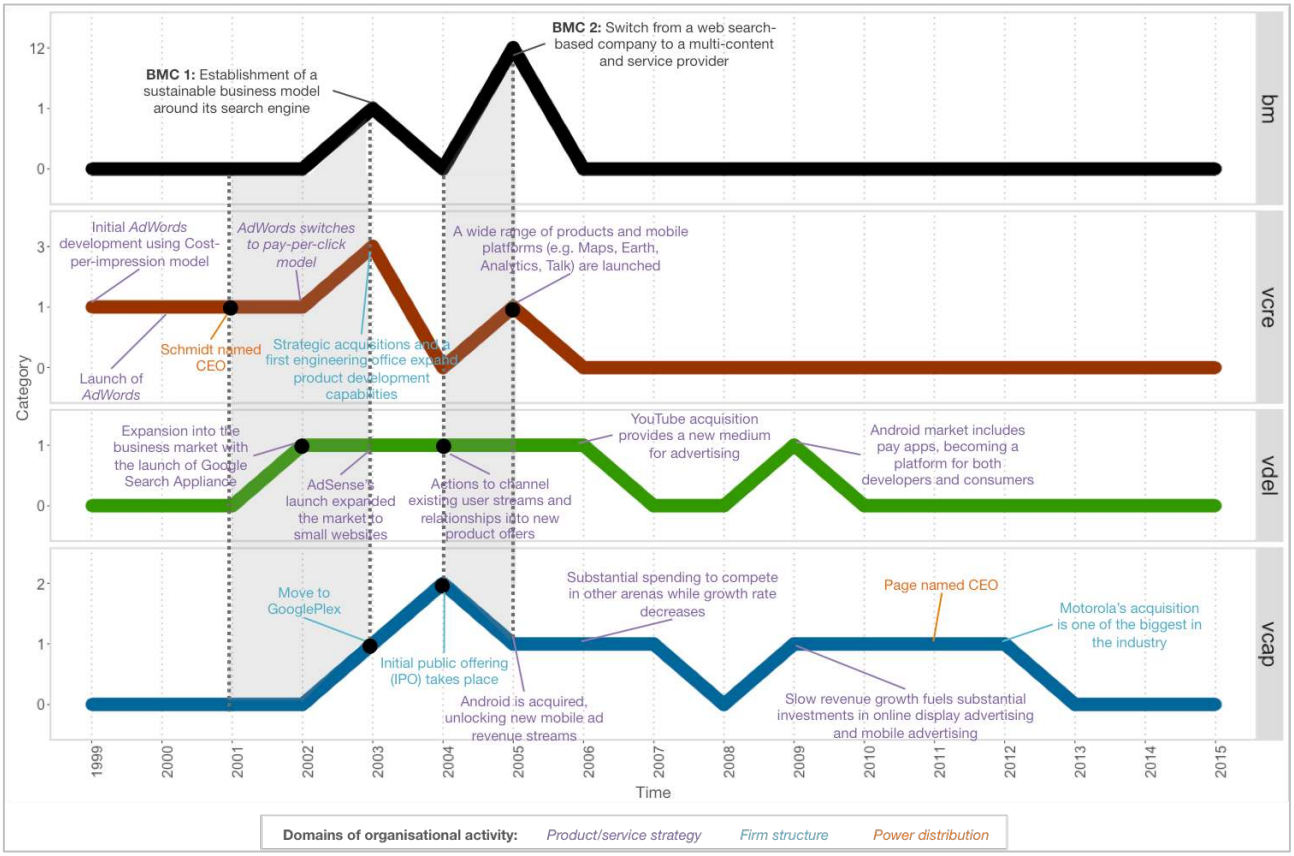


Figure 9 – Relationship between business model changes from Alphabet Inc. and qualitative events based on their effect on each value dimension

The development of Adwords started in 1999 in an effort to reinforce the value capture logic of the firm's business model built around the PageRank algorithm (Google Inc., 2000). When launched in 2000, the original version of Google's Adwords was built on a cost-per-thousand-impression model, in which advertisers paid each time their text ads were displayed in a search result. As this revenue model was not as successful as expected by Google founders (Karp, 2008), the company adopted a cost-per-click auction model in 2002 in which prices paid by advertisers were estimated from a combination of ads' click-through rate and advertisers' bids, representing a much more effective revenue logic (Beattie, 2015). This strategy helped build a sustainable business model around Adwords. From the value delivery perspective, the firm introduced its Google Search Appliance to expand their market segment by targeting the corporate market (Finkle, 2012). Google's customer base expanded again the next year in 2003 with the launch of AdSense, an online advertisement program based on website content, to include a long-tailed market of small-sized website owners as customers (Voigt et al., 2017). From the value capture perspective, the firm incurred exceptional expenses from 2003 resulting from restructuring processes as it grew in size. The move to the massive four-building complex known as GooglePlex reflected expenses driven by the firm's expansion (Silicon Valley Business Journal, 2003).

The second business model change event implemented by Google occurred in 2005. This two-year change event started in 2004 with the firm's public offering that resulted in a capital expansion of US $1.7 billion, one of the largest public offerings in the history of the industry (Fiegerman, 2014). An additional value capture event was the purchase of Android in 2005, which represented the starting point of the firm's incursion into the lucrative, expanding mobile market (Arthur, 2012). From the value delivery perspective, the acquisition and subsequent launch of Blogger and Picasa in 2004 reflected the firm's strategy to expand its value proposition and to channel current users and customers towards new offerings beyond its search engine (Deighton & Kornfeld, 2013; Wirtz, 2011). On the value creation dimension, the firm developed and launched a wide range of mobile-based products and apps including Google Maps, Gmail (mobile version), Earth, Blogger mobile and mobile web search (McFadden, 2017). In addition, the launch of an R&D centre in China and the formalisation of the 20% rule, that employees must dedicate 20% of their time to the development of individual projects and product ideas, completed a particularly active year of value creation activities (Finkle, 2012; Steiber, 2014).

All in all, the business model reconfiguration of 2005 enabled an organisation-wide transformation that took Google from a web search provider to a technology-based, multi-product and service

provider. Although a large proportion of Google's revenues still comes from its web search engine (Neal, 2016), this business model change allowed Google to establish itself as a leader in other emerging markets such as mobile apps, and cement its dominance in the IT sector (Beattie, 2015).

Aside from business model change events, the additional change events on the value delivery and capture dimensions identified in the quantitative detection process coincide with the occurrence of important incidents in the qualitative data. For instance, the value delivery event in 2009 matched the expansion of the firm's client base and development of a two-sided market to include app developers through the addition of paid apps to the Android market (Callaham, 2017). On the value capture dimension, the increased activity from 2005 onwards coincides with a slowing growth rate and consequential increase in spending to discover additional sources of revenue (Vascellaro, 2009), reflected by the purchase of YouTube (Voigt et al., 2017), increased advertising expenditures and the multi-billion dollar acquisition of Motorola (Rowe, 2016).

In conclusion, the two business model changes that allowed Google to build a profitable business around web search and to become a dominant force in the IT sector have also been confirmed by the qualitative data, as well as the periods of increased changes seen on each value dimension in separate.

5.3.2 Apple Inc.

Apple Inc., founded in California, United States and incorporated in 1977, is a manufacturer and seller of desktop and laptop computers, mobile communication and media devices. It also develops and provides software, networking solutions and services, as well as selling and distributing digital content through a range of online stores (Bloomberg, 2017b). In 2016, Apple Inc. had revenue of US $216 billion, total assets of US $322 billion and around 116,000 employees (Apple Inc., 2016). Table 16 shows the 34 events identified for Apple Inc. during 1987 to 2015 obtained from research publications, news articles, press releases and cases studies.

Year	Event	Domain of organisational activity affected	Reference
1987	Macintosh II ships with a colour display	Product/service strategy	(Rawlinson, 2017)
1988	The company undertakes a wholesale decentralisation	Firm structure	(Schlender, 1990)
1989	Macintosh Portable is introduced	Product/service strategy	(Regan, 2015)
1991	PowerBook is introduced	Product/service strategy	(Regan, 2015)
1991	Alliance with IBM and Motorola is announced	Product/service strategy	(Rawlinson, 2017)
1992	Marketing strategies and distribution channels are reorganised	Firm structure	(Swartz, 1992)
1993	Newton Message PDA is released	Product/service strategy	(Regan, 2015)
1993	Michael Spindler replaces John Sculley as CEO	Power distribution	(Kossovsky, 2012)

1994	The first PowerPC-based Macintosh is introduced	Product/service strategy	(Rawlinson, 2017)
1995	Macintosh clone program is launched	Product/service strategy	(Linzmayer, 2004)
1996	Gil Amelio replaces Michael Spindler as CEO	Power distribution	(Chaffin, 2001)
1997	Steve Jobs returns to the company as interim CEO	Power distribution	(Kossovsky, 2012)
1997	NeXT is purchased	Firm structure	(Regan, 2015)
1997	A built-to-order manufacturing strategy is introduced	Firm structure	(Mardesich, 1997)
1997	Apple online store is launched	Product/service strategy	(Dormehl, 2016)
1998	The iMac is released	Product/service strategy	(Regan, 2015)
1999	The company initiates direct-to-consumer retail strategy	Product/service strategy	(Kaplan, 2012)
2000	R&D activities for consumer digital device begins	Product/service strategy	(Ashcroft, 2012)
2000	Ron Johnson is hired to build direct retailing capacity	Power distribution	(Kaplan, 2012)
2001	The first physical stores open in Virginia	Product/service strategy	(Kaplan, 2012)
2001	The iPod is launched	Product/service strategy	(Osterwalder & Pigneur, 2010)
2003	The iTunes music store is launched	Product/service strategy	(Afuah, 2014)
2005	Macs switch from Motorola to Intel processors	Product/service strategy	(Rawlinson, 2017)
2006	iTunes starts selling full-length movies	Product/service strategy	(Afuah, 2014)
2007	The iPhone is introduced	Product/service strategy	(Mickalowski, Mickelson, & Keltgen, 2008)
2007	The company alters its consumer distribution channels	Firm structure	(Mickalowski et al., 2008)
2008	The App store for iPhone is launched	Product/service strategy	(Osterwalder & Pigneur, 2010)
2009	All iTunes songs are digital rights management-free	Product/service strategy	(Afuah, 2014)
2010	The iPad is introduced	Product/service strategy	(Kossovsky, 2012)
2011	Steve Job dies and Tim Cook is named CEO	Power distribution	(Primack, 2011)
2011	A new subscription service for the App store is launched	Product/service strategy	(Thomasch, 2011)
2014	R&D expenses grow at unprecedented levels	Firm structure	(Hughes, 2014)
2015	Apple Watch is launched	Product/service strategy	(Gibbs & Hern, 2015)
2015	Apple Music is launched	Product/service strategy	(Dredge, 2015)

Table 16 – Qualitative change events by organisational domain for Apple Inc.

Figure 10 presents the results of the second step of the qualitative validation process. The quantitative-based event detection procedure for Apple identified two business model changes implemented in 1997 and 2001, as shown in Figure 10. The first business model change was implemented between 1995 and 1997, and coincided with the return of founder Steve Jobs to the company as advisor, then interim CEO, a key event that marked the emergence of the entrepreneurial culture characterising Apple (Kossovsky, 2012). In particular, Jobs reorganised the cost structure by simplifying the number of product offerings (Rawlinson, 2017). An additional value capture event was the appointment of Gil Amelio as CEO in 1996, who then implemented massive restructuring to reduce costs, and decided to purchase NeXT Computer to improve the company's operating system (Chaffin, 2001).

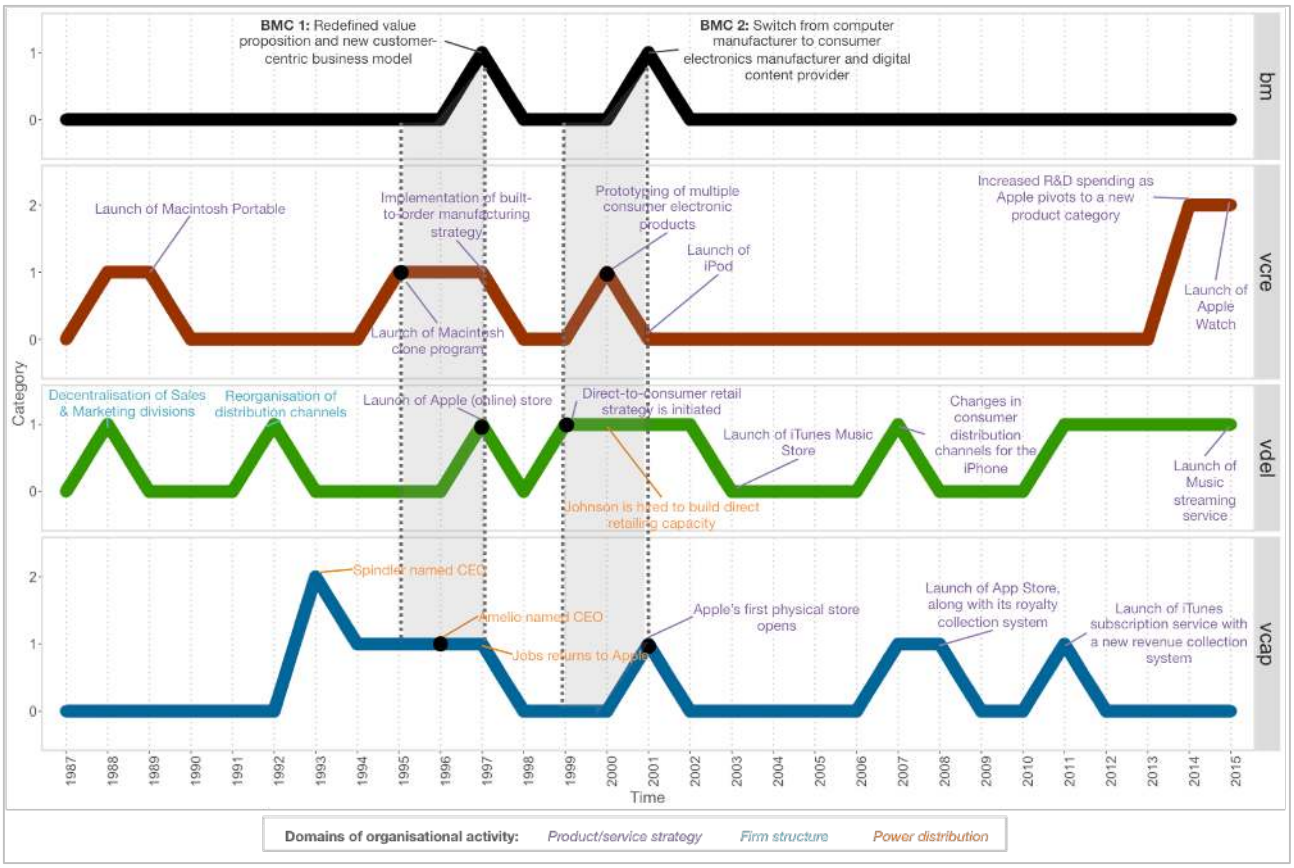


Figure 10 – Relationship between business model changes from Apple Inc. and events identified based on their effect on each value dimension

On the value creation dimension, Apple's executives launched the Macintosh clone program in 1995 to license Apple's operating systems to hardware vendors such as IBM and Motorola to further penetrate the desktop market (Linzmayer, 2004). As the program negatively affected the sales of their own Mac computers, the company developed an alternative product-based strategy from 1996 to 1997 to gain market share; the diverse and complex suite of product offerings, which were confusing for consumers, were streamlined to two main computer categories: consumer and professional (Low End Mac, 2006). The user-friendly, highly acclaimed iMac (launched in 1998) was the first product from this reorganisation of the product development processes (Regan, 2015). These events were complemented by the implementation of a built-to-order manufacturing strategy and subsequent launch of the Apple online store in 1997 as a value delivery mechanism facilitating the purchasing process for consumers (Dormehl, 2016; Mardesich, 1997). When these changes are analysed together, the business model change initiated in 1995 and finalised in 1997 involved a redefined value proposition towards a simplified family of computers, each one specifically tailored to a different type of consumer who could select and purchase the computer directly, resulting in a more customer-centric business model (Low End Mac, 2006).

As illustrated in Figure 10, Apple's second business model change was initiated in 1999 and completed in 2001. The reconfiguration co-occurred with the launch of the successful iPod music player in 2001 (Osterwalder & Pigneur, 2010). Although launched in 2001, the research and development began in 2000, when the firm considered a number of prototypes in gaming, video players and cameras before deciding on the music player (Ashcroft, 2012). But the first events associated with the business model reconfiguration took place in the value delivery dimension in 1999. Firstly, the firm started a hiring campaign to secure experienced retail executives from Gap, Target and Sony, initiating a plan to deliver their product offerings directly to consumers (Tam & McWilliams, 2000). Secondly, the adoption of a new enterprise resource planning system allowed the company to finetune their distribution channels and reduce excessive inventory (West, 2002), key achievements to their upcoming retail operations. These events were later complemented by hiring Ron Johnson, then Target's CEO, in 2000 to lead the direct-to-customer retail strategy, as well as the opening of Apple's first brick-and-mortar store with a particular effect on the firm's cost structure or value capture dimension (Kaplan, 2012).

In summary, the business model reconfiguration in 2001 enabled a strategic redirection from a company that designs and manufactures computers to a company that designs, manufactures and sells a portfolio of consumer electronics as well as computers. This change event established the retailing structure, distribution networks, product development processes and cost structures that supported the emergence of a variety of consumer electronics including smartphones, tablets, watches and digital content (Apple Inc., 2017).

In addition to the events associated with the two business model changes discussed previously, the qualitative analysis confirmed the other value dimension events. For the value delivery dimension, examples are the decentralisation of the sales and marketing divisions in 1988 (Schlender, 1990), the reorganisation of distribution channels in 1992 (Swartz, 1992) and the reorganisation of iPhone's distribution channels in 2007 (Mickalowski et al., 2008). For the value creation dimension, examples are the launch of the world's first portable computer in 1989 (Regan, 2015) and the considerable increase in R&D expenditures from 2014 onwards as the firm expanded its product categories (Hughes, 2014). For the value capture dimension, examples are the launch of the App store with royalty collection system in 2008 and the launch of iTunes's subscription service in 2011, events that unlocked additional revenue streams for the firm (Osterwalder & Pigneur, 2010; Thomasch, 2011).

In conclusion, the two business model reconfigurations for Apple occurring from 1995 to 1997 and 1999 to 2001 have been confirmed by the qualitative data and subsequent analysis. In addition, the qualitative analysis has shown that both reconfigurations redefined Apple's value propositions and expanded its product base, key actions underpinning the firm's success. Individual events at the value dimension level were also confirmed by the qualitative sources.

5.3.3 International Business Machines Corp.

International Business Machines (IBM) Corporation is a provider of IT products and services founded in 1910 in New York, United States. IBM provides a variety of solutions and services ranging from cognitive computing, analytics and data management platforms to cloud data services, transaction-processing software and business consulting services (Bloomberg, 2017c). In 2016, the company had revenue of US $80 billion, total assets of US $117 billion and 380,300 employees across more than 175 countries (IBM, 2017a). Table 17 presents the 36 change events identified and gathered from news articles, press releases, case studies, industry reports and scholarly publications.

Year	Event	Domain of organisational activity affected	Reference
1991	Printer manufacturer Lexmark is spun-off	Firm structure	(IBM, 2017b)
1991	One of the largest yearly losses ever reported by a US business is recorded	Firm structure	(Moffat, 1992)
1992	The IBM Consulting Group is established	Product/service strategy	(IBM, 2002b)
1993	Louis Gerstner is hired as CEO	Power distribution	(DiCarlo, 2002)
1993	Abby Kohnstamm is hired to lead a new marketing strategy	Power distribution	(McDonough & Egolf, 2015)
1994	Advertising accounts are centralised into a single agency	Product/service strategy	(McDonough & Egolf, 2015)
1995	The firm adds network-based system integration to its main product offerings	Product/service strategy	(Hitt, Ireland, & Hoskisson, 2006)
1995	Lotus is acquired	Firm structure	(Hitt et al., 2006)
1996	A number of network computing products and services are added to the firm's offerings	Product/service strategy	(IBM, 2017b)
1997	A major strategic campaign around e-business is launched	Product/service strategy	(IBM, 2017b)
1998	The firm announces important strategic agreements with AT&T	Product/service strategy	(IBM, 1998)
1999	The firm exits desktop retail channels in the United States and Europe	Product/service strategy	(IBM, 2002a)
1999	A redefinition of products, services and expertise around the new e-business market is initiated	Product/service strategy	(IBM, 2000)
2000	Strategic actions to align operations and cost structures of the Technology Group are finalised	Product/service strategy	(IBM, 2002a)
2001	The world's most powerful UNIX server is launched	Product/service strategy	(IBM, 2017b)
2002	Samuel Palmisano is appointed CEO	Power distribution	(Hempel, 2011)
2002	The firm doubles its consulting capabilities with the acquisition of PwC's consulting business	Firm structure	(Management Consulted, 2017)
2002	The firm announces the outsourcing of most of its desktop PC manufacturing activities	Product/service strategy	(Margevicius, 2002)
2003	The company sells its hard disk drive business to Hitachi and acquires Rational Software	Product/service strategy	(IBM, 2004)
2004	Investments in software solutions, consulting and services business lines are continued	Product/service strategy	(IBM, 2005)

2005	Acquisition of IBM's PC business by Lenovo is completed	Firm structure	(Lemon, 2005)
2005	The services unit is reorganised in a move to cut costs and achieve efficiency in delivering services	Firm structure	(Kirkpatrick, 2005)
2006	The entire Global Procurement Division is relocated to China	Firm structure	(Malone, 2006)
2006	Significant changes are implemented to reduce costs	Firm structure	(LaMonica, 2005)
2007	Cognos is acquired, making it IBM's biggest acquisition to date	Firm structure	(Bulkeley, 2007)
2008	Growth market strategies are implemented to increase presence in BRIC and other emerging markets	Product/service strategy	(IBM, 2009)
2008	Yearly income grows by 15%, the highest in the firm's history, due to improvements in Global Services and Software segments	Firm structure	(IBM, 2009)
2009	A new consulting service line for analytics and optimisation is created	Product/service strategy	(IBM, 2010a)
2010	The firm announces its first R&D innovation centre	Product/service strategy	(IBM, 2010b)
2010	The firm doubles the number of consultants in the business analytics practice	Firm structure	(IBM, 2011)
2010	Smarter Planet initiative is launched as a marketing and sales channel multiplatform strategy	Product/service strategy	(IBM, 2017c)
2011	Revenues from cloud services are triple last year's revenues	Strategy	(IBM, 2012)
2012	Virginia Rometty is appointed CEO	Power distribution	(Lohr, 2011)
2013	The firm implements a global restructuring plan to reduce more than 6,000 jobs	Firm structure	(Frier, 2013)
2014	The firm launches new cloud services marketplace	Product/service strategy	(Miller, 2014)
2015	The firm unveils a new line of solutions around cognitive computing and the Internet of Things	Product/service strategy	(IBM, 2016)

Table 17 – Qualitative change events by organisational domain for IBM

The second step of the validation on the interpretation of qualitative events is summarised in Figure 11. One relevant aspect of the history of IBM is the accelerated pace and depth of changes in the value delivery dimension between 1992 and 1999. This is explained by the qualitative data in two ways. Firstly, the firm altered its value proposition multiple times as it was strategically transitioning to a consulting services model (Hitt et al., 2006). Secondly, on his arrival as CEO in 1993, Louis Gerstner was particularly focused on rethinking marketing strategies and strengthening customer relationships, activities to which he devoted the first five years of his tenure (Gifford, 2011). Similarly, other value delivery events from 2005 onwards signal important events identified from the qualitative data, where the firm implemented new marketing strategies, new service offerings and actions affecting the firm's ability to deliver the value created from in-house knowledge and consulting capabilities (Kirkpatrick, 2005).

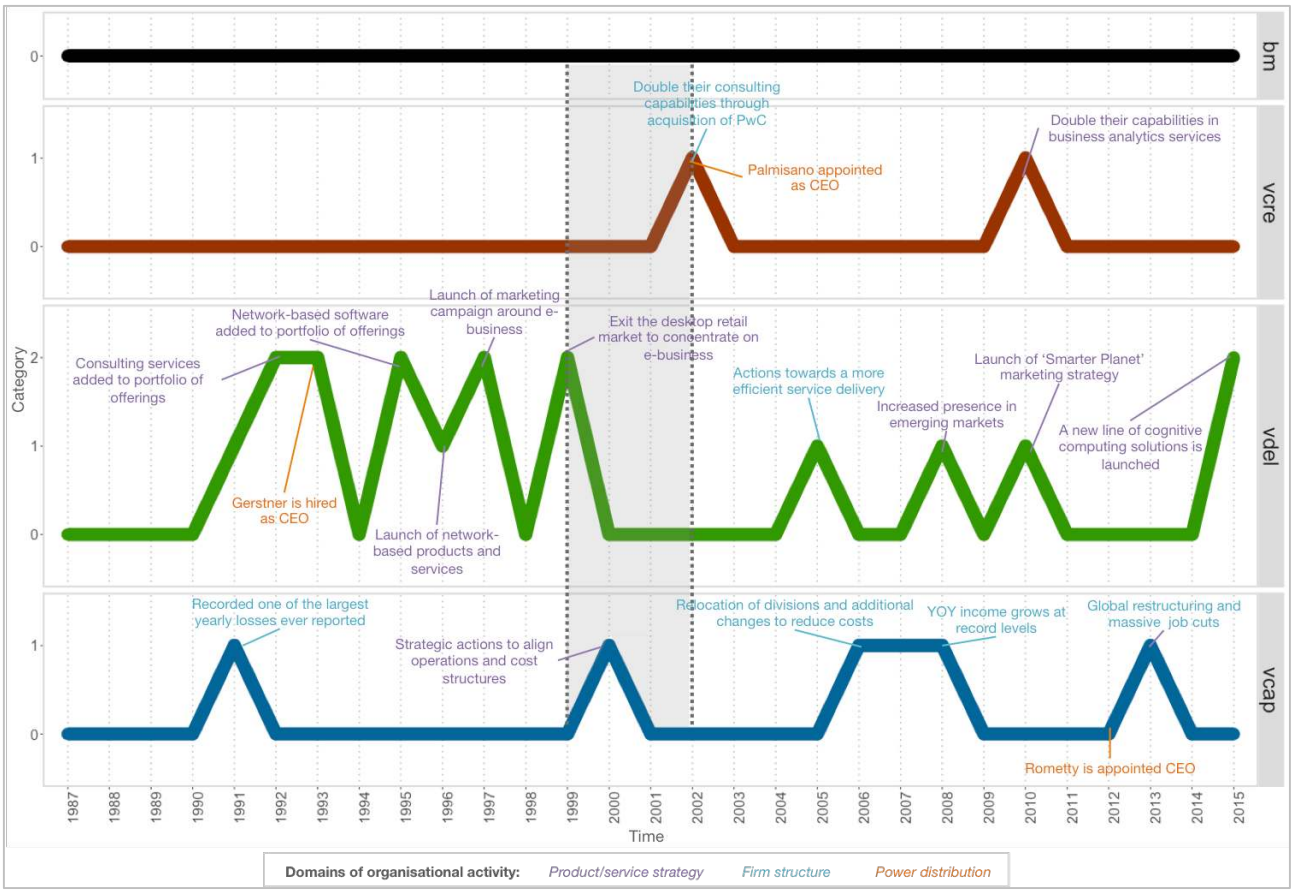


Figure 11 – Relationship between business model changes from IBM Corp. and events identified based on their effect on each value dimension

Two value creation change events were detected in the quantitative event detection procedure. In both cases, the events matched crucial qualitative events that affected the firm's pool of resources for value creation. The first event corresponded to the acquisition of PwC's consulting business in 2002, leading to substantial growth in consulting capabilities (Management Consulted, 2017). The second event corresponded to the firm's dedicated efforts in enhancing their business analytics expertise in 2010, when the firm doubled the number of consultants in the area of business analytics services (IBM, 2011).

The value capture change events detected in the quantitative phase corresponded to fundamental actions on cost reduction, particularly in 1991, 2000, 2006 and 2012. Following the billion dollar losses in 1991 was a sequence of changes that allowed the firm to reduce operational expenses (Moffat, 1992). A similar situation was seen in 2006 and 2013 (LaMonica, 2005) (Frier, 2013), while the cost restructuring in 2000 was better aligned between the operations and cost structures of the firm's Technology Group fuelled by changes in the market (IBM, 2002a).

Although there were no business model change events between 1999 and 2002 detected in the quantitative phase, the literature reported fundamental events occurring in that period. The firm started a long-term transformation towards an IT services and consultancy model in the 1990s, particularly after Gerstner's appointment (Lazonick, 2009). However, the dependence on hardware product lines (particularly desktop PCs) was still considerable, for which some analysts pointed out that IBM followed a balanced product-service strategy (Bittman, 2001). It was not until 2002 that it outsourced the entire PC manufacturing operations (Margevicius, 2002). From that point on, the firm put more emphasis on non-hardware offerings including consulting services and software solutions, while the hardware offerings were reduced to Intel-based servers (IBM, 2004). This important milestone in 2002 was identified as a value creation change event, along with the preceding changes in the value proposition from 1995 to 1999 and cost restructuring in 2000 (see Figure 11). Thus, it could be argued that the value delivery event in 1999, the value capture event in 2000 and the value creation event in 2002 were all related and were part of the fundamental transition that the firm achieved in the early 2000s (Lohr, 2010).

Under this perspective, the quantitative phase should have identified a business model change starting in 1999 and ending in 2002. It was not identified because the change process took four years to be implemented. The rigour and consistency in the methodology used to identify business model change events prevents labelling of change events outside the three-year window. However, if the rules were changed to a four-year window, a business model change would have been identified between 1999 and 2002.

Some qualitative sources indicated organisational transformation processes occurring from 2002 onwards, which resulted in a business model configuration based on the provision of high-value IT offerings such as analytics and cognitive computing solutions through a globally distributed business structure (IBM, 2016; Woerner & Ross, 2010). Although the business model configuration from 2002 and the current configuration have a number of differences (Wharton School, 2014), the reconfiguration process unfolded gradually (George, 2012). This type of prolonged business model transformation is out of the scope of what is considered a singular business model change by the research design of this study, which explains why there were no business model changes detected from 2002 onwards, as some sources argue.

5.3.4 Microsoft Corp.

Microsoft Corporation is a technology company founded in 1975 and headquartered in Washington, United States. The company develops and licenses software products, services and devices that include software-based commercial solutions, cloud services, enterprise services and personal computing solutions, as well as electronic devices such as tablet, phones, PC accessories and gaming systems (Bloomberg, 2017d). In 2015-2016, Microsoft had revenue of US $80 billion, total assets of US $194 billion, and 114,000 full-time equivalent employees (Microsoft, 2016). Table 18 shows the 36 events identified from the qualitative analysis from data sources including corporate reports and press releases, news articles, case studies (books and scholarly publications) and industry reports.

Year	Event	Domain of organisational activity affected	Reference
1987	End-user and OEM support teams are combined into a single Product Support Services	Firm structure	(The History of Computing Project, 2014)
1987	Corporate material and logo are completely redesigned	Product/service strategy	(Microsoft, 2009)
1988	The Applications Division is restructured to streamline product development	Firm structure	(Microsoft, 2009)
1988	A two-way electronic support service is introduced	Product/service strategy	(Microsoft, 2009)
1989	A new support service for corporations is launched	Product/service strategy	(Microsoft, 2009)
1989	A new Multimedia Division is formed	Firm structure	(The History of Computing Project, 2014)
1990	The firm's largest marketing campaign to date is launched	Product/service strategy	(Microsoft, 2009)
1990	A Product Support Services site on the East Coast opens	Product/service strategy	(Microsoft, 2009)
1991	A new Product Support Services centre opens in Dallas, completing the firm’s renovation plan to improve customer support	Product/service strategy	(Dally, 1992)
1992	Fox Software Inc. is acquired in the firm's largest acquisition to date	Firm structure	(Pollack, 1992)
1992	The first-ever television marketing campaign is launched	Product/service strategy	(The History of Computing Project, 2014)
1994	Partnership with keyboard manufacturer to bring their first keyboard to market is launched	Product/service strategy	(Fisher, 1994)
1994	Extensive development efforts are made to produce a multimedia server platform	Product/service strategy	(Mace, 1994)
1995	Substantial investments in R&D are made as part of the development efforts for Windows 95	Product/service strategy	(Microsoft, 1997)
1995	The launch of Microsoft Network presents a new online-based delivery vehicle for a number of offerings	Product/service strategy	(Lewis, 1995)
1996	Launch of a new online ordering system allows the firm to save millions in procurement costs	Firm structure	(Neef, 2001)
1997	A research facility in UK is established, its first outside United States	Firm structure	(Wired, 1997)
1998	The firm’s second largest development centre, located in India, is launched	Firm structure	(The History of Computing Project, 2014)
1998	First research office in China opens	Firm structure	(Meredith, 2003)

1998	A 32-acre campus is established to centralise the location of all employees in California	Firm structure	(Microsoft, 1998)
1999	Cost of revenues decreases due to reliance of organisational licenses over physical products as key revenue stream	Product/service strategy	(Microsoft, 1999)
1999	The Programmer Productivity Research Center is established to revamp product engineering processes	Firm structure	(Anthes, 2006)
2000	Steve Ballmer is appointed CEO	Firm structure	(Nayak, 2014)
2001	Xbox, the company's first gaming console, is developed and launched	Product/service strategy	(Marshall, 2013)
2002	R&D expenses increase by 20% and 5,000 employees added for the development of .NET framework	Product/service strategy	(Davila, Epstein, Shelton, Cagan, & Vogel, 2013)
2005	The seven business units are reorganised into three main divisions to achieve a higher degree of flexibility	Firm structure	(University of St. Gallen, 2010)
2005	Digital Pharma Initiative is launched to enter the life-sciences computing market	Product/service strategy	(Bio-IT World, 2006)
2008	A research laboratory is established in New England (US) and three others in Europe	Product/service strategy	(Microsoft, 2008)
2011	90% of research budget is spent on cloud computing	Product/service strategy	(Jackson, 2011)
2011	Partnership with Nokia to build a competitive mobile ecosystem is launched	Product/service strategy	(Ionescu, 2011)
2012	Surface is introduced	Product/service strategy	(McCracken, 2012)
2014	Satya Nadella succeeds Ballmer as CEO	Firm structure	(Nayak, 2014)
2014	Windows is declared free for all devices with nine inch screens or smaller	Product/service strategy	(Bort, 2015)
2014	Marketing capabilities are reorganised to shift from product-specific ads to broader campaigns	Product/service strategy	(McMains, 2014)
2015	Upgrades to its new operating system are offered for free	Product/service strategy	(Novet, 2015)
2015	Windows ceases to be manufactured as a product and starts being offered as a service with ongoing updates	Product/service strategy	(Protalinski, 2015)

Table 18 – Qualitative change events by organisational domain for Microsoft

Figure 12 summarises the interpretation step, the second step in the process of the qualitative validation for Microsoft. The high activity levels in value delivery from 1987 to 1992 shown in the figure correspond to a period in which the firm concentrated on creating a solid product support platform and improving its customer support capabilities, which were then employed as a competitive advantage over its rivals (Dally, 1992).

As seen in Figure 12, the first of the two business model changes for Microsoft took place in 1996. It began with a change event in the value creation dimension in 1994, followed by a value delivery event in 1995, and was completed in 1996 with a change in the value capture dimension.

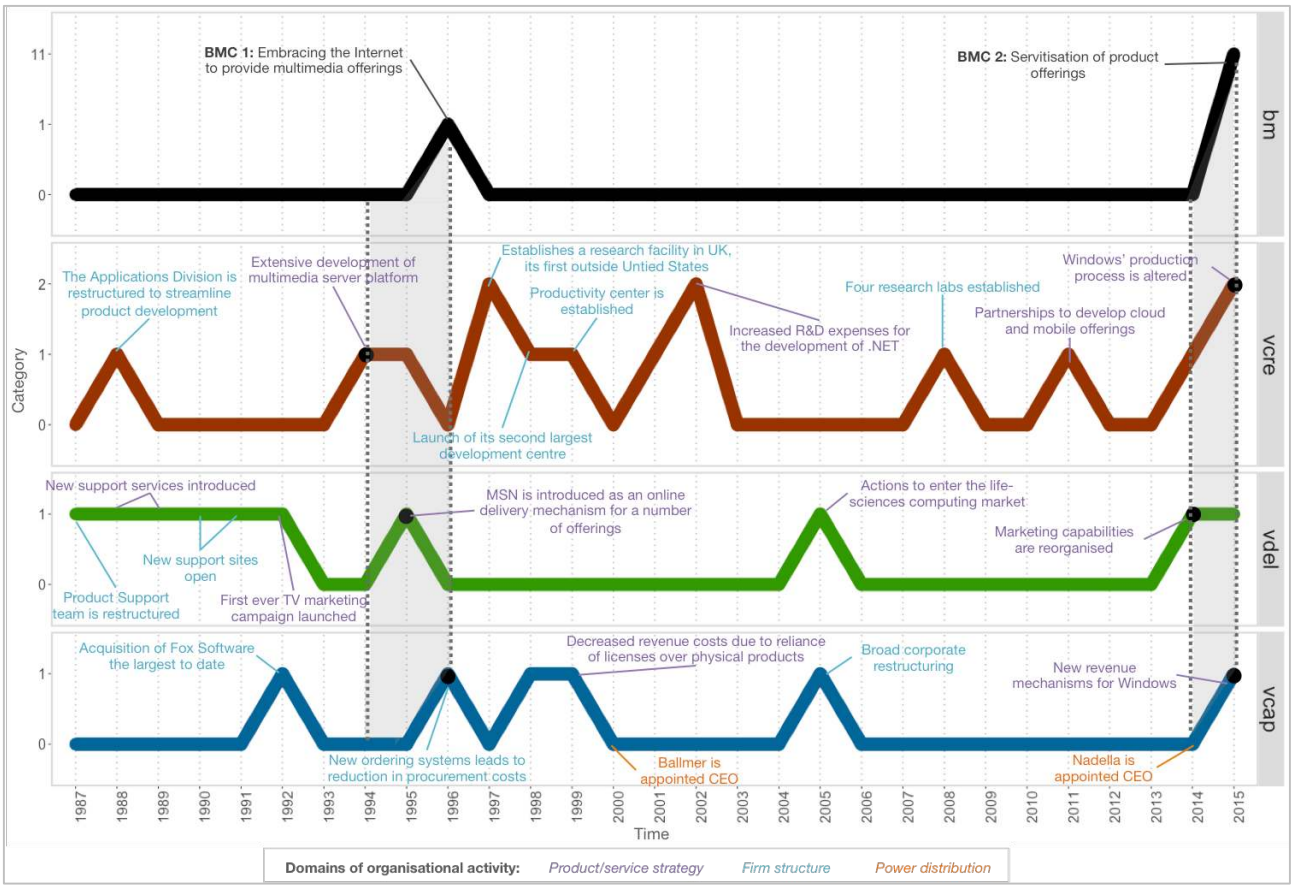


Figure 12 – Relationship between business model changes from Microsoft Corp. and events identified based on their effect on each value dimension

From 1994 to 1995, Microsoft invested considerably in developing and testing software for multimedia, interactive television and Internet-based products (Jacobs, 1994), which corresponds with the quantitative value creation events in 1994 and 1995. On the value delivery dimension, the event in 1995 signalled the emergence of Microsoft Network as a new online delivery vehicle for many of the firm's offerings including electronic banking, email, information and games (Lewis, 1995). Lastly, the event in the value capture dimension in 1996 corresponded to the incorporation of an online ordering system into the firm's internal IT platform that resulted in considerable savings in procurement costs (Neef, 2001). In summary, the business model change in 1996 allowed Microsoft to adopt the Internet in their product development strategies to deliver a variety of new multimedia offerings being created. This insight converges with a variety of sources arguing that the firm reinvented itself in 1996 to respond to the rapid emergence of the Internet (The History of Computing Project, 2014).

The increased level of activity in value creation seen from 1997 and 1999 (see Figure 12) corresponds to Microsoft's strategic plan to triple its research activities over a period of three years,

a strategy that started in 1997 with the launch of the firm's first research laboratory outside the United States located in Cambridge, United Kingdom (Wired, 1997). Its product development capabilities were also reinforced during that period, which included events like the establishment of the second largest development centre outside the United States (The History of Computing Project, 2014).

As seen in Figure 12, the quantitative-based event detection process indicated a business model change in 2015 that started with a value delivery change in 2014. This event in the value delivery dimension corresponds to the reorganisation of the firm's marketing division seeking to shift from marketing strategies based on individual products that are periodically launched, to ongoing campaigns centred on specific consumer and business markets (McMains, 2014). The business model change was finalised with an event in the value capture and creation dimensions in 2015, corresponding with the introduction of new revenue mechanisms and reconfiguration of production processes to move from sporadic product launches to a more continuous provision of solutions at a low cost (Protalinski, 2015), while monetising subscriptions of additional services (Novet, 2015). Thus, the 2015 business model change emerged as a consequence of servitising the firm's products and solutions.

Many sources agreed that the firm transitioned to a new business model configuration in 2015. Some argue that the firm moved away from licensing its software to computer manufacturers and corporate clients and has adopted a "freemium" business model, where some of its digital products and services are offered for free then additional features are offered at a cost (Foley, 2015). In addition, the new model emphasises product integration across a variety of offerings from tablets and cloud-based software to video communication services (Ross, 2015). Among the evidence suggesting this shift towards a free-based model, in 2015 the firm offered upgrades to its new operating system for free (Novet, 2015). Other sources argue that the firm adopted a subscription-based model, where solutions are not offered as individual products for which the firm sells licences, but as a continuous service for which the firm charges a subscription (Guppta, 2015). Regardless of how the change has been described in the literature, these sources provide evidence of the occurrence of a business model change in 2015.

In conclusion, the two business model changes for Microsoft were corroborated by the qualitative sources. The qualitative analysis has indicated that both business model reconfigurations allowed Microsoft to remain competitive by providing multimedia offerings through the Internet and

servitising its product base. Individual change events at the value dimension level were also confirmed by the qualitative data.

5.4 Conclusions

The results of the qualitative validation indicate a convergence between quantitative and qualitative evidence, thus corroborating the accuracy of the quantitative methods in identifying business model change events. The years for which a business model change was quantitatively detected signalled periods of fundamental transformation in the way the four firms generated products and/or services for their customers, in the methods by which the market segments were targeted and the mechanisms for value delivery, and in the cost and revenue structures underpinning their commercial operations.

All of the six business model change events detected by the quantitative phase of the study were also detected by the qualitative phase, while one business model change was detected by the qualitative phase but not by the quantitative. This anomaly is IBM, where qualitative sources noted a business model alteration between 1999 and 2002. But the quantitative-based event detection procedure did not identify any business model change in that period because the algorithm for event detection only considered events occurring within a three-year time window, and IBM's transformation took at least four years to finalise. This case does not threaten the validity of the quantitative phase of the study. It can be considered an exception to the norm for the IT sector which is characterised by an accelerated pace of change, whereas a time window of four or more years might be more appropriate for other sectors (Brown & Eisenhardt, 1997).

This qualitative phase of the study also showed the correct identification of change events at the value dimension level, events that were not associated with a business model change. There were also periods with a high level of activity in a particular dimension, with multiple events in a row, that converged with qualitative sources pointing to periods of transformation in the same dimension, as is the case for Google's succession of investments and increased expenditures from 2005 onwards, Apple's increase in R&D activity from 2013 onwards, IBM's redefinition of its value proposition and targeted markets between 1990 and 1999, and Microsoft's restructuring of its platforms for customer support and relationships between 1987 and 1992.

The next chapter discusses the analytic methods conducted to the business model change sequence data, as well as the results of the analyses, for each driver and property of change in separate.

Chapter 6: Analyses and Results

6.1 Introduction

This chapter describes the five main analyses of business model change events data, with each one explaining a particular feature of the business model development process. Analyses on the order, frequency and magnitude of change compare high-performing firms with the rest of the sample as a way to detect meaningful change patterns in high performers. On the other hand, the investigation on the mechanisms driving business model change is built on a dedicated analysis of the change patterns in high performers across multiple organisational dimensions.

Each of the five sections begins with a description of the analytic steps carried out and parameters implemented, concluding with the presentation of results and interpretation based on the research propositions.

6.2 Assessing the existence of distinctive patterns of business model change

6.2.1 Analysis

Explicating the dynamics of business model development by observing the phenomenon in high-performing firms is the foundation of the research. This assumes that the business model dynamic seen in firms with *X* degree of performance is significantly different from the dynamic seen in firms with *Y* degree of performance. This section assesses the extent to which there are significant differences in the patterns of business model change from firms at different performance levels. Unlike the other analyses testing the validity of the propositions, this analysis is a validation step supporting the rest of the empirical tests performed in the study.

6.2.1.1 Performance measure

Coad and Rao (2008) argued that, for "superstar" high-growth technology firms, innovation is the main cause of rapid and sustained growth, a relationships that is not observed in the average technology firm (Coad & Rao, 2008). More than half of the firms reaching the Fortune 500 before their 25th anniversary are classified as business model innovators (Anthony, 2013). This supports the importance of business model renewal for firm performance, but also supports the associations between rapid growth and business model innovation. In addition, when organisational change is caused by customer-centric strategies, the effect on sales volume appears more rapidly than the effect on other performance indicators (Stuart, 2000). This quick responsiveness of revenue growth

leads to statistical models with shorter lag structures (Stuart, 2000), enabling a more accurate identification of the moment in which the causing event took place. For these reasons, revenue growth is used as a performance measure to identify above-average growing firms.

Nevertheless, sustained growth is only one aspect of firm performance, and an indicator of profitability is always required to form a more integral perspective on how well a firm performs and how efficient it is in turning revenue into profit. Equity-based profitability measures such as return on equity (ROE) are usually used as a complement of sales growth to identify high-performing firms (Boyd, 1990). Likewise, return on assets (ROA) is widely used by analysts and researchers because it is affected by managerial actions more directly than other measures (Frankenberger et al., 2013). In any case, the number of studies using either ROA or ROE seems to be equal, which is expected given both ratios are highly correlated (Bettis, 1981). However, ROA and ROE ratios are biased if the firms examined have different asset-intensity requirements, and might not be suitable in studies on industries that do not depend on high use of capital to generate value, such as the IT sector (Florin et al., 2003). Thus, profit margin provides a less biased performance statistics in this study.

As a result, the two measures of performance used are revenue growth and profit margin. Revenue growth is used as an indicator of the speed of positive growth in a firm, whereas profit margin is used as an estimation of the firm's capacity to turn increased revenue into profit on a sustained basis. Revenue growth rate has been calculated as the percentage growth of revenue in time $t+1$ in relation to revenue in time t, similar to the procedure used by Kor and Sundaramurthy (2008). Then, to obtain a single measure of revenue growth per firm, the median of the resulting revenue growth rates was calculated for all the available years of the firm. Similarly, profit margin was calculated as the median of the yearly profit margins for all the available years of the firm.

6.2.1.2 Hierarchical cluster analysis

After the construction of a suitable performance measure, the next step was to conduct hierarchical clustering in a firm's sequences containing the magnitudes of business model change events per firm (e.g. 0—2—0—21). Thus, the clustering mechanism was the pattern similarities among a firm's sequences, an approach inspired by Shi and Prescott (2011) and their implementation of cluster analysis in sequences of firm behaviour. The distances between sequences were calculated by a variant of the optimal matching method (OM) particularly appropriate for event sequences, known as OME (Ritschard, Bürgin, & Studer, 2013). The insertion/deletion cost attribute of the

optimal matching algorithm for all the levels of magnitude was set to "1", meaning that the "distance" between a magnitude "11" event and a magnitude "13" event was the same as the distance between a magnitude "3" and a magnitude "21" event. The insertion/deletion cost between similar events lagged by one time unit was set to 0.75 as it was important to have a value lower than one to reflect that events from different magnitudes at the same time point are more dissimilar between each other than events of identical magnitudes misaligned by one time point. This procedure resulted in a distance matrix containing pairwise comparisons of any pair of sequences.

The hierarchical clustering algorithm was then performed on the distance matrix from the OME method. The linkage method chosen for the construction of clusters was the Ward's minimum variance method, a cluster method that calculates variance as a function of the deviations from the mean, and particularly effective in minimising within-cluster variance (Punj & Stewart, 1983). The algorithm, available as a function in R, begins with a number of clusters equal to the number of cases, and then agglomerates similar cases based on the distance matrix.

A final validation step was the construction of two identical synthetic sequences, which were inserted in the dataset along with the real sequences. As expected, both sequences were placed in the same cluster by the hierarchical clustering algorithm. The sequences were then removed from the dataset prior to the formal analysis.

6.2.1.3 Multivariate analysis of variance

The next analytic step was to determine whether the change patterns vary significantly across firms with dissimilar performance levels. For this purpose, the cluster memberships obtained after clustering were used as a variable representing patterns of business model change in a multivariate analysis of variance (MANOVA) using the Wilk's Lambda test. Thus, the MANOVA test was implemented using the cluster members as the independent categorical variable and the performance measures (revenue growth and profit margin) as the two dependent continuous variables. This test determined the existence of significant differences among the population means of the performance variables in different clusters. Combining clustering and MANOVA is an approach that has been proposed and implemented by several authors in strategic management research (Ketchen & Shook, 1996).

6.2.2 Results

6.2.2.1 Multivariate analysis of variance

The hierarchical clustering algorithm was performed multiple times with different cluster configurations (i.e. target number of clusters) across the four age-size groups in the sample, recalling that the four groups are young-small, young-large, mature-small and mature-large. MANOVA tests were then performed for each cluster configuration, in search for the configuration with the highest statistical significance. Section 6.2.2.2 discusses in detail the resulting clusters stemming from configurations that maximise the significance of the differences across firm performances.

Table 19 presents the results of the MANOVA test applied over the different clusters configurations. The table shows the f-values and significance based on p-values from: (1) a model with revenue growth as the dependent variable and cluster membership as the independent variable; (2) a model with profit margin as the dependent variable and cluster membership as the independent variable; and (3) a model with revenue growth and profit margin as dependent variables and cluster membership as the independent variable.

In young-small firms, the results of models with revenue growth alone were not significant. When the two performance measures are used (combination model), there was significance at the $p<0.01$ level in configurations based on eight and 10 clusters. For young-large firms, none of the cluster configurations resulted in statistically significant differences when the profit margin was used in isolation, and the highest significance ($p<0.05$) was observed for the combination model with a nine-cluster configuration. For mature-small firms, models using profit margin alone did not yield significant results, but the combination model showed significance at the $p<0.001$ level for every cluster configuration. Lastly, for mature-large firms, the highest significance level ($p<0.01$) was achieved with the combination model in 5, 6, 11 and 12 cluster configurations.

Test	Cluster configuration													
	5 clusters		8 clusters		9 clusters		10 clusters		11 clusters		12 clusters		15 clusters	
Young-small firms:														
Revenue growth	0.642		1.869	.	1.632		1.448		1.300		1.180		0.922	
Profit margin	3.196	*	2.597	*	2.329	*	2.477	**	2.487	**	2.268	*	1.891	*
Revenue growth x profit margin	1.898	.	2.239	**	1.986	*	**1.965**	**	1.895	*	1.725	*	1.406	.
Young-large firms:														
Revenue growth	1.897		1.446		2.908	**	2.578	**	2.315	*	2.099	*	1.717	.
Profit margin	0.796		0.822		1.332		1.345		1.428		1.308		1.020	
Revenue growth x profit margin	1.394		1.219		**1.985**	*	1.852	*	1.777	*	1.619	*	1.306	
Mature-small firms:														
Revenue growth	9.921	***	6.358	***	5.559	***	4.926	***	4.446	***	4.236	***	3.647	***
Profit margin	1.285		1.234		1.242		1.350		1.215		1.125		1.064	
Revenue growth x profit margin	5.493	***	**3.729**	***	3.345	***	3.094	***	2.791	***	2.641	***	2.316	***
Mature-large firms:														
Revenue growth	3.384	**	2.422	*	2.208	*	1.983	*	2.240	*	2.134	*	1.747	*
Profit margin	3.664	**	2.387	*	2.109	*	1.942	*	1.833	.	1.876	*	1.647	.
Revenue growth x profit margin	3.206	**	2.147	**	1.922	*	1.742	*	**1.970**	**	2.038	**	1.800	**

*Significance codes: .p<0.1; *p<0.05; **p<0.01; ***p<0.001*

Table 19 – F-values and p-value significance of MANOVA tests for each cluster configuration

In addition to statistical significance, the final selection ensured a symmetrical number of clusters across the age-size groups to ensure consistency in successive cluster analyses. This process resulted in the selection of a 10-cluster configuration for the young-small group, nine clusters for the young-large group, eight clusters for the mature-small group and 11 clusters for the mature-large group.

In summary, for all the four age-size groups of firms, there is evidence of statistically significant differences in firm performance means across clusters of firms with different business model change sequences. Such differences in firm performance are more or less significant depending on the number of clusters used in the hierarchical clustering process.

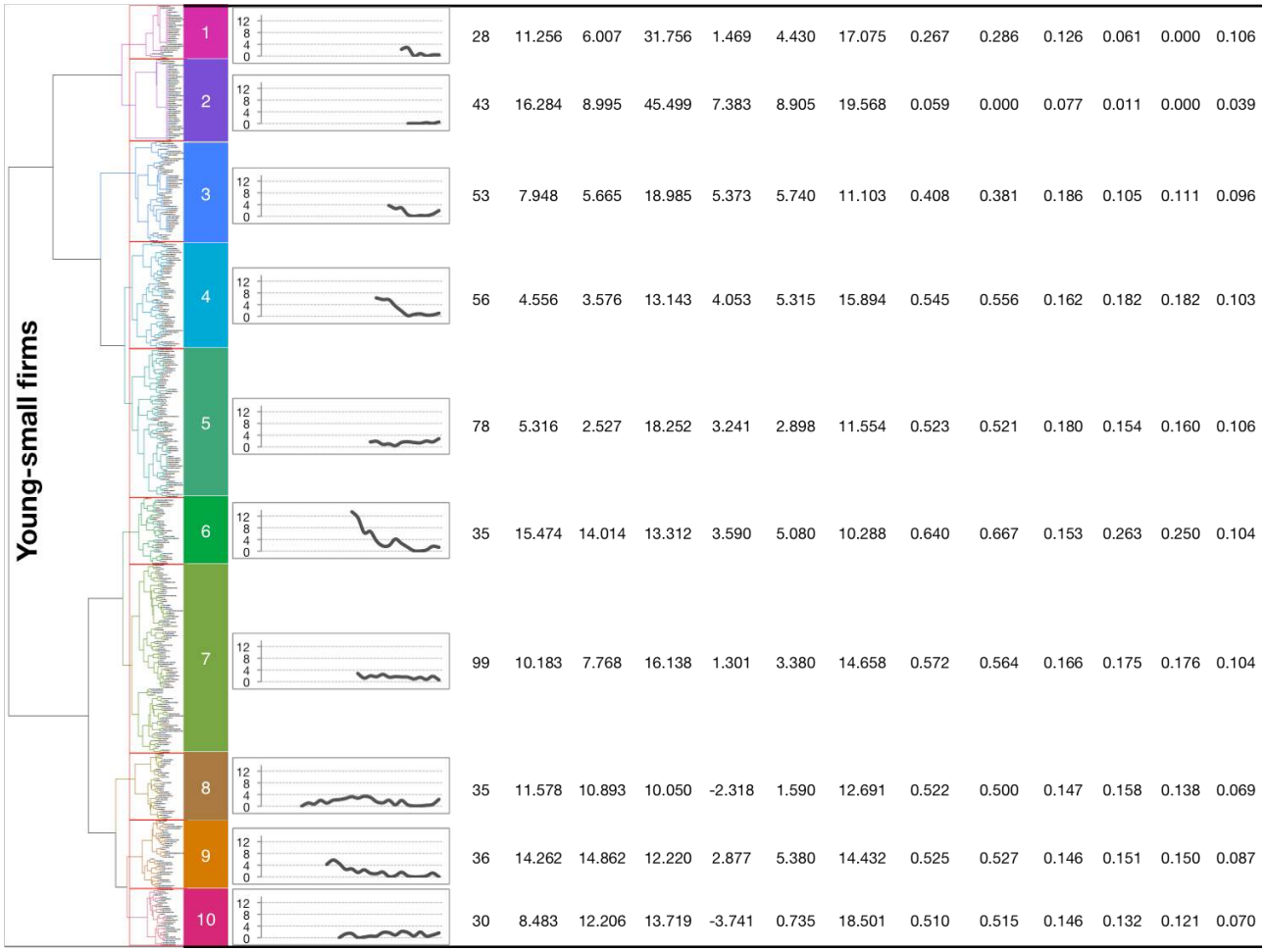
6.2.2.2 Hierarchical cluster analysis

The results from hierarchical clustering are organised by age-size firm and presented in Figure 13, Figure 14, Figure 15 and Figure 16. Each figure contains a dendrogram illustrating the arrangements of firm clusters. The cluster centroids were constructed by averaging the magnitudes of the cluster members for each of the 29 time points in the dataset, conditioned on the number of non-missing values. If more than half of the cluster members had missing values, no average is computed and the value for that particular time point is set as "NA" (not available).

In addition, the figure also contains descriptive statistics for sales growth, profit margin, frequency of total events per year and frequency of business model change events per year. The frequency of total events was calculated for each firm as the sum of the categories of all the dimension change events (including those not involved in business model change events) divided by the number of years with non-missing values, whereas the frequency of business model change events per year was calculated for each firm as the sum of the magnitudes of business model change events equal or greater than "1", divided by the number of years with non-missing values.

For the young-small group (Figure 13), the highest sales growth mean and profit margin mean is achieved by cluster 2. This same cluster shares the lowest count of business model change events, a behaviour that is also evidenced by the cluster's centroid. A different situation is observed in cluster 6, which shares the second highest sales growth mean and the highest count of business model change events. This suggests a positive association between counts of business model change events and sales growth, but a negative association when profit margin is also considered in the relation.

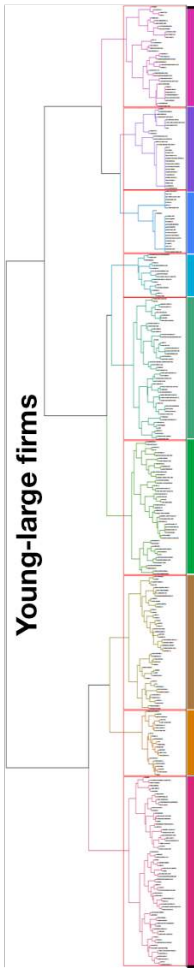
On the observed patterns in cluster centroids, cluster 6 reports intensive changes in early years, a behaviour that is also seen in clusters 4 and 9, although on a minor scale. An additional observation of cluster 9 is that it shares the third highest revenue growth mean, which suggests an association between highly active early years and high sales growth.



ID	Centroid	No. firms	Sales growth			Profit margin			Events per year			BMC events per year		
			M	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
1		28	11.256	6.007	31.756	1.469	4.430	17.075	0.267	0.286	0.126	0.061	0.000	0.106
2		43	16.284	8.995	45.499	7.383	8.905	19.568	0.059	0.000	0.077	0.011	0.000	0.039
3		53	7.948	5.665	18.985	5.373	5.740	11.103	0.408	0.381	0.186	0.105	0.111	0.096
4		56	4.556	3.576	13.143	4.053	5.315	15.894	0.545	0.556	0.162	0.182	0.182	0.103
5		78	5.316	2.527	18.252	3.241	2.898	11.554	0.523	0.521	0.180	0.154	0.160	0.106
6		35	15.474	14.014	13.312	3.590	5.080	10.288	0.640	0.667	0.153	0.263	0.250	0.104
7		99	10.183	7.768	16.138	1.301	3.380	14.658	0.572	0.564	0.166	0.175	0.176	0.104
8		35	11.578	10.893	10.050	-2.318	1.590	12.691	0.522	0.500	0.147	0.158	0.138	0.069
9		36	14.262	14.862	12.220	2.877	5.380	14.432	0.525	0.527	0.146	0.151	0.150	0.087
10		30	8.483	12.206	13.719	-3.741	0.735	18.501	0.510	0.515	0.146	0.132	0.121	0.070

Figure 13 – Clustering configuration for the young-small group, with descriptive statistics and centroid for each cluster

In young-large firms (Figure 14), cluster 3 presents both the highest sales growth and profit margin means, and the lowest count of business model change events. On the other hand, cluster 7 has the second highest sales growth and the second highest count of business model change events. The largest count of business model change events is in cluster 4, which also shares the lowest sales growth in the group. These insights from clusters 4 and 7 suggest that moderate to high counts of business model change events (and not intensively high) are associated with high sales growth.



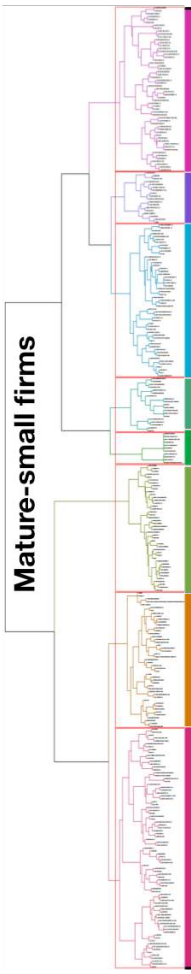
ID	Centroid	No. firms	Sales growth			Profit margin			Events per year			BMC events per year		
			M	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
1		37	13.109	10.425	11.168	4.223	4.030	10.477	0.494	0.519	0.185	0.172	0.125	0.127
2		30	11.192	5.602	17.499	5.047	3.450	10.804	0.269	0.238	0.177	0.070	0.000	0.119
3		23	28.150	11.152	43.613	11.417	10.335	14.780	0.075	0.000	0.099	0.013	0.000	0.045
4		16	5.796	7.628	10.141	7.586	6.460	7.495	0.700	0.712	0.214	0.333	0.348	0.135
5		52	14.867	10.782	18.777	6.614	6.725	11.276	0.525	0.528	0.191	0.163	0.167	0.099
6		49	11.698	7.623	13.336	6.281	5.230	5.819	0.563	0.564	0.199	0.196	0.214	0.121
7		49	15.442	14.578	10.435	5.110	5.330	11.272	0.577	0.569	0.145	0.205	0.200	0.097
8		24	12.963	14.238	5.762	8.971	3.370	13.877	0.441	0.404	0.126	0.139	0.125	0.064
9		69	12.055	9.543	12.466	7.502	5.940	10.512	0.512	0.490	0.123	0.158	0.133	0.092

Figure 14 – Clustering configuration for the young-large group, with descriptive statistics and centroid for each cluster

In terms of the patterns of change extracted from the clusters' centroids, cluster 4 presents high activity levels in early years, as well as cluster 1 to some extent. As these are clusters with either low sales growth or low profit margin, this insight indicates an association between substantial early business model change and low performance.

For mature-small firms (Figure 15), the highest profit margin mean is observed in cluster 2. At the same time, cluster 2 presents the highest count of business model change events, indicating a positive association between profit margin and number of business model change events. Cluster 7 presents the highest sales growth mean and also the second highest count of business model change events, but the lowest profit margin mean in the group. Thus, the evidence suggests a positive

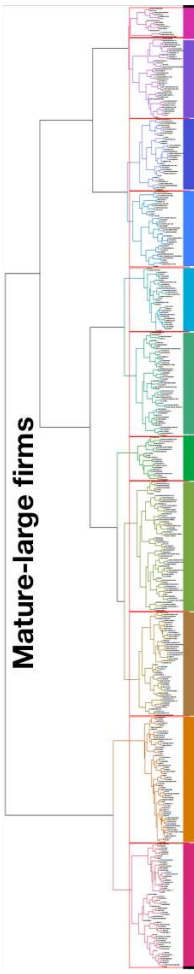
association between counts of business model change events and either sales growth or profit margin (but not for both measures).



ID	Centroid	No. firms	Sales growth			Profit margin			Events per year			BMC events per year		
			M	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
1		57	-0.775	-1.123	10.220	4.868	4.020	10.596	0.511	0.528	0.161	0.144	0.111	0.094
2		18	2.438	2.327	5.935	6.854	6.925	6.618	0.585	0.582	0.130	0.280	0.279	0.070
3		53	5.296	4.536	9.724	4.641	5.460	13.929	0.520	0.524	0.121	0.136	0.143	0.081
4		19	-3.569	-4.262	13.139	1.444	4.020	14.963	0.505	0.611	0.237	0.185	0.222	0.162
5		11	1.922	-0.547	10.586	5.226	4.780	5.110	0.035	0.000	0.080	0.000	0.000	0.000
6		44	6.387	6.355	6.183	0.816	2.440	9.970	0.452	0.448	0.110	0.140	0.143	0.071
7		47	7.686	6.955	11.234	0.920	1.850	11.553	0.522	0.537	0.126	0.186	0.167	0.094
8		83	5.556	4.936	8.982	4.075	5.180	11.700	0.513	0.500	0.132	0.165	0.167	0.091

Figure 15 – Clustering configuration for the mature-small group, with descriptive statistics and centroid for each cluster

An examination of the centroids reveals intensive business model changes being implemented by firms from cluster 2 in early years. As cluster 2 shares the highest profit margin in the group, this observation suggests an association between intense early changes and profit margin. In addition, cluster 4 (lowest sales growth performer) is the only cluster with intense changes in late stages, which indicates an association between low sales growth and intense late business model changes.



ID	Centroid	No. firms	Sales growth			Profit margin			Events per year			BMC events per year		
			M	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
1		15	9.469	7.906	9.500	6.350	4.635	5.584	0.557	0.593	0.229	0.238	0.273	0.121
2		40	4.012	3.844	7.102	8.378	5.360	9.456	0.512	0.545	0.155	0.145	0.146	0.098
3		36	5.363	1.958	10.534	5.937	5.160	4.643	0.461	0.471	0.126	0.125	0.143	0.075
4		38	6.322	4.540	10.867	7.259	6.100	7.016	0.511	0.517	0.172	0.185	0.194	0.093
5		32	3.230	2.202	7.454	7.175	4.803	7.581	0.464	0.457	0.100	0.120	0.095	0.084
6		52	6.078	5.795	7.894	8.051	6.050	9.560	0.538	0.533	0.107	0.169	0.158	0.059
7		22	5.446	4.434	9.896	4.618	3.585	6.337	0.642	0.638	0.162	0.297	0.294	0.099
8		65	5.637	5.277	9.814	5.537	4.505	7.832	0.473	0.474	0.124	0.129	0.118	0.079
9		52	7.008	4.724	9.802	6.134	5.835	3.885	0.444	0.444	0.137	0.118	0.111	0.079
10		63	9.650	9.411	6.060	9.601	7.810	7.284	0.419	0.414	0.107	0.112	0.103	0.065
11		62	8.730	6.319	8.279	8.128	6.478	6.664	0.444	0.440	0.112	0.146	0.137	0.076

Figure 16 – Clustering configuration for the mature-large group, with descriptive statistics and centroid for each cluster

For mature-large firms (Figure 16), cluster 10 presents the highest sales growth and profit margin means in the entire group, while at the same time reporting the lowest level of business model change activity. The highest frequency of business model change events is observed in cluster 7 (lowest profit margin mean), and the second highest in cluster 1 (second highest sales growth mean). These observations from both clusters suggest a positive association between counts of business model change events and sales growth, but a negative association when profit margin is included in the relation.

The centroids of clusters 1 and 7 present intensive changes at early stages, which explains the high counts of business model change events. The centroid of cluster 10 reveals a smooth and continuous business model trajectory, a similar pattern seen in cluster 11 (both are high-performing clusters).

In summary, the following insights can be drawn from the cluster analysis:

- Evidence of a positive association between sales growth and counts of business model change events has been found for young-small, young-large and mature-large groups.
- Evidence of a negative association between counts of business model change events and both sales growth and profit margin (combined) has been found for all groups.
- Evidence of intense changes in early stages in clusters with high sales growth has been found for young-small and mature-large groups.
- Evidence of intense changes in early stages in clusters with high counts of business model change events has been found for young-small, mature-small and mature-large groups.

6.3 Drivers and properties of business model development

This section discusses the analytic methods used to assess the drivers and frequency, magnitude and order properties of business model development, together with the corresponding results. Firstly, the procedures for segmenting the age-size groups into performance deciles and the application of sequential pattern mining algorithms are explicated, as these are used in most of the analyses.

6.3.1 Performance deciles

As described in previous chapters, the research attention in exploring the patterns of business model development lies in successful, high-performing firms, as discovering the dynamics of business model change in those firms has significant implications for established firms. As discussed in Section 6.2 , revenue growth and profit margin are used as measures of performance. Building on the practice of using median values to examine operating performance due to the skewness of financial ratios (Loughran & Ritter, 1997), and based on previous studies showing the effectiveness of integrating revenue growth and profit margin to measure performance effects of cumulative organisational process (Batjargal, 2003; Von Nordenflycht, 2007), firm-level performance is measured as:

$$Performance = \frac{Mdn(rev.growth) + Mdn(prof.margin)}{2}$$

where *rev. growth* and *prof. margin* represents the medians of the year-on-year revenue growth and the medians of the yearly profit margins (respectively), for every firm in the age-size group. At the firm level, both indicators have been calculated for the total number of available years. Estimating a firm's performance by aggregating and averaging multiple indicators has been extensively used in studies supporting the view that performance is multidimensional, and that a variety of indicators enriches the estimation of the financial position of an organisation (Westhead & Howorth, 2006; Wiklund & Shepherd, 2003).

Once the performance measure was calculated for each firm, the four age-size groups of firms were segmented into deciles so that the top end, or 1st decile, represents the top 10% firms organised by performance, and the lower end, or 10th decile, represents the bottom 10% firms. Segmenting a sample of firms by performance deciles is a common practice in finance research, and it has led to significant findings on governance mechanisms in high and low performers (Weir, Laing, & McKnight, 2002) and in explaining the causal relationship between a firm's board structures and level of CEO monitoring (Guo & Masulis, 2015).

6.3.2 Sequential pattern mining

For the identification, description and quantification of the most frequent sub-sequences of business model change, the R package known as "TraMineR" is used. The package includes algorithms for the analysis of sequence data developed by Gabadinho, Ritschard, Mueller, and Studer (2011), originally designed to examine patterns in life course trajectories at the individual level. It contains specific algorithms for both state and event sequence data, with the latter derived from the work of Ritschard et al. (2013) and Bürgin and Ritschard (2014) on longitudinal analyses of life event histories.

Once the sample of firms for each age-size group was segmented into performance deciles, the algorithm for the detection of frequent sub-sequences was implemented on the sequences of business model change. The sequences are comprised of change events represented by the value dimension being changed and corresponding category (e.g. CRE2, which refers to a value creation change event of category 2). The algorithm was set to search for sub-sequences with a maximum

length of two years and involving events with a maximum gap of one year between them. Also, the procedure only considered sub-sequences occurring in at least 20% of the sequences.

6.3.3 Mechanisms driving business model development

6.3.3.1 Analysis

The examination of the drivers of business model development had two major analyses. The first analysis focused on the agents driving change and assessed the extent to which firms in the same industry acted as a collective force influencing certain patterns of business model innovation, and the extent to which the individual characteristics of the firm (i.e. age and size), and not the external actors, are the major force influencing particular patterns of business model innovation. The second analysis focused on the nature of the actions driving change, and assessed the extent to which the business model change events are the results of involuntary actions undertaken by the firm—thus, actions that are predefined to a firm according to its characteristics such as age, size, performance levels and industry of operation, or the extent to which the change events are the product of involuntary moves that emerge randomly as the firm develops over time. In both analyses (agents and actions), the observation of patterns of change focused on the top 10% performing firms, which corresponds to the 1st decile described in Section 6.3.1. Within the top decile, firms with no business model change event for any of the available years were removed from the group, as the analysis centred on observing variations in the sub-sequences of business model change events.

Additionally, an initial step for both analyses was implementing the frequent sequential pattern mining algorithm discussed in Section 6.3.2 to identify the most frequent sub-sequences for each firm. As the search for sub-sequences was done for each firm individually, and not for a group of firms, the counting method for the pattern mining procedure was different from the one used in previous analyses; instead of counting the number of full sequences (i.e. firms) that contain a sub-sequence, the number of distinct occurrences of a sub-sequence was counted for a single sequence. The sub-sequence (or sub-sequences) with the maximum number of counts was then selected for each firm.

The following additional information was extracted from each of the sub-sequences identified: the sub-sequences without the dimension categories, the intensity and the duration. For instance, the sub-sequence (CRE1)—(CAP2)—(DEL1) resulted in three additional ways to write them: (CRE)—(CAP)—(DEL) which is the sub-sequence without the categories; "4", which is the intensity

calculated by summing the categories; and "3", which is the duration in years. Lastly, statistical tests were conducted using these four different forms of sub-sequence data as dependent variables (one form at a time), while the firm-related attributes of firm size, age and industry of operation were used as independent variables (one attribute at a time). The statistical tests used were the Pearson's Chi-square test of independence for the analysis on the agents of change, and one-way analysis of variance (ANOVA) for the analysis on the actions driving change.

6.3.3.1.1 Agents driving business model change

Proposition 1 (see Section 3.3.1) deals with the nature of the agents driving business model innovation, stating that the interaction between the collection of firms sharing the same sub-industry (the population level), as well as the interaction between a firm's elements (the individual level) are both drivers of business model development. To assess this proposition, the most frequent sub-sequences for high-performing firms were identified only for those high-performing firms with at least one change event through their history, and then the association between sub-sequences and the firm's industry of operation was examined, representing the population level on the one hand, and the association between sub-sequences and the firm's characteristics of age and size, representing the individual level on the other hand. Significance in these two relationships validates the influence of population and individual dynamics as agents of business model development.

6.3.3.1.2 Actions driving business model change

Proposition 2 states that, in some instances, business models develop through steps predefined by the firm's circumstances, and in others, business model development is the product of deliberate actions taken by the firm at particular points in time. The rationale of the test for this proposition is that, if business model development is influenced by involuntary forces imposing predetermined changes, firms with similar characteristics of age, size, performance and operating in the same industry must share similar sequences of business model change events. If, on the other hand, there are significant variations in the patterns of business model change, then the process is comprised of undetermined progressions of events that emerge as firms decide when and what to change. For this purpose, the variability of frequent sub-sequences across firms with identical characteristics (within-group variance) was tested and compared with the variability across firms with dissimilar characteristics (between-group variance).

6.3.3.2 Results

6.3.3.2.1 Agents driving business model change

As observed in Table 20, multiple Chi-square tests were conducted using multiple forms of sub-sequence data—full sub-sequence, sub-sequence without the dimension's categories, intensity, duration—as one categorical variable, and the firm's attributes—age, size, sub-industry of operation—as the other categorical variable. Then, the independence between each selected categorical variable was tested.

Form of BMC events	Result	Groups by firm's characteristics			Group by industry classification system		
		Age and size	Age	Size	3 ind. groups	7 industries	14 sub-ind.
Full sub-sequence	$\chi 2$	338.490	105.240	178.280	308.640	955.000	2108.800
	df	486	162	162	324	972	2106
	p-value	1.000	1.000	0.181	0.721	0.645	0.479
Sub-sequence w/o categories	$\chi 2$	13.290	5.434	3.804	8.918	33.416	94.950
	df	36	12	12	24	72	156
	p-value	1.000	0.942	0.987	0.998	1.000	1.000
Intensity	$\chi 2$	79.740	56.981	36.959	26.055	42.991	85.356
	df	15	5	5	10	30	65
	p-value	8×10^{-11} ***	5×10^{-11} ***	6×10^{-7} ***	0.004 **	0.059 .	0.046 *
Duration	$\chi 2$	6.000	0.061	0.577	1.254	8.156	15.510
	df	1	2	2	4	12	26
	p-value	0.981	0.970	0.749	0.869	0.773	0.947

*Significance codes: .p<0.1; *p<0.05; **p<0.01; ***p<0.001*

Table 20 – Results from Pearson's Chi-square test of independence with different combinations of categorical variables

Table 20 indicates that the sub-sequences of business model change are significantly related, with firm's age and firm's size at the $p<0.001$ level, but only when the intensity of the sub-sequences are considered. Statistically significant relationships at the $p<0.01$ level were also found between the intensity of business model change and the sub-industry in which the firms operate, specifically when firms were classified by industry (seven industries comprising the IT sector), while a relationship at the $p<0.05$ level was observed when firms were classified by sub-industry (14 sub-industries comprising the IT sector).

These results suggest that both the characteristics of the firm and the industry of operation determine the way high-performing firms typically alter their business models, but only when the

intensity of such changes is considered. According to this evidence, the order in which the dimensions are altered, as well as the duration in which such alterations are implemented are influenced by neither the industry in which the firm operates, nor the individual characteristics of the firm.

In conclusion, Proposition 1 ("For high-performing firms, both environmental and internal dynamics are likely to influence business model development at proportionate levels") is partially supported by the results only for the case of the intensity (i.e. number of firm's elements altered) of the business model changes. The environmental forces, resulting from the interaction between firms sharing the same industry of operation, indeed influence the intensity of business model changes, as seen from the results of the Chi-square test using the industry of operation as one of the variables. On the other hand, the internal forces, resulting from the firm's particular stage of growth and scale of operation, also influence the intensity of business model changes, evidenced by the Chi-square test using the age and size of the firm as one of the variables. However, when the significance of the influence is accounted for, the internal characteristics of the firm present a superior statistical significance ($p<0.001$ level) than that of the environmental or industry forces, for which statistical significance across the different GICS code used ranges from $p<0.01$ to $p<0.1$ level. Under these circumstances, the influence of both internal and external factors is not symmetric, thus Proposition 1 is not fully supported.

6.3.3.2.2 Actions driving business model change

As with the previous analysis on the agents of business model change, the analysis on the nature of the actions driving business model change began with the identification of the most frequent sub-sequences of business model change for high performers. For each sub-sequence, the intensities were calculated as the sum of the categories for each dimension, as well as the duration (the number of years comprising the change). Firms were then aggregated in separate classes according to their age, size and industry of operation.

Then, one-way ANOVA tests were conducted to compare the variance of intensity and duration means for firms within classes, over the variance between classes. As shown in Table 21, different configurations of variables were tested in separate ANOVA tests. One configuration used the firm's classes as independent variables and the average firm's intensities as the dependent variable. Another configuration used the classes as independent variables, and the average firm's duration as the dependent variable. Additionally, the classes were computed using nine different arrangements of the firm's elements (age, size and industry classification levels) to assess whether the number of

classes, and the homogeneity among firms, affected the intensity and duration variances. Additional ANOVA results such as p-values and significance levels were not reported, as the aim was to assess the ratio of between variance to within variance (F-statistics).

Indep. variable (categorical)		Dep. variable (continuous) = Intensity			Dep. variable(continuous) = Duration		
No. classes	**Parameters for class formation** (firm's elements & industries)	**Mean Sq: Class** (between-group)	**Mean Sq: Residuals** (within-group)	**F value**	**Mean Sq: Class** (between-group)	**Mean Sq: Residuals** (within-group)	**F value**
38	4 age-size groups & 14 sub-ind.	0.586	0.613	0.957	0.293	0.225	1.304
23	4 age-size groups & 7 ind.	0.615	0.603	1.021	0.406	0.211	1.926
12	4 age-size groups & 3 ind. groups	0.934	0.573	1.629	0.327	0.237	1.382
24	2 age groups &14 sub-ind.	0.578	0.611	0.946	0.305	0.231	1.320
13	2 age groups & 7 ind.	0.778	0.587	1.326	0.330	0.236	1.401
6	2 age groups & 3 ind. groups	1.544	0.566	2.728	0.231	0.245	0.943
24	2 size groups & 14 sub-ind.	0.639	0.597	1.069	0.304	0.231	1.314
13	2 size groups & 7 ind.	0.709	0.594	1.194	0.438	0.224	1.954
6	2 size groups & 3 ind. groups	1.075	0.586	1.837	0.087	0.251	0.346

Table 21 – Results from one-way ANOVA tests with different combinations of variables

The results of the model with intensity as the dependent variable indicate that the within-group variance is greater than the between-group variance (f-value < 0), an observation that holds true for cases when age-size, age and sub-industry are used to classify similar firms. The model with duration as the dependent variable also results in within-group variances greater than between-group variances, when the firms are classified according to their age, size and industry.

This indicates that firms with similar characteristics of age and industry of operation change their business models at significantly different intensities; if unconscious actions were to drive business model innovation, we would have expected insignificant variations in the intensities of the change for firms operating under similar circumstances. Additionally, firms with similar sizes and operating in the same industry change their business models at significantly different durations. In sum, these findings support that business model development is, under certain conditions of firm age and size, driven by undetermined, emergent actions taken by the firm.

On the other hand, the model with intensity as the dependent variable and firm classifications based on size results in greater between-group variations compared to within-group variations, and the same result is observed in the model with duration as the dependent variable and firm classification

based on a combination of age and size. This indicates that the firm's age, size and industry of operation predetermine the duration of the change events introduced in their business models, and that the size and industry of operation predetermine the intensity at which they alter their business models. These findings support that, under certain circumstances of age, size and industry of operation, business model development is driven by preconditioned—thus involuntary—change actions.

In conclusion, Proposition 2 ("For high-performing firms, both deliberate and unconscious actions are likely to drive business model development at proportionate levels") is supported by the ANOVA analyses on the intensity and duration of frequent sub-sequences of business model changes in high performers, as there is evidence of both predetermined and emergent alterations when different external and internal conditions of the firm are considered. Nevertheless, when the proportion of ANOVA analyses suggesting within-group variance over those suggesting between-group variance is considered, the evidence suggests a lesser influence of deliberate actions on business model development than that from unconscious actions, as only four of the 18 ANOVA analyses performed had greater within-group variance than between-group variance (recalling that this combination reflects that, no matter how similar two firms are, the patterns of business model changes between them are never the same). Therefore, the extent of the influence from both deliberate and unconscious actions on business model development is not symmetric, thus Proposition 2 is not fully supported.

6.3.4 Frequency of events in business model development

6.3.4.1 Analysis

To examine the dominant frequencies at which high-performing firms alter their business models, the first step was to classify firms by performance by segmenting the sample into performance deciles (a procedure described in Section 6.3.1), so that the resulting frequencies for top performers can be estimated separately and contrasted with the frequencies at the remaining firms.

The second major step was the implementation of frequency domain analysis. Business model change events for each firm were concatenated to form a time series with lengths equal to the number of available years for the firm. Discrete Fourier transforms were calculated for each time series, using the Fast Fourier Transforms (FFT) algorithm in R.

Following the procedure proposed by Shumway and Stoffer (2010), the periodogram function was implemented to the resulting discrete Fourier transforms to compute the power spectral densities of the frequencies identified as the most significant for the time series. The greater the spectral power of a frequency, the more dominant the frequency is in determining the periodicity of the time series.

The list of frequencies and corresponding spectral power generated for each firm were all combined to form a list of frequencies for each firm within a performance decile. This was done by counting the occurrence of each frequency across the entire list. For instance, the frequency $f = 2.25$ Hz with a count of "7" indicates that such frequency was identified as significant for seven firms.

This procedure was performed for each performance decile. Then, for the firms in the 2nd to 10th deciles, the total counts for all the frequencies were aggregated by frequency. The entire process was performed four times, one for each age-size group.

6.3.4.2 Results

As the main goal of this analysis is to determine how frequently firms change their business models, it remains more intuitive to report the number of years between one change and the next one—known as the *period* in the field of signal processing—rather the frequency, which represents the number of changes made by year (typically less than one for the case of business models). Thus, the period (T) was calculated as $T = 1/f$, where f is the frequency obtained from the frequency domain analysis.

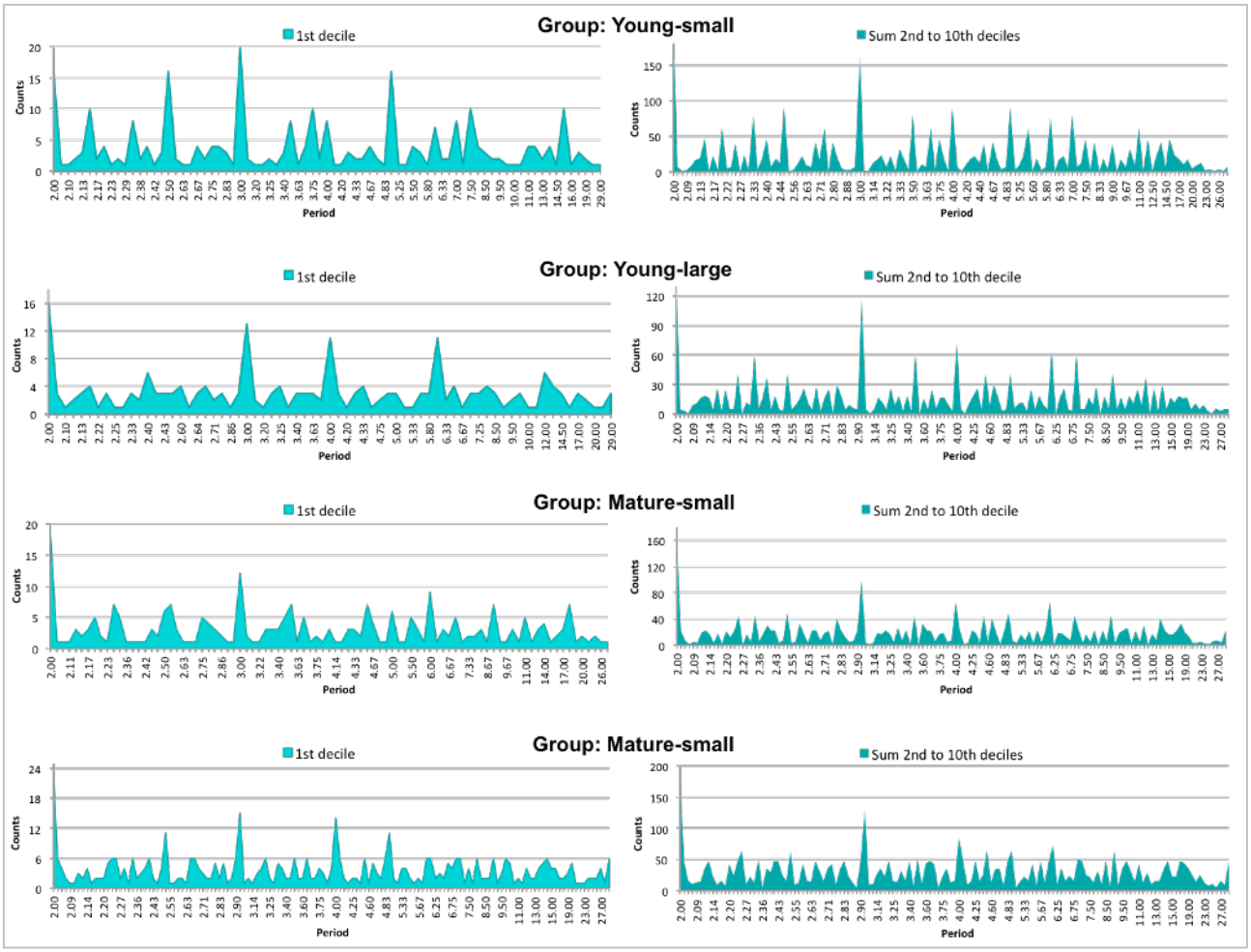


Figure 17 – Periods resulting from the frequency analysis for firms in the top 1st performance decile, and for firms in the rest of the performance deciles (aggregation), by age-size group

Figure 17 presents the periods of business model change resulting from the FFT algorithm and the periodogram function. It illustrates the counts of the most significant periods for all the firms in the top 1st decile, as well as for the rest of the firms. Table 22 contains the values for the top three periods with largest counts for the 1st decile and aggregation of the rest, organised by age-size groups. As a general observation, there is a substantial dominance of T = 2 years and T = 3 years across all deciles and across all groups. However, the size of that dominance compared to the other time periods varies across groups.

Decile	Period in years (weighted mean)	Period in years (weighted SD)	Top 3 periods with largest counts		
			Period	Frequency	Count
Young-small group					
1st decile	5.269	17.246	3.0	0.333	20
			2.0	0.500	16
			2.5	0.400	16
			5.0	0.200	16
Rest (sum 2nd to 10th deciles)	5.336	18.745	2.0	0.500	207
			3.0	0.333	162
			2.5	0.400	91
			5.0	0.200	91
Young-large group					
1st decile	5.450	23.037	2.0	0.500	16
			3.0	0.333	13
			4.0	0.250	11
			6.0	0.167	11
Rest (sum 2nd to 10th deciles)	5.519	22.239	2.0	0.500	148
			3.0	0.333	117
			4.0	0.250	72
Mature-small group					
1st decile	5.654	23.927	2.0	0.500	19
			3.0	0.333	12
			6.0	0.167	9
Rest (sum 2nd to 10th deciles)	5.732	26.370	2.0	0.500	162
			3.0	0.333	98
			4.0	0.250	66
			6.0	0.167	66
Mature-large group					
1st decile	6.089	33.423	2.0	0.500	23
			3.0	0.333	15
			4.0	0.250	14
Rest (sum 2nd to 10th deciles)	5.979	30.660	2.0	0.500	191
			3.0	0.333	129
			4.00	0.250	85

Table 22 – Top 3 periods with largest counts for the 1st performance decile and for the aggregation of the rest of the performance deciles (from 2nd to 10th), by age-size group

When comparing the 1st performance deciles across groups, the young-small is the only group for which T = 2 years is not the most dominant period. Although T = 3 years is the most dominant, there are also significant counts for T = 5 years, which indicates that firms in this decile alter their business models at a slower pace. However, when the total counts for the entire set of periods are considered, high performers in the young-small group shared the lowest weighted mean from all high performers, making them the cohort of most recurrent business model changes. The 1st decile for the mature-large group shared the largest weighted mean period from the entire cohort of 1st

deciles, which indicates that high performers in the mature-large group reconfigure their business models less frequently than their counterparts from other age-size groups. In term of variance, periods from high performers in the mature-large group were the most heterogeneous across the entire sample, indicating that their business models change at significantly different timings.

When the 1st performance deciles were compared with the rest of the deciles at the same age-group level, there were no clear significant differences in the top three periods found for each cohort. However, the weighted mean periods of the high performers were greater than the weighted mean periods from the rest of the firms in all groups. The only exception was the mature-large group, where the high performers introduce changes to their business models at an (weighted) average period of T = 6.089 years, whereas the rest of the firms change their business models at an (weighted) average period of T = 5.979 years. In summary, the number of years between one business model change and another is lower in high performers than in the rest of the firms, except for the mature-large firms. Nevertheless, the differences were small: 0.067 years for the young-small group; 0.069 years for the young-large group; and 0.078 years for the mature-large group.

Having discussed the most dominant periods of business model change, the next step in the analysis is assessment of the size of such dominance compared to other periods, to determine the extent to which business model development occurs at a single rate (i.e. constant rate of development), or whether it occurs through multiple rates of change (i.e. variable rate of development). The periods of change for high performing young-small firms illustrated in Figure 17 indicate significant counts in periods equalling 2.5 and 5 years, apart from the significance of 2 and 3 years already discussed. From a quantitative perspective, Table 22 shows even counts of T = 2, 2.5 and 5 years (16 cases). In contrast, the rest of the firms in the group show significantly more counts of T = 3 years than 2.5 and 5 years (192, 91 and 91 cases respectively), evidencing a stronger dominance of 2 and 3 year periods than for high performers. A visual assessment of Figure 17 indicates that no other period is anywhere near T = 2 and T = 3 years in terms of dominance. This insight suggests that high-performing firms are more likely to change their business models at variable rates, which includes periods of 2, 2.5, 3 and 5 years, than the rest of the firms in the group. The latter observation also holds true for young-large (periods include 2, 3, 4 and 6 years), mature-small (periods include 2, 3 and 6 years) and mature-large groups (periods include 2, 3 and 4 years).

In conclusion, for Proposition 3 ("High-performing firms are more likely to develop their business models at a variable (rather than constant) rate of change than other firms"), the evidence from the frequency domain analysis indicates there is a higher probability that a high-performing firm

changes its business model at multiple rates over time (e.g. a business model change every 2, 2.5, 3, 4, 5 or 6 years) than that observed for the rest of the firms in each age-size group. Thus, Proposition 3 is supported by the results from the frequency domain analysis.

6.3.5 Magnitude of events in business model development

6.3.5.1 Analysis

Similar to the frequency analysis, the assessment of the patterns of magnitudes at which business models are reconfigured began with the agglomeration of firms by performance deciles, as a key objective is to compare the proportion of radical and incremental changes observed in high-performing firms with the proportion in the rest of the sample. The procedure to measure firm performances and construction of the deciles is explained in Section 6.3.1.

The second step was the implementation of the sequential pattern mining algorithm described in Section 6.3.2. The parameter of minimum support was set to 0.20, i.e. only events occurring in at least 20% of the cases were considered. Additionally, the sub-sequences discovered were filtered to discard those having more than one event and one or more transitions—e.g. sub-sequences such as (1)—(0)—(23) were discarded, whereas sub-sequences such as —(1)— were kept. This mining process was performed for each of the four age-size groups separately.

6.3.5.2 Results

As described in Chapter 4: Research Design, incremental changes are events with magnitudes between “1” and “15”, while radical events have magnitudes between “16” and “30”. Table 23 summarises the number of occurrences for incremental and radical business model change events found when firms were agglomerated by performance deciles, and Figure 18 illustrates the results.

This evidence explains patterns in the magnitude of the change from two perspectives: (1) cross-observation between the four age-size groups (with no consideration on performance); and (2) cross-observation between the performance deciles for each firm group separately, with the analytic focus centred on the top 1st decile.

From the first perspective, mature-large firms had the greatest number of radical changes. However, when the proportion of incremental to radical changes is considered, the young-large group was more likely to introduce radical changes, as 31.7% of the total changes were radical. The proportion

of radical changes for the remaining groups was 23.5% for the young-small group, 23.3% for the mature-small group and 20.6% for the mature-large group.

Firms group	BMC magnitude	Decile										Descriptive statistics			
		1st	2nd	3rd	4rd	5th	6th	7th	8th	9th	10th	Total	Mean	Median	SD
Young-small	Incremental	35	20	11	57	47	52	45	20	42	30	359	35.9	38.5	14.522
	Radical	0	11	21	22	10	10	26	0	0	10	110	11.0	10.0	9.011
Young-large	Incremental	22	42	41	30	49	32	40	39	37	27	359	35.9	38.0	7.648
	Radical	7	20	17	25	18	21	22	19	10	8	167	16.7	18.5	5.900
Mature-small	Incremental	42	51	34	47	33	52	43	35	51	40	428	42.8	42.5	6.925
	Radical	10	21	18	8	16	19	7	14	17	0	130	13.0	15.0	6.245
Mature-large	Incremental	78	77	74	62	55	59	66	62	70	63	666	66.6	64.5	7.432
	Radical	28	15	11	21	10	0	27	24	12	25	173	17.3	18.0	8.672

Table 23 – Counts of business model change events by magnitude, computed for each firm's performance decile across the four age-size groups

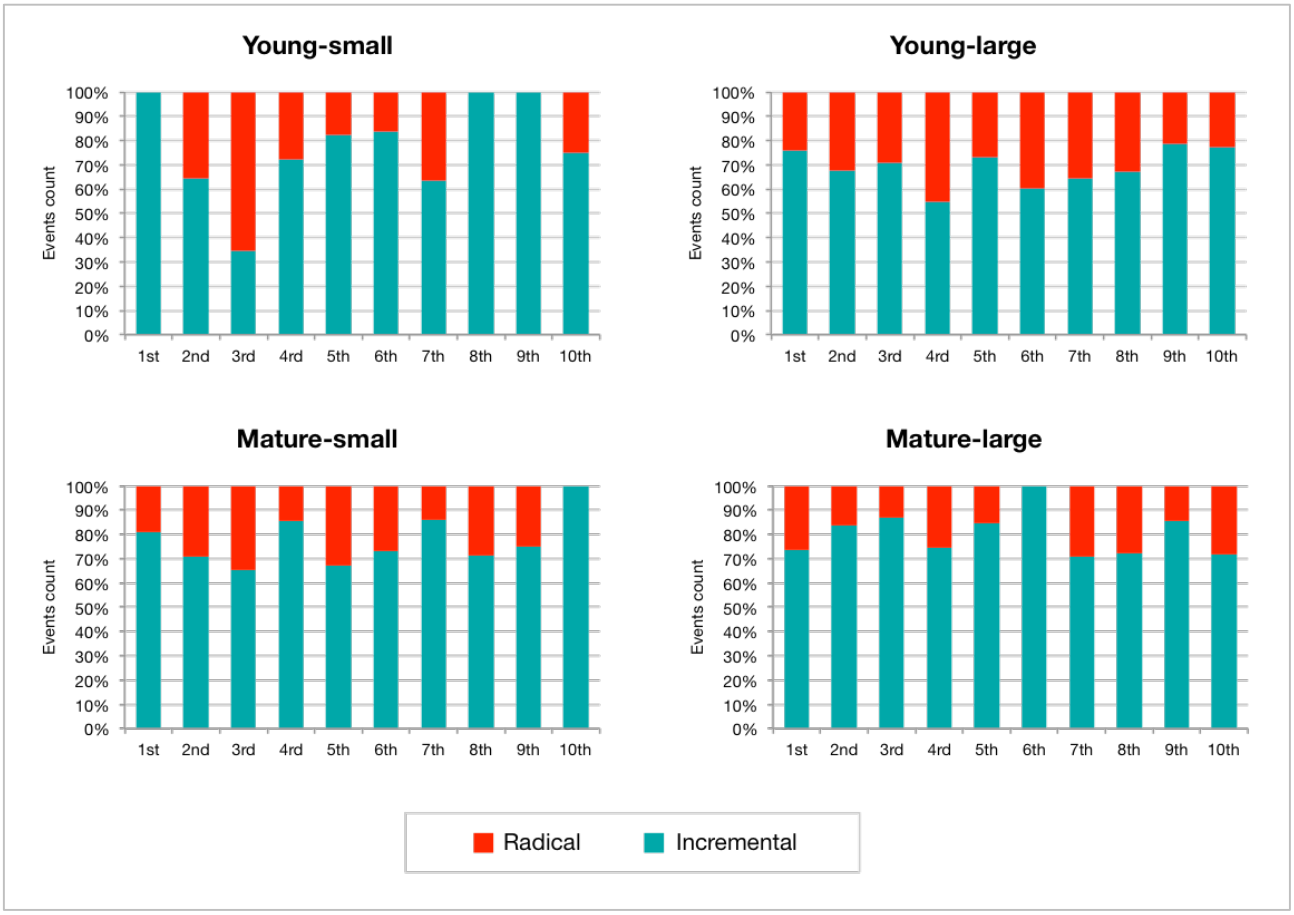


Figure 18 – Proportion of radical and incremental business model change events in firms grouped by performance deciles, across the four age-size groups

All of the groups had at least one decile with no counts of radical changes, except for the young-large group. The young-small group has the greatest number of deciles with no counts of radical changes (three), but it also contains the individual decile with the biggest proportion of radical change across the sample (3rd decile). Such heterogeneity is evidenced by the standard deviation of both incremental and radical changes, the largest across the entire sample.

From the second perspective, the top 1st decile in the young-small group is the only 1st decile across the four age-size groups with no counts of radical changes. Firms in the 1st decile of the young-large group implemented radical alterations at a ratio of 0.32 radical changes for every incremental change introduced, a ratio below those from the remaining deciles. In a group that shows a significant proportion of radical changes compared to other groups, young-large high performers are certainly not the most radical firms compared to the rest of the young-large firms. A proportion of 19.2% radical changes of the total changes was observed for the top 1st decile of the mature-small group, which is below what is seen in the rest of the firms from that group. Lastly, for mature-large firms, the 1st decile has a larger proportion of radical changes of total changes (26.4%) than the proportion observed for the entire group. To summarise, in terms of the radical-incremental ratio, the results indicate that the high performers are likely to be more inclined towards incremental business model changes than what is considered average for their age-size groups, with the exception of high performers in the mature-large group, which are likely to be more radical than the rest of the firms.

In terms of the number of changes, none of the high performers across the four age-size groups showed counts of radical changes greater than the mean or median values for their respective groups, except the high performers of the mature-large group. A similar situation is seen for incremental changes, where the 1st decile of the mature-large groups is the only top decile having counts of incremental changes greater than the group mean and median. In sum, this evidence indicates that high performers implement alterations (either incremental or radical) to their business models at a lower scale than the average firm, except for mature-large firms.

In summary, the trajectory of business model change in high performers is likely to be characterised by incremental adjustments over time, a behaviour more profound among high performers in the young-small group, for which there was no count of a radical business model change event (occurring in at least 20% of the firms sharing the same performance level). Moreover, depending on their age and size, some high performers are more radical in nature than others (when compared with average performers of the same age and size). For instance, high-performing mature-large

firms have a higher proportion of radical types of business model change events that what is considered the average for the rest of the mature-large firms.

The confirmation of Proposition 4 ("High-performing firms are more likely to develop their business models through a similar number of radical and incremental changes than the rest of the sampled firms") required that the proportion of incremental to radical changes for the case of high-performing firms is 50% (or closer to 50% than that of the rest of the firms in the group). The results from the sequential pattern mining suggest that this is not the case. Although the dominance of incremental over radical alterations is a common behaviour across the sample, high performers in each of the age-size groups had one of the most uneven incremental-radical ratios compared to the rest of the firms in their groups. The preponderance for incremental adjustments over radical changes is most obviously seen in young-small high performers, for which no single radical change event was recorded. An exception to this behaviour is seen in the mature-large group, where high-performers recorded the 4th most even incremental-radical ratio with 2.8 incremental changes for each radical change, while the most even ratio was 2.44 (based on the values presented in Table 23). In conclusion, Proposition 4 is not supported by the results of the sequential pattern mining analysis, however, mature-large high-performing firms are more likely to introduce a balanced proportion of radical and incremental changes than high performers from the other three age-size groups.

6.3.6 Order of events in business model development

6.3.6.1 Analysis

Similarly to the previous analysis, a firm's performance plays a fundamental role in the order analysis, as it defines the cohort of firms that are the main focus. To understand the sequential order in which business models are developed over time, the firm's business model change sequences were grouped based on the firm's financial performance by splitting the sample of firms in each age-size group in deciles, a procedure explained in Section 6.3.1.

Then, two main analyses were conducted. The first analysis used the sequential pattern mining procedure explained in Section 6.3.2 to discover the most frequent sub-sequences of business model change for each decile. Although the algorithm was also used for the analysis of magnitude of change (Section 6.3.5), the major difference between both implementations is that, for the analysis of magnitude, sequences comprising the numeric magnitudes of business model change were used,

instead of the textual sequences comprising the succession of dimensions changed used in the analysis of order of change events. The secondary analysis used association rule mining algorithm to assess the probabilities of occurrence for each individual sub-sequence. The latter procedure is based on the classic association rule mining or "market basket analysis", a data mining task studying the probability of co-occurrence between two or more item sets. A variation of association rule mining was used that accommodates temporally ordered data, which assesses the likelihood of a sub-sequence *A* being followed by a sub-sequence *B* (Harms & Deogun, 2004). This analysis involved the detection of meaningful rules among change events to identify significant temporal relationships across dimensions within business model change events, providing an alternative way to assess the temporal order of business model innovation. Rules of temporal association between change events were mined across firms within the same performance decile for each age-size group separately. The most significant rules observed in the high performers were then compared with those found from the rest of the deciles to test the uniqueness of such rules.

As in frequent sequential pattern mining, the "TraMineR" package in R implemented the algorithm for mining sequence association rules to the sequences of business model change. Before (sequence) association rules were mined, the frequent sequence mining algorithm was executed and used as input for the former, with the following search parameters: sub-sequences with a maximum length of three years and comprising events separated by a maximum of two years. As noticed, these two parameters are larger than those from frequent sequence mining given that an initial run with the original parameters resulted in the detection of few-to-none statistically significant rules. In addition, the minimum support was set to 0.10, meaning that only sub-sequences occurring in at least 10% of the sequences were considered.

6.3.6.2 Results

6.3.6.2.1 Visual inspection

The sequences of business model change were plotted as chronologically-ordered horizontal bars, for the visual inspection and examination of pattern similarities (and differences) across deciles and across age-size groups. Each horizontal bar in the graphs presented in Figure 19, Figure 20, Figure 21 and Figure 22 represents business model change events for each individual firm, where time progresses from left to right. The events are coloured depending on the type of business model dimensions that are altered at each time point.

In general, a visual depiction of the business model change trajectories demonstrates the complexity and variety of events across the different firms in the sample. Although detecting patterns of change from these diagrams was laborious given the heterogeneity of the sequences, this form of representation enables high-level observations on the periods in which changes are largely implemented, and compares the overall level of business model change activity across deciles.

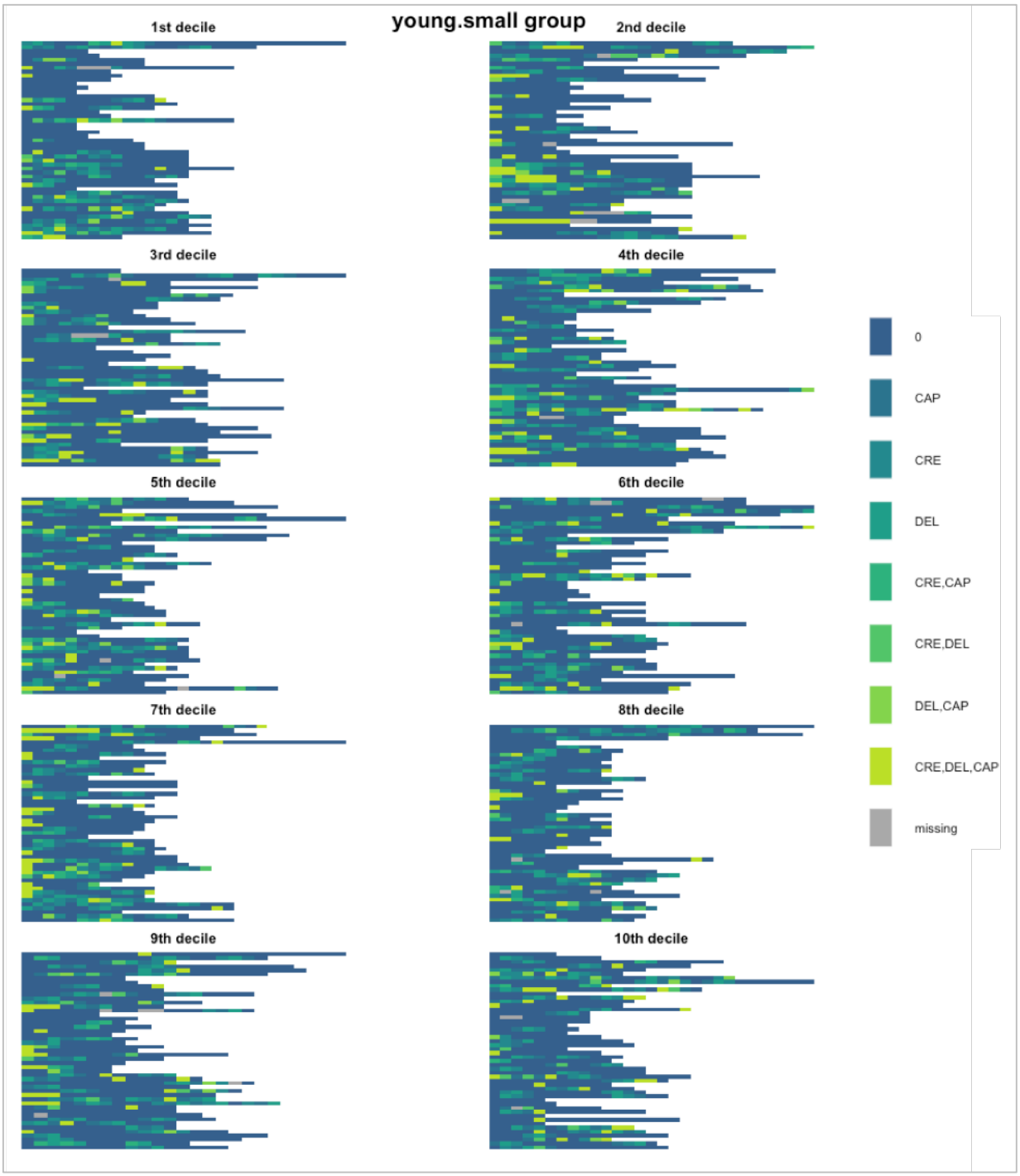


Figure 19 – Visual representation of the business model change sequences for young-small firms with corresponding events, grouped by performance decile

For young-small firms, Figure 19 shows a low presence of <CRE,DEL,CAP> events in firms in the 1st performance decile, compared to the 2nd and 7th deciles. For the 2nd and 7th deciles, <CRE,DEL,CAP> events are not only more frequent, but span several years (which indicates re-occurrence of the same event year after year). A closer look also reveals that 1st decile firms rely more on the type of events where one dimension is changed by year, such as <CAP>—<CRE>—<DEL>.

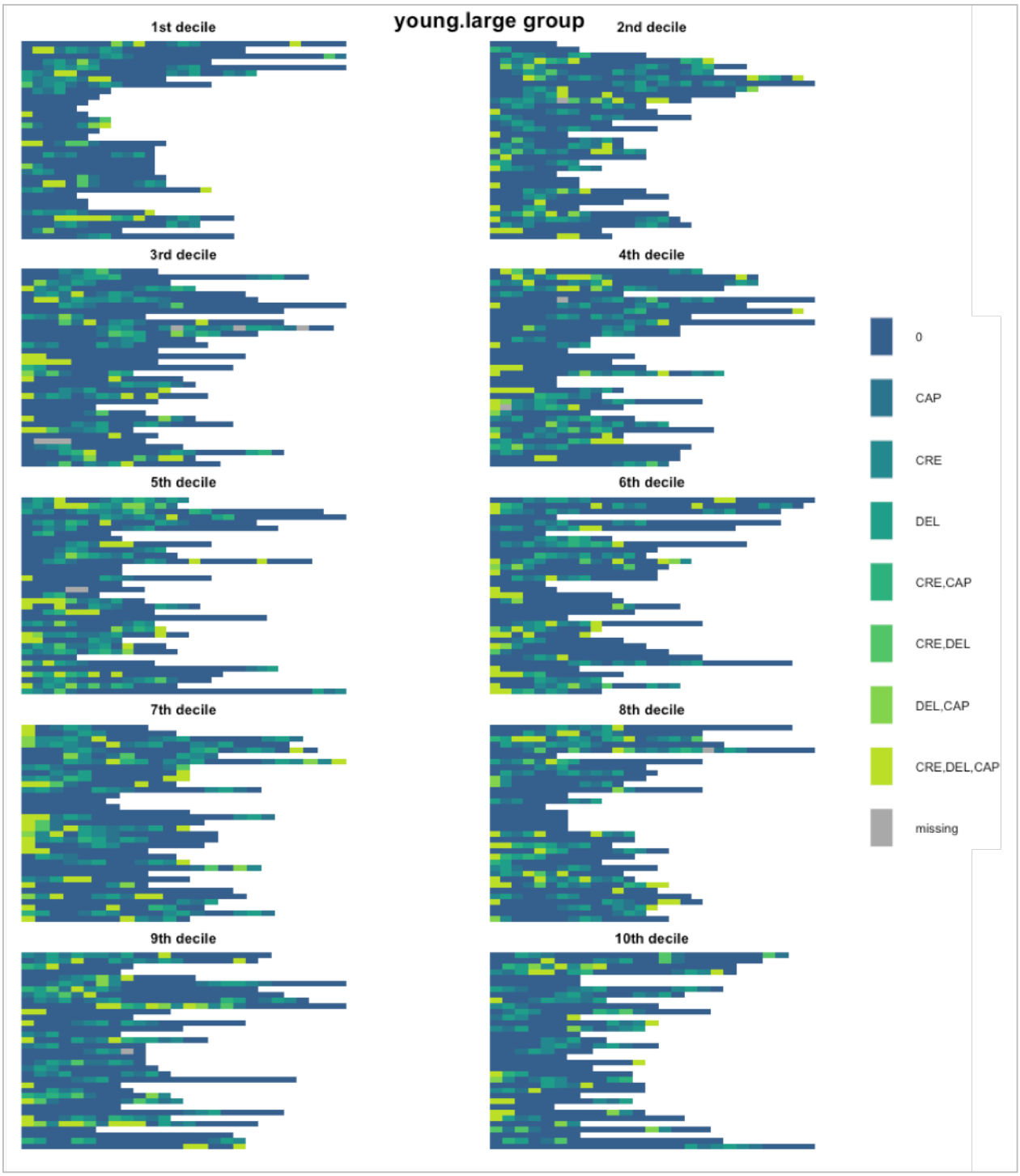


Figure 20 – Visual representation of the business model change sequences for young-large firms with corresponding events, grouped by performance decile

For young-large firms (Figure 20), the 3rd and 7th deciles present higher activity on <CRE,DEL,CAP> events than the 1st decile. Long periods of inactivity can also be seen in the 1st

decile, compared to other deciles. Additionally, the majority of <CRE,DEL,CAP> event instances in the 1st decile start from t = 2 onwards.

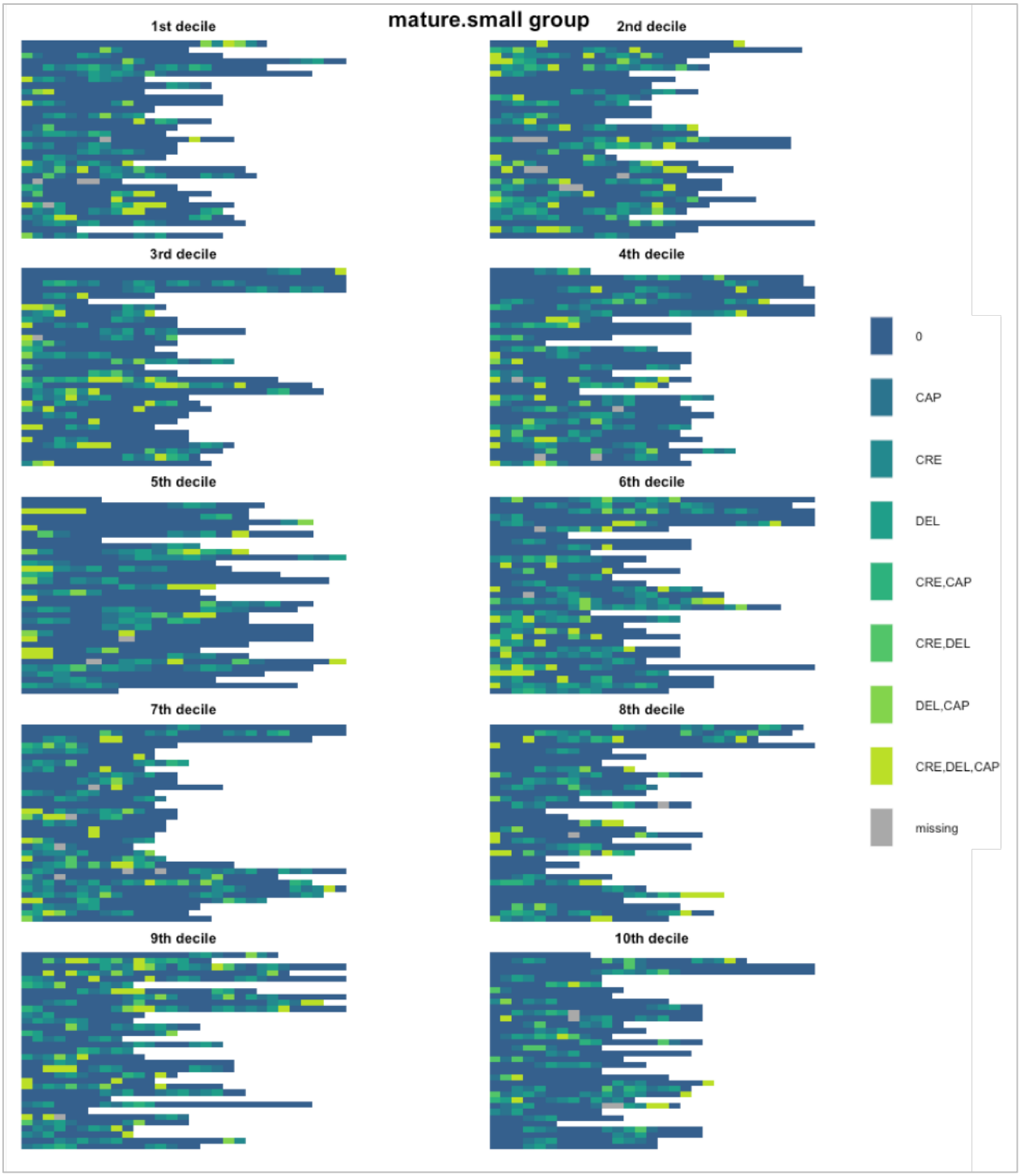


Figure 21 – Visual representation of the business model change sequences for mature-small firms with corresponding events, grouped by performance decile

Similar insights can be drawn for mature-small firms (Figure 21), where more frequent and larger periods of <CRE,DEL,CAP> events are seen in other deciles such as the 5th and 6th deciles than in

the 1st decile. Also, there are considerable cases in the 1st decile with <CRE,DEL,CAP> events occurring between t = 9 and t = 13, a pattern that is also observed in the 8th and 9th deciles.

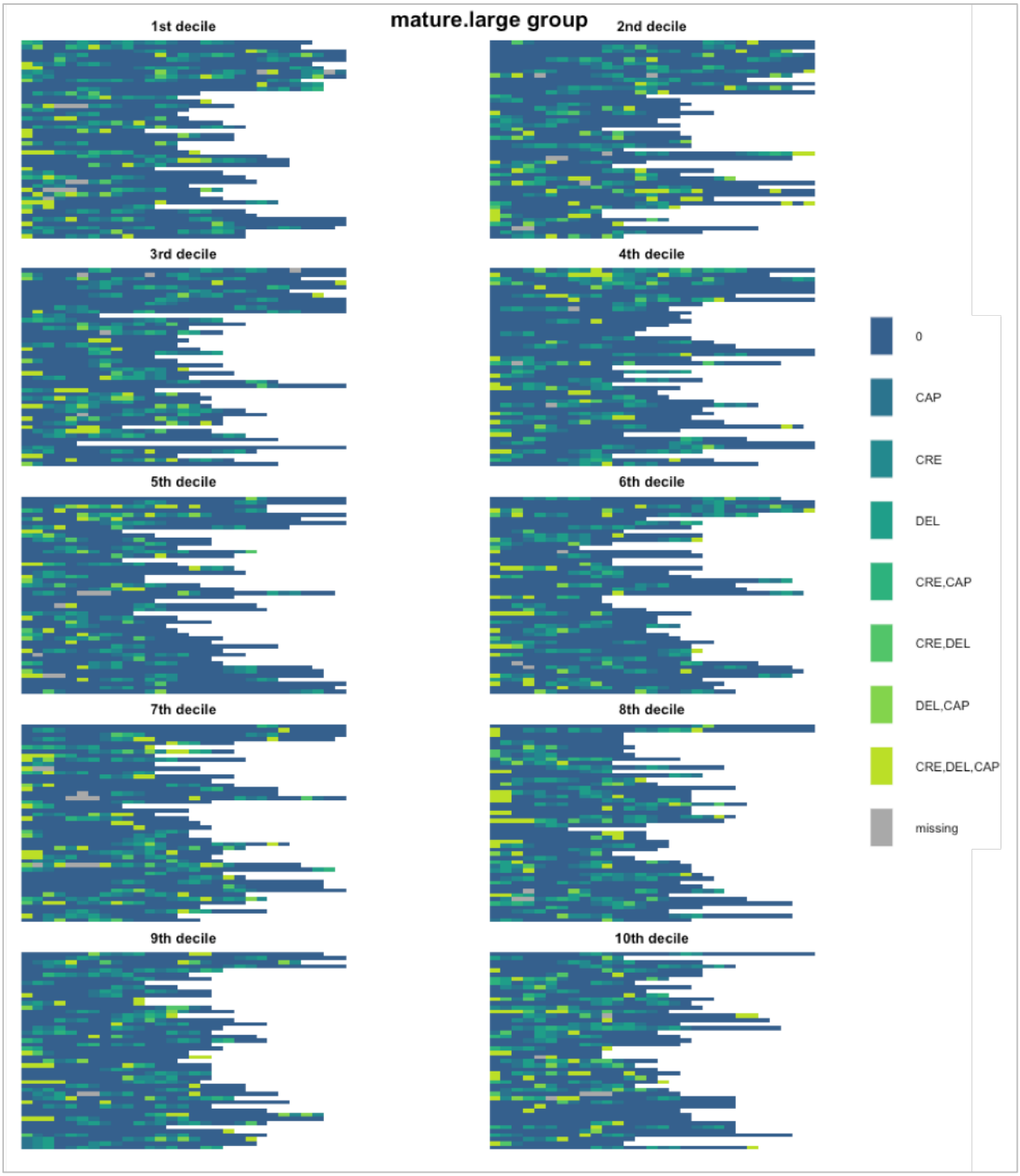


Figure 22 – Visual representation of the business model change sequences for mature-large firms with corresponding events, grouped by performance decile

For mature-large firms (Figure 22), the number of <CRE,DEL,CAP> events in the 1st decile is moderate compared to the rest of the deciles, and it is only comparable with the 7th and 8th deciles.

<CRE,DEL,CAP> events in the 1st decile are predominantly seen in t = 1, with few instances across successive years.

In summary, high-performing firms in young-small, young-large and mature-small groups have lower activities in <CRE,DEL,CAP> type of events than other deciles, indicating that these firms rely more on changes involving one or two dimensions per year. The exception is the mature-large firms, where the high performers had a considerable number of <CRE,DEL,CAP> events compared to other deciles. Nevertheless, more detailed inferences on the particular order of events cannot be determined using the visual inspection type of analysis.

As discussed previously, the identification of commonalities with this level of data heterogeneity remains an intensive task for the human eye. Examination of the order in which high-performing firms alter their business models required a more robust and higher level of quantification to account for statistically significant differences across sequences, which is the goal of the following two analyses presented in this section.

6.3.6.2.2 Sequential pattern mining

A total of 1,245 frequent sub-sequences were identified for the entire sample of firms. According to Han et al. (2011), what makes a sub-sequence meaningful and interesting is a high count (number of cases containing the sub-sequence) and a high support (value between "0" and "1" representing the percentage of cases containing the sub-sequence). Table 24 summarises the top 61 sub-sequences with the highest count for each of the performance deciles, organised by age-group. Multiple sub-sequences are presented for cases where two or more sub-sequences shared the same count.

The results indicate that 31% of high-performers in the young-small group change their business model by altering value creation first, then value capture and lastly value delivery, all of them in subsequent years. This sub-sequence is unique to high performers and not seen in any other decile. Other deciles where value creation changes are implemented in the first year are the 5th, 6th and 8th deciles.

For the young-large group, 39% of high performers introduce full changes to the three dimensions in a single year. However, the same sub-sequence is observed for the 3rd and 5th deciles with greater support, which means that such behaviour is not as dominant in high performers as it is in firms with lower performance.

Decile	Sub-sequence	Support	Count
Group: young-small			
1st	(CRE1)-(CAP1)-(DEL1)	0.310	13
2nd	(CAP1,CRE1,DEL1)	0.422	19
3rd	(CAP1,CRE1,DEL1)	0.333	16
	(CRE1,DEL1)-(CAP1)	0.333	16
4th	(CAP1)-(CRE1,DEL1)	0.429	21
	(CAP1)-(CRE1)-(DEL1)	0.429	21
5th	(CAP1,CRE1)-(DEL1)	0.396	19
	(CRE1)-(DEL1)-(CAP1)	0.396	19
	(DEL1)-(CAP1)-(CRE1)	0.396	19
6th	(CAP1,CRE1)-(DEL1)	0.375	18
	(CRE1,DEL1)-(CAP1)	0.375	18
	(CRE1)-(CAP1,DEL1)	0.375	18
	(DEL1)-(CAP1,CRE1)	0.375	18
7th	(CAP1,CRE1)-(DEL1)	0.500	24
	(CAP1)-(CRE1,DEL1)	0.500	24
8th	(CRE1)-(CAP1,DEL1)	0.313	15
9th	(CAP1)-(CRE1)-(DEL1)	0.333	16
	(DEL1)-(CAP1)-(CRE1)	0.333	16
10th	(CAP1,DEL1)-(CRE1)	0.326	15

Decile	Sub-sequence	Support	Count
Group: mature-small			
1st	(CAP1)-(CRE1,DEL1)	0.406	13
	(CRE1)-(CAP1,DEL1)	0.406	13
	(CRE1)-(CAP1)-(DEL1)	0.406	13
	(DEL1)-(CAP1,CRE1)	0.406	13
2nd	(CAP1,CRE1,DEL1)	0.636	21
3rd	(CRE1)-(DEL1)-(CAP1)	0.455	15
4th	(DEL1)-(CAP1)-(CRE1)	0.594	19
5th	(CAP1)-(CRE1,DEL1)	0.452	14
6th	(CAP1,CRE1)-(DEL1)	0.606	20
	(DEL1)-(CAP1,CRE1)	0.606	20
7th	(CRE1)-(CAP1)-(DEL1)	0.485	16
8th	(CAP1,DEL1)-(CRE1)	0.433	13
9th	(CRE1)-(CAP1,DEL1)	0.594	19
10th	(CRE1)-(CAP1)-(DEL1)	0.559	19

Decile	Sub-sequence	Support	Count
Group: young-large			
1st	(CAP1,CRE1,DEL1)	0.387	12
2nd	(DEL1)-(CAP1,CRE1)	0.471	16
3rd	(CAP1)-(DEL1)-(CRE1)	0.559	19
	(CAP1,CRE1,DEL1)	0.400	14
4th	(CAP1,DEL1)-(CRE1)	0.400	14
	(DEL1)-(CAP1,CRE1)	0.400	14
5th	(DEL1)-(CRE1)-(CAP1)	0.471	16
	(CAP1,CRE1,DEL1)	0.438	14
6th	(CAP1)-(CRE1,DEL1)	0.438	14
	(CAP1)-(DEL1)-(CRE1)	0.438	14
	(DEL1)-(CAP1,CRE1)	0.438	14
7th	(CAP1,DEL1)-(CRE1)	0.486	17
	(CAP1)-(CRE1,DEL1)	0.486	17
8th	(CAP1,CRE1,DEL1)	0.485	16
9th	(CAP1,CRE1)-(DEL1)	0.429	15
10th	(CRE1)-(CAP1)-(DEL1)	0.441	15

Decile	Sub-sequence	Support	Count
Group: mature-large			
1st	(CAP1,CRE1)-(DEL1)	0.574	27
2nd	(CAP1,CRE1)-(DEL1)	0.542	26
	(CRE1)-(CAP1,DEL1)	0.542	26
3rd	(CAP1,DEL1)-(CRE1)	0.511	24
4th	(CRE1)-(CAP1,DEL1)	0.532	25
5th	(CAP1,DEL1)-(CRE1)	0.563	27
6th	(CAP1,CRE1)-(DEL1)	0.479	23
7th	(CRE1)-(DEL1)-(CAP1)	0.489	23
	(DEL1)-(CAP1)-(CRE1)	0.489	23
8th	(CAP1)-(CRE1)-(DEL1)	0.500	24
9th	(CAP1,CRE1)-(DEL1)	0.500	24
10th	(CRE1)-(CAP1)-(DEL1)	0.479	23

Note:
Support: percentage of sequences from all sequences in the group containing the sub-sequence, where 1 = 100%

Table 24 – The most frequent sub-sequences identified for each performance decile, by age-size group

There are four frequent sub-sequences equally present in high performers from the mature-small group, and three of them involve a change in the value delivery dimension as the final action. Also, all of them involve a single dimension being changed in the first year and the rest in the second year. Regarding similarities across the group, all of the four sub-sequences are observed in other deciles with greater support, which suggests a lower dominance in high performers than that seen in the rest of the firms.

Lastly, 57% of high performers in the mature-large group change both value capture and creation in the first year, with a change in value delivery as the final action. Although the sub-sequence is also present in other deciles, the level of support is greater than the support in other deciles, which indicates that the sub-sequence is significantly dominant for high performers than for other firms.

In terms of inter-group comparison, there is no individual sub-sequence shared across the high performers across the four age-size groups. If the order in which the value dimensions are changed distinguishes high performers from the rest, two conditions would be expected: at the inter-group level, high performers across age-size groups would have shared an identical sub-sequence; and at the intra-group-level, high performers would have unique sub-sequences that are not shared by other deciles. None of these conditions were supported by the data.

However, two insights can be drawn from the inter-group assessment of high performers: (1) there is a predominance for sub-sequences ending in a value delivery change, and it is a significant distinctive feature in mature-large high performers; and (2) moving from small to large firms, regardless of firm age, more substantial changes are likely to be implemented in the first year.

6.3.6.2.3 Sequential association rule mining

The resulting association rules identified for high-performing firms are presented in Table 25. The results for the remaining deciles are also incorporated in the table, as it helps determine the significance of the rules for the rest of the sample. Three parameters are reported: count, referring to the number of sequences containing both sub-sequences; confidence, referring to the probability of finding the conclusion of the rule among sequences containing the premise of the rule*;* and lift, referring to the ratio between the probability of observing the conclusion and the premise together in the same sequence, and the probabilities of observing both the rule's premise and conclusion independently in all sequences. Only rules with counts >= 5, as well as rules with a lift >= 1 were considered in the results.

The rules have two elements: a sub-sequence representing the premise of the rule (left-hand side of the "=>" symbol), and a sub-sequence representing the conclusion of the rule (right-hand side of the "=>" symbol. The rule is interpreted as the probability that the premising sub-sequence is followed by the concluding sub-sequence.

Although the count (also known as support) and confidence are the standard measures for association rule analysis, several authors argue that the lift is the most robust measure of the significance of the rule as it assesses the correlation between the occurrences of both sub-sequences (Han et al., 2011). Under this perspective, the higher the lift, the more significant the rule, given that a lift of one or lower means that the probability of co-occurrence is not greater than the probability of separate occurrence.

Rules	1st decile			Rest of deciles (mean)			
	Count	Confidence	Lift	Count	Confidence	Lift	Deciles
Group: young-small							
(CRE2) => (DEL1)-(CAP2)	8	0.381	1.067	0	na	na	na
(CRE2,DEL1) => (CRE1)-(CAP2)	6	0.429	1.200	0	na	na	na
(CRE2) => (CRE1,DEL1)-(CAP2)	6	0.286	1.500	0	na	na	na
(CAP1,DEL2)-(CAP1,CRE1) => (CRE1)	5	1.000	1.200	0	na	na	na
(CRE1) => (CAP1,CRE2)-(CRE1,DEL1)	5	0.143	1.000	0	na	na	na
(CRE1)-(CAP1,CRE2) => (CRE1,DEL1)	5	0.625	1.010	0	na	na	na
Group: young-large							
(DEL1) => (CAP1,CRE1,DEL1)-(DEL1)	5	0.185	1.148	0	na	na	na
Group: mature-small							
(CAP1,CRE1,DEL2) => (CRE1)	6	1.000	1.067	0	na	na	na
(CAP2,CRE1) => (CRE2,DEL1)	6	0.429	1.247	0	na	na	na
(CRE1,DEL1)-(CAP1,CRE1) => (CAP1)	6	1.000	1.032	0	na	na	na
(CRE1) => (CAP1,CRE1,DEL1)-(DEL1)	6	0.200	1.067	0	na	na	na
(CRE1) => (CRE1,DEL1)-(CAP1,CRE1)	6	0.200	1.067	0	na	na	na
(CRE1,DEL2)-(CAP1) => (CAP1)	5	1.000	1.032	0	na	na	na
(CRE1) => (CRE1,DEL1)-(CAP2)	5	0.167	1.067	0	na	na	na
(CRE2) => (CAP1,CRE2,DEL1)	5	0.250	1.000	0	na	na	na
(CRE2) => (CAP1,CRE2)-(DEL1)	5	0.250	1.143	3	0.188	1.125	8th
Group: mature-large							
(CAP1,CRE1,DEL1)-(CAP2) => (DEL1)	6	1.000	1.000	0	na	na	na
(CAP1) => (CAP1,CRE2)-(CRE1,DEL1)	5	0.106	1.000	0	na	na	na

Notes:
Confidence: probability of finding the conclusion of the rule among sequences containing the premise of the rule
Lift: ratio between the probability of observing the conclusion and the premise together in the same sequence, and the probabilities of observing both the rule's premise and conclusion independently in all sequences

Table 25 – Significant sequence association rules identified in firms from the 1st decile compared with the rest of the firms, by age-size group

For the young-small group, the rule with the highest lift is (CRE2) => (CRE1,DEL1)-(CAP2), which indicates that the occurrence of CRE2 increases the occurrence of (CRE1,DEL1)-(CAP2) by a factor of 1.5. This rule suggests a significant dependence on value creation changes as a previous step for business model changes performed over two years.

There was only one rule observed for the high performers in the young-large group. It indicates that the presence of a DEL1 event is positively correlated with the occurrence of a business model change event of type (CAP1,CRE1,DEL1) followed by an additional DEL1 event. This shows a significant dependence on altering the value delivery before and after business model changes performed over one year.

The most significant rule for the mature-small group is (CAP2,CRE1) => (CRE2,DEL1), reporting lift = 1.247. This rule implies that the occurrence of change events for value capture and creation is positively correlated with the occurrence of changes in value creation and delivery. It reveals that an additional change event in the value creation dimension complements business model changes of type (CAP,CRE)-(DEL).

Lastly, there are two rules for mature-large high performers with identical levels of significance. Nevertheless, the confidence for the rule (CAP1,CRE1,DEL1)-(CAP2) => (DEL1) is substantially higher than the second rule (confidence = 1). This rule indicates a significant relationship between business model changes implemented in a single year complemented by a value capture change, and a change in value delivery.

An inter-group comparison indicates that three of the four rules ended in alterations in the value delivery dimension. The most significant rule in the young-small group does not end in a value delivery change, however there are two highly significant rules that do end in a value delivery changes. In addition, rules involving business model changes in which all the dimensions are altered in a single year become more significant for larger firms regardless of firm age. Importantly, none of the rules identified are observed in firms from the rest of the deciles. The uniqueness of these rules evidences the relevance of certain patterns of temporal order for business model development. However, identical rules (or at least highly similar) were expected across the four age-size groups, and that was not the case.

6.3.6.2.4 Summary of results and conclusion

A visual depiction of business model sequences suggested a low frequency of business model changes in high performers compared to the rest of the sample, except in the mature-large group. However, it was not sufficient to determine significant commonalities in the order in which business models are changed, given the degree of heterogeneity across firm sequences. Thus, frequent sequence mining and sequence association rule mining analyses were required to test the validity of the propositions on the order of business model innovation.

From an intra-group perspective (i.e. firms within the same age-size group), high performers are less likely to rely on a particular sub-sequence of change when reconfiguring their business models than the rest of the firms in their groups. The only group for which this behaviour is not observed is mature-large, where the significant dominance of the (CAP1,CRE1)-(DEL1) sub-sequence suggests that high performers are more likely to implement changes following a particular order than the rest of the firms in the group. The association rules analysis indicated that none of the rules identified are observed in firms from the rest of the deciles, which supports the relevance of certain patterns of temporal order for business model development.

In terms of inter-group comparison, there is no individual sub-sequence shared across the high performers across the four age-size groups. However, two insights can be drawn from the analysis: there is a predominance for sub-sequences ending in a value delivery change, and large high performers are more likely to implement substantial changes in the first year of the process. As for association rule analysis, none of the rules discovered were shared across the four age-size groups. However, a close look at the rules indicated a predominance for alterations in the value delivery dimension in the last year of the process. In addition, rules involving business model changes in which all the dimensions are altered in a single year become more significant for larger firms regardless of firm age.

In summary, the following insights have been obtained from the sequence mining analyses:

- Business model changes across high performers from any age and size are more likely to end in changes at the value delivery dimension.
- High-performing large firms are more likely to become more active in the first year of change than high-performing small firms regardless of their age.

- High-performing large firms are more likely to implement business model changes where all the dimensions are changed at once than high-performing small firms regardless of their age.

To support Proposition 5 ("High-performing firms are more likely to develop their business models through a similar number of temporally ordered changes and unordered changes than the rest of the sampled firms"), support of 50% for a particular sub-sequence (or at least closer to 50% than the rest of the deciles) would be expected from the sequence mining analysis, which would have shown a balance between events unfolding in a certain order and events with no apparent order. However, the results indicated a trend towards unordered sequences of change in high performers, where frequent sub-sequences of change occurred in less than 50% of the cases. The latter is true except for mature-large high performers, for which the frequent sub-sequences occurred in more than 50% of the cases, implying that this group of firms tend to change their business models following a certain order. The rules obtained from association rules analysis, although sharing high lift and high confidence, only occur in a small percentage of firms in each group. Although this analysis is a detailed look at the probability of occurrence of certain types of business model changes, it does not provide clues on the balance between ordered and unordered changes, unlike the sequential pattern mining analysis.

In conclusion, Proposition 5 is not supported by the analyses. Rather, evidence suggests that high performers are more likely to change their business models using a variety of sequences of change and not a single sequence, except for mature-large high performers, which are more likely than the rest of the sample for that group to change their business models in a certain order.

6.4 Summary

The results of MANOVA tests indicated that there are statistically significant differences in the performance means of firms where they are clustered by business model change pattern similarities. The hierarchical cluster analysis reveals evidence on the association between intense business model change events in early phases of organisational history and high sales growth for young-small and mature-large firms. Also, intense business model change activity in early stages and high counts of business model changes per year are associated in all groups except in young-large firms. In addition, sales growth is positively associated with the number of business model changes per

year in all groups except for mature-small firms. However, when sales growth is considered in combination with profit margin, the association is negative.

Of the mechanisms influencing patterns of business model change, both the collective action of the firms sharing an industry, as well as the firm's individual situation of age and size, influence the intensity at which high performers typically alter their business models. There is evidence of both predetermined and emergent actions driving business model development when the intensity and duration of changes are considered as separate components. Of the propositions, Proposition 1 is partially supported by the results (only when intensity of the changes are considered) as, though there is evidence of the influence of both environmental and internal forces on business model change, the influence of the latter is significantly greater than the former. Similarly, Proposition 2 is partially supported, given that, regardless of the evidence suggesting influence of both deliberate and unconscious actions on business model change, the magnitude of the influence of the latter is significantly greater than the influence of the former.

The analysis of the business model change events data at the frequency domain indicated that business model change events occur at a higher frequency in high-performing firms than in the rest of the firms for each of the age-size groups, except for the mature-large group. Nevertheless, the difference in frequencies from high performers and the rest is not substantial. Additionally, Proposition 3 is supported by the results from the frequency domain analysis, as there is a higher probability that a high-performing firm changes its business model at multiple (rather than a single) rates over time than that observed for the rest of the firms in each age-size group.

The assessment of the magnitudes of business model change indicated a larger proportion of incremental alterations over radical changes. Nevertheless, young-large firms are more likely to implement radical changes throughout their business model development trajectories than young-small, mature-small and mature-large firms. High-performing firms in the mature-large group had larger counts of radical business model changes than seen for the rest of the firms, an observation not true for the remaining age-size groups. In addition, Proposition 4 is not supported, as high performers presented an unbalanced predominance towards incremental changes. However, mature-large high-performing firms are more likely to introduce a balanced proportion of radical and incremental changes than high performers from the other three age-size groups.

The frequent sequence and sequence association rule mining analyses revealed that business model change in high-performing firms is likely to end in events where the value delivery dimension is altered. In addition, events where the three dimensions are simultaneously changed are more likely

to be found in large firms than in small firms regardless of their age, as well as changes where two value dimensions are altered in the first year of the change process. Proposition 5 is not supported by the analyses, as evidence suggests that high performers are more likely to change their business models without an apparent sequential order (except for mature-large high performers), whereas the rest of the sample are more likely to combine ordered and unordered changes evenly. Figure 23 summarises the research findings and corresponding analytic methods that have been presented and discussed in this chapter, as well as their associations with the study's research questions and propositions.

The next chapter discusses the implications of the quantitative analyses and presents the conclusions of this research.

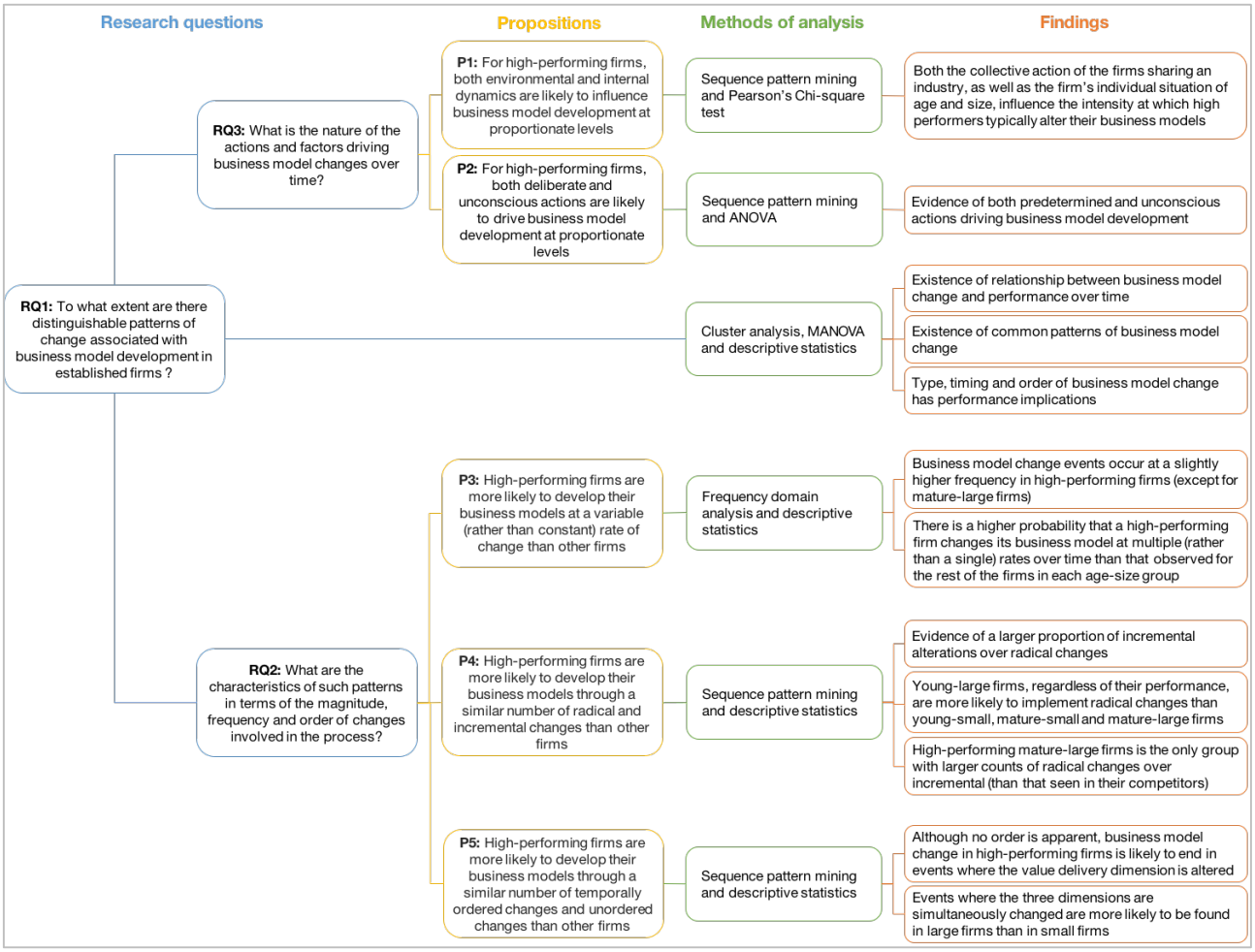


Figure 23 – Research findings with associated research questions, propositions and analytic methods

Chapter 7: Discussion and Conclusions

7.1 Discussion

7.1.1 Business model change and financial performance

The evidence of significant performance differences between firms with different business model change patterns supports three key insights. Firstly, and in line with Teece (2010), it provides evidence on the existence of a relationship between business model change and performance over time. Secondly, it novelly demonstrates that the sequences of business model development identified in this study reflect an underlying dynamic mechanism occurring at the firm level, which are not the representation of pure random organisational processes. Thus, there are pattern commonalities on the type of business model change implemented that suggest an implicit order in place. Thirdly, and also novelly, it demonstrates that the type, timing and order of changes introduced to a firm's business models matter for their overall performance over time. As shown in Figure 23, these findings address Research Question 1 of this study: To what extent are there distinguishable patterns of change associated with business model development in established firms?

These observations were possible by using hierarchical clustering combined with analyses of variance. The agglomeration of firms by dynamic pattern similarities helped identify statistically significant differentiation in the performance of the firms, as well as recognition of an underlying order in change patterns. It also facilitated the inference of helpful insights suggesting a relationship between the trajectories of business model development, revenue growth and profit margin (the two performance metrics employed).

7.1.1.1 On the existence of a relationship between business model change and performance over time

Although describing the nature and size of the relationship between business model change and performance were not part of the objectives of this thesis, the confirmation of the existence of such relationship was. In general, this confirmation converges with other studies suggesting the existence of performance effects associated with innovation (Hall & Wagner, 2012; Kim & Min, 2015; Zott & Amit, 2007). However, certain points of disagreement and substantial expansion of previous findings have been identified.

In particular, the confirmation of the existence of the business model change-performance relationship was also highlighted by Mitchell and Bruckner Coles (2004). However, the authors

suggested that continuous business model change always lead to superior performance. Indeed, many of the clusters of high-performing firms across the thesis's sample are characterised by multiple business model changes over time, but there were other high-performing clusters with only one business model change implemented. This indicate that, in certain cases, continuing business model change might not necessarily lead to superior performance, thereby contradicting the cited work. There are multiple patterns of change leading to superior performance, and continuous change is not the only one.

This thesis also extends previous work. Cucculelli and Bettinelli (2015) concluded that changes in a firm's business model, together with investment in intangibles, affect the firm's performance. But the authors did not account for multiple business model changes over time in their sampled firms. Thus, this thesis extends such findings by providing evidence that, when the number of changes over time is accounted for, the relationship between business model change and performance still exists. This also evidences the substantial value of adopting a longitudinal perspective when investigating business models.

In a similar cross-sectional example, Pohle and Chapman (2006) found that high-performing firms (particularly those with above-average growth) were more likely to engage in business model change than other firms. As Pohle and Chapman's work was predominantly static, this thesis extends their findings by evidencing that the pattern in which changes occur, and not only the final outcome of the change, also has performance repercussions.

7.1.1.2 On the existence of common patterns of business model change

Identifying the existence of common patterns of change among groups of firms with similar performance levels amplifies previous findings from Linder and Cantrell (2000), who argued that managers from industry-leading firms are more likely to "deliberately manage patterns of (business model) change" (Linder & Cantrell, 2000: 2). Although this does not imply pattern commonalities, it indeed indicates a similar behaviour followed by professionals in similar positions and in similar firms. This thesis advances such findings by providing evidence on similar business model change actions, which implies that certain mechanisms and knowledge are commonly shared by similar firms.

In their study on the behavioural approaches driving business model emergence, Andries et al. (2013) found commonalities in the sequence of actions driving the emergence of new business models in a sample of six firms. They concluded that firms focus on developing a core model first,

and then engage in experimentation with multiple business models in search for future growth opportunities. Although the authors observed this generic pattern, they also found that each firm followed a relatively distinct pattern. For instance, some firms focused on the existing business model longer than others, and some engaged in experimentation sooner than others. The fact that their sample was relatively limited and uncategorised in terms of firm performance prevent us from knowing more on how performance affect the identified patterns. Thus, this thesis extends the author's insights by confirming that performance plays a fundamental role in driving a variety of patterns of business model development.

7.1.1.3 Type, timing and order of the business model change has performance implications

In one of the most influential studies on business models and performance available to date, Zott and Amit (2007) found that business models designed around novelty are positively associated with firm performance, and such effect remains stable over time. Just as the choice of business model design theme affects performance, this thesis augments the knowledge on business models and performance by discovering that the choice of the type, the timing and the sequence in which business model changes are executed also affect performance. A point of divergence with Zott and Amit study is that, given their finding on the sustained positive effect of novelty-centred business model design themes on performance, we should not expect much change in the business models over time, as the incentive is not to change their inherent design (particularly if there were designed around novelty). This thesis presents evidence that, while some high-performers do not introduce many changes in their business models over time, some others do. The diverse taxonomy of change patterns identified in this thesis indicates that there are other factors such as the order, timing and the type of change implemented that are mediating the relationship between business model design and performance.

7.1.2 Characteristics of business model development

7.1.2.1 Mechanisms driving business model development

The assessment on the driving forces of business model development resulted in two main findings. Firstly, both the collective action of the firms sharing an industry, as well as the firm's individual situation of age and size, influence the intensity in which high performers typically alter their business models. Secondly, there is evidence that both predetermined and emergent actions drive business model development. As shown in Figure 23, these findings address Research Question 3 of this study: What is the nature of the actions and factors driving business model changes over time?

7.1.2.1.1 Collective actions of the environment and firm's individual situation influence business model change intensity

This thesis found that the choice of the breadth of the change (number of elements changed) is driven by a particular characteristic of the firm and the industry of operation. In other words, aside from the collective force of the players in the industry, factors associated with size and age including the amount of resources a firm possesses, the strategic mindset given the scale of the revenue generated, the knowledge gathered through years of operation, and strategic connotations of the particular stages of growth of the firm are all factors motivating the decision of whether to change a single element within a business model dimension, or the entire dimension. Although a similar perspective has also been suggested by other authors (Demil & Lecocq, 2010; Foss & Stieglitz, 2015), this thesis provides insights that extend the work done on the drivers of business model change.

Insights from Sosna et al. (2010) evidence the crucial role of the environment, and thus collective forces of firms in the same industry, in driving changes to a business model over time. The authors argued that environmental conditions induce changes and adoption of a new business model, as well as to mediate the firm's learning process while experimenting with the new model. The results from this thesis supplement this finding of collective forces and external situation affecting the developmental trajectory of a business model, by providing evidence that such forces particularly affect the intensity of the changes implemented. However, apart from recognising that the personal characteristics of the entrepreneur driving the change process play a role in the choice of the changes, Sosna et al. failed to suggest that the individual characteristics of the firm also have a crucial influence on business model change.

On the contrary, Santos et al. (2009) argued that organisational characteristics around particular structural and behavioural aspects stimulate business model changes and innovation. Insights on the agents driving business model development presented in this thesis supplement those from Santos et al., specifically by providing evidence that firms with similar characteristics of size, age and industry of operation tend to change their business models at similar intensities. In regards to the collective effect of firms around the core organisation, Santos et al. failed to suggest that the collection of firms operating in the same industry affect the emergence of business model changes in the focal firm.

The work of Sosna et al. and Santos et al. separately present evidence on the effect of environment (in the case of the former) and individual firm characteristics (in the case of the latter) on the way business models are developed over time. This thesis expands the findings from these studies in two ways. Firstly, this thesis produced evidence on equal effects of both mechanisms, which indicates that the environment and individual situations are both equally important drivers of change, thereby reconciling both views. Secondly, this thesis provided clues on the specific feature of the change process that is being affected by environmental and individual agents, and that is the intensity of the changes (measured by the number of changes made to a business model dimension).

7.1.2.1.2 Both predetermined and emergent actions drive business model development

The statistical tests and the pattern mining analyses produced evidence on the nature of the actions driving business model development. The results from examining within and between-group variances in groups with identical characteristics show the presence of both predetermined and spontaneous forces shaping the trajectories of business model development. This insight extends the findings from Reymen, Berends, Oudehand, and Stultiëns (2016). The authors found that both effectual (emergent) and causal (predetermined) logics drive decision-makers to implement business model changes over time. While the authors explained the reasons why firms engage in both type of actions, they did not elaborate on how do these logics affect the trajectory of the business model. This thesis contributes to this knowledge by evidencing that both types of actions affect: (a) the intensity of changes introduced, and (b) the duration of the change events made to the business model over time.

7.1.2.2 Frequency

The frequency domain analysis of business model change sequence data resulted in two main findings. Firstly, business model change events occur at a slightly higher frequency in high-

performing firms. Secondly, there is a higher probability that a high-performing firm changes its business model at multiple (rather than at single) rates over time than that observed for the rest of the firms in each age-size group. As shown in Figure 23, these findings address Research Question 2 of this study: What are the characteristics of such patterns in terms of the magnitude, frequency and order of changes involved in the process?

7.1.2.2.1 Business model change in high performers occur at a higher frequency

Although the size of the frequency differences is not extensive, they are sufficiently ample to support that, regardless of the magnitude of the changes, business model innovation processes tend to be more continuous in successful firms than in average firms. Constant innovation has been highlighted as a crucial strategy for sustained competitiveness (Brown & Eisenhardt, 1997), and the insights from this thesis not only endorse, but extends this perspective.

The work of Mitchell and Coles (2003) on business model innovation in high-performing firms found that high performers were more likely to execute alterations to their business models more frequently than companies with lower performance levels. The results of this thesis not only confirm these findings, but also evidence that the observation also holds true for firms of different ages and sizes. Thus, this thesis contributes with empirical evidence supporting the fact that, regardless of their size or age, frequent business model change is associated with high performance.

The exception to the rule is mature-large high-performing firms where the frequency of change is lower than that of the average firm. An interpretation of this exception is that continuous business model change might be counterproductive for the performance of mature-large firms, and that these organisations favour more episodic alterations given their lack of flexibility to modify their operational processes, contrary to more agile, smaller firms (Fiegenbaum & Karnani, 1991).

7.1.2.2.2 High-performing firms are likely to change their business model at multiple rates over time

Saebi (2015) suggested that business models are innovated according to three different types of change and that each one has a distinctive frequency of occurrence, namely evolution (involving continuous changes), adaptation (involving periodic changes) and innovation (involving infrequent changes). Building on this view, this thesis's findings suggesting that high-performing firms change their models at multiple rates over time evidence the occurrence of multiple instances of business model evolution, adaptation and innovation in parallel over the lifetime of the model, an insight that is not explicitly stated in Saebi's work. Thus, this thesis extends the author's work on business

model dynamics. Another contribution is the generation of evidence that high-performers manage to adjust the pace at which they reconfigure their business models according to the external conditions and internal fit (Dodgson, 1993; Hambrick & D'Aveni, 1988; Sastry, 1997) more efficiently than average-performing firms.

7.1.2.3 Magnitude

The analysis of the sequences of business model change using sequential pattern mining indicated that high-performing firms are less inclined to introduce radical alterations to their business models over time. Also, the analysis found that young-large firms, regardless of their performance, are more likely to implement radical changes than young-small, mature-small and mature-large firms. An additional finding is that high-performing mature-large firms is the only group with larger counts of radical changes over incremental. The discussion presented below evidences that these insights are in disagreement with most of the studies investigating the magnitude of business model change. As shown in Figure 23, these findings address Research Question 2 of this study: What are the characteristics of such patterns in terms of the magnitude, frequency and order of changes involved in the process?

7.1.2.3.1 A larger proportion of incremental alterations over radical changes

This finding contradicts those from Cucculelli and Bettinelli (2015), who argued that radical business model changes are more likely to result in increased firm performance. Their sample, however, is quite different from the sample in this thesis. The authors studied SME firms from the clothing industry. It is possible than the relatively low levels of dynamism and technological innovation activity characterising the industry create a setting in which the radicalness of change is the single most important attribute in order to disrupt the market (Christensen, 1997). Another difference between the author's work and this thesis is their cross-sectional approach, which does not account for the number of changes implemented over time and the duration of changes implemented. Many incremental alterations made over time could accumulate and provide performance benefits that can surpass those obtained from individual radical alterations (Romanelli & Tushman, 1994). This emphasises, argued previously, the benefits of conducting longitudinal studies to observe the dynamic mechanisms of business model development in a more consistent manner.

7.1.2.3.2 Young-large firms are more likely to implement radical changes

On their work on business model changes in bioscience firms, (Brink & Holmén, 2009) found that seven out of eight of their sampled firms changed their business models through radical changes. Given that the level of performance of the firms was not considered as variable in the study, it is not possible to directly determine whether if this work supports or contradict the results of this thesis. However, they do consider firms with different ages. The only firm that did not engage in radical changes was neither the oldest, nor the youngest firm in the sample, suggesting that the longevity of the firm does not play a role in the magnitude of the changes implemented to a business model. This thesis found the opposite (young-large firms were more likely to implement radical changes than the rest of the firms).

7.1.2.3.3 High-performing mature-large firms have larger counts of radical changes over incremental

Using a case study approach, Yip (2004) suggested a positive association between radical changes and business model innovation. In fact, the author argued that radical changes are needed in order to transform a business model. By considering high performers as cases of successful business model change, this thesis found that Yip's observation does not hold true for most of the high performers in the sample. Only mature-large firms showed a preference for radical over incremental changes that is greater than the average preference seen in the rest of mature-large firms. This indicates that, in many cases, incremental strategies are preferred over radical strategies when changing a business model.

In contrast, Foss and Stieglitz (2015) agree that business model innovation can be achieved through a variety of strategies with different degrees of radicalness. They reference examples of firms that implemented incremental, rather than radical, changes to their business models with equally successful outcomes over competitors that those implementing more radical changes. This thesis extends this view by providing evidence that the way firms respond to competition by choosing incremental or radical business model change strategies depends on their age and size. For instance, mature-large firms are more radical than their competitors. An interpretation of the reason why mature-large firms engage in radical changes is that, recalling Christensen's theory of disruption (1997), this behaviour may reflect the defensive strategic changes from established large firms every time a small disruptor enters their markets with a fundamentally different business model, which forces established successful firms to transform their models entirely.

7.1.2.4 Sequential order

Insights from data mining analyses provide answers to the research questions on the chronological order of the changes in business model development processes in established high-performing firms. There were two key findings emerging for this analysis. Firstly, evidence suggests that business model change in high-performing firms is likely to end in events where the value delivery dimension is altered. Secondly, events where the three dimensions are simultaneously changed are more likely to be found in large firms than in small firms. Both of these insights extend (and in some cases, contradicts) the insights from similar work, as seen in the discussion below. As shown in Figure 23, these findings address Research Question 2 of this study: What are the characteristics of such patterns in terms of the magnitude, frequency and order of changes involved in the process?

7.1.2.4.1 High performers are more likely to end the business model change process with changes in the value delivery dimension

The insight suggesting that the value delivery dimension is altered in the late stages of the change process opposes Christensen, Bartman, and van Bever (2016), who suggested that business model change typically starts from alterations in the value proposition, considered a sub-component of the value delivery dimension, and some aspects of the value creation dimension. The authors also suggested that value capture is the last component to be altered, which occurs in the final stage of development where the business model gains efficiency.

In another study, Cortimiglia, Ghezzi, and Frank (2016) found patterns suggesting than most firms tend to alter the value creation dimension at earlier stages, while the rest of dimensions (including value delivery) are altered in later stages. Although this thesis did not find evidence that altering the value creation dimension as the initial step is a common pattern across high-performers, it did find significant evidence that the value delivery is altered late in the process, which partially confirms Cortimiglia et al. finding. The authors did not include firm characteristics and performance, which makes it difficult to generalise on the patterns that are associated with high performance, certain size and age of the firm. Consequently, their work did not offer any clues on whether changing the value creation first correlates with superior performance. From this perspective, this thesis extends Cortimiglia et al. work by providing evidence on the performance implications associated with changing the value delivery as the final step in the process.

On the sequential order of actions during business model change, Andries et al. (2013) found that a focussed commitment on the existing business model is followed by experimentation with multiple business models. The authors revealed sequential patterns in the behaviour driving business models,

but did not provide clues on the sequence in which the components of the model are altered. Given that this thesis provides detailed evidence on the latter point, it extends Andries et al. findings by arguing that the tendency to alter the value delivery dimension at later stages might provide additional interpretations on why firms, according to Andries at al., engage in multiple search at later stages of business model change: firms experiment with multiple configurations in search for sustainable value delivery mechanisms. Indeed, the authors explicitly mentioned this by saying that firms "postponed the decision to commit to one option until more information with respect to a range of value propositions became available" (Andries et al., 2013: 18). As evidenced, a greater specificity of analysis (as this thesis did by narrowing down sequences of change to the component-level) adds substantial research value given that it enables additional insights on how business model develops over time.

7.1.2.4.2 Events where the three dimensions are simultaneously changed are more likely to be found in large firms than in small firms

This thesis found that large high performers are more likely to alter more than one business model dimensions at the same time, typically within the first and second year. This is contrary to the idea that larger firms are less focused than smaller firms when it comes to organisational transformations due to barriers associated with coordination issues, linking and collaboration toward change (Dougherty, 1992).

Berends, Smits, Reymen, and Podoynitsyna (2016) found that the trajectories of business model change are characterised by alternating sequences of cognitive search and experimental learning, where the former involves changes of multiple business model elements at once, and the latter involves a succession of changes made to individual elements. However, Berends et al. work did not offer any insight on which of the two behaviours are more dominant and the factors driving such dominance. This thesis extends the author's findings, and thereby advances the discussion on the sequence of events and actions by which firms develop their models, by providing evidence on the significant dominance of events where all of the business model elements are changed at once in large firms. In Berends et al. terms, this thesis suggests that larger firms are more likely to engage in cognitive search, in which the change plan is rationalised and analysed upfront by the managers before its implementation, than in experiential learning, in which the business model is changed one element at a time by the managers as they learn how the model is behaving over time. This also suggest that smaller firms rely more on learn-by-doing when changing their business models than

larger firms, which implies that structural factors, as well as amount of resources, might affect the sequences and nature of business model change actions in stablished firms.

7.1.2.5 The case of mature-large high-performing firms and comparison with other groups

The findings on the mature-large group from the data mining and frequency domain analyses are aligned. According to the order, frequency and magnitude assessments, high performers in that group are more likely to concentrate changes in all of the business model dimensions in a short burst. In other words, the evidence suggests that the way mature-large high performers develop their business models over time is by episodes of radical changes concentrated in a short timeframe, resembling a punctuated model of development found in other types of innovation and organisational processes (Gersick, 1991; Romanelli & Tushman, 1994). For the rest of the firm groups, business model developments are more likely to be characterised by continuous, incremental changes, a behaviour driving development in innovative organisations (Brown & Eisenhardt, 1997), that typically concludes with alterations in the value delivery dimension.

7.2 Addressing validity threats

The selection and implementation of data manipulation and analytic techniques employed in this study has been conducted in a way that addresses the key threats to validity found in social science research.

From a general perspective, validity concerns the extent to which the measurements comprising the research design truly measures the phenomenon they intend to measure, making it a key requirement for the development of knowledge in social sciences (Sethi & King, 1991). "If the measures used in a discipline have not been demonstrated to have a high degree of validity, that discipline is not a science" (Peter, 1979: 6). Below is a discussion on the four key types of research validity for social science studies according to Cook and Campbell (1979), as well as the mechanisms employed to minimise the associated threats.

Firstly, construct validity is an assessment of how well the theoretical constructs are operationalised in a way that accurately measure the phenomenon that are supposed to measure (Flynn et al., 1990). Ensuring construct validity is particularly relevant to the business model development research topic, given the lack of construct clarity characterising business model research, which in turns hinders operationalisation and measurement (Foss & Saebi, 2016). It is for this reason that this

study incorporates a qualitative validation component (Chapter 5) dedicated to confirm the existence of business model changes in a selection of firms, using alternative data sources and analytic tools. The results of the qualitative validation confirm that the quantitative operationalisation of business model change effectively measures the phenomenon. Additionally, the systematic procedure for construct definition, dimensionalisation and operationalisation thoroughly described in Chapters 3 and 4 responds to concerns raised by authors such as Foss and Saebi (2017) and Massa et al. (2017) on the lack of rigour in defining, dimensionalising and operationalising the business model and business model innovation concepts.

Secondly, internal validity relates to the veracity of the causal relationships between independent and dependent variables (Modell, 2005). Several decisions made along the course of the research design process obey to minimise threats to internal validity. For instance, the choice of secondary financial data avoids threats of maturation, attrition, pre-test sensitisation and behaviour bias (Onwuegbuzie, 2003). Similarly, the choice of historical data and its automatic collection in a singular point in time reduces the threats associated with instrumentation, as it guarantees that the same instruments and measures are consistently employed for all the data points, and, at the same time, that there are no issues of discrepancies between multiple data collectors/analysts and observational bias (Onwuegbuzie, 2003). In addition, dedicated tests have been performed to the data in order to actively assess validity threats. An example is the test for cross-correlation among the 12 financial ratios used to measure business model changes, seeking to identify high correlations among the 12 time series corresponding to each ratio. No statistically high correlations were identified (see section 4.3.6.4 for more details). Testing for multicollinearity and cross-correlations is an effective assessment of internal validity threats, as well as discriminant validity (Onwuegbuzie, 2003).

Thirdly, external validity concerns the generalisability of research findings across a variety of contexts, individuals and points in time (Scandura & Williams, 2000). Similar to internal validity, several decisions have been taken to minimise external validity threats along the research process. For instance, the utilisation of a large sample of firms tend to decrease the population validity threats to the results (Onwuegbuzie, 2003). Also, the variety of the sample, including firms from multiple countries, IT industries and sizes, ages and performance levels seek to minimise the risks associated with ecological validity and intends to increase generalisability (Onwuegbuzie, 2003), although the generalisation power is limited to the IT sector as well as to public firms. Additionally, the selection of standard financial measures as basis for the independent variables of the study

ensures that the same operationalisation is applicable to the majority of business globally, irrespective of their public/private ownership status, thereby increasing generalisability and minimising threads associated with specificity of variables (Onwuegbuzie, 2003).

Lastly, statistical conclusion validity refers to the ability of the statistical tests performed in a study to provide support for statements on the relationships between the dependent and independent variables (Austin, Boyle, & Lualhati, 1998). One of the most relevant threats to statistical conclusion validity concerns the adverse effects from the utilisation of small samples, as larger samples lead to stronger statistical assertions on links between variables (Barling, Slater, & Kevin Kelloway, 2000). In avoiding these risks, the research design builds not only on a large sample of firms compared to other business model innovation studies, but on a large number of data points comprising a period of around three decades worth of data. Such richness maximises the statistical power of the tests performed. In addition, choices on the number of variables to measure business model change as well as the number and variety of statistical analyses employed obeys to actions towards maximising the ability to draw valid conclusions from the results (Scandura & Williams, 2000).

7.3 Conclusions

This study investigated business model innovation in established firms by examining the sequential development of change, rather than the causal mechanisms and effects associated with the phenomenon.

By establishing previously absent links between process research, business model innovation, sequence analysis and data mining, this research contributes to the business model innovation body of knowledge by proposing novel theoretical tools to understand business model change, and by advancing empirical research on a phenomenon that is gaining substantial attention in corporate and academic domains. This attention is rapidly increasing to the point where there is now a crucial demand for data-intensive experiments that validate, complement and redefine the fundamental concepts of business model innovation known to date (Bjorkdahl & Holmen, 2013; Demil et al., 2015). As Zott and Amit (Zott & Amit, 2013: 409) stated, “Empirical research on the measurement of business models and business model innovations holds great promise to enhance our understanding of wealth creation”.

7.3.1 Contributions

7.3.1.1 Theoretical

This thesis contributes to theory on business model change and innovation in three ways. Firstly, it builds on the concept of business model innovation to propose a new phenomenon known as business model development. Stressing that business model innovation studies focus on the transition from an existing configuration to a novel version, this work is extended by using a theoretical view that moves from the assessment of single transitions to propose that a business model is a dynamic entity in continuous development driven by ongoing changes in its key dimensions. By focusing on the whole trajectory of business model development rather than on isolated changes, the study has generated insights on the nature and timing of the multiple changes firms implement in their business models over extended periods of time. For most of the firms in the sample, the data suggests that business models are in constant dynamism, implying the existence of a previously unexplored process in which the business model develops as the firm develops. Thus, the study examines a previously unexplored process, which may potentially "serve as the foundation for brand new theory" (Colquitt & Zapata-Phelan, 2007: 1284).

Secondly, by adopting the process-based approach, this study contributes to the foundation of new thinking and research in business model innovation that centres on analysing the flow of events leading to business model emergence and on identifying patterns of the process across multiple cases (Pettigrew, 1992). A well-established stream of process-based research will complement the more traditional variance-based studies that explain change in terms of cause-effect relationships, forming an integral theoretical base to support the evolution of the business model innovation field of study (Van de Ven & Poole, 2005).

Thirdly, in satisfying the condition that a robust process theory should explore the time parameters associated with change as it facilitates the construction of process models (Monge, 1990), the study provides evidence of the existence of unique patterns of business model change in high-performing firms across three time parameters: magnitude, frequency and order of change. These parameters act as dimensions to characterise the trajectories of business model change, and can be used as a starting point to build and test models of business model development. This represents an advance in the business model innovation field, as the parameterisation of change across the magnitude, frequency and order dimensions helps determine why and how the change processes generated by other organisational phenomena affect the development of business models (Tsoukas, 1989). By

offering a framework that could be used to explore the temporal relationship between business model development and other phenomena such as dynamic capabilities, ambidexterity, organisational learning and open innovation, this thesis has potential theoretical implications in other fields including business strategy, innovation management and organisation studies, as it directs research attention back to age-old enquiry on the dynamics driving economic change and development at the macro and micro-level (Chandler, 1962; Nelson & Winter, 1982; Penrose, 1959; Schumpeter, 1934).

7.3.1.2 Methodological

The quantitative, longitudinal and multi-firm approaches in this study are a noticeable departure from the typical case study approach dominating the literature, in which a business model innovation is studied in isolation from the multitude of other instances of business model innovations. The agglomeration of individual time series into a single sequence of change is a novel approach that can be replicated in different research contexts, and leads to the identification of dynamic patterns of change.

In terms of conceptualisation and operationalisation, this study provides a business model framework flexible enough to support further empirical investigation. The proposed tridimensional business model framework can be used to compare developmental trajectories of fundamentally different business model configurations from different firms, or even different developmental trajectories of a particular business model, given that it builds on the principle that every firm's element, activity and resource has a purpose in terms of value, and the purpose can be classified into three main dimensions. It is not rigidly based on a predefined set of components, like most business model frameworks proposed in the past.

Furthermore, with its proposed set of parameters, this study offers a way to analyse multiple business models (and their developmental trajectories) in a systematic and consistent manner, which may inspire further statistically based studies, thus increasing generalisation of research findings. The procedure for parameterisation of business model changes from a firm's financial data and the subsequent coding system designed for this study may serve as an example for future quantitative studies in the business model and business model innovation field.

Lastly, the integration of three different analytical techniques is also a relevant contribution. The integration of dissimilar methods that observe processes from different angles requires an articulated research design that accommodates and connects the conceptual model with each

analytical tool at multiple linking points. Such flexibility is achieved through the observation of the process of business model change from different perspectives, so each method discloses a characteristic of the developmental path of the model. This is a novel alternative that could be applied to investigate change process in a more comprehensive way. The implementation of data mining algorithms for data analysis is also a major methodological novelty in social science research. Previous studies on life course trajectories are among the rare social science research examples using data mining techniques. This thesis adds to this small group of empirical studies that uses knowledge discovery algorithms to mine meaningful patterns from the data.

7.3.2 Practical implications

From a managerial standpoint, this study may assist practitioners in adjusting established business models. Altering existing business models is a complex task, with a different set of challenges that differs from those associated with the design of a business model for start-up firms (Massa & Tucci, 2014). Such a difference demands a deeper understanding of how a change in an individual element of the business model impacts the remaining elements, how a particular action affects future business model change possibilities and also how to recognise when a change is needed, to anticipate and develop strategic plans for business models innovation either as a competitive response or as a proactive move for better market positioning.

This study assesses not just the sequence of events leading to successful business model change, but also the rate and timing at which a business model change is implemented, two of the most relevant issues facing practitioners pursuing innovation strategies (Christensen, 1997). The knowledge gained from this study could guide existing businesses in anticipating and developing innovation plans with a greater degree of certainty to transform their business models faster and more effectively. For instance, the evidence indicating that high-performing firms tend to modify their business models more frequently and at more variable rates than other firms suggests that a well-established capacity to respond to environmental fluctuations and to quickly transform knowledge into action are key to success. Another example is the evidence presented on the magnitude of change, where high performers are more likely to introduce incremental adjustments to their business models than other firms. These insights inform managers on the requirements when pursuing business model innovation strategies in terms of speed and scope of actions.

Apart from providing high-level guidance on the rate, breadth and temporal order of change that are likely to characterise successful business model development, this study encourages practitioners to

use the set of ratios and methodology presented here to build their own sequences of change and correlate past business model changes with financial performance to determine the extent to which the type and timing of changes produce the desired performance. The analysis of past events of business model change could also help assess how efficient the firm is in responding to external and internal circumstances requiring an adjustment in its business model, as well as how efficient the firm is in achieving the business model reconfigurations promoted by the managerial team.

In addition, managers could compare their sequences to those from the firms in this study (see Chapter 4 for the cluster-level sequences). A benchmark comparison may help managers compare their level of business model change activity to similar firms. Given that the results of this study suggest that high-performing firms with the same size, age and industry of operation are more likely to implement business model changes of similar intensity and duration, firms could determine if there is a need to decrease or increase efforts on business model change.

Lastly, managers could estimate time series models that fit their historical trajectories of business model change to predict future changes, which would help them anticipate potential business model innovation in the future, and also give them tangible evidence to decide whether to stay on track or change their course of business model development, selecting and creating the most suitable scenarios that better align with their long-term strategies.

7.3.3 Limitations

7.3.3.1 Business model innovation and financial indicators

The research is built on measures using a combination of financial indicators obtained from publicly available information. While this suits investigations with large samples and/or large datasets, there are certain limitations to measuring business model innovation processes through financial data. One limitation is the capacity of financial data to quantitatively measure aspects of supplier and customer interaction, value propositions, customer relationship structures and supplier involvement in product development, given that financial statements and reports are not intended to measure such elements.

Nevertheless, as Morris et al. (2015) argued, a key measurement obstacle is the lack of an appropriate conceptualisation and operationalisation of business models, which makes it difficult to know what to measure. Knowing what to measure is as problematic as the lack of direct indicators. For this reason, the theoretical framework and the research design chapters discussed a suitable

operationalisation of business model innovation, which is centred on measuring the impact of business model change rather on measuring the business model per se.

A key reason for the use of financial data is the lack of available information on business models and business model change. To date, there is no standard to measure a business model, and there is no official and consistent definition of a business model in place. This study provides ways to overcome this barrier and quantify change in business models.

Studies in the past have relied on surveys and interviews with executives and managers to collect data on firm-level innovation. However, this approach relies on the respondent's memory to recall types of changes, time of occurrence and the particular elements changed. This was not an appropriate approach given accuracy issues, distorted impressions and biased recall associated with studies depending on the memory of individuals (Golden, 1992). For this reason, this study used a large financial database as the main data source.

7.3.3.2 Effects of other organisational processes in financial data

The identification of events of business model change at each of the business model dimensions relies on the ability to discriminate the events associated with business models from other events occurring in the organisation. As a potential threat to internal validity, this dependence imposes a research limitation, given that the accurate identification of change events is contingent on how distinguishable the effects are from other events.

To compensate for this, the sample was limited to firms in a single sector to control for external factors that may trigger firm-firm differences not attributable to business model change. In addition, the analyses on the existence of patterns and detection of key characteristics of development compared firms with similar characteristics of age and size. This comparison based on firm similarities works as a control mechanism for internal factors by assuming that age and size are crucial factors inducing changes in the structure, strategy, operations and governance of a firm (Kelly & Amburgey, 1991; Koberg, Detienne, & Heppard, 2003; Van de Ven, Polley, & Garud, 2008). The comparison of events across firms with similar age and size allows to neutralise factors mentioned previously, increasing the chances that the residual differences reflect change events attributable to business model changes. Nonetheless, the accuracy of this procedure is limited, and future studies on business model innovation using similar research design must deal with alternative ways to rule out events not associated with business model change.

7.3.3.3 Other limitations

Additional limitations include: (1) the time frame used, where 1987 is the earliest year of analysis; (2) the proportion of missing data values; (3) delayed effects of business model changes; and (4) the consideration of a sample comprised entirely of publicly listed firms. The first and second limitations are constraints imposed at the data source level. Osiris only makes the last 30 years available for queries involving multiple firms. Nevertheless, the 30-year period captures interesting events that occurred in the IT sector such as the emergence of the Internet and the dotcom collapse in the late 1990s. The presence of such events makes it an illustrative window of time where numerous episodes of organisational transformation took place, with many requiring business model reconfigurations. Chapter 4 described the missing data treatment implemented in the study. Nevertheless, many interesting cases with potential business model changes were discarded due to data inconsistencies. Although a large sample was important, ensuring reliability and data accuracy was even more critical.

The third limitation concerns the delays that could exists from the moment companies implement the business model changes to the moment when the changes are reflected in the financial data. This does not represent an issue if the lag remains constants across all cases and across all the types of business model change. However, different organisational changes may have lead-lagged effects of different durations (Ancona, Goodman, Lawrence, & Tushman, 2001). Though certainly a limitation, this may only affect the assessment of the frequency of changes, as the assessment of the magnitude, sequence (assuming that order is not altered) and drivers of change are not contingent on the point in time in which the change occurred. In any case, there is no evidence suggesting that business model changes with substantially delayed effects are the norm, rather, they could be considered outliers. Moreover, given that most of the analyses involve mean values of multiple firms across multiple time points, the potential discrepancies are minimised given the way the analyses are designed. To avoid this issue, future studies could incorporate interviews with management team members in addition to the quantitative data in order to compare the time of events as they appear in the financial data with the insights from the managers.

Lastly, the fourth limitation is due to a research decision to maximise the consistency of data, as listed firms must comply with standardised procedures for information reporting. This affects the degree of generalisability, as the findings from this research might not be applicable to small and medium sized firms, or to large private firms. However, a main goal of this study was to explore business model change in established firms, recognising that there is already considerable research

on start-ups and spin-off organisations. Further research could apply the methodology described in this study to a sample of privately-held firms to either expand understanding on business model innovation or to test whether the findings apply to private firms.

7.3.4 Future research directions and future areas of research

It is a key aspiration of this study to stimulate and encourage further research to increase our understanding of the dynamic mechanisms of business model innovation. The research model designed and developed in this study paves a new way for longitudinal examination of change events driving the emergence of business model innovation within a firm. An advantage of the methodology is that it can be replicated to other types of innovation, such as technological, process and product, as well as to other types of organisational processes that are not associated with a final tangible product such as emergence of new strategies. This can be done by replacing the financial ratios with a new set associated with the phenomenon under analysis.

There are considerable opportunities to expand the study conducted in this thesis into other industries. Business model innovation is not limited to a particular sector; regardless of the economic activity conducted, every business entity has some form of business model in place (Chesbrough, 2007). It is interesting to observe whether the findings from IT firms diverge (or converge) with findings from sectors such as health care or financial services. A convergence might suggest a reduced influence of the type of goods produced on the process of business model innovation, whereas a divergence could be interpreted as strong influence of the rate of technological development, regulatory forces, and product lifecycles on the dynamics of business model innovation.

An additional avenue for further research on business model innovation is the use of more detailed data from a smaller sample of firms, increasing the number of parameters to more than 12. Incorporating measures such as type and number of commercial partners, number of distribution channels used, and percentage of revenue from new products allows increased measurements of business model changes per unit of time. Future studies could incorporate qualitative information to either enrich or validate the patterns found from quantitative data. Lastly, research could develop predictive models to project how a business model could or should evolve over time, providing that the internal and external forces driving the development of a business model can be modelled as well.

Future areas of research	Field of study		
	Business model innovation (and development)	Business strategy; organisation studies; entrepreneurship & innovation	Practical domain
Exploring sequences of change associated with other forms of innovation (technological, process, product)		X	
Explore similarities and differences in business model change patterns in firms from different sectors	X		
Develop customised operationalisations of business model change to assess business model development in an individual firm			X
Complement the financial measures used to operationalise business model change with qualitative interview data in order to examine differences between business model change intent and realised effect of business model change	X		
Develop predictive models to project business model development trajectories in the future			X
Assess the longitudinal effects of business model development on the development of other organisational aspects (e.g. technological, capability development), by examining degree of cross-correlation between the associated trajectories		X	
Assess the longitudinal effects of the development of other organisational aspects (e.g. technological, capability development) on business model development, by examining degree of cross-correlation between the associated trajectories	X		
Assess the longitudinal effects of business model development on firm performance over time, by examining degree of cross-correlation between the associated trajectories		X	
Assess the longitudinal effects of changes in firm performance over time on business model development, by examining degree of cross-correlation between the associated trajectories	X		
Developing frameworks based on the operationalisation of business model change to assess the impact of an emerging technology, regulatory changes or potential alterations in the economic landscape, on the dominant business models of the industry	X		
Examine the effects of the emergence of particular organisational events, such as mergers & acquisitions or changes in the leadership team, on the capacity to change the business model	X		
Identify typologies of trajectories of business model change to inform strategic decision-making			X

Table 26 – Future research areas derived from the study

Future studies could also seek ways to complement the theoretical and methodological propositions of this thesis with additional principles and data to observe how other organisational aspects from the field of corporate strategy and innovation impact are impacted by the trajectories of business model development. For instance, trajectories of technological development can be examined in combination with business model change trajectories in search of inflection points, where events demarcate a change in behaviour of one trajectory caused by the other, as well as degree of cross-correlation between the two trajectories. In another example, juxtaposing trajectories of change of organisational capabilities with trajectories of business model change could help understand the role of capability development on business model innovation.

Table 26 provides a comprehensive list of future areas of research derived from the research questions, methodology and findings presented in this thesis. Some of these areas of research were discussed thorough tis section.

7.3.5 Concluding comments

The central motivation of this thesis was to investigate how established firms reconfigure their business models over time. The main research objective was to build a theoretical framework and research model to empirically explore the dynamics driving business model development using a process-based perspective. As a result, the study developed a theoretical model integrating multiple principles from organisation studies, systems theory, business strategy, innovation management and entrepreneurship research that helps observe and explore business model change events as they unfold over time. Lastly, a purposeful selection of analytic methods including data mining techniques, frequency domain analysis and statistical methods generated insights on key properties of business model development such as the order, magnitude and frequency of change, and provided insights on the nature of the actions and agents driving particular patterns of business model change.

The insights on business model change in this research incrementally expand our knowledge on a phenomenon that is becoming central to strategy and innovation studies. In today's business environment characterised by accelerated technological development, fluctuating economic conditions and constant shifts in customer demand, business model innovation is allowing businesses to not only stay relevant, but also to lead the way.

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Appendices

Appendix 1: R scripts designed and used in this study

Script name	Size	Description	R packages used
01_01_store_data	125 lines of code	Obtains data from export .csv file and stores it in database	RSQLite
01_02_calculate_perf_score	69 lines of code	Calculate performance scores for each company. Then, it stores the scores in companies_table (perf_score field) and the yearly values in a separate table	RSQLite, plyr, data.table, xlsx
02_01_calculate_LOFs	74 lines of code	Calculate Local Outlier Factors for each ratio, with k-neighbours = 4. Stores them in the field "delta_values" in ratios_table	RSQLite, Rlof, DMwR
02_02_LOF_cutoff_val-by-params	24 lines of code	Computes percentile .80 and percentile .99 for each individual ratio and stores them in the field lower_bound and upper_bounds in parameters_table	
02_03_create_events_nonbinary	66 lines of code	Identifies events per dimension and stores them in database. It uses LOFs calculated in previous steps, and lower/upper bound levels by parameter stored in parameters_table	RSQLite, Rlof, DMwR
03_02_calculate_bmc3	174 lines of code	Calculates bmcs as a combination of vcre, vdel and vcap events occurring in a serialised or sequential way. Then, populates the events_x_bm_table in database	RSQLite
03_03_insert_synth_data	41 lines of codes	Inserts synthetic data in companies_table and events_x_dim_table comprising two (almost) identical sequences for the validation of cluster analysis	RSQLite
03_04_generate_clusters_bmc	132 lines of code	Generates clusters of companies by sequence similarities. Then the dendrogram is generated and the lists of clusters are stored in database	TraMineR, cluster, dendextend, RSQLite, TraMineRextras, plyr, xlsx
03_06_calculate_centroids	60 lines of code	Computes the centroids for each cluster of each age-size group, then generates a .xlsx file as output	RSQLite, xlsx
04_01_ratios_cross-corr	66 lines of code	Calculate cross-correlation between the 12 ratios by company, and then averages the correlation coefficients to determine the total cross-correlation	RSQLite, xlsx
04_02_desc_stats	47 lines of code	Creates a table with descriptive statistical information on sales growth, profit margin, dim events and bmc events, per cluster	RSQLite, xlsx, plyr
04_03_analysis_of_variance	83 lines of code	Performs analysis of variance to determine the difference in the population means of firm's performance scores between clusters	RSQLite, xlsx, plyr, psych
04_04_seq_ana_FREQ_deciles_2	136 lines of code	Performs frequency-domain/spectrum analysis of the change event sequences by calculating periodograms	RSQLite, xlsx, plyr
04_04_seq_ana_MAG_deciles	108 lines of code	Mine the event sequences (BMC magnitude) is search for frequencies of sub-sequences	TraMineR, TraMineRextras, RSQLite, xlsx, dplyr, psych
04_04_seq_ana_MECH_new	250 lines of code	Employs Chi-square test and ANOVA tests to examine the drivers of BMC. As preliminary step, frequent sub-sequences are mined.	MASS, RSQLite, TraMineR, TraMineRextras, xlsx, stringr, dplyr, plyr
04_04_seq_ana_ORD_all	191 lines of code	Mine the event sequences is search for frequencies of sub-sequences (for both between and within firm analysis). It also run association rule mining	TraMineR, TraMineRextras, RSQLite, xlsx, dplyr, plyr
04_04_seq_ana_ORD_graph	104 lines of code	Plot event sequences (a prior transformation into state events is required). Based on dimensional events without categories	RColorBrewer, viridis, TraMineR, TraMineRextras, RSQLite, xlsx, dplyr, plyr
05_plot_event_seqs	46 lines of code	Plots each dimension and bm aggregate in a single space, for single or an entire group of companies	ggplot2, RSQLite

Appendix 2: Most frequent sub-sequences (magnitude) of business model change

Group: Young-small			
Decile	Subseq.	Support	Count
1st	(2)	0.265	13
1st	(1)	0.245	12
1st	(11)	0.204	10
2nd	(21)	0.224	11
2nd	(1)	0.204	10
2nd	(2)	0.204	10
3rd	(2)	0.224	11
3rd	(21)	0.224	11
3rd	(22)	0.204	10
4th	(1)	0.440	22
4th	(2)	0.240	12
4th	(11)	0.240	12
4th	(21)	0.240	12
4th	(12)	0.220	11
4th	(22)	0.200	10
5th	(1)	0.449	22
5th	(11)	0.306	15
5th	(12)	0.204	10
5th	(22)	0.204	10
6th	(1)	0.388	19
6th	(2)	0.347	17
6th	(11)	0.327	16
6th	(22)	0.204	10
7th	(1)	0.400	20
7th	(11)	0.300	15
7th	(22)	0.280	14
7th	(21)	0.240	12
7th	(2)	0.200	10
8th	(1)	0.408	20
9th	(2)	0.327	16
9th	(1)	0.286	14
9th	(11)	0.245	12
10th	(2)	0.380	19
10th	(1)	0.220	11
10th	(22)	0.200	10

Group: Young-large			
Decile	Subseq.	Support	Count
1st	(1)	0.382	13
1st	(11)	0.265	9
1st	(21)	0.206	7
2nd	(1)	0.486	17
2nd	(21)	0.371	13
2nd	(2)	0.257	9
2nd	(11)	0.257	9
2nd	(12)	0.200	7
2nd	(22)	0.200	7
3rd	(1)	0.400	14
3rd	(11)	0.286	10
3rd	(21)	0.286	10
3rd	(2)	0.257	9
3rd	(12)	0.229	8
3rd	(22)	0.200	7
4th	(2)	0.343	12
4th	(1)	0.314	11
4th	(21)	0.286	10
4th	(22)	0.229	8
4th	(11)	0.200	7
4th	(23)	0.200	7
5th	(1)	0.514	18
5th	(12)	0.371	13
5th	(22)	0.286	10
5th	(2)	0.257	9
5th	(11)	0.257	9
5th	(21)	0.229	8
6th	(1)	0.486	17
6th	(22)	0.343	12
6th	(21)	0.257	9
6th	(12)	0.229	8
6th	(2)	0.200	7
7th	(2)	0.429	15
7th	(1)	0.400	14
7th	(22)	0.371	13
7th	(11)	0.314	11
7th	(21)	0.257	9
8th	(1)	0.429	15
8th	(21)	0.314	11
8th	(2)	0.257	9
8th	(11)	0.229	8
8th	(22)	0.229	8
8th	(12)	0.200	7
9th	(1)	0.429	15
9th	(22)	0.286	10
9th	(11)	0.229	8
9th	(2)	0.200	7
9th	(12)	0.200	7
10th	(1)	0.343	12
10th	(2)	0.229	8
10th	(22)	0.229	8
10th	(11)	0.200	7

Group: Mature-small			
Decile	Subseq.	Support	Count
1st	(1)	0.455	15
1st	(11)	0.455	15
1st	(2)	0.364	12
1st	(22)	0.303	10
2nd	(12)	0.485	16
2nd	(1)	0.394	13
2nd	(2)	0.394	13
2nd	(21)	0.394	13
2nd	(11)	0.273	9
2nd	(22)	0.242	8
3rd	(1)	0.455	15
3rd	(11)	0.364	12
3rd	(22)	0.333	11
3rd	(2)	0.212	7
3rd	(23)	0.212	7
4th	(1)	0.697	23
4th	(11)	0.394	13
4th	(2)	0.333	11
4th	(22)	0.242	8
5th	(2)	0.382	13
5th	(11)	0.324	11
5th	(1)	0.265	9
5th	(22)	0.265	9
5th	(21)	0.206	7
6th	(1)	0.545	18
6th	(2)	0.455	15
6th	(11)	0.303	10
6th	(21)	0.303	10
6th	(12)	0.273	9
6th	(22)	0.273	9
7th	(1)	0.545	18
7th	(11)	0.394	13
7th	(2)	0.364	12
7th	(23)	0.212	7
8th	(1)	0.333	11
8th	(12)	0.273	9
8th	(11)	0.242	8
8th	(2)	0.212	7
8th	(21)	0.212	7
8th	(22)	0.212	7
9th	(1)	0.606	20
9th	(2)	0.485	16
9th	(11)	0.455	15
9th	(21)	0.303	10
9th	(22)	0.212	7
10th	(1)	0.559	19
10th	(11)	0.382	13
10th	(2)	0.235	8

Group: Mature-large			
Decile	Subseq.	Support	Count
1st	(1)	0.660	31
1st	(11)	0.383	18
1st	(21)	0.383	18
1st	(2)	0.362	17
1st	(12)	0.255	12
1st	(22)	0.213	10
2nd	(1)	0.563	27
2nd	(11)	0.500	24
2nd	(21)	0.313	15
2nd	(12)	0.292	14
2nd	(2)	0.250	12
3rd	(1)	0.500	24
3rd	(2)	0.396	19
3rd	(11)	0.333	16
3rd	(12)	0.313	15
3rd	(22)	0.229	11
4th	(1)	0.553	26
4th	(2)	0.277	13
4th	(11)	0.255	12
4th	(12)	0.234	11
4th	(22)	0.234	11
4th	(21)	0.213	10
5th	(1)	0.563	27
5th	(11)	0.333	16
5th	(12)	0.250	12
5th	(21)	0.208	10
6th	(1)	0.521	25
6th	(2)	0.375	18
6th	(11)	0.333	16
7th	(1)	0.574	27
7th	(22)	0.319	15
7th	(11)	0.298	14
7th	(12)	0.298	14
7th	(21)	0.255	12
7th	(2)	0.234	11
8th	(1)	0.458	22
8th	(12)	0.333	16
8th	(2)	0.250	12
8th	(11)	0.250	12
8th	(21)	0.250	12
8th	(22)	0.250	12
9th	(1)	0.583	28
9th	(2)	0.375	18
9th	(11)	0.292	14
9th	(21)	0.250	12
9th	(12)	0.208	10
10th	(1)	0.417	20
10th	(2)	0.333	16
10th	(11)	0.333	16
10th	(22)	0.313	15
10th	(12)	0.229	11
10th	(21)	0.208	10

Appendix 3: Most frequent sub-sequences (value dimensions) of business model change

Group: Young-small			Group: Young-large			Group: Mature-small			Group: Mature-large		
Sub-sequence	Support	Count	Sub-sequence	Support	Count	Sub-sequence	Support	Count	Sub-sequence	Support	Count
(CRE1)-(CAP1)-(DEL1)	0.310	13	(CAP1,CRE1,DEL1)	0.387	12	(CAP1)-(CRE1,DEL1)	0.406	13	(CAP1,CRE1)-(DEL1)	0.574	27
(CAP1,CRE1,DEL1)	0.286	12	(CRE1)-(CAP1,DEL1)	0.323	10	(CRE1)-(CAP1,DEL1)	0.406	13	(CAP1,CRE1,DEL1)	0.553	26
(CRE1,DEL1)-(CAP1)	0.262	11	(CRE1)-(CAP1)-(DEL1)	0.323	10	(CRE1)-(CAP1)-(DEL1)	0.406	13	(CRE1,DEL1)-(CAP1)	0.553	26
(DEL1)-(CRE1)-(CAP1)	0.262	11	(DEL1)-(CAP1,CRE1)	0.323	10	(DEL1)-(CAP1,CRE1)	0.406	13	(CRE1)-(CAP1,DEL1)	0.532	25
(CAP1,DEL1)-(CRE1)	0.238	10	(DEL1)-(CRE1)-(CAP1)	0.323	10	(CAP1)-(DEL1)-(CRE1)	0.375	12	(DEL1)-(CRE1)-(CAP1)	0.511	24
(CAP1)-(DEL1)-(CRE1)	0.238	10	(CAP1,DEL1)-(CRE1)	0.290	9	(CAP1,DEL1)-(CRE1)	0.344	11	(CAP1,DEL1)-(CRE1)	0.468	22
(CAP1,CRE1)-(DEL1)	0.214	9	(CAP1)-(DEL1)-(CRE1)	0.290	9	(CAP1)-(CRE1)-(DEL1)	0.344	11	(CAP1)-(CRE1,DEL1)	0.468	22
(CAP1)-(CRE1,DEL1)	0.214	9	(CRE1,DEL1)-(CAP1)	0.290	9	(CRE1,DEL1)-(CAP1)	0.344	11	(CAP1)-(DEL1)-(CRE1)	0.468	22
(CAP1)-(CRE1)-(DEL1)	0.214	9	(CAP1,CRE1)-(DEL1)	0.258	8	(CRE1)-(DEL1)-(CAP1)	0.344	11	(CRE1)-(DEL1)-(CAP1)	0.468	22
(DEL1)-(CAP1)-(CRE1)	0.214	9	(CAP1)-(CRE1,DEL1)	0.258	8	(DEL1)-(CRE1)-(CAP1)	0.344	11	(DEL1)-(CAP1,CRE1)	0.468	22
(DEL2)-(CAP1)-(CRE1)	0.214	9	(CAP1)-(CRE1)-(DEL1)	0.258	8	(CAP1,CRE1)-(DEL1)	0.313	10	(DEL1)-(CAP1)-(CRE1)	0.447	21
			(CRE1)-(DEL1)-(CAP1)	0.258	8	(CAP1,CRE1,DEL1)	0.281	9	(CAP1)-(CRE1)-(DEL1)	0.383	18
			(DEL1)-(CAP1)-(CRE1)	0.258	8	(CAP1,CRE1)-(DEL1)-(DEL1)	0.250	8	(CRE1)-(CAP1)-(DEL1)	0.383	18
			(CAP1,DEL1)-(DEL1)-(CRE1)	0.226	7	(CAP1,CRE2,DEL1)	0.250	8	(CRE1,DEL1)-(CAP1,CRE1)	0.340	16
			(DEL1)-(CAP1,CRE1)-(DEL1)	0.226	7	(CRE1)-(CAP1,CRE1)-(DEL1)	0.250	8	(CRE1,DEL1)-(CAP1,DEL1)	0.340	16
			(DEL1)-(DEL1)-(CAP1,CRE1)	0.226	7	(CRE1)-(CAP1,DEL1)-(DEL1)	0.250	8	(CRE1,DEL1)-(CRE1)-(CAP1)	0.340	16
						(DEL1)-(CAP1)-(CRE1)	0.250	8	(CRE1)-(CRE1,DEL1)-(CAP1)	0.340	16
						(CAP1,CRE1)-(CRE1)-(DEL1)	0.219	7	(DEL1)-(CRE1)-(CAP1,CRE1)	0.340	16
						(CAP1,DEL1)-(CRE1)-(CRE1)	0.219	7	(CAP2,CRE1,DEL1)	0.319	15
						(CAP1)-(CRE1,DEL1)-(CAP1)	0.219	7	(CRE1,DEL1)-(DEL1)-(CAP1)	0.319	15
						(CAP1)-(CRE1,DEL1)-(CRE1)	0.219	7	(CRE1)-(CAP1,CRE1,DEL1)	0.319	15
						(CAP1)-(CRE1,DEL1)-(DEL1)	0.219	7	(CRE1)-(CAP1,CRE1)-(DEL1)	0.319	15
						(CAP1)-(CRE1)-(CRE1,DEL1)	0.219	7	(CAP1,DEL1)-(CRE1)-(CRE1)	0.298	14
						(CRE1,DEL1)-(CAP1,DEL1)	0.219	7	(CRE1)-(CRE1)-(CAP1,DEL1)	0.298	14
						(CRE1)-(CAP1)-(CRE1,DEL1)	0.219	7	(CAP1,CRE1,DEL1)-(CAP1)	0.277	13
						(CRE1)-(DEL1)-(CAP1,DEL1)	0.219	7	(DEL1)-(CAP1,CRE1)-(CRE1)	0.277	13
									(DEL1)-(CRE1,DEL1)-(CAP1)	0.277	13
									(CAP1,CRE1)-(CAP1,DEL1)	0.255	12
									(CAP1,CRE1)-(CRE1,DEL1)	0.255	12
									(CAP1)-(CRE1,DEL1)-(CRE1)	0.255	12
									(CAP1)-(CRE1)-(CRE1,DEL1)	0.255	12
									(CAP1)-(DEL1)-(CRE1,DEL1)	0.255	12
									(CRE1,DEL1)-(CAP2)	0.255	12
									(CRE1,DEL1)-(CRE1,DEL1)-(CAP1)	0.255	12
									(CRE1)-(CAP1)-(CAP1,DEL1)	0.255	12
									(CRE1)-(DEL1)-(CAP1,CRE1)	0.255	12
									(DEL1)-(DEL1)-(CAP1,CRE1)	0.255	12
									(CAP1,CRE1,DEL1)-(DEL1)	0.234	11
									(CAP1)-(CRE1,DEL1)-(DEL1)	0.234	11
									(CRE1,DEL1)-(CAP1)-(CRE1)	0.234	11
									(DEL1)-(CAP1,CRE1,DEL1)	0.234	11
									(DEL1)-(CRE1)-(CAP1,DEL1)	0.234	11
									(CAP1,CRE1)-(DEL1)-(CAP1)	0.213	10
									(CAP1,DEL1)-(CAP1,CRE1)	0.213	10
									(CAP1,DEL1)-(DEL1)-(CRE1)	0.213	10
									(CAP1,DEL2)-(CRE1)	0.213	10
									(CAP1)-(CAP1,DEL1)-(CRE1)	0.213	10
									(CAP1)-(CAP1)-(CRE1,DEL1)	0.213	10
									(CAP2)-(CRE1,DEL1)	0.213	10
									(CRE1,DEL1)-(CAP1,CRE1,DEL1)	0.213	10
									(CRE1,DEL1)-(CAP1)-(CAP1)	0.213	10
									(CRE1,DEL1)-(CAP1)-(DEL1)	0.213	10
									(CRE1)-(CAP1,DEL1)-(CAP1)	0.213	10
									(DEL1)-(CAP1,CRE1)-(CAP1)	0.213	10
									(DEL1)-(CAP1,CRE1)-(DEL1)	0.213	10

Appendix 4: List of companies included in the study: young-small group

No.	Company name	Country
1	3DFAMILY TECHNOLOGY CO., LTD.	TW
2	ABICO FS CO., LTD.	TW
3	ABOCOM SYSTEMS INCORPORATED	TW
4	ACCESSO TECHNOLOGY GROUP PLC	GB
5	ACMOS INC.	JP
6	ACRODEA, INC.	JP
7	ACTI CORPORATION	TW
8	ACULA TECHNOLOGY CORP.	TW
9	ADDCN TECHNOLOGY CORPORATION	TW
10	ADLINK TECHNOLOGY INC.	TW
11	ADVANCE MATERIALS CORP.	TW
12	ADVANCED CARD SYSTEMS HOLDINGS LIMITED	KY
13	ADVANCED CERAMIC X CORP.	TW
14	ADVANCED CONNECTION TECHNOLOGY INC.	TW
15	ADVANCED MEDIA INC.	JP
16	ADVANCED POWER ELECTRONICS CORP.	TW
17	ADVANCED VISION TECHNOLOGY LIMITED	IL
18	ADVANCED WIRELESS SEMICONDUCTOR COMPANY	TW
19	AE MULTI HOLDINGS BERHAD	MY
20	AERIA INC.	JP
21	AEROHIVE NETWORKS, INC.	US
22	AEWIN TECHNOLOGIES CO., LTD.	TW
23	AGTECH HOLDINGS LIMITED	BM
24	AIC INC.	TW
25	AJINEXTEK CO, LTD	KR
26	AKM INDUSTRIAL COMPANY LIMITED	HK
27	ALCHIP TECHNOLOGIES LIMITED	KY
28	ALCOR MICRO CORP.	TW
29	ALI, RING TECH CO., LTD.	TW
30	ALLTOP TECHNOLOGY COMPANY LIMITED	TW
31	ALPHA MICROLECTRONICS CORP.	TW
32	AME INC.	TW
33	AMERI HOLDINGS, INC.	US
34	AMIGO TECHNOLOGY CO., LTD.	TW
35	AMINO TECHNOLOGIES PLC	GB
36	AMPIRE CO., LTD.	TW
37	ANA PASS INC.	KR
38	ANOTO GROUP AB	SE
39	ANPEC ELECTRONICS CORPORATION	TW
40	ANSWER TECHNOLOGY CO. LTD.	TW
41	ANT PRECISION INDUSTRY COMPANY LIMITED	TW
42	APAC OPTO ELECTRONICS INC.	TW
43	APPLIED OPTOELECTRONICS, INC.	US
44	ARBOR TECHNOLOGY CORP.	TW
45	ARRAY INC.	KY
46	ASIA ELECTRONIC MATERIAL COMPANY LIMITED	TW
47	ASIA PACIFIC SATELLITE-COMMUNICATIONS INC.	KR
48	ASMEDIA TECHNOLOGY INC.	TW
49	ASPEED TECHNOLOGY INC.	TW
50	ASTI HOLDINGS LIMITED	SG
51	ASTRAL SUPREME BERHAD	MY
52	ATE ENERGY INTERNATIONAL CO., LTD.	TW
53	ATEC CO.,LTD.	KR
54	AURAS TECHNOLOGY CO., LTD.	TW
55	AURONA INDUSTRIES, INC.	TW
56	AUROTEK CORP.	TW
57	AURUM PACIFIC (CHINA) GROUP LIMITED	KY
58	AVALUE TECHNOLOGY INC.	TW
59	AVANT CORPORATION	JP
60	AVER INFORMATION INC.	TW
61	AVERLOGIC TECHNOLOGIES CORP.	TW
62	AVID ELECTRONICS CORPORATION	TW
63	AVY PRECISION TECHNOLOGY INC.	TW
64	AXT INC	US
65	B+S BANKSYSTEME AKTIENGESELLSCHAFT	DE
66	BAIOO FAMILY INTERACTIVE LIMITED	KY
67	BATM ADVANCED COMMUNICATIONS LTD	IL
68	BEIJING BEIDA JADE BIRD UNIVERSAL SCI-TECH COMPANY LIMITED	CN
69	BIG SUN ENERGY TECHNOLOGY INC.	TW
70	BIO-KEY INTERNATIONAL, INC.	US
71	BIRLA SHLOKA EDUTECH LTD.	IN
72	BISON ELECTRONICS INC.	TW
73	BOTTOMLINE TECHNOLOGIES INC	US
74	BRIDGETEC CORP.	KR
75	BRIGHTEK OPTOELECTRONIC CO., LTD.	TW
76	BROWAVE CORP.	TW
77	BULL WILL CO., LTD.	TW

No.	Company name	Country
247	ISENTRIC LIMITED	AU
248	ITBOOK CO., LTD.	JP
249	ITX-M2M CO., LTD.	KR
250	I-STREAM INC.	JP
251	JASTECH, LTD.	KR
252	JAZZ HIPSTER CORP.	TW
253	JCURVE SOLUTIONS LTD	AU
254	JIH LIN TECHNOLOGY CO., LTD.	TW
255	JIU RONG HOLDINGS LIMITED	KY
256	JMICRON TECHNOLOGY CORPORATION	TW
257	JOIN WELL TECHNOLOGY CO., LTD.	TW
258	JOLIMARK HOLDINGS LIMITED	KY
259	JORJIN TECHNOLOGIES INC	TW
260	JSW PACIFIC CORPORATION	TW
261	JUSTPLANNING INC.	JP
262	KINGTONE WIRELESSINFO SOLUTIONS HOLDING LTD	VG
263	KO JA (CAYMAN) CO., LTD.	KY
264	KODI-M CO.,LTD.	KR
265	KOREA COMPUTER & SYSTEM INC.	KR
266	KOREA COMPUTER TERMINAL INC.	KR
267	KROMEK GROUP PLC	GB
268	KRON TELEKOMUNIKASYON HIZMETLERI A.S.	TR
269	KWORLD COMPUTER CO., LTD.	TW
270	LASTER TECH CORPORATION LTD.	TW
271	LATTICE, INC.	US
272	LB CEMICON CO.,LTD.	KR
273	LDT INC.	KR
274	LEDLINK OPTICS, INC.	TW
275	LGL GROUP, INC. (THE)	US
276	LIGHTPATH TECHNOLOGIES INC	US
277	LIN HORN TECHNOLOGY COMPANY LIMITED	TW
278	LINCO TECHNOLOGY COMPANY LIMITED	TW
279	LIYU TECHNOLOGY CO., LTD.	TW
280	LS TELCOM AG	DE
281	LUMIMICRO CO., LTD.	KR
282	LUNA INNOVATIONS INCORPORATED	US
283	LUXNET CORPORATION	TW
284	MACHVISION, INC.	TW
285	MACROBLOCK, INC.	TW
286	MACROWELL OMG DIGITAL ENTERTAINMENT CO., LTD.	TW
287	MAGIC TECHNOLOGY CO., LTD.	TW
288	MAM SOFTWARE GROUP, INC.	US
289	MARVELOUS INC.	JP
290	MATERIALS ANALYSIS TECHNOLOGY INC.	TW
291	MAXLINEAR, INC.	US
292	MAXWELL TECHNOLOGIES INC	US
293	MEDIA KOBO, INC.	JP
294	MEDIASEEK, INC.	JP
295	MEDIFRON DBT CO.,LTD.	KR
296	MEGAWIN TECHNOLOGY CORP.	TW
297	MELFAS INC.	KR
298	MEXTER TECHNOLOGY BERHAD	MY
299	MICROCOSM TECHNOLOGY CO., LTD.	TW
300	MICROJET TECHNOLOGY CO., LTD	TW
301	MICROTIPS TECHNOLOGY INC.	TW
302	MIRAE TECHNOLOGY CO.,LTD.	KR
303	MLABS SYSTEM BERHAD	MY
304	MOBILARM LIMITED	AU
305	MOBILE EMBRACE LIMITED	AU
306	MOBOTIX AG	DE
307	MODACOM CO.,LTD.	KR
308	MPI CORPORATION	TW
309	MQ TECHNOLOGY BERHAD	MY
310	MTI WIRELESS EDGE LIMITED	IL
311	NANOMETRICS INC	US
312	NENG TYI PRECISION INDUSTRIES CO., LTD.	TW
313	NEONODE INC.	US
314	NEOS CORP.	JP
315	NEPES ADVANCED MATERIALS CORPORATION	KR
316	NET INSIGHT AB	SE
317	NETDIMENSIONS (HOLDINGS) LIMITED	KY
318	NETDRAGON WEBSOFT HOLDINGS LIMITED	KY
319	NETRONIX, INC	TW
320	NETSCOUT SYSTEMS INC	US
321	NETSOL TECHNOLOGIES, INC.	US
322	NETYEAR GROUP CORPORATION	JP
323	NEWMAX TECHNOLOGY CO., LTD.	TW

78	C&G SYSTEMS INC.	JP
79	C-TECH UNITED CORPORATION	TW
80	CALIN TECHNOLOGY COMPANY LIMITED	TW
81	CAPINFO COMPANY LIMITED	CN
82	CASING MACRON TECHNOLOGY CO., LTD.	TW
83	CASTLENET TECHNOLOGY INC.	TW
84	CASTLES TECHNOLOGY CO., LTD.	TW
85	CAVE INTERACTIVE CO., LTD.	JP
86	CCS INC.	JP
87	CEC INTERNATIONAL HOLDINGS LIMITED	BM
88	CHAMPION MICROELECTRONIC CORPORATION	TW
89	CHANGHONG JIAHUA HOLDINGS LIMITED	BM
90	CHIALIN PRECISION INDUSTRIAL CO., LTD.	TW
91	CHIME BALL TECHNOLOGY CO. LTD.	TW
92	CHINA ALL ACCESS (HOLDINGS) LIMITED	KY
93	CHINA BIO CASSAVA HOLDINGS LIMITED	KY
94	CHINA DIGITAL CULTURE (GROUP) LIMITED	BM
95	CHINA DIGITAL TV HOLDING CO., LTD.	KY
96	CHINA PUBLIC PROCUREMENT LIMITED	BM
97	CHINA TECHNOLOGY SOLAR POWER HOLDINGS LIMITED	KY
98	CHINASING INVESTMENT HOLDINGS LIMITED	BM
99	CHIP HOPE CO., LTD.	TW
100	CHIPSIP TECHNOLOGY COMPANY LIMITED	TW
101	COADNA HOLDINGS, INC.	KY
102	COLLABORATE CORPORATION LIMITED	AU
103	COME TRUE BIOMEDICAL INC.	TW
104	COMINTEL CORPORATION BHD	MY
105	COMPUCON COMPUTER APPLICATIONS SA	GR
106	CONCRAFT HOLDING CO., LTD	KY
107	CONTREL TECHNOLOGY COMPANY LIMITED	TW
108	CONTROL4 CORPORATION	US
109	CORETEK OPTO CORP.	TW
110	COROWARE, INC.	US
111	COSTAR TECHNOLOGIES, INC.	US
112	CREATIVE REALITIES, INC.	US
113	CREXENDO, INC.	US
114	CRYSTALWISE TECHNOLOGY INC.	TW
115	CUI GLOBAL, INC.	US
116	CYBERSTEP INC	JP
117	CYBOZU INC	JP
118	D&O GREEN TECHNOLOGIES BERHAD	MY
119	DADNY INC.	TW
120	DATA IMAGE CORP.	TW
121	DATALEX PLC	IE
122	DATARAM CORP	US
123	DATRONIX HOLDINGS LIMITED	BM
124	DAVICOM SEMICONDUCTOR, INC.	TW
125	DDS INC	JP
126	DEXIN CORP.	TW
127	DFNN INC.	PH
128	DIGITAL ALLY, INC	US
129	DIGITAL DESIGN CO LTD	JP
130	DIONIC S.A.	GR
131	DONGWOON ANATECH CO.,LTD.	KR
132	DONPON PRECISION INC.	TW
133	DRAGONWAVE INC	CA
134	DRAYTEK CORPORATION	TW
135	DRECOM CO LTD	JP
136	DX.COM HOLDINGS LIMITED	BM
137	E&R ENGINEERING CORP.	TW
138	E-SUPPORTLINK, LTD.	JP
139	EARTHPORT PLC	GB
140	EBIX, INC.	US
141	ECKOH PLC	GB
142	ECLAT FOREVER MACHINERY CO., LTD.	TW
143	EDISON OPTO CORP.	TW
144	EFUN TECHNOLOGY CO., LTD.	TW
145	EGALAX-EMIPIA TECHNOLOGY INC.	TW
146	EKINOPS	FR
147	ELLIPSIZ LTD	SG
148	EM SYSTEMS CO., LTD.	JP
149	EMAGIN CORP	US
150	EPISIL-PRECISION INC.	TW
151	EPOCH CHEMTRONICS CORP.	TW
152	ERIS TECHNOLOGY CORPORATION	TW
153	EROOMSYSTEM TECHNOLOGIES, INC.	US
154	EVERFOCUS ELECTRONICS CORPORATION	TW
155	EXCELLENCE OPTOELECTRONIC INC.	TW
156	EYANG HOLDINGS (GROUP) CO., LTD.	KY
324	NEXCOM INTERNATIONAL CO., LTD.	TW
325	NEXON GT CO.,LTD.	KR
326	NICHING INDUSTRIAL CORP.	TW
327	NIKO SEMICONDUCTOR CO., LTD.	TW
328	NINGBO WANHAO HOLDINGS CO., LTD.	CN
329	NOVA MEASURING INSTRUMENTS LTD.	IL
330	NOVAVISIONS AG	CH
331	NPC INCORPORATED	JP
332	NUMEREX CORP	US
333	O-NET TECHNOLOGIES (GROUP) LIMITED	KY
334	OMG PLC	GB
335	ON-BRIGHT ELECTRONICS INCORPORATED	KY
336	ONVIA, INC.	US
337	OPENSYS (M) BERHAD	MY
338	OPTICIS CO.,LTD.	KR
339	OPTIVISION TECHNOLOGY INC.	TW
340	OURGAME INTERNATIONAL HOLDINGS LIMITED	KY
341	PA POWER AUTOMATION AG	DE
342	PACIFIC IMAGE ELECTRONICS CO., LTD.	TW
343	PAPAGO INC.	TW
344	PARAGON TECHNOLOGIES CO., LTD.	TW
345	PAYTON PLANAR MAGNETICS LTD.	IL
346	PC TEL INC	US
347	PCL TECHNOLOGIES, INC.	KY
348	PHOENITRON HOLDINGS LIMITED	KY
349	PIRONET NDH AG	DE
350	PIXELWORKS INC	US
351	PLASTIKKART AKILLI KART ILETISIM SISTEMLERI SANAYI VETICARET A.S.	TR
352	PNC TECHNOLOGIES CO.,LTD.	KR
353	POLYTRONICS TECHNOLOGY CORP.	TW
354	PROLIFIC TECHNOLOGY INC.	TW
355	RALEC ELECTRONIC CORPORATION	TW
356	RDC SEMICONDUCTOR CO., LTD.	TW
357	REALCOM INC	JP
358	REALTECH AG	DE
359	RECOMM CO., LTD.	JP
360	REDFLEX HOLDINGS LIMITED	AU
361	RELM WIRELESS CORP	US
362	RICHWAVE TECHNOLOGY CORPORATION	TW
363	RN2 TECHNOLOGIES CO.,LTD.	KR
364	RORZE SYSTEMS CORPORATION	KR
365	RUDOLPH TECHNOLOGIES, INC.	US
366	SAJAN, INC.	US
367	SALON MEDIA GROUP INC	US
368	SAMYUNG ENC CO.,LTD.	KR
369	SANDERSON GROUP PLC	GB
370	SCHMITT INDUSTRIES, INC.	US
371	SD SYSTEM CO.,LTD.	KR
372	SECUNET SECURITY NETWORKS AG	DE
373	SECUVE CO.,LTD.	KR
374	SEEING MACHINES LIMITED	AU
375	SERVELEC GROUP PLC	GB
376	SERVICE & QUALITY TECHNOLOGY CO., LTD.	TW
377	SHANXI CHANGCHENG MICROLIGHT EQUIPMENT COMPANY LIMITED	CN
378	SHENZHEN MINGWAH AOHAN HIGH TECHNOLOGY CORP. LTD	CN
379	SHIH HER TECHNOLOGIES INC.	TW
380	SHINEMORE TECHNOLOGY MATERIALS CO., LTD.	TW
381	SHUN ON ELECTRONIC CO., LTD.	TW
382	SILICON TOUCH TECHNOLOGY INC.	TW
383	SILVERSUN TECHNOLOGIES, INC.	US
384	SIMULA TECHNOLOGY INC.	TW
385	SING LEE SOFTWARE (GROUP) LIMITED	BM
386	SINBER TECHNOLOGY INC	TW
387	SINNERSCHRADER AG	DE
388	SINOPOWER SEMICONDUCTOR, INC.	TW
389	SINOSOFT TECHNOLOGY GROUP LIMITED	KY
390	SIOS TECHNOLOGY, INC.	JP
391	SMITH MICRO SOFTWARE INC	US
392	SNP SCHNEIDER - NEUREITHER & PARTNER AG	DE
393	SNU PRECISION CO.,LTD.	KR
394	SOCKET MOBILE, INC.	US
395	SOFTBRAIN CO LTD	JP
396	SOFTSTAR ENTERTAINMENT INC.	TW
397	SOLACIA INC.	KR
398	SOLID STATE SYSTEM CO., LTD.	TW
399	SOLIDWIZARD TECHNOLOGY CO. LTD.	TW
400	SOLOMON SYSTECH (INTERNATIONAL) LIMITED	KY
401	SOLXYZ CO., LTD.	JP
402	SONIX TECHNOLOGY COMPANY LIMITED	TW

157	FARO TECHNOLOGIES INC.	US
158	FASTEPS CO., LTD.	JP
159	FEEI CHERNG ENTERPRISE CO., LTD.	TW
160	FEELING TECHNOLOGY CORP.	TW
161	FIELD SYSTEMS DESIGNS HOLDINGS PLC	GB
162	FIREEYE INC.	US
163	FIRICH ENTERPRISES CO., LTD.	TW
164	FITIPOWER INTEGRATED TECHNOLOGY INC	TW
165	FLIGHT HOLDINGS INC.	JP
166	FOCI FIBER OPTIC COMMUNICATIONS, INC.	TW
167	FORCE MOS TECHNOLOGY LIMITED.	TW
168	FORCECON TECHNOLOGY CO., LTD.	TW
169	FORSIDE CO., LTD.	JP
170	FORTUNE ORIENTAL COMPANY LIMITED	TW
171	FOXSEMICON INTEGRATED TECHNOLOGY INC.	TW
172	FRANKLIN WIRELESS CORP.	US
173	FUETREK CO LTD	JP
174	FULLERTON TECHNOLOGY COMPANY LIMITED	TW
175	G THREE HOLDINGS CORPORATION	JP
176	G-SMATT GLOBAL CO.,LTD.	KR
177	G.T. INTERNET INFORMATION CO., LTD.	TW
178	GAMING REALMS PLC	GB
179	GAMMA OPTICAL CO., LTD.	TW
180	GCS HOLDINGS, INC.	KY
181	GENERALPLUS TECHNOLOGY INC.	TW
182	GENESEM INC.	KR
183	GENESIS TECHNOLOGY, INC.	TW
184	GENESYSLOGIC INC	TW
185	GEOVISION INCORPORATION	TW
186	GET HOLDINGS LIMITED	BM
187	GHL SYSTEMS BERHAD	MY
188	GIGA SOLUTION TECH. CO., LTD.	TW
189	GIGASTORAGE CORPORATION	TW
190	GLOBAL INVACOM GROUP LIMITED	SG
191	GLOBAL LINK COMMUNICATIONS HOLDINGS LIMITED	KY
192	GLORY MARK HI-TECH (HOLDINGS) LIMITED	BM
193	GLORY SCIENCE CO., LTD.	TW
194	GLOTECH INDUSTRIAL CORPORATION	TW
195	GLOWPOINT, INC.	US
196	GODEX INTERNATIONAL CO., LTD.	TW
197	GOOD WAY TECHNOLOGY CO., LTD.	TW
198	GRAND PLASTIC TECHNOLOGY CORPORATION	TW
199	GUIDANCE SOFTWARE, INC	US
200	HAILIANG INTERNATIONAL HOLDINGS LIMITED	KY
201	HANCOM SECURE INC.	KR
202	HARVATEK CORPORATION	TW
203	HB TECHNOLOGY CO.,LTD.	KR
204	HC INTERNATIONAL INC	KY
205	HD PRO CO.,LTD.	KR
206	HEP TECH COMPANY LIMITED	TW
207	HI-LIGHT TEK COMPANY LIMITED	TW
208	HITI DIGITAL INC.	TW
209	HORNG TONG ENTERPRISE CO., LTD.	TW
210	HYUNWOO INDUSTRIAL CO.,LTD.	KR
211	HYWEB TECHNOLOGY CO., LTD.	TW
212	I-COMPONENTS CO.,LTD.	KR
213	IBASE TECHNOLOGY INC.	TW
214	IC PLUS CORP.	TW
215	ICP DAS CO., LTD.	TW
216	ID SYSTEMS INC	US
217	ILJIN DISPLAY CO.,LTD.	KR
218	ILYDA S.A.	GR
219	IM TECH INC.	KR
220	IMAGINATION TECHNOLOGIES GROUP PLC	GB
221	IMMERSION CORP	US
222	INDIGOVISION GROUP PLC	GB
223	INFOMARK CO.,LTD.	KR
224	INFORTREND TECHNOLOGY INC	TW
225	INFOSONICS CORPORATION	US
226	INFOTERIA CORPORATION	JP
227	INIT INNOVATION IN TRAFFIC SYSTEMS AG	DE
228	INIX TECHNOLOGIES HOLDINGS BERHAD	MY
229	INNODISK CORPORATION	TW
230	INPAQ TECHNOLOGY CO., LTD	TW
231	INTEGRATED SERVICE TECHNOLOGY INC.	TW
232	INTEK PLUS CO.,LTD.	KR
233	INTELLI-CHECK - MOBILISA, INC.	US
234	INTELLIEPI INC.(CAYMAN)	KY
235	INTER ACTION CORPORATION	JP
236	INTERDIGITAL, INC.	US
403	SPIRAL TOYS INC.	US
404	SSH COMMUNICATIONS SECURITY OYJ	FI
405	STAMPS.COM INC.	US
406	STAR TRAVEL CORPORATION	TW
407	STL TECHNOLOGY COMPANY LIMITED	TW
408	SUNFLEX TECHNOLOGY CORP.	TW
409	SUNWORKS, INC.	US
410	T-FLEX TECHVEST PCB CO., LTD.	TW
411	TAI SHING INTERNATIONAL (HOLDINGS) LIMITED	KY
412	TAI-SAW TECHNOLOGY CO., LTD.	TW
413	TAI-TECH ADVANCED ELECTRONICS CO., LTD.	TW
414	TAISOL ELECTRONICS CO., LTD.	TW
415	TAITIEN ELECTRONICS CO., LTD.	TW
416	TAIWAN OASIS TECHNOLOGY CO., LTD.	TW
417	TAIWAN OSTOR CORP.	TW
418	TAMUL MULTIMEDIA CO.,LTD.	KR
419	TC ORIENT LIGHTING HOLDINGS LIMITED	KY
420	TECO IMAGE SYSTEMS COMPANY LIMITED	TW
421	TECSTAR TECHNOLOGY CO., LTD.	TW
422	TELECHIPS INC.	KR
423	TELEEYE HOLDINGS LIMITED	KY
424	TELEFIELD INC.	KR
425	TERRASEM CO.,LTD.	KR
426	THERMALTAKE TECHNOLOGY CO., LTD.	TW
427	THETA EDGE BERHAD	MY
428	THINFLEX CORP.	TW
429	TIAN GE INTERACTIVE HOLDINGS LIMITED	KY
430	TM TECHNOLOGY INC.	TW
431	TOKAI CARBON KOREA CO., LTD.	KR
432	TOPOINT TECHNOLOGY CO., LTD.	TW
433	TRACK GROUP, INC.	US
434	TRADE-VAN INFORMATION SERVICES COMPANY	TW
435	TRANSACT TECHNOLOGIES INC	US
436	TRANSTOUCH TECHNOLOGY INC.	TW
437	TREK 2000 INTERNATIONAL LIMITED	SG
438	TRUELIGHT CORP.	TW
439	TSC AUTO ID TECHNOLOGY COMPANY LIMITED	TW
440	TURTLE BEACH CORPORATION	US
441	TYNSOLAR CORP.	TW
442	U-TECH MEDIA CORPORATION	TW
443	UBITEQ, INC.	JP
444	ULTRA CHIP, INC.	TW
445	UNIROYAL GLOBAL ENGINEERED PRODUCTS, INC.	US
446	UNITECH ELECTRONIC COMPANY LIMITED	TW
447	UNITED, INC.	JP
448	UNITY OPTO TECHNOLOGY COMPANY LIMITED	TW
449	UNIVERSAL MICROWAVE TECHNOLOGY INC	TW
450	UPEC ELECTRONICS CORP	TW
451	USA TECHNOLOGIES, INC.	US
452	USERJOY TECHNOLOGY CO., LTD.	TW
453	USHINE PHOTONICS CORPORATION	TW
454	USU SOFTWARE AG	DE
455	UTECHZONE CO., LTD.	TW
456	UVAT TECHNOLOGY CO., LTD.	TW
457	V-TAC TECHNOLOGY CO., LTD.	TW
458	VALIANT COMMUNICATIONS LIMITED	IN
459	VASCO DATA SECURITY INTERNATIONAL INC	US
460	VIATRON TECHNOLOGIES INC.	KR
461	VIKING TECH CORPORATION	TW
462	VIRTUALTEK CORPORATION	KR
463	VISCOUNT SYSTEMS INC	US
464	VISDYNAMICS HOLDINGS BERHAD	MY
465	VISUAL PHOTONICS EPITAXY COMPANY LIMITED	TW
466	VIVOTEK INC.	TW
467	VODATEL NETWORKS HOLDINGS LIMITED	BM
468	VTC ELECTRONICS CORP.	TW
469	WAYI INTERNATIONAL DIGITAL ENTERTAINMENT CO., LTD	TW
470	WELLTEND TECHNOLOGY CORPORATION	TW
471	WIDEPOINT CORPORATION	US
472	WIN PAC INC.	KR
473	WIN WIN PRECISION TECHNOLOGY COMPANY LIMITED	TW
474	WINS CO.,LTD.	KR
475	WISECHIP SEMICONDUCTOR INC.	TW
476	WISTRON INFORMATION TECHNOLOGY& SERVICES CORPORATION	TW
477	WOORNET INC.	KR
478	XAAR PLC	GB
479	XAC AUTOMATION CORPORATION	TW
480	XI AN HAITIAN ANTENNA HOLDINGS CO., LTD.	CN
481	XPEC ENTERTAINMENT INC.	TW
482	YAO SHENG ELECTRONIC CO., LTD.	TW

237	INTERLINK ELECTRONICS INC	US
238	INTERTRADE CO LTD	JP
239	INTEST CORP	US
240	INTEVAC INC	US
241	INTICA SYSTEMS AG	DE
242	INVISIO COMMUNICATIONS AB	SE
243	INVISION AG	DE
244	IONES CO.,LTD.	KR
245	IPS CO LTD	JP
246	IROC CO., LTD.	TW

483	YEST CO.,LTD.	KR
484	YOC AG	DE
485	YOUNGWOO DSP CO.,LTD.	KR
486	YUKE S CO., LTD.	JP
487	YUNBO DIGITAL SYNERGY GROUP LIMITED	KY
488	Z-COM, INC.	TW
489	ZEN TECHNOLOGIES LTD	IN
490	ZEN VOCE CORP.	TW
491	ZENTEL ELECTRONIC CORPORATION	TW
492	ZHEDA LANDE SCITECH LIMITED	CN
493	ZYTRONIC PLC	GB

Appendix 5: List of companies included in the study: young-large group

No.	Company name	Country
1	21VIANET GROUP, INC.	KY
2	3D SYSTEMS CORPORATION	US
3	A-DATA TECHNOLOGY CO., LTD.	TW
4	A10 NETWORKS, INC.	US
5	AAC TECHNOLOGIES HOLDINGS INC.	KY
6	ACCESS CO LTD	JP
7	ACES ELECTRONIC CO., LTD.	TW
8	ACTIVISION BLIZZARD, INC.	US
9	ADOBE SYSTEMS INC	US
10	ADVA OPTICAL NETWORKING SE	DE
11	ADVANCED OPTOELECTRONIC TECHNOLOGY INC.	TW
12	AFFECTO OYJ	FI
13	AI HOLDINGS CORPORATION	JP
14	ALI CORPORATION	TW
15	ALPHA AND OMEGA SEMICONDUCTOR LIMITED	BM
16	ALPHA NETWORKS INCORPORATION	TW
17	ALPHABET INC.	US
18	AMKOR TECHNOLOGY INC	US
19	AOPEN INC	TW
20	APACER TECHNOLOGY INC.	TW
21	ARCADYAN TECHNOLOGY CORP.	TW
22	ARGO GRAPHICS INC	JP
23	ARIMA COMMUNICATIONS CORPORATION	TW
24	ARRIS INTERNATIONAL PLC	US
25	ASIA TECH IMAGE INC.	TW
26	ASROCK INC.	TW
27	AU OPTRONICS CORPORATION	TW
28	AUDIOCODES LTD.	IL
29	AUTOHOME INC.	KY
30	AVEVA GROUP PLC	GB
31	AVIAT NETWORKS, INC.	US
32	AXCELIS TECHNOLOGIES INC	US
33	AXWAY SOFTWARE SA	FR
34	AZUREWAVE TECHNOLOGIES, INC.	TW
35	BARCO NV	BE
36	BE SEMICONDUCTOR INDUSTRIES NV	NL
37	BENQ MATERIALS CORP.	TW
38	BLUCORA, INC.	US
39	BOE TECHNOLOGY GROUP CO., LTD.	CN
40	BROADBAND TOWER, INC.	JP
41	BROADCOM LIMITED	SG
42	BROADWAY INDUSTRIAL GROUP LTD	SG
43	BROCADE COMMUNICATIONS SYSTEMS INC	US
44	BROOKS AUTOMATION, INC.	US
45	BYD ELECTRONIC (INTERNATIONAL) CO. LTD.	HK
46	CABOT MICROELECTRONICS CORP	US
47	CALIX, INC.	US
48	CANCOM SE	DE
49	CAPXON INTERNATIONAL ELECTRONIC CO LTD	KY
50	CAREER TECHNOLOGY (MFG.) COMPANY LIMITED	TW
51	CASETEK HOLDINGS LIMITED	KY
52	CAVIUM, INC.	US
53	CCT LAND HOLDINGS LIMITED	BM
54	CELESTICA INC	CA
55	CELXPERT ENERGY CORP.	TW
56	CENTRON TELECOM INTERNATIONAL HOLDING LIMITED	KY
57	CHANNEL WELL TECHNOLOGY CO., LTD.	TW
58	CHI MEI MATERIALS TECHNOLOGY CORP.	TW
59	CHINA FIBER OPTIC NETWORK SYSTEM GROUP LTD.	KY
60	CHINA FIRE SAFETY ENTERPRISE GROUP HOLDINGS LIMITED	KY
61	CHINA GOLDJOY GROUP LIMITED	KY
62	CHINA HEALTHCARE ENTERPRISE GROUP LIMITED	KY
63	CHINA TECHFAITH WIRELESS COMMUNICATION TECHNOLOGY LIMITED	KY
64	CHINASOFT INTERNATIONAL LIMITED	KY
65	CHIPMOS TECHNOLOGIES (BERMUDA) LTD.	BM
66	CHIPMOS TECHNOLOGIES INC.	TW
67	CIENA CORP	US
68	CIMPRESS N.V.	NL
69	CIRRUS LOGIC INC	US
70	CMC CORPORATION	VN
71	CO-TECH DEVELOPMENT CORP.	TW
72	COASIA MICROELECTRONICS CORPORATION	TW
73	COLOPL, INC.	JP
74	COMBA TELECOM SYSTEMS HOLDINGS LIMITED	KY
75	COMMSCOPE HOLDING COMPANY, INC.	US
76	COMPUTER INSTITUTE OF JAPAN LTD	JP
77	CONEXIO CORPORATION	JP
175	J2 GLOBAL, INC.	US
176	JABIL CIRCUIT INC	US
177	JAPAN ASIA GROUP LTD.	JP
178	JARLLYTEC CO., LTD.	TW
179	JESS-LINK PRODUCTS COMPANY LIMITED	TW
180	JOCHU TECHNOLOGY CO., LTD.	TW
181	JUNIPER NETWORKS INC	US
182	KENMOS TECHNOLOGY COMPANY LIMITED	TW
183	KEYSIGHT TECHNOLOGIES, INC.	US
184	KINGSOFT CORPORATION LIMITED	KY
185	KINSUS INTERCONNECT TECHNOLOGY CORPORATION	TW
186	KNOWLES CORPORATION	US
187	LEAD DATA INC.	TW
188	LEIDOS HOLDINGS, INC.	US
189	LEXTAR ELECTRONICS CORPORATION	TW
190	LINEAR TECHNOLOGY CORP	US
191	LIONBRIDGE TECHNOLOGIES INC	US
192	LONGCHEER HOLDINGS LIMITED	BM
193	MAIL.RU GROUP LIMITED	VG
194	MAXTEK TECHNOLOGY CO., LTD.	TW
195	MEDIATEK INC.	TW
196	MEGACHIPS CORPORATION	JP
197	MICROSOFT CORP	US
198	MILDEX OPTICAL INC.	TW
199	MITEL NETWORKS CORPORATION	CA
200	MOBI DEVELOPMENT COMPANY LIMITED	KY
201	MODUSLINK GLOBAL SOLUTIONS, INC.	US
202	MRV COMMUNICATIONS INC	US
203	MTI LTD	JP
204	MULTI-FINELINE ELECTRONIX, INC.	US
205	NAGANO KEIKI CO LTD	JP
206	NANJING PANDA ELECTRONICS COMPANY LIMITED	CN
207	NANYA TECHNOLOGY CORPORATION	TW
208	NATIONAL INSTRUMENTS CORP	US
209	NEO SOLAR POWER CORP.	TW
210	NEOPHOTONICS CORP	US
211	NEOPOST SA	FR
212	NETAPP, INC.	US
213	NETEASE, INC.	KY
214	NETGEAR, INC.	US
215	NEXON CO LTD	JP
216	NOVATEK MICROELECTRONICS CORPORATION	TW
217	NOVATEL WIRELESS INC	US
218	NQ MOBILE INC.	KY
219	NUANCE COMMUNICATIONS, INC.	US
220	NUVOTON TECHNOLOGY CORPORATION	TW
221	NVIDIA CORP	US
222	NXP SEMICONDUCTORS N.V.	NL
223	OCLARO, INC.	US
224	ON SEMICONDUCTOR CORP	US
225	OPTIMAX TECHNOLOGY CORPORATION	TW
226	ORACLE CORP	US
227	OSI SYSTEMS INC	US
228	PANRAM INTERNATIONAL CORP.	TW
229	PARROT	FR
230	PAX GLOBAL TECHNOLOGY LIMITED	BM
231	PC DIRECT INC.	KR
232	PC PARTNER GROUP LIMITED	KY
233	PCHOME ONLINE INC.	TW
234	PEGATRON CORPORATION	TW
235	PERFECT OPTRONICS LIMITED	KY
236	PHISON ELECTRONICS CORP.	TW
237	PHOENIX SOLAR AG	DE
238	PINE TECHNOLOGY HOLDINGS LIMITED	BM
239	PIXART IMAGING INC.	TW
240	PORTWELL INC	TW
241	POWER INTEGRATIONS INC	US
242	POWER QUOTIENT INTERNATIONAL COMPANY LIMITED	TW
243	POWERTECH TECHNOLOGY INC.	TW
244	PRIME ELECTRONICS & SATELLITICS INC	TW
245	PROFESSIONAL COMPUTER TECHNOLOGY LTD.	TW
246	PV CRYSTALOX SOLAR PLC	GB
247	QUANTA STORAGE INC.	TW
248	RADIANT OPTO-ELECTRONICS CORP.	TW
249	RAYDIUM SEMICONDUCTOR CORP.	TW
250	REC SILICON ASA	NO
251	RED HAT INC	US

78	COOLPAD GROUP LTD.	KY
79	CORETRONIC CORPORATION	TW
80	CREATIVE SENSOR INC.	TW
81	CYBERPOWER SYSTEMS INC.	TW
82	CYBERTAN TECHNOLOGY INC.	TW
83	DAQO NEW ENERGY CORP.	KY
84	DARFON ELECTRONICS CORPORATION	TW
85	DATAGROUP AG	DE
86	DIGITAL CHINA HOLDINGS LIMITED	BM
87	DIGITAL GARAGE INC	JP
88	DISPLAY TECH CO.,LTD.	KR
89	DSP GROUP INC	US
90	DYNACARD CO., LTD.	TW
91	DYNAPACK INTERNATIONAL TECHNOLOGY CORP.	TW
92	E INK HOLDINGS INC	TW
93	E-TON SOLAR TECH. CO., LTD.	TW
94	E2V TECHNOLOGIES PLC	GB
95	EASTERN COMMUNICATIONS CO., LTD.	CN
96	ECHOSTAR CORPORATION	US
97	ELAN MICROELECTRONICS CORP.	TW
98	ELITE MATERIAL COMPANY LIMITED	TW
99	ELITE SEMICONDUCTOR MEMORY TECHNOLOGY INC	TW
100	EMERGING DISPLAY TECHNOLOGING CORPORATION	TW
101	ENTEGRIS INC	US
102	ENTIRE TECHNOLOGY CO., LTD.	TW
103	EPISTAR CORPORATION	TW
104	ERICSSON NIKOLA TESLA D.D	HR
105	ESON PRECISION IND. COMPANY, LIMITED.	TW
106	EUROMICRON AG	DE
107	EVERI HOLDINGS INC	US
108	EVOC INTELLIGENT TECHNOLOGY COMPANY LIMITED	CN
109	EVS BROADCAST EQUIPMENT SA	BE
110	EXTREME NETWORKS INC	US
111	F5 NETWORKS INC	US
112	FAIRCHILD SEMICONDUCTOR INTERNATIONAL INC	US
113	FAITH INC	JP
114	FARADAY TECHNOLOGY CORPORATION	TW
115	FIDELITY NATIONAL INFORMATION SERVICES, INC.	US
116	FIH MOBILE LIMITED	KY
117	FINISAR CORP	US
118	FIRST SOLAR, INC.	US
119	FLEXIUM INTERCONNECT INC	TW
120	FORMFACTOR, INC.	US
121	FOUNDER HOLDINGS LIMITED	BM
122	FOXLINK IMAGE TECHNOLOGY CO., LTD.	TW
123	FUNKWERK AG	DE
124	FUTONG TECHNOLOGY DEVELOPMENT HOLDINGS LTD	KY
125	G-TECH OPTOELECTRONICS CORP.	TW
126	G.M.I TECHNOLOGY INC	TW
127	GAMANIA DIGITAL ENTERTAINMENT CO., LTD.	TW
128	GCL-POLY ENERGY HOLDINGS LTD.	KY
129	GEMALTO N.V.	NL
130	GENESIS PHOTONICS INC.	TW
131	GIANTPLUS TECHNOLOGY CO., LTD.	TW
132	GIGASTONE CORPORATION	TW
133	GINTECH ENERGY CORPORATION	TW
134	GLOBAL LIGHTING TECHNOLOGIES INC.	KY
135	GLOBAL MIXED-MODE TECHNOLOGY INC.	TW
136	GLOBAL UNICHIP CORP.	TW
137	GOGO INC.	US
138	GOLDPAC GROUP LIMITED	HK
139	GREEN ENERGY TECHNOLOGY INC.	TW
140	GUNGHO ONLINE ENTERTAINMENT INC.	JP
141	HANNSTAR DISPLAY CORPORATION	TW
142	HANNSTOUCH SOLUTION INCORPORATED	TW
143	HANWHA Q CELLS CO., LTD.	KY
144	HARMONIC INC	US
145	HENGXIN TECHNOLOGY LTD.	SG
146	HERAN CO., LTD.	TW
147	HERMES MICROVISION, INC.	TW
148	HEXAGON AB	SE
149	HIMAX TECHNOLOGIES, INC.	KY
150	HOLLYSYS AUTOMATION TECHNOLOGIES LTD.	VG
151	HP INC.	US
152	HTC CORPORATION	TW
153	HUA HONG SEMICONDUCTOR LIMITED	HK
154	IEI INTEGRATION CORP.	TW
155	IMATION CORP	US
156	INDRA SISTEMAS SA	ES
157	INFICON HOLDING AG	CH
252	RENESAS ELECTRONICS CORPORATION	JP
253	RENESOLA LTD	VG
254	ROFIN SINAR TECHNOLOGIES INC	US
255	ROSETTA STONE INC	US
256	ROVI CORP.	US
257	S.O.I.TEC SILICON ON INSULATOR TECHNOLOGIES	FR
258	SAN CHIH SEMICONDUCTOR CO., LTD.	TW
259	SANDMARTIN INTERNATIONAL HOLDINGS LIMITED	BM
260	SEACHANGE INTERNATIONAL INC	US
261	SEAGATE TECHNOLOGY PUBLIC LIMITED COMPANY	IE
262	SENAO NETWORKS, INC.	TW
263	SERCOMM CORPORATION	TW
264	SERIAL SYSTEM LTD	SG
265	SHANGHAI BAOSIGHT SOFTWARE CO., LTD.	CN
266	SHINSEGEA I & C CO.,LTD.	KR
267	SHINSUNG FA CO.,LTD.	KR
268	SHORETEL, INC.	US
269	SHUNFENG INTERNATIONAL CLEAN ENERGY LIMITED	KY
270	SIIX CORP	JP
271	SILICON GRAPHICS INTERNATIONAL CORP	US
272	SILICON LABORATORIES INC	US
273	SILICON MOTION TECHNOLOGY CORPORATION	KY
274	SILICON POWER COMPUTER & COMMUNICATIONS INC.	TW
275	SILITECH TECHNOLOGY CORPORATION	TW
276	SILVER SPRING NETWORKS, INC.	US
277	SIM TECHNOLOGY GROUP LIMITED	BM
278	SIMPLO TECHNOLOGY COMPANY LIMITED	TW
279	SITRONIX TECHNOLOGY CORPORATION	TW
280	SK-ELECTRONICS CO LTD	JP
281	SMS CO., LTD.	JP
282	SOLARGIGA ENERGY HOLDINGS LIMITED	KY
283	SOLARWORLD AG	DE
284	SONUS NETWORKS INC	US
285	STARK TECHNOLOGY INC.	TW
286	STR HOLDINGS, INC.	US
287	SUMCO CORPORATION	JP
288	SUNNY OPTICAL TECHNOLOGY (GROUP) COMPANY LIMITED	KY
289	SUNPOWER CORPORATION	US
290	SUNWAY INTERNATIONAL HOLDINGS LIMITED	BM
291	SYNAPTICS INCORPORATED	US
292	SYSAGE TECHNOLOGY CO., LTD.	TW
293	SYSTEX CORPORATION	TW
294	TAIFLEX SCIENTIFIC COMPANY LIMITED	TW
295	TAINERGY TECH COMPANY LIMITED	TW
296	TAIWAN PRINTED CIRCUIT BOARD TECHVEST CO., LTD	TW
297	TAIWAN UNION TECHNOLOGY CORPORATION	TW
298	TAKE TWO INTERACTIVE SOFTWARE INC	US
299	TATUNG SYSTEM TECHNOLOGIES INC.	TW
300	TCL COMMUNICATION TECHNOLOGY HOLDINGS LIMITED	KY
301	TE CONNECTIVITY LTD.	CH
302	TEAM GROUP INC.	TW
303	TECHNOVATOR INTERNATIONAL LIMITED	SG
304	TELIT COMMUNICATIONS PLC	GB
305	TENCENT HOLDINGS LIMITED	KY
306	THINTECH MATERIALS TECHNOLOGY COMPANY LIMITED	TW
307	TIS INC.	JP
308	TIVO INC	US
309	TONGDA GROUP HOLDINGS LIMITED	KY
310	TOWER SEMICONDUCTOR LTD.	IL
311	TPK HOLDING COMPANY LIMITED	KY
312	TRAVELSKY TECHNOLOGY LIMITED	CN
313	TRIGIANT GROUP LIMITED	KY
314	TUL CORP.	TW
315	U-BLOX HOLDING AG	CH
316	U.D. ELECTRONIC CORP.	TW
317	ULTRATECH INC	US
318	UNIFOSA CORP.	TW
319	UNIZYX HOLDING CORPORATION	TW
320	VANGUARD INTERNATIONAL SEMICONDUCTOR CORPORATION	TW
321	VERIFONE SYSTEMS, INC.	US
322	VERINT SYSTEMS, INC.	US
323	VIA TECHNOLOGIES, INC.	TW
324	VIASAT INC	US
325	VIAVI SOLUTIONS INC.	US
326	VISLINK PLC	GB
327	WAFER WORKS CORPORATION	TW
328	WALTON ADVANCED ENGINEERING, INC	TW
329	WASION GROUP HOLDINGS LIMITED	KY
330	WEB.COM GROUP, INC.	US
331	WESTERN DIGITAL CORP	US

158	INFINEON TECHNOLOGIES AG	DE
159	INFINERA CORP.	US
160	INFOBLOX INC.	US
161	INNOLUX CORP.	TW
162	INSIDE SECURE	FR
163	INSPUR INTERNATIONAL LIMITED	KY
164	INTERNAP CORPORATION	US
165	INTERNET INITIATIVE JAPAN INC.	JP
166	INTERSIL CORP	US
167	INTUIT INC.	US
168	IRICO GROUP NEW ENERGY COMPANY LIMITED	CN
169	ITE TECH, INC.	TW
170	ITEQ CORP.	TW
171	ITFOR INC.	JP
172	ITURAN LOCATION & CONTROL LIMITED	IL
173	IXIA	US
174	IXYS CORP	US

332	WILLAS - ARRAY ELECTRONICS (HOLDINGS) LIMITED	BM
333	WIN SEMICONDUCTORS CORPORATION	TW
334	WINCOR NIXDORF AG	DE
335	WIRECARD AG	DE
336	WISTRON CORPORATION	TW
337	WISTRON NEWEB CORPORATION	TW
338	WOONGJIN ENERGY CO.,LTD.	KR
339	WT MICROELECTRONICS CO., LTD.	TW
340	XINTEC INC.	TW
341	XINYI SOLAR HOLDINGS LIMITED	KY
342	XURA, INC.	US
343	YINGLI GREEN ENERGY HOLDING COMPANY LIMITED	KY
344	YOUNG FAST OPTOELECTRONICS COMPANY LIMITED	TW
345	YOUNG OPTICS INC.	TW
346	YY INC.	KY
347	ZHEN DING TECHNOLOGY HOLDING LIMITED	KY
348	ZHONE TECHNOLOGIES, INC.	US
349	ZTE CORP.	CN

Appendix 6: List of companies included in the study: mature-small group

No.	Company name	Country
1	AAMRA TECHNOLOGIES LIMITED	BD
2	ABC TAIWAN ELECTRONICS CORP.	TW
3	ABILITY OPTO-ELECTRONICS TECHNOLOGY CO.	TW
4	ACCELYA KALE SOLUTIONS LIMITED	IN
5	ACME ELECTRONICS CORPORATION	TW
6	ACORN ENERGY INC.	US
7	ADACEL TECHNOLOGIES LIMITED	AU
8	ADDA CORP.	TW
9	ADO OPTRONICS CORPORATION	TW
10	ADTEC PLASMA TECHNOLOGY CO LTD	JP
11	ADVANCED SYSTEMS AUTOMATION LTD	SG
12	AEHR TEST SYSTEMS	US
13	AKER TECHNOLOGY CO., LTD.	TW
14	ALTIUM LIMITED	AU
15	AMPOC FAR-EAST COMPANY LIMITED	TW
16	ANDREA ELECTRONICS CORP	US
17	ANTEC INC.	TW
18	APC TECHNOLOGY GROUP PLC	GB
19	APEX INTERNATIONAL FINANCIAL ENGINEERING	TW
20	ARES INTERNATIONAL CORPORATION	TW
21	ARGOSY RESEARCH INC.	TW
22	ARTIZA NETWORKS, INC.	JP
23	ASJ INC.	JP
24	ASSOCIATED INDUSTRIES CHINA, INC.	TW
25	ASTRONOVA, INC.	US
26	ASURE SOFTWARE, INC.	US
27	ATOSS SOFTWARE AG	DE
28	ATW TECHNOLOGY INC.	TW
29	AUDEN TECHNO CORP.	TW
30	AVERTRONICS INC.	TW
31	AXIOMTEK CO., LTD.	TW
32	AXXIS TECHNOLOGY GROUP LIMITED	AU
33	BASLER AG	DE
34	BEING CO LTD	JP
35	BEST FRIEND TECHNOLOGY CO., LTD.	TW
36	BETA SYSTEMS SOFTWARE AG	DE
37	BILLION ELECTRIC COMPANY LIMITED	TW
38	BLONDER TONGUE LABORATORIES INC	US
39	BRIGHT LED ELECTRONICS CORPORATION	TW
40	BYTE COMPUTER SA	GR
41	C-MEDIA ELECTRONICS INC.	TW
42	C.C.P. CONTACT PROBES CO., LTD.	TW
43	CALAMP CORP.	US
44	CAMTEK LTD.	IL
45	CANDMARK ELECTROPTICS CO., LTD.	TW
46	CEOTRONICS AG	DE
47	CHANT SINCERE CO., LTD.	TW
48	CHEN FULL INTERNATIONAL CO., LTD.	TW
49	CHENGXIN TECHNOLOGY DEVELOPMENT CORPORATION	TW
50	CHIEF LAND ELECTRONIC CO., LTD.	TW
51	CHIEN WEI PRECISE TECHNOLOGY CO., LTD.	TW
52	CHILISIN ELECTRONICS CORP.	TW
53	CHINA INFORMATION TECHNOLOGY, INC.	VG
54	CIPHERLAB CO., LTD.	TW
55	CLEARFIELD, INC.	US
56	CLEARONE INC.	US
57	CODAN LIMITED	AU
58	COMOPS LIMITED	AU
59	COMPUCASE ENTERPRISE COMPANY LIMITED	TW
60	COMPUTER WAREHOUSE GROUP PLC	NG
61	CONCURRENT COMPUTER CORP	US
62	CORUM GROUP LIMITED	AU
63	COSMO ELECTRONICS CORPORATION	TW
64	CSP INC	US
65	CUBE SYSTEM INC	JP
66	CVD EQUIPMENT CORPORATION	US
67	DAFFODIL COMPUTERS LTD	BD
68	DAIWA COMPUTER CO., LTD.	JP
69	DATA I/O CORP	US
70	DESCARTES SYSTEMS GROUP INC (THE)	CA
71	DFI INC.	TW
72	DOCUMENT SECURITY SYSTEMS, INC.	US
73	DRS DATA AND RESEARCH SERVICES PUBLIC LIMITED COMPANY	GB
74	DSIC CO.,LTD.	KR
75	DYNACOLOR, INC	TW
76	EASY SOFTWARE AG	DE
77	ECHELON CORP	US
167	LEO SYSTEMS INC.	TW
168	LI KANG BIOMEDICAL CO., LTD.	TW
169	LIEN CHANG ELECTRONIC ENTERPRISE CO., LTD.	TW
170	LIFELOC TECHNOLOGIES, INC.	US
171	LIGITEK ELECTRONIC CO., LTD.	TW
172	LIWANLI INNOVATION CO., LTD.	TW
173	LOGISMOS INFORMATION SYSTEMS S.A.	GR
174	LOGO YAZILIM SANAYI VE TICARET A.S	TR
175	LOOP TELECOMMUNICATION INTERNATIONAL INC	TW
176	LOYALTY FOUNDER ENTERPRISE COMPANY LIMITED	TW
177	LPKF LASER & ELECTRONICS AG	DE
178	MAG. LAYERS SCIENTIFIC-TECHNICS CO., LTD	TW
179	MAGAL SECURITY SYSTEMS, LTD.	IL
180	MAGIC SOFTWARE ENTERPRISES LIMITED	IL
181	MECHANICAL TECHNOLOGY INC	US
182	MERCURIES DATA SYSTEMS LIMITED	TW
183	METRIC MOBILITY SOLUTIONS AG	DE
184	MICRONET LTD	IL
185	MICROTEK INTERNATIONAL, INC.	TW
186	MILDEF CRETE INC.	TW
187	MITEK SYSTEMS INC	US
188	MKS CORPORATION	TW
189	MOCON INC	US
190	MSG LIFE AG	DE
191	MULTIQ INTERNATIONAL AB	SE
192	MUSTANG INDUSTRIAL CORPORATION	TW
193	MUTUAL-TEK INDUSTRIES COMPANY LIMITED	TW
194	MYSON CENTURY, INC	TW
195	NCXX GROUP INC	JP
196	NETCOMM WIRELESS LIMITED	AU
197	NETWORK VALUE COMPONENTS LTD	JP
198	NEW ERA ELECTRONICS CO., LTD.	TW
199	NEWSOFT TECHNOLOGY CORPORATION	TW
200	NEWTECH CO LTD	JP
201	NEXTRONICS ENGINEERING CORP.	TW
202	NORDIC SEMICONDUCTOR ASA	NO
203	NORTECH SYSTEMS INC	US
204	NVE CORPORATION	US
205	OBDUCAT AB	SE
206	OBJECTIVE CORPORATION LIMITED	AU
207	ODAWARA AUTO-MACHINE MFG CO LTD	JP
208	ON TRACK INNOVATIONS LTD.	IL
209	OPNET TECHNOLOGIES CO., LTD.	TW
210	OPTEX FA COMPANY LIMITED	JP
211	OPTOELECTRONICS CO LTD	JP
212	ORBIS AG	DE
213	OSTERREICHISCHE STAATSDRUCKEREI HOLDING AG	AT
214	PAL WONN (TAIWAN) CO., LTD.	TW
215	PARA LIGHT ELECTRONICS CO., LTD.	TW
216	PARTNER TECH CORP.	TW
217	PATH CORPORATION	JP
218	PCA CORPORATION	JP
219	PENPOWER TECHNOLOGY LTD.	TW
220	PERCEPTRON INC	US
221	PIXELA CORPORATION	JP
222	PI ELECTRONIC CO.,LTD.	KR
223	PLASTRON PRECISION CO., LTD.	TW
224	PLENUM AG	DE
225	PLOTECH COMPANY LIMITED	TW
226	POSIFLEX TECHNOLOGIES, INC.	TW
227	POWERMATIC DATA SYSTEMS LIMITED	SG
228	POWERTIP TECH CORP.	TW
229	PRESCOPE TECHNOLOGIES CO., LTD.	TW
230	PRICER AB	SE
231	PRINCETON TECHNOLOGY CORPORATION	TW
232	PROLINK MICROSYSTEMS CORPORATION	TW
233	PROMISE TECHNOLOGY INC	TW
234	PROSPERITY DIELECTRICS CO., LTD.	TW
235	PVA TEPLA AG	DE
236	QUADRANT 4 SYSTEMS CORPORATION	US
237	R F INDUSTRIES LTD	US
238	RAKON LIMITED	NZ
239	RECKON LIMITED	AU
240	RECTRON LTD	TW
241	RORZE CORPORATION	JP
242	RUBIK FINANCIAL LIMITED	AU
243	RUIXIN INTERNATIONAL HOLDINGS LIMITED	BM

78	EDIMAX TECHNOLOGY CO., LTD	TW
79	ELECOSOFT PLC	GB
80	ELECTRO SENSORS INC	US
81	ELECTRONIC TELE-COMMUNICATIONS, INC.	US
82	ELMA ELECTRONIC AG	CH
83	EMCORE CORP	US
84	ENERMAX TECHNOLOGY CORP.	TW
85	EQUATION SUMMIT LIMITED	SG
86	EUROCONSULTANTS SA	GR
87	EVERSPRING INDUSTRY CO., LTD.	TW
88	FABASOFT AG	AT
89	FINGERPRINT CARDS AB	SE
90	FIRST SENSOR AG	DE
91	FLYTECH TECHNOLOGY COMPANY LIMITED	TW
92	FOREBASE INTERNATIONAL HOLDINGS LIMITED	HK
93	FORMULA VISION TECHNOLOGIES (F.V.T) LTD.	IL
94	FREQUENCY ELECTRONICS INC	US
95	FU YU PROPERTY CO., LTD.	TW
96	FUKUI COMPUTER HOLDINGS INC.	JP
97	FUSION PARTNERS CO., LTD.	JP
98	GALAXY FAR EAST CORP.	TW
99	GALLANT PRECISION MACHINING COMPANY LIMITED	TW
100	GB GROUP PLC	GB
101	GCL NEW ENERGY HOLDINGS LIMITED	BM
102	GIA TZOONG ENTERPRISE COMPANY LIMITED	TW
103	GOOCH & HOUSEGO PLC	GB
104	GOOD WILL INSTRUMENT CO., LTD	TW
105	GRANDTECH C.G. SYSTEMS INC	TW
106	GS INSTRUMENT CO.,LTD.	KR
107	GTM HOLDINGS CORPORATION	TW
108	HANSOL PNS CO.,LTD.	KR
109	HARMONY ELECTRONICS COMPANY LIMITED	TW
110	HAUMAN TECHNOLOGIES CORP.	TW
111	HI SHARP ELECTRONICS CO., LTD.	TW
112	HIGH-TEK HARNESS ENTERPRISE CO., LTD.	TW
113	HIGHER WAY ELECTRONIC CO., LTD.	TW
114	HMS NETWORKS AB	SE
115	HNA HOLDING GROUP CO. LIMITED	HK
116	HOLD JINN ELECTRONICS CO., LTD.	TW
117	HOLDERS TECHNOLOGY PLC	GB
118	HOWTEH TECHNOLOGY CO., LTD.	TW
119	HTM INTERNATIONAL HOLDING LIMITED	KY
120	HUNT ELECTRONIC CO., LTD.	TW
121	IMAGE ONE CO., LTD.	JP
122	IMAGE SENSING SYSTEMS INC	US
123	IMV CORPORATION	JP
124	INFINITE GROUP INC	US
125	INFORMATION PLANNING CO LTD	JP
126	INGENTA PLC	GB
127	INNOFACTOR OYJ	FI
128	INTELLIGENT WAVE INC.	JP
129	INTERNATIONAL GAMES SYSTEM CO., LTD.	TW
130	INTERSERV INTERNATIONAL INC.	TW
131	INTRICON CORPORATION	US
132	IQE PLC	GB
133	ISHII HYOKI CO LTD	JP
134	ISRA VISION AG	DE
135	ITERIS, INC.	US
136	ITUS CORPORATION	US
137	IVU TRAFFIC TECHNOLOGIES AG	DE
138	JAPAN PROCESS DEVELOPMENT CO., LTD.	JP
139	JAPAN RESISTOR MFG CO LTD	JP
140	JAPAN SYSTEM TECHNIQUES CO LTD	JP
141	JBIEN YEI ELECTRONIC CO., LTD.	TW
142	JI-HAW INDUSTRIAL COMPANY LIMITED	TW
143	JIN MING INDUSTRY COMPANY LIMITEND	TW
144	JOINSOON ELECTRONICS MFG. CO., LTD.	TW
145	JORUDAN CO., LTD.	JP
146	JYE TAI PRECISION INDUSTRIAL COMPANY LIMITED	TW
147	K3 BUSINESS TECHNOLOGY GROUP PLC	GB
148	KAIMEI ELECTRONIC CORPORATION	TW
149	KING CORE ELECTRONICS INC.	TW
150	KINGPAK TECHNOLOGY INC.	TW
151	KINGSTATE ELECTRONICS CORP.	TW
152	KOLLAKORN CORPORATION LIMITED	AU
153	KOPIN CORP	US
154	KORTEK CORPORATION	KR
155	KOZO KEIKAKU ENGINEERING INC	JP
156	KUBOTEK CORPORATION	JP
157	KVH INDUSTRIES INC	US
244	SAMCO INC.	JP
245	SAN LIEN TECHNOLOGY CORPORATION	TW
246	SASKEN COMMUNICATION TECHNOLOGIES LTD.	IN
247	SCHWEIZER ELECTRONIC AG	DE
248	SCI ENGINEERED MATERIALS, INC.	US
249	SCIENTECH CORPORATION	TW
250	SEA SONIC ELECTRONICS CO., LTD.	TW
251	SENETAS CORPORATION LIMITED	AU
252	SENSYS GATSO GROUP AB	SE
253	SENTRONIC INTERNATIONAL CORP.	TW
254	SEOHWA, INC.	KR
255	SEVCON INC	US
256	SHIAN YIH ELECTRONIC INDUSTRY CO., LTD.	TW
257	SHINSUNG SOLAR ENERGY CO.,LTD.	KR
258	SIGMA DESIGNS INC	US
259	SIGMA KOKI CO., LTD.	JP
260	SINGATRON ENTERPRISE CO., LTD.	TW
261	SINGLE WELL INDUSTRIAL CORPORATION	TW
262	SIWARD CRYSTAL TECHNOLOGY CO., LTD	TW
263	SKARDIN INDUSTRIAL CORP.	TW
264	SOBAL CORPORATION	JP
265	SOFTING AG	DE
266	SONO-TEK CORPORATION	US
267	SPACE HELLAS S.A. TELECOMMUNICATIONS, IT, SECURITY SERVICES PRIVATE ENTERPRISE FOR PROVISION OF SECU	GR
268	SPEED TECH CORPORATION	TW
269	STADIUM GROUP PLC	GB
270	SUCCESS PRIME CORPORATION	TW
271	SUKEGAWA ELECTRIC CO., LTD.	JP
272	SUN BROTHERS DEVELOPMENT CO., LTD.	TW
273	SUPERCOM LTD.	IL
274	SYNECTICS PLC	GB
275	SYNTEK SEMICONDUCTOR CO., LTD.	TW
276	SYSCOM COMPUTER ENGINEERING CORPORATION	TW
277	SYSGRATION LIMITED	TW
278	SYSTEMS & TECHNOLOGY CORPORATION	TW
279	TA LIANG TECHNOLOGY CO., LTD.	TW
280	TA YANG GROUP HOLDINGS LIMITED	KY
281	TA-I TECHNOLOGY CO., LTD.	TW
282	TAI TWUN ENTERPRISE CO., LTD.	TW
283	TAILYN TECHNOLOGIES, INC.	TW
284	TAIWAN ALPHA ELECTRONIC CO., LTD.	TW
285	TAIWAN CHINSAN ELECTRONIC INDUSTRIAL CO.	TW
286	TAIWAN KONG KING CO., LTD.	TW
287	TAIWAN MASK CORPORATION	TW
288	TAIWAN THICK-FILM IND. CORP.	TW
289	TAIYO INDUSTRIAL CO., LTD.	JP
290	TAZMO COMPANY LIMITED	JP
291	TEAM YOUNG ADVANCED TECHNOLOGY CO., LTD.	TW
292	TEAPO ELECTRONIC CORPORATION	TW
293	TECHFIRM HOLDINGS INC.	JP
294	TECHNICAL COMMUNICATIONS CORP	US
295	TECSYS INC	CA
296	TELES AG INFORMATIONSTECHNOLOGIEN	DE
297	TELKONET, INC.	US
298	TEST RESEARCH INC	TW
299	THINKING ELECTRONIC INDUSTRIAL CO., LTD.	TW
300	TOKYO KOKI CO., LTD.	JP
301	TONTEK DESIGN TECHNOLOGY LIMITED	TW
302	TOSE CO LTD	JP
303	TOTAL SOFT BANK CO.,LTD.	KR
304	TOUCHSTAR PLC	GB
305	TOUKEI COMPUTER CO LTD	JP
306	TRADETOOL AUTO CO., LTD.	TW
307	TRANSYSTEM,INC.	TW
308	TRIO-TECH INTERNATIONAL	US
309	TYNTEK CORPORATION	TW
310	U.I.D CO.,LTD.	KR
311	UNIFORM INDUSTRIAL CORP.	TW
312	UNIQUE OPTICAL INDUSTRIAL CO., LTD.	TW
313	UNITED FIBER OPTIC COMMUNICATION INCORPORATED	TW
314	UNITED RADIANT TECHNOLOGY CORPORATION	TW
315	UNITEL HIGH TECHNOLOGY CORPORATION	TW
316	UNITRONICS	IL
317	UNIVERSAL DISPLAY CORP	US
318	UNIVERSAL MICROELECTRONICS COMPANY LIMITED	TW
319	USUN TECHNOLOGY COMPANY LIMITED	TW
320	VATE TECHNOLOGY COMPANY LIMITED	TW
321	VERITEC INC.	US
322	VICON INDUSTRIES, INC.	US
323	VICTORY CIRCUIT COMPANY LIMITED	TW

158	LANNER ELECTRONICS INC.	TW
159	LASER TEK TAIWAN CO., LTD.	TW
160	LASERTEC CORPORATION	JP
161	LEALEA HOTELS & RESORTS CO., LTD.	TW
162	LEATEC FINE CERAMICS COMPANY LIMITED	TW
163	LEDTECH ELECTRONICS CORP.	TW
164	LEGEND CORPORATION LIMITED	AU
165	LEM HOLDING SA	CH
166	LENECO CO.,LTD.	KR

324	VISCOM AG	DE
325	WELTREND SEMICONDUCTOR, INC.	TW
326	WHA YU INDUSTRIAL CO., LTD.	TW
327	WHOLETECH SYSTEM HITECH LTD.	TW
328	WIRELESS TELECOM GROUP INC	US
329	WORLD REACH LIMITED	AU
330	Y-S ELECTRONIC CO., LTD.	TW
331	YUAN HIGH-TECH DEVELOPMENT COMPANY LIMITED	TW
332	YUFO ELECTRONIC CORP.	TW

Appendix 7: List of companies included in the study: mature-large group

No.	Company name	Country
1	A&D COMPANY LIMITED	JP
2	ACCTON TECHNOLOGY CORPORATION	TW
3	ACER INC.	TW
4	ADTRAN INC	US
5	ADVANCED CONNECTEK INC.	TW
6	ADVANCED MICRO DEVICES INC	US
7	ADVANCED SEMICONDUCTOR ENGINEERING INC	TW
8	ADVANCED SEMICONDUCTOR MANUFACTURING CORPORATION LTD	CN
9	ADVANTECH CO., LTD.	TW
10	ADVANTEST CORPORATION	JP
11	AGILYSYS, INC.	US
12	AICHI TOKEI DENKI CO LTD	JP
13	AIPHONE CO., LTD.	JP
14	AIXTRON SE	DE
15	ALCATEL LUCENT TELETAS TELEKOMUNIKASYON A.S	TR
16	ALCATEL-LUCENT S.A.	FR
17	ALLGEIER SE	DE
18	ALLIED TELESIS HOLDINGS K.K.	JP
19	ALLTEK TECHNOLOGY CORP.	TW
20	ALPHA SYSTEMS INC	JP
21	ALPS ELECTRIC CO LTD	JP
22	ALTRAN TECHNOLOGIES SA	FR
23	AMANO CORPORATION	JP
24	AMS AG	AT
25	ANALOG DEVICES INC	US
26	AOI ELECTRONICS CO LTD	JP
27	APIC YAMADA CORPORATION	JP
28	APPLE INC.	US
29	APPLIED MATERIALS INC	US
30	ARCHOS	FR
31	ARISAWA MANUFACTURING CO LTD	JP
32	ARM HOLDINGS PLC	GB
33	ASCOM HOLDING AG	CH
34	ASIA OPTICAL COMPANY INC	TW
35	ASIA VITAL COMPONENTS COMPANY LIMITED	TW
36	ASM PACIFIC TECHNOLOGY LIMITED	KY
37	ASML HOLDING N.V.	NL
38	ASUSTEK COMPUTER INCORPORATION	TW
39	AT&S AUSTRIA TECHNOLOGIE & SYSTEMTECHNIK AG	AT
40	ATEN INTERNATIONAL COMPANY LIMITED	TW
41	AUTOMATED SYSTEMS HOLDINGS LIMITED	BM
42	AVID TECHNOLOGY INC	US
43	AVISION INC.	TW
44	AXIS AB	SE
45	AZBIL CORPORATION	JP
46	AZION CORPORATION	TW
47	BADGER METER INC	US
48	BELIER ELECTRONICS AB	SE
49	BELDEN INC.	US
50	BOARDTEK ELECTRONICS CORPORATION	TW
51	BROTHER INDUSTRIES LTD	JP
52	CA, INC.	US
53	CAC HOLDINGS CORPORATION	JP
54	CADENCE DESIGN SYSTEMS INC	US
55	CAMEO COMMUNICATIONS INC.	TW
56	CANON ELECTRONICS INC	JP
57	CANON INC	JP
58	CAPCOM CO LTD	JP
59	CATCHER TECHNOLOGY COMPANY LIMITED	TW
60	CENIT AG	DE
61	CENTROTHERM PHOTOVOLTAICS AG	DE
62	CHAINTECH TECHNOLOGY CORPORATION	TW
63	CHAMPION TECHNOLOGY HOLDINGS LIMITED	BM
64	CHANG WAH ELECTRONMATERIALS INC.	TW
65	CHAUN-CHOUNG TECHNOLOGY CORP.	TW
66	CHENBRO MICOM CO., LTD.	TW
67	CHENG UEI PRECISION INDUSTRY CO., LTD.	TW
68	CHENMING MOLD INDUSTRIAL CORPORATION	TW
69	CHICONY ELECTRONICS CO., LTD.	TW
70	CHIN-POON INDUSTRIAL COMPANY LIMITED	TW
71	CHINO CORPORATION	JP
72	CHROMA ATE INC.	TW
73	CHUNGHWA PICTURE TUBES, LTD.	TW
74	CICOR TECHNOLOGIES SA	CH
75	CISCO SYSTEMS INC	US
76	CITIZEN HOLDINGS CO., LTD.	JP
77	CITRIX SYSTEMS INC	US

No.	Company name	Country
239	LAM RESEARCH CORP	US
240	LARGAN PRECISION COMPANY LIMITED	TW
241	LATTICE SEMICONDUCTOR CORP	US
242	LEADTEK RESEARCH INC	TW
243	LECTRA SA	FR
244	LELON ELECTRONICS CORPORATION	TW
245	LENOVO GROUP LIMITED	HK
246	LEXMARK INTERNATIONAL INC	US
247	LINGSEN PRECISION INDUSTRIES LIMITED	TW
248	LITE-ON JAPAN LTD	JP
249	LITE-ON SEMICONDUCTOR CORP.	TW
250	LITE-ON TECHNOLOGY CORPORATION	TW
251	LOGITECH INTERNATIONAL SA	CH
252	LOTES CO., LTD.	TW
253	LUMAX INTERNATIONAL CORP. LTD.	TW
254	MACRONIX INTERNATIONAL COMPANY LIMITED	TW
255	MALAYSIAN PACIFIC INDUSTRIES BHD	MY
256	MANZ AG	DE
257	MARKETECH INTERNATIONAL CORP.	TW
258	MARUWA CO LTD	JP
259	MATRIX IT LIMITED	IL
260	MAXIM INTEGRATED PRODUCTS INC	US
261	MEGAFORCE CO., LTD.	TW
262	MELEXIS N.V.	BE
263	MENSCH UND MASCHINE SOFTWARE SE	DE
264	MENTOR GRAPHICS CORP	US
265	MERRY ELECTRONICS CO., LTD.	TW
266	MICRO FOCUS INTERNATIONAL PLC	GB
267	MICRO-STAR INTERNATIONAL CO., LTD.	TW
268	MICROCHIP TECHNOLOGY INC	US
269	MICROELECTRONICS TECHNOLOGY INC	TW
270	MICRON TECHNOLOGY INC	US
271	MICRONAS SEMICONDUCTOR HOLDING AG	CH
272	MICRONICS JAPAN CO LTD	JP
273	MICROSEMI CORP	US
274	MIMASU SEMICONDUCTOR INDUSTRY CO LTD	JP
275	MIN AIK TECHNOLOGY COMPANY LIMITED	TW
276	MIRAIAL CO., LTD.	JP
277	MITAC INC.	TW
278	MITACHI CO LTD	JP
279	MITSUBISHI RESEARCH INSTITUTE, INC.	JP
280	MITSUI HIGH-TEC INC	JP
281	MITSUMI ELECTRIC CO LTD	JP
282	MKS INSTRUMENTS INC	US
283	MOSEL VITELIC INC	TW
284	MOTECH INDUSTRIES INC.	TW
285	MOTOROLA SOLUTIONS, INC.	US
286	MTS SYSTEMS CORP	US
287	MURATA MANUFACTURING CO. LIMITED	JP
288	MUTOH HOLDINGS CO., LTD.	JP
289	NAKAYO, INC.	JP
290	NANJING PUTIAN TELECOMMUNICATIONS CO., LTD.	CN
291	NCR CORP	US
292	NEC CORPORATION	JP
293	NEC NETWORKS & SYSTEM INTEGRATION CORPORATION	JP
294	NEMETSCHEK SE	DE
295	NET ONE SYSTEMS CO LTD	JP
296	NETAS TELEKOMUNIKASYON A.S.	TR
297	NEW JAPAN RADIO CO LTD	JP
298	NICE LTD	IL
299	NICHICON CORPORATION	JP
300	NIFTY CORPORATION	JP
301	NIHON INTER ELECTRONICS CORP	JP
302	NIHON UNISYS LTD	JP
303	NIIT LIMITED	IN
304	NINTENDO CO LTD	JP
305	NIPPON AVIONICS CO LTD	JP
306	NIPPON CERAMIC CO LTD	JP
307	NIPPON CHEMI-CON CORPORATION	JP
308	NIPPON COMPUTER DYNAMICS CO, LTD.	JP
309	NIPPON ELECTRIC GLASS CO., LTD.	JP
310	NIPPON SIGNAL CO LTD	JP
311	NIPPON SYSTEMWARE CO LTD	JP
312	NJK CORPORATION	JP
313	NOHMI BOSAI LTD	JP
314	NOKIA OYJ	FI
315	NOMURA RESEARCH INSTITUTE, LTD.	JP

78	CLEVO COMPUTER COMPANY LIMITED	TW
79	CMC MAGNETICS CORPORATION	TW
80	CMK CORPORATION	JP
81	COHERENT INC	US
82	COMPAL ELECTRONICS INC	TW
83	COMPEQ MANUFACTURING COMPANY LIMITED	TW
84	COMPUTER ENGINEERING & CONSULTING LTD	JP
85	COMTECH TELECOMMUNICATIONS CORP	US
86	CONTEC CO., LTD.	JP
87	CORE CORPORATION	JP
88	CORNING INC	US
89	COSMO ADVANCED MATERIALS & TECHNOLOGY CO.,LTD.	KR
90	COXON PRECISE INDUSTRIAL COMPANY LIMTED	TW
91	CRAY INC.	US
92	CREATIVE TECHNOLOGY LTD	SG
93	CRESCO LTD	JP
94	CTS CORP	US
95	CYBERNET SYSTEMS COMPANY LIMITED	JP
96	CYPRESS SEMICONDUCTOR CORP	US
97	D-LINK CORPORATION	TW
98	DAI-ICHI SEIKO CO., LTD.	JP
99	DAIDO SIGNAL CO LTD	JP
100	DAIKO DENSHI TSUSHIN LIMITED	JP
101	DAISHINKU CORPORATION	JP
102	DAITO ELECTRON CO LTD	JP
103	DAIWABO HOLDINGS CO., LTD.	JP
104	DAKTRONICS INC	US
105	DARWIN PRECISIONS CORPORATION	TW
106	DATA MODUL AG	DE
107	DATACOLOR AG	CH
108	DATALINK CORP	US
109	DATALOGIC SPA	IT
110	DBTEL INCORPORATED	TW
111	DELTA ELECTRONICS (THAILAND) PCL	TH
112	DELTA ELECTRONICS INC	TW
113	DENKI KOGYO CO LTD	JP
114	DENSAN SYSTEM CO LTD	JP
115	DI-NIKKO ENGINEERING	JP
116	DIALOG SEMICONDUCTOR PLC	GB
117	DIGI INTERNATIONAL INC	US
118	DIODES INC	US
119	DISCO CORPORATION	JP
120	DKK TOA CORPORATION	JP
121	DTS CORP.	JP
122	DYNAMIC ELECTRONICS CO., LTD.	TW
123	EIZO CORPORATION	JP
124	ELECTRONIC ARTS INC	US
125	ELECTRONICS FOR IMAGING INC	US
126	ELITEGROUP COMPUTER SYSTEMS CO., LTD.	TW
127	ELMOS SEMICONDUCTOR AG	DE
128	ELNA CO LTD	JP
129	ENLIGHT CORPORATION	TW
130	ENOMOTO CO LTD	JP
131	ENPLAS CORPORATION	JP
132	ESPEC CORPORATION	JP
133	ETRON TECHNOLOGY, INCORPORATED	TW
134	EVANS & SUTHERLAND COMPUTER CORP	US
135	EVERLIGHT ELECTRONICS CO., LTD.	TW
136	EXAR CORP	US
137	EXFO INC.	CA
138	F-SECURE OYJ	FI
139	FAIR ISAAC CORPORATION	US
140	FDK CORPORATION	JP
141	FEI COMPANY	US
142	FENWAL CONTROLS OF JAPAN LTD	JP
143	FLIR SYSTEMS INC	US
144	FORMOSA ADVANCED TECHNOLOGIES CO., LTD	TW
145	FORMULA SYSTEMS (1985) LIMITED	IL
146	FORWARD ELECTRONICS CO., LTD.	TW
147	FOXCONN TECHNOLOGY CO., LTD.	TW
148	FUJI SOFT INC.	JP
149	FUJIFILM HOLDINGS CORP.	JP
150	FUJITSU FRONTECH LTD.	JP
151	FUJITSU LIMITED	JP
152	FURUNO ELECTRIC CO LTD	JP
153	FURUYA METAL CO., LTD.	JP
154	FUTURE CORPORATION	JP
155	GEMTEK TECHNOLOGY COMPANY LIMITED	TW
156	GENIUS ELECTRONIC OPTICAL CO., LTD.	TW
316	NOVABASE - SOCIEDADE GESTORA DE PARTICIPACOES SOCIAIS, SA	PT
317	NOVANTA INC	CA
318	NS SOLUTIONS CORPORATION	JP
319	NSD CO., LTD.	JP
320	NTT DATA CORPORATION	JP
321	OBIC BUSINESS CONSULTANTS CO LTD	JP
322	OBIC CO LTD	JP
323	OHARA INC	JP
324	OIZUMI CORPORATION	JP
325	OKAYA ELECTRIC INDUSTRIES CO LTD	JP
326	OKI ELECTRIC INDUSTRY CO LTD	JP
327	OMRON CORPORATION	JP
328	ONO SOKKI CO LTD	JP
329	OPEN TEXT CORPORATION	CA
330	OPTEX CO LTD	JP
331	OPTO TECH CORPORATION	TW
332	ORBOTECH LTD.	IL
333	ORIENT SEMICONDUCTOR ELECTRONICS, LIMITED	TW
334	ORIGIN ELECTRIC CO LTD	JP
335	OSAKI ELECTRIC CO LTD	JP
336	OTSUKA CORPORATION	JP
337	OXFORD INSTRUMENTS PLC	GB
338	P-TWO INDUSTRIES INC.	TW
339	PALTEK CORPORATION	JP
340	PAN JIT INTERNATIONAL INC.	TW
341	PAN-INTERNATIONAL INDUSTRIAL CORP.	TW
342	PANASONIC INDUSTRIAL DEVICES SUNX CO., LTD.	JP
343	PCI LTD	SG
344	PHOTRONICS INC	US
345	PLANTRONICS INC	US
346	POLYCOM INC	US
347	PREMIER FARNELL PLC	GB
348	PRIMAX ELECTRONICS LIMITED	TW
349	PROGRESS SOFTWARE CORP	US
350	PROMATE ELECTRONIC COMPANY LIMITED	TW
351	PSI AG FUR PRODUKTE UND SYSTEME DER INFORMATIONSTECHNOLOGIE	DE
352	QISDA CORPORATION	TW
353	QUALCOMM INC	US
354	QUANTA COMPUTER INC.	TW
355	QUEST HOLDINGS S.A.	GR
356	RADISYS CORP	US
357	REALTEK SEMICONDUCTOR CORP.	TW
358	RENISHAW P L C	GB
359	RISO KAGAKU CORPORATION	JP
360	RITEK CORPORATION	TW
361	RM PLC	GB
362	ROHM COMPANY LIMITED	JP
363	ROLAND DG CORPORATION	JP
364	RYODEN CORPORATION	JP
365	RYOSAN CO LTD	JP
366	S&T AG	AT
367	SANKEN ELECTRIC CO LTD	JP
368	SANKO CO LTD	JP
369	SANMINA CORPORATION	US
370	SANSHIN ELECTRONICS CO., LTD.	JP
371	SAP SE	DE
372	SATORI ELECTRIC CO LTD	JP
373	SCHAFFNER HOLDING AG	CH
374	SCREEN HOLDINGS CO., LTD.	JP
375	SCSK CORPORATION	JP
376	SDI CORPORATION	TW
377	SEKONIC HOLDINGS CORPORATION	JP
378	SEMTECH CORP	US
379	SHINDENGEN ELECTRIC MANUFACTURING CO LTD	JP
380	SHINKAWA LTD	JP
381	SHINKO ELECTRIC INDUSTRIES CO., LTD.	JP
382	SHUTTLE INC.	TW
383	SIGURD MICROELECTRONICS CORPORATION	TW
384	SILICON INTEGRATED SYSTEMS CORP.	TW
385	SILICONWARE PRECISION INDUSTRIES COMPANY LIMITED	TW
386	SINBON ELECTRONICS COMPANY LIMITED	TW
387	SINO-AMERICAN SILICON PRODUCTS INCORPORATED	TW
388	SIRTEC INTERNATIONAL COMPANY LIMITED	TW
389	SMA SOLAR TECHNOLOGY AG	DE
390	SMK CORPORATION	JP
391	SOFT-WORLD INTERNATIONAL CORPORATION	TW
392	SOFTWARE AG	DE
393	SOLITON SYSTEMS K.K.	JP
394	SOLOMON TECHNOLOGY CORP.	TW

157	GETAC TECHNOLOGY CORPORATION	TW
158	GFT TECHNOLOGIES SE	DE
159	GIGABYTE TECHNOLOGY COMPANY LIMITED	TW
160	GIGASET AG	DE
161	GILAT SATELLITE NETWORKS LTD.	IL
162	GL SCIENCES INC	JP
163	GLOBAL BRANDS MANUFACTURE LTD.	TW
164	GMO INTERNET INC.	JP
165	GOLD CIRCUIT ELECTRONICS LIMITED	TW
166	GREATEK ELECTRONICS INC.	TW
167	HAKUTO CO LTD	JP
168	HAMAMATSU PHOTONICS KK	JP
169	HANNSTAR BOARD CORPORATION	TW
170	HARRIS CORP	US
171	HCL INFOSYSTEMS LTD	IN
172	HCL TECHNOLOGIES LIMITED	IN
173	HEXAWARE TECHNOLOGIES LTD	IN
174	HI-P INTERNATIONAL LTD	SG
175	HILLS LIMITED	AU
176	HIOKI E E CORPORATION	JP
177	HIROSE ELECTRIC COMPANY LIMITED	JP
178	HITRON TECHNOLOGIES INC	TW
179	HOCHIKI CORPORATION	JP
180	HOKURIKU ELECTRIC INDUSTRY CO LTD	JP
181	HOLY STONE ENTERPRISE COMPANY LIMITED	TW
182	HON HAI PRECISION INDUSTRY CO., LTD.	TW
183	HONDA TSUSHIN KOGYO CO LTD	JP
184	HORIBA LTD	JP
185	I-CHIUN PRECISION INDUSTRY COMPANY LIMITED	TW
186	I-NET CORP	JP
187	I-O DATA DEVICE INC	JP
188	IAC/INTERACTIVECORP	US
189	IBIDEN CO LTD	JP
190	ICHIA TECHNOLOGIES, INC	TW
191	ICOM INCORPORATED	JP
192	IKEGAMI TSUSHINKI CO LTD	JP
193	INES CORPORATION	JP
194	INFO-TEK CORP.	TW
195	INFORMATION SERVICES INTERNATIONAL-DENTSU LTD	JP
196	INGENICO GROUP SA	FR
197	INNOTECH CORPORATION	JP
198	INTEL CORP	US
199	INTERNATIONAL BUSINESS MACHINES CORP	US
200	INVENTEC CORPORATION	TW
201	ISB CORPORATION	JP
202	ITOCHU TECHNO-SOLUTIONS CORPORATION	JP
203	ITRON INC	US
204	IWATSU ELECTRIC CO LTD	JP
205	JAPAN AVIATION ELECTRONICS INDUSTRY LIMITED	JP
206	JAPAN CASH MACHINE CO LTD	JP
207	JAPAN DIGITAL LABORATORY CO LTD	JP
208	JAPAN ELECTRONIC MATERIALS CORPORATION	JP
209	JAPAN RADIO CO LTD	JP
210	JASTEC COMPANY LIMITED	JP
211	JBCC HOLDINGS INC.	JP
212	JENOPTIK AG	DE
213	JENTECH PRECISION INDUSTRIAL COMPANY LIMITED	TW
214	JETWAY INFORMATION COMPANY LIMITED	TW
215	JFE SYSTEMS INC.	JP
216	JOOYON TECH CO.,LTD.	KR
217	JUSTSYSTEMS CORPORATION	JP
218	KAGA ELECTRONICS CO LTD	JP
219	KANEMATSU ELECTRONICS LTD	JP
220	KAPSCH TRAFFICCOM AG	AT
221	KATSURAGAWA ELECTRIC CO LTD	JP
222	KEMET CORP	US
223	KEY TRONIC CORP	US
224	KEYENCE CORPORATION	JP
225	KING YUAN ELECTRONICS COMPANY LIMITED	TW
226	KINKO OPTICAL COMPANY LIMITED	TW
227	KLA-TENCOR CORP	US
228	KOA CORPORATION	JP
229	KONTRON AG	DE
230	KORYO ELECTRONICS CO., LTD.	TW
231	KPIT TECHNOLOGIES LIMITED	IN
232	KUDELSKI SA	CH
233	KULICKE & SOFFA INDUSTRIES INC	US
234	KURAMOTO CO., LTD.	JP
235	KYOCERA CORPORATION	JP
395	SOLYTECH ENTERPRISE CORPORATION	TW
396	SONG SHANG ELECTRONICS CO., LTD.	TW
397	SOPRA STERIA GROUP	FR
398	SPECTRIS PLC	GB
399	SPIRENT COMMUNICATIONS PLC	GB
400	SPIROX CORPORATION	TW
401	SQS SOFTWARE QUALITY SYSTEMS AG	DE
402	SQUARE ENIX HOLDINGS CO., LTD.	JP
403	STMICROELECTRONICS N.V.	NL
404	SUMIDA CORPORATION	JP
405	SUNNIC TECHNOLOGY & MERCHANDISE INC.	TW
406	SUNPLUS TECHNOLOGY CO., LTD.	TW
407	SUNREX TECHNOLOGY CORPORATION	TW
408	SUPREME ELECTRONICS COMPANY LIMITED	TW
409	SUSS MICROTEC AG	DE
410	SUZUKI CO LTD	JP
411	SYMANTEC CORP	US
412	SYNNEX TECHNOLOGY INTERNATIONAL CORPORATION	TW
413	T-MAC TECHVEST PCB CO., LTD.	TW
414	TAIWAN SEMICONDUCTOR CO., LTD.	TW
415	TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY LIMITED	TW
416	TAIWAN SURFACE MOUNTING TECHNOLOGY CORPORATION	TW
417	TAIYO YUDEN COMPANY LIMITED	JP
418	TAMURA CORPORATION	JP
419	TCL DISPLAY TECHNOLOGY HOLDINGS LIMITED	BM
420	TECOM COMPANY LIMITED	TW
421	TELEFONAKTIEBOLAGET LM ERICSSON	SE
422	TERADYNE INC	US
423	TEXAS INSTRUMENTS INC	US
424	THE SAGE GROUP PLC.	GB
425	TIETO OYJ	FI
426	TKC CORPORATION	JP
427	TOKYO ELECTRON DEVICE LIMITED	JP
428	TOKYO ELECTRON LIMITED	JP
429	TOKYO SEIMITSU COMPANY LIMITED	JP
430	TONG HSING ELECTRONIC INDUSTRIES, LTD.	TW
431	TOPCON CORPORATION	JP
432	TOSHIBA TEC CORPORATION	JP
433	TOTVS S.A.	BR
434	TOYO CORPORATION	JP
435	TRANSCEND INFORMATION, INC.	TW
436	TRANSCOSMOS INC	JP
437	TREND MICRO INCORPORATED	JP
438	TRIMBLE NAVIGATION LTD	US
439	TRIPOD TECHNOLOGY CORPORATION	TW
440	TRULY INTERNATIONAL HOLDINGS LIMITED	KY
441	TT ELECTRONICS PLC	GB
442	TWINHEAD INTERNATIONAL CORP.	TW
443	TXC CORPORATION	TW
444	TYLER TECHNOLOGIES INC	US
445	ULVAC INC	JP
446	UNIDEN HOLDINGS CORPORATION	JP
447	UNIMICRON TECHNOLOGY CORPORATION	TW
448	UNIPLUS ELECTRONICS COMPANY LIMITED	TW
449	UNISYS CORP	US
450	UNITECH COMPUTER CO., LTD.	TW
451	UNITECH PRINTED CIRCUIT BOARD CORP.	TW
452	UNITED MICROELECTRONICS CORPORATION	TW
453	UTSTARCOM HOLDINGS CORP.	KY
454	VEECO INSTRUMENTS INC	US
455	VTECH HOLDINGS LIMITED	BM
456	WACOM CO LTD	JP
457	WAH HONG INDUSTRIAL CORPORATION	TW
458	WAH LEE INDUSTRIAL CORPORATION	TW
459	WALSIN TECHNOLOGY CORPORATION	TW
460	WINBOND ELECTRONICS CORPORATION	TW
461	WUS PRINTED CIRCUIT CO., LTD.	TW
462	XCERRA CORPORATION	US
463	YAGEO CORPORATION	TW
464	YAMAICHI ELECTRONICS CO LTD	JP
465	YANGTZE OPTICAL FIBRE AND CABLE JOINT STOCK LIMITED COMPANY	CN
466	YASKAWA ELECTRIC CORPORATION	JP
467	YASKAWA INFORMATION SYSTEMS CORPORATION	JP
468	YFC-BONEAGLE ELECTRIC CO., LTD.	TW
469	YOKOGAWA ELECTRIC CORPORATION	JP
470	YOKOWO CO LTD	JP
471	YOUNGTEK ELECTRONICS CORP.	TW
472	ZEBRA TECHNOLOGIES CORP	US
473	ZENITRON CORPORATION	TW

236	KYORITSU ELECTRIC CORPORATION	JP
237	KYOSAN ELECTRIC MANUFACTURING CO LTD	JP
238	KYOWA ELECTRONIC INSTRUMENTS CO LTD	JP

474	ZENSAR TECHNOLOGIES LIMITED	IN
475	ZETES INDUSTRIES	BE
476	ZINWELL CORPORATION	TW
477	ZUKEN INC	JP