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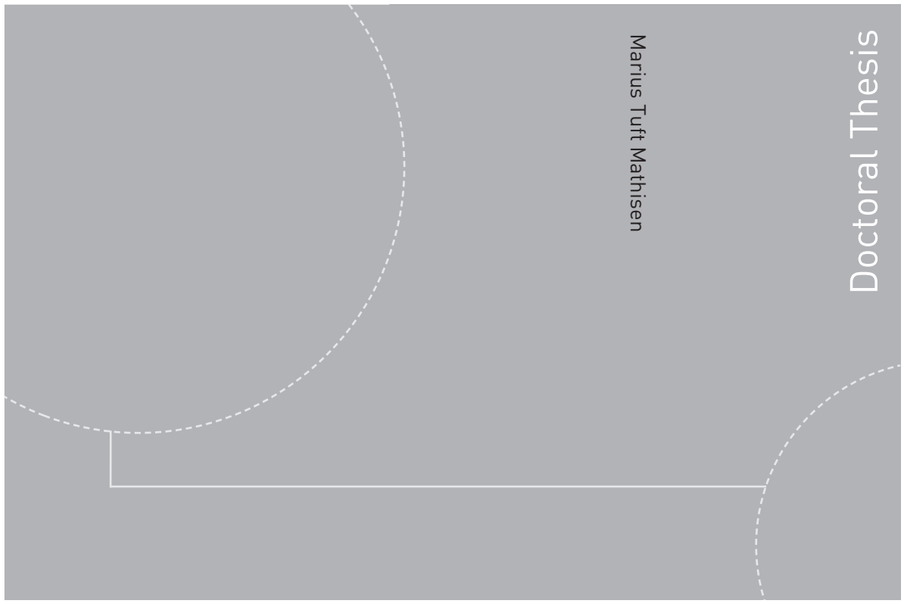

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Marius Tuft Mathisen

The Growth of Research-Based Spin-Offs:

Unleashing the Value of Academic Entrepreneurship

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Thesis for the degree of Philosophiae Doctor

Trondheim, August 2017

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THE GROWTH OF RESEARCH-BASED SPIN-OFFS: UNLEASHING THE VALUE OF ACADEMIC ENTREPRENEURSHIP

by

Marius Tuft Mathisen

Dissertation submitted to:

Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Industrial Economics and Technology Management

for the degree of Ph.D.

ABSTRACT

This dissertation explores the phenomenon of new ventures established to commercialize scientific knowledge, technologies, and inventions from universities and public research institutions. These research-based spin-off companies (RBSOs) are considered to be a source of significant wealth creation, and an important mechanism for transferring technology to industry. However, most research of RBSOs focus on how many new ventures are established with limited attention given to the growth of these firms. While existing studies point to celebrated success stories, other studies claim that the majority of RBSOs remain small, achieve negligible growth, and deliver limited economic impact. Our knowledge into the growth of such ventures remains fragmented and lack robust theoretical foundations. This motivates this dissertation's overall research question: *"How do research-based spin-offs develop, grow, and perform?"*

The dissertation pursues two related objectives. From a practical perspective, it aims to elucidate how RBSOs successfully transform scientific research into commercial product and services. From a theoretical perspective, it seeks to increase our conceptual understanding of how RBSOs grow, with emphasis on heterogeneity and complexity of growth processes and outcomes. With this, the dissertation contributes into the literatures of academic entrepreneurship and new venture growth.

These objectives are addressed through five independent research papers and a cover essay. The cover essay provides an overarching theoretical framework for the dissertation, adopting a Penrosean perspective of growth which integrates the concepts of uncertainty and knowledge resources. The cover essay consolidates the individual research papers in a coherent manner that responds to the dissertation's overall research question. The empirical research is conducted within a critical realist research tradition, and follow a mixed method approach which combine both quantitative and qualitative research designs. A unique and comprehensive database was developed which longitudinally track the national population of all Norwegian RBSOs which were established between the years 1999 and 2011. The database is comprised of 373 RBSOs, and was developed by integrating a range of high-quality archival data sources with proprietary data based on detailed manual coding of the growth process of each firm. Further, this quantitative data is supplemented with a multiple case study of nine trade sales, theoretically sampled from the population of RBSOs.

The first research paper is a comprehensive literature review synthesizing the fragmented literature of the development, growth, and performance of RBSOs. It contributes with a state-of-the-art assessment of the current state of knowledge and outlines promising areas of further research. Two research papers address the growth of RBSOs at an aggregated portfolio level. The second research paper studies the effect of national- and university level framework conditions on the quantity and quality of RBSOs. Through a longitudinal, multilevel, and cross-country analysis of the populations of RBSOs in the UK, Italy and Norway, this study finds that changes in framework conditions are conducive to the creation of RBSOs but at the expense of the quality of these firms. This finding demonstrates that growth and performance of RBSOs are distinct issues from number of firms established, and that the effect of "top-down" changes in framework conditions seems to be more symbolic than substantive. Hence, "bottom-up" support structures are likely more important to assist with the resource demanding commercialization processes RBSOs face.

The third research paper uses a portfolio perspective to assess the economic value creation of the national population of RBSOs in Norway. The study finds that the timespan to successful commercialization can be very long. The most promising and growth-oriented firms spend several years with high losses when developing their technologies. Further, value creation follow highly skewed distributions, where a few firms dominate the total output. Also, trade sales appear on the surface to provide marginal value creation, but more precise analyses reveal that trade sales carry substantial value which is not recognized through conventional financial growth measures. Finally, supporting analysis finds that growth is not uniform and consistent, but rather characterized as discontinuous and erratic. Only a small minority of firms achieve consistent growth, and growth setbacks are equally frequent. Overall, these findings increase our understanding on the growth paths and outcomes RBSOs take on an aggregate level.

Two research papers address the growth of RBSOs at the firm level, focusing specifically on trade sales as a specific growth outcome. The fourth research paper is a qualitative case study of nine trade sales from the portfolio, and aims to develop new conceptual insights into how RBSOs grow firm value in the context of trade sales. Drawing on fifty-two interviews with entrepreneurs, investors, board members, advisors, and buyer representatives, the study inductively develops propositions which outline dynamic relationships of the mechanisms in RBSOs' development processes which contribute to growth in firm value. The study provides new insights into the process of growth, demonstrating how growth is path-dependent, context-

sensitive, and takes complex trajectories. A novel finding is that the extent of growth is related to the idiosyncratic dyad of the firm and its potential partners. Finally, trade sales can act as a distinct mechanism of growth used by RBSOs to fulfil commercialization processes. The final paper in the dissertation uses RBSOs as the empirical context to test and extend signaling theory. Event history analysis is conducted on the national population of RBSOs in Norway, and the findings contribute with new insights of the signal value of the entrepreneurs' ownership in the firm. More specifically, the study finds that the relationship between the entrepreneurs' ownership stakes and trade sale probability is curvilinear, and conditional on both professional investor ownership and time unfolding.

Overall, this dissertation advances new insights into the complex and heterogeneous growth processes, mechanisms, and outcomes that RBSOs pursue to overcome technological, market and organizational uncertainty, and successfully commercialize new scientific discoveries. It contributes to the academic entrepreneurship literature with novel perspectives on the growth of RBSOs which has been overlooked compared with new venture creation. Through a longitudinal study of the full population of RBSOs in a single country, this research demonstrates that growth outcomes follow highly skewed distributions, and that successful commercialization often need long time to materialize. Further, growth is shown to be primarily discontinuous and shaped by technological and market breakthroughs. Finally, the dissertation draws attention to trade sales being a frequent venture outcome, which has been largely ignored in the existing literature. More specifically, this research points to the tendency of promising firms to be acquired while still being young and unprofitable.

The dissertation contributes to the new venture growth literature with new conceptual insights into growth modes and measures. The study broadens the current conceptualization of growth modes by demonstrating how trade sales can act as a distinct mechanism of growth used by RBSOs to fulfil commercialization processes. Finally, it demonstrates that firm value is a critical facet of growth for knowledge-intensive new ventures. Firm value permeates other more commonly used growth measures such as sales and employment, which are better understood as intermediary variables facilitating growth in firm value.

Besides theoretical development, the dissertation provides a number of important implications for entrepreneurs, public research organizations and policymakers.

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A Ph.D. project is an individual, and sometimes lonely journey, but at the same time it is a team effort. I am indebted to many people over the last four years who have helped, supported, instructed, inspired, guided, challenged, and collaborated with me along that journey.

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Thank you Einar (Rasmussen) for inviting me to be your deputy in the ambitious research endeavor to map the life history of all research-based spin-offs in Norway. We have come a long way since we started in 2013. You have graciously opened up and invited me into your academic network, which has allowed me to interact and cooperate with the leading authorities in our field. This entire dissertation is influenced by your academic imprint, and we have co-authored two of the research papers included here. You are an outstanding scholar, and it has been a pleasure to learn from and work with you. I will particularly remember our numerous discussions over lunch and late night beers during our joint research visit in Bologna.

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Marius Tuft Mathisen,
Oslo, May 2017.

NOMENCLATURE

ASO:	See RBSO
BOD:	Board of directors
BRREG:	The Brønnøysund Register Centre
B/S:	The balance sheet in financial statements
CEO:	Chief executive officer
CR:	Critical realism
FORNY:	The most important governmental funding program for supporting activities related to commercialization of research results. The program was managed by RCN, and operated from 1995-2012
ICT:	Information and communication technology
IP:	Intellectual property
IPO:	Initial public offering
IPR:	Intellectual property rights
NTBF:	New technology-based firm
RBSO:	Research-based spin-off. Also known in the literature as university spin-off (USO), academic spin-off (ASO), science-based entrepreneurial firm (SBEF), among others
RCN:	The Research Council of Norway
RCT:	Randomized controlled trial
R&D:	Research and development
P&L:	The profit and loss statement in financial statements
PRI:	Publicly funded research institutes
PRO:	Public research organizations, including universities (incl. university hospitals), university colleges and publicly funded research institutes
SBEF:	See RBSO
TTO:	Technology transfer office. Used in this dissertation as a collective term for technology transfer offices, science parks, and incubators associated with universities and PRIs
USO:	See RBSO
VC:	Venture capitalist firm

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PART 1:

COVER ESSAY

1 INTRODUCTION

Universities are increasingly involved in establishing new ventures aiming to commercialize scientific research results, technologies, and inventions (Clarysse et al., 2007; Colombo et al., 2010a; Lubik and Garnsey, 2016; Mustar et al., 2008). These **research-based spin-offs (RBSOs)** represent a small part of all knowledge transfer from academic institutions, but are considered to be economically impactful new firms with significant wealth creation potential (Shane, 2004). RBSOs are expected to enhance economic development by creating new knowledge-based employment, tax revenues, and indirect effects through the dissemination of new technology and, thereby, improve the absorptive capacity of the region (Criaco et al., 2014; Hindle and Yencken, 2004; Lawton Smith et al., 2008; Vincett, 2010). Scholars have also argued that RBSOs are important because they commercialize research results that might have remained undeveloped otherwise (Fontes, 2005). As basic scientific research has a different or, rather, non-commercial agenda compared with research in industry, this could result in the serendipitous discovery of technologies and know-how that can save and protect human life, property, and the environment. More generally, RBSOs often commercialize new, radical technologies with significant technical advances typically not suitable for licensing to industry (Clausen and Rasmussen, 2013; Shane, 2004). In other words, RBSOs are new ventures with the potential of engaging in the type of entrepreneurial activity that challenges existing technologies and markets (Mohr and Garnsey, 2011; Schumpeter, 1934; Walter et al., 2006), and it is the phenomenon under study in this dissertation.

The high expectations to the economic and societal impacts of RBSOs are evident. Yet, the academic entrepreneurship literature has predominantly looked at what determines the number of RBSOs universities create (O'Shea et al., 2008), i.e., the process from discovery to creation. Albeit important to understand, this focus leaves a serious gap in our understanding of RBSOs as this stream of research has paid less attention to the quality of these firms, and provides limited insight for explaining how RBSOs grow to become successful firms and create economic impact (Colombo et al., 2010a; Powers and McDougall, 2005; Van Looy et al., 2011). Recent research has pointed out that successful RBSOs are few and far in between (Harrison and Leitch, 2010; Mustar et al., 2008). Paradoxically, when successes do occur, they can generate tremendous impact (Rasmussen and Mathisen, 2017) and many extremely valuable firms, including some of most important firms globally (e.g., Google), originated by virtue of academic research. Further, RBSOs face exceptional growth challenges (Mustar et al., 2008), being characterized with high levels of innovation and often exploiting novel, early-stage, and

general purpose technologies (Knockaert et al., 2011; Shane, 2001a, b). In addition, RBSOs often struggle with attracting critical resources (e.g., Patzelt and Shepherd, 2009; Wright et al., 2006) and knowledge (e.g., Ensley and Hmieleski, 2005; Hayter, 2016a; Rasmussen et al., 2015). To succeed, RBSOs must overcome technological, market, and organizational uncertainty in the process of transforming scientific knowledge into commercial products and services (Rasmussen and Mathisen, 2017). It remains clear that we still have a limited understanding of the development processes, growth trajectories, and ultimate performance of RBSOs (Ambos and Birkinshaw, 2010; Meoli et al., 2013; Zerbinati et al., 2012). To advance our knowledge of RBSOs, and provide research with meaningful implications for theory and practitioners, I argue research should be realigned toward the growth of RBSOs, i.e., the process from creation to outcome. Accordingly, the overall research question for this dissertation is:

"How do research-based spin-offs develop, grow, and perform?"

This dissertation builds on the literatures of academic entrepreneurship and new venture growth, seeking to advance our understanding of the development, growth, and performance of RBSOs. The theoretical framework is inspired by Penrose (1959), which conceptualized growth as a cumulative process of development in which the firm builds knowledge and competencies. From this, a multidimensional, heterogeneous, and dynamic perspective of growth is adopted (Leitch et al., 2010), with a stronger emphasis on growth processes, modes, mechanisms, and trajectories. Further, the theoretical concepts of uncertainty (Knight, 1921) and knowledge resources (e.g., Grant, 1996a; Kogut and Zander, 1992; Nonaka and Konno, 1998; Zahra et al., 2007) are integrated to conceptualize the challenges and obstacles RBSOs must overcome to achieve growth. While there is entrepreneurial zest in the growth for firms of all sizes (cf. Penrose, 1959), the growth of young knowledge-intensive ventures is distinct due to the challenges generated by uncertainty and knowledge resources. Growth has long been a major theme in entrepreneurship research (and vice versa) (Davidsson et al., 2006: 20-38), and the distinction of when entrepreneurship ends and growth begins is like two sides of the same coin (Garnsey, 1998). I develop a conceptual framework for the dissertation that links the concepts of development, growth, and performance of new ventures in the context of academic entrepreneurship.

The overall research question is primarily addressed through five research papers, each exploring specific research questions relevant to informing the dissertation's overall topic. The

development, growth, and performance of RBSOs are studied on both the firm as well as an aggregate portfolio level of analysis. The focus of the firm-level studies is *trade sales* (i.e., acquisitions[1]), which is determined to be a very important performance outcome for RBSOs. The focus of the portfolio-level studies is to explore the heterogeneity of RBSO performance outcomes as well as the quantity/quality relationship. The common thread for all empirical papers is the research context, which is the nationwide population of RBSOs established in Norway between 1999 and 2011, and tracked longitudinally until 2015. A sequential mixed-method research design (Creswell and Clark, 2007: 211) is adopted that combines a comprehensive quantitative portfolio analysis followed by qualitative multiple case studies of nine trade sales in the portfolio. This research design answers calls in the new venture growth literature for more multi-level and longitudinal evidence tracking cohorts of new ventures from their genesis (Anyadike-Danes et al., 2009; Mohr and Garnsey, 2011).

The research papers presented in Part 2 of this dissertation are stand-alone works, responding to gaps and contributing to specific streams of literature. To be clear, not all the research papers are positioned explicitly in the literature of new venture growth or draw directly on the concepts of uncertainty and knowledge resources. Rather, each paper is narrowly focused, exploring specific aspects of RBSO development, growth, and performance and often drawing on other relevant literature and theories. Together, the introductory cover essay of Part 1 and the five research papers in Part 2 address the dissertation's overall research question. Table 1-1 provides a brief overview of the research papers in Part 2.

Research Paper	Research Questions	Level of Analysis	Literature/ Theoretical Frameworks	Research Design
1. *The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications*	Which factors impact the development, growth, and performance of university spin-offs?	Firm	• Academic Entrepreneurship	• Conceptual (Literature Review)
2. *Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study*	How do changes in the institutional framework at national and university levels influence the quantity and the quality of spin-offs from a university?	Portfolio	• Institutional Theory • Entrepreneurship Framework Conditions	• Quantitative
3. *Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012*	What is the value creation of a national population of science-based entrepreneurial firms?	Portfolio	• Uncertainty • Real Options	• Quantitative
4. *Growing Firm Value: New Venture Growth and Trade Sales of Research-Based Spin-Offs*	How do technology-based entrepreneurial ventures grow firm value in the context of trade sales to industry incumbents?	Firm	• Uncertainty • Information Asymmetry • Knowledge Resources • New Venture Growth • Technology Acquisitions	• Qualitative
5. *Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions*	How does insider ownership provide signals to facilitate transactions in contexts characterized by large information asymmetries? How is the value of insider ownership signals affected by time and other ownership-related signals?	Firm	• Signaling Theory • Technology Acquisitions	• Quantitative
Dissertation	How do research-based spin-offs develop, grow, and perform?	Portfolio Firm	• Academic Entrepreneurship • New Venture Growth • Uncertainty • Knowledge Resources	• Mixed Method

Table 1-1: Brief overview over the research papers in Part 2.

Overall, this dissertation advances new insights into the complex and heterogeneous growth processes, mechanisms, and outcomes that RBSOs pursue to overcome technological, market and organizational uncertainty, and successfully commercialize new scientific discoveries. It contributes to the academic entrepreneurship literature with novel perspectives on the growth of RBSOs which has been overlooked compared with new venture creation. Through a longitudinal study of the full population of RBSOs in a single country, this research demonstrates that growth outcomes follow highly skewed distributions, and that successful commercialization often need long time to materialize. Further, growth is shown to be primarily discontinuous and shaped by technological and market breakthroughs. Finally, the dissertation draws attention to trade sales being a frequent venture outcome, which has been largely ignored in the existing literature. More specifically, this research points to the tendency of promising firms to be acquired while still being young and unprofitable.

The dissertation contributes to the new venture growth literature with new conceptual insights into growth modes and measures. The study broadens the current conceptualization of growth modes by demonstrating how trade sales can act as a distinct mechanism of growth used by RBSOs to fulfil commercialization processes. Finally, it demonstrates that firm value is a critical facet of growth for knowledge-intensive new ventures. Firm value permeates other more commonly used growth measures such as sales and employment, which are better understood as intermediary variables facilitating growth in firm value.

1.1 Outline of Dissertation

This dissertation has two main parts. Part 1 is a cover essay providing the overall theoretical, methodological, and empirical foundations for the research conducted. It also outlines the main content, findings, and implications of the dissertation. Part 2 contains five independent research papers, each connected to the overall theme of the dissertation. Part 1 proceeds as follows. Chapter 2 develops a theoretical and conceptual framework suitable to study the development and growth of RBSOs. Chapter 3 presents the methodology of the dissertation, including philosophical perspectives, methodological measurements, positions and influences, research design, and data collection. Chapter 4 presents a descriptive analysis of the empirical research context of this dissertation (i.e., the population of RBSOs in Norway). Chapter 5 provides summaries of the five research papers in Part 2. In conclusion, Chapter 6 discusses the dissertation's overall findings, contributions and implications.

2 THEORETICAL FRAMEWORK

This chapter develops a theoretical framework specifically suitable for exploring the development, growth, and performance of RBSOs. This research is informed by, and aims to contribute to, two distinct bodies of literature. First, the dissertation will be positioned within the academic entrepreneurship literature, identifying the research gaps that have inspired this dissertation's overall research question. Only a limited review will be conducted, as Paper 1 in Part 2 is a comprehensive literature review of aspects of academic entrepreneurship directly relevant to this dissertation. Second, the dissertation will be positioned within the new venture growth literature, adopting a Penrosean perspective that conceptualizes growth as an internal process of development. In addition to drawing on these two literatures, Knightian uncertainty is integrated with the concept of knowledge resources to help conceptualize the theoretical obstacles RBSOs must overcome during the growth process. Finally, these theoretical components are integrated together in a conceptual framework where the intended contribution of the dissertation is positioned.

2.1 Academic Entrepreneurship

The expectations of universities are changing. Traditionally, the university is an institution of higher education and scientific research. However, universities are increasingly expected to be commercial exploiters of their scientific and technological advances (Hayter, 2016b; Leitch et al., 2010; Pries and Guild, 2007; Rothaermel et al., 2007). As such, the modern university is best understood within the context of Academic Capitalism (Slaughter and Rhoades, 2004) or Triple Helix (Etzkowitz and Leydesdorff, 2000) frameworks, which emphasizes its role in knowledge-based economic development (Hayter, 2011). Academic entrepreneurship is usually defined broadly as entrepreneurial activity at academic institutions, including patenting, technology licensing, and spinning off new ventures; all with the objective of commercializing research results discovered by academic researchers (Grimaldi et al., 2011; Rothaermel et al., 2007). As a field of research, it is connected to and overlaps with subjects such as technology and knowledge transfer (see Bozeman, 2000; Perkmann et al., 2013), university-industry collaboration (see Agrawal, 2001; Bozeman et al., 2013), and technology commercialization (see Kirchberger and Pohl, 2016; Markman et al., 2008). Further, academic entrepreneurship has been studied at several levels, ranging from the role of the entrepreneurial university in socio-economic development (e.g., Etzkowitz et al., 2000), down to the entrepreneurial behavior of scientists (e.g., Huyghe and Knockaert, 2015; Stuart and Ding, 2006). In between are policy-level studies focusing on the effects of legislation and policy instruments (e.g.,

Goldfarb and Henrekson, 2003; Kochenkova et al., 2016); institutional-level studies focusing on intermediary agents, such as science parks, incubators, and technology transfer offices (TTOs) (e.g., Mian et al., 2016; Phan et al., 2005; Siegel et al., 2007), and firm-level studies focusing on new ventures (e.g., Djokovic and Souitaris, 2008). In sum, academic entrepreneurship is a multidisciplinary field with many objectives and perspectives.

The narrow focus of this dissertation is RBSOs, i.e., new ventures established to commercialize scientific research results, technologies, and inventions from universities and public research institutions (PRIs) (Clarysse et al., 2005). Significant growth in the creation of RBSOs has been observed in recent years (Colombo et al., 2010a; Mustar et al., 2008). Several environmental and institutional changes motivating this development have been proposed. Inspired by the Bayh-Dole Act in the US, many countries have implemented new intellectual property rights (IPR) legislation that grant universities control over internally developed inventions (ending the so-called "professor's privilege") (Damsgaard and Thursby, 2013; Grimaldi et al., 2011). These changes provide an increased incentive and opportunity for universities to capitalize on their assets (Wright et al., 2007). In addition, a range of other factors play a role, including: 1) funding for universities are decreasing and/or becoming more competitive; (2) social accountability pressures and institutional expectations from governments and society; (3) the emergence of new technological areas where new scientific discoveries have direct industrial value; (4) increased availability of public and venture capital (VC) funding; and (5) new support institutions like science parks, incubators, and technology transfer offices established by or close to the university (Chiesa and Piccaluga, 2000; Clarysse et al., 2007; Mowery, 2011; Mustar et al., 2008).

The vast majority of research on RBSOs has focused on the antecedents of spin-off activity, more specifically how individual (e.g., scientist, entrepreneur), institutional (e.g., university, technology transfer office), and environmental (e.g., legislation, ecosystems) conditions impact spin-off creation (O'Shea et al., 2008). This "black box" approach to RBSOs implicitly assumes that firms are homogeneous (Mustar et al., 2008) and that the number of firms corresponds to economic impact (Harrison and Leitch, 2010). The former is challenged by researchers finding that RBSOs are a surprisingly heterogeneous group of firms that differs in terms of resources, business model, and institutional links (Mustar et al., 2008). Table 2-1 presents a brief overview of the sources of heterogeneity.

Area	Source	Examples
Resources	Type of knowledge	• Explicit or tacit knowledge (e.g., Bathelt et al., 2010; Djokovic and Souitaris, 2008; Karnani, 2013; Pirnay et al., 2003)
	Individuals involved	• Academic, student or external entrepreneur (e.g., Franklin et al., 2001; Kassicieh, 2011; Lundqvist, 2014; Nicolaou and Birley, 2003; Radosevich, 1995)
Business Model	Business activities	• Contract R&D, licensing, technical consulting, products, or services (e.g., Druilhe and Garnsey, 2004; Hindle and Yencken, 2004)
	Growth orientation	• High-growth or lifestyle business (e.g., Mustar et al., 2008)
Institutional Links	Partnerships	• Industry joint ventures (e.g., Wright et al., 2004)
	Sponsorship	• Degree of support from university or PRO (e.g., Bathelt et al., 2010; Clarysse et al., 2005; Fini et al., 2010)
	Technology transfer	• Equity, license, or no transfer (Hindle and Yencken, 2004)

Table 2-1: Sources of heterogeneity of RBSOs at establishment.

With respect to the latter, scholars have questioned the expected impact of RBSOs, arguing they are predominantly small firms (e.g., Criaco et al., 2014; Salvador, 2011), showing negligible growth on average (e.g., Hayter, 2011; Wright et al., 2006), and occurring in such small numbers they have limited total economic impact as to not justify the public support they receive (Borlaug et al., 2009; Harrison and Leitch, 2010). In sum, although our understanding of the antecedents of spin-off creation is maturing, these divergent views illustrate that this stream of research provides very limited insight explaining how RBSOs become successful firms and create economic impact (Colombo et al., 2010a). While scholars have paid more attention to such issues recently (Patzelt and Shepherd, 2009), this emerging literature is fragmented and lacks theoretical grounding (cf. Paper 1 in Part 2). These gaps are important to address because governments and universities are investing heavily to encourage and support RBSOs, including establishing TTOs, incubators, and internal seed funds (Rasmussen et al., 2006). Policy work will be ineffective without understanding the differences of circumstances affecting the creation and subsequent growth of RBSOs (Harrison and Leitch, 2010). Obviously, the genuine policy objective is to generate successful firms creating wealth for society; not just establish many firms. Further, scientists, entrepreneurs, and investors seek better knowledge on how to successfully develop RBSOs given the tremendous growth challenges they face (Mustar et al., 2008). Hence, these identified gaps represent the area where this dissertation intends to

contribute, and the main motivation for the overall research question of this thesis: *"How do research-based spin-offs develop, grow, and perform?"*

2.2 Theoretical Perspectives on New Venture Growth

With the dissertation's research question in mind, the relevant theoretical realm to consider is new venture growth. Before focusing on new venture growth, the literature on firm growth more generally, which typically targets larger firms, will be briefly reviewed. I will demonstrate that new venture growth is theoretically distinct from growth for larger firms. Further, for the specific context of RBSOs, this dissertation adopts a Penrosean conceptualization of an internal process of development as the most meaningful way to understand growth.

Firm Growth

Firm growth is a fundamental topic in both economics and strategic management, and can be traced back to Penrose (1959) seminal contribution. Penrose opposed the way the firm, its size and growth were understood at the time. Neoclassical economics viewed firms as rational, profit-maximizing, and single-product entities that only interact with the market to determine price based on supply and demand. The objective of the firm was to reach its optimal size (in terms of output), and growth was just a process of adjustment to that end (Coad, 2009: 5). Penrose's position was that the firm in economic theory did not correspond to the "'*flesh and blood' organizations that businessmen call firms*" (Penrose, 1959: 12). She argued that firm size was just a consequence of the growth process, and the idea of optimal firm size was fundamentally flawed. Although Penrose principally studied growth by diversification for large firms and her theoretical reasoning mostly concerned the reasons and limits of growth, her contributions have profoundly influenced later theorizing on firm growth, including new venture growth (Garnsey, 1998) as well as a range of other theoretical work in management[2].

In the study of firm growth, much research has confirmed that the distribution of growth rates is fat-tailed, implying that extreme and sudden growth events are expected relatively frequently (Coad, 2009: 25). Explaining growth rates, however, has proven very challenging and modeling growth as a purely random stochastic process, independent of firm size, remains the leading approximate description (known as Gibrat's law of proportionate effect) (Coad, 2009: 12; Gibrat, 1931). To be clear, previous research has found many variables to have statistically significant impact, but each contributes very little to an overall explanation of firm growth (Dobbs and Hamilton, 2007). This includes factors such as profitability, productivity,

innovation, competition, industry, macroeconomics, and several other firm-specific factors (Coad, 2009: 84-100). Overall, firm growth appears to be remarkably idiosyncratic and the low explanatory power of proposed variables implies that growth cannot be predicted with any accuracy (Coad, 2009: 96).

However, there is a large and growing body of research that rejects Gibrat's law based on evidence that small and young firms grow faster, and in different ways, than large and old firms (Coad, 2009: 40). For instance, smaller firms are found to have more erratic and mean-reverting growth than larger firms, where exceptional growth is unlikely to be consistent over time (Coad, 2007). Further, smaller firms are associated more with organic growth, whereas acquisitive growth is more common for larger firms (Delmar et al., 2003). Perhaps most importantly, new ventures may not have any other choice than to grow. Growth provides legitimacy[3] (Nason and Wiklund, 2015) and has consistently been shown to lead to lower failure rates for new ventures (Coad et al., 2013; Gilbert et al., 2006; Phillips and Kirchhoff, 1989). In contrast, the objectives of growth, survival, and profits for larger firms are distinct and may conflict at times (Coad, 2009: 135). Further, Penrose (1959: 87) argues that larger firms may benefit from "economics of growth" derived from their accumulated resource bases. Among all the various apparent differences between small and large firms, perhaps the most acute is the entrepreneur's decision making gradually being replaced with a bureaucratic structure as a consequence of growth. In sum, new venture growth is a theoretically distinct phenomenon (Gilbert et al., 2006).

New Venture Growth

The literature on new venture growth can be categorized into two streams of research, which can be traced back to two distinct Penrosean perspectives on growth. Penrose (1959: 1) argued that growth can be understood either as 1) merely an increase in amount, e.g., in output, sales, employment, or 2) an *internal process of development*, where an interactive series of events leads to expansion, accompanied by changes in the characteristics of the growing object. The majority of research on new venture growth has been concerned with the former. Most of this research attempts to explain variance in growth rates across ventures and link this to particular variables of interest (McKelvie and Wiklund, 2010). This essentially extends the approach applied for firm growth more generally. It may seem obvious that entrepreneurs must access resources that enable growth, arrange an organization that accommodates growth, and deploy a growth strategy in an industry conducive for growth (Gilbert et al., 2006). However, few determinants have received consistent empirical support predicting the rate of growth for new

ventures, and most studies only consider one particular perspective on growth (for a notable exception see Wiklund et al., 2009).

Another approach within this stream of research are stage-based models of growth (Garnsey et al., 2006), which assume new ventures expand consecutively through a sequence of stages (Levie and Lichtenstein, 2010). Stage-based models of growth have been a very popular approach, but also received major criticism. First, there is no agreement on the number, type, or description of stages, which leads to most stage-based models claiming to be "universal" (Levie and Lichtenstein, 2010). Second, the models assume that ventures progress through stages in a deterministic manner. In reality, many new ventures fail or do not experience any significant growth (Garnsey, 1998). In addition, many ventures face recurring problems or several obstacles at the same time (Garnsey et al., 2006). Third, the major focus of such models is on identifying factors that enable advancement to the next stage. Hence, this research is not really about growth itself, but on the consequences of growth (McKelvie and Wiklund, 2010). Finally, stage-based models are mostly static and assume linear and incremental transitions between stages (Levie and Lichtenstein, 2010). Research suggests that new venture growth is highly dynamic and discontinuous (Garnsey et al., 2006), and can occur through mechanisms other than organic growth (McKelvie and Wiklund, 2010). Case in point, Penrose (1952) was not a supporter of stage-based models, stating that they: "contribute little […] to the theory of growth and development of firms and in general tend to confuse the nature of the important issues." In short, stage-based models do not reflect the chaotic reality of how entrepreneurs grow firms. Overall, the results from both variance- and stage-based models of growth have been disappointing with respect to theoretical development (Delmar et al., 2003; McKelvie and Wiklund, 2010; Nason and Wiklund, 2015; Wright and Stigliani, 2013).

In light of limited theoretical progress, some scholars have argued that the search for a unified theory of new venture growth is futile because growth is a multidimensional, heterogeneous, and complex phenomenon (Leitch et al., 2010; Stam et al., 2006). This position corresponds to the second Penrosean growth perspective and several arguments have been advanced supporting a radical change in the focus of growth research. First, there is no consensus on how to measure growth and, typically, low shared variance between different growth measures (Achtenhagen et al., 2010; Shepherd and Wiklund, 2009). Theoretical development is dubious when results are sensitive to which measure of growth is applied.

Second, the measures of growth typically used may not represent the most relevant for entrepreneurial practice. For instance, Achtenhagen et al. (2010) found that many entrepreneurs are mostly concerned with growth in *firm value*. The commonly studied measures of growth (e.g., sales, employment etc.) were only seen as important in the role of intermediary variables that facilitate an increase in firm value (Garnsey, 1998). In fact, Penrose (1959: 22) preferred firm value as the appropriate measure of growth although recognizing the empirical challenges with this construct in practical research.

Third, attempts to explain differences in growth rates do not recognize qualitatively distinctive means to achieve growth. McKelvie and Wiklund (2010) argue that organic, acquisitive, and hybrid (e.g., licensing, strategic alliances) represent distinct *modes of growth*. Other researchers have built on this perspective and suggested other qualitative differences in ways of growing such as domestic vs. international growth, product improvement vs. new product introductions, reselling to existing customers vs. acquisition of new customers (Navarro et al., 2012), as well as combinations of growth modes (Achtenhagen et al., 2016). Most growth research assumes organic growth; but the mechanisms causing organic growth may be different from other modes of growth. McKelvie and Wiklund (2010) thus recommend that theoretical development can be advanced by changing the focus from growth rates to growth modes.

Fourth, new ventures are highly heterogeneous with respect to growth. For instance, entrepreneurs with ambition and motivation to grow are more likely to experience actual growth (Delmar and Wiklund, 2008; Wiklund and Shepherd, 2003). Another example is that innovation is found to be of crucial importance for the fastest growing ventures, but not generally (Coad and Rao, 2008).

Finally, there is a greater need to understand the dynamic processes that underlie growth (Stam, 2010; Wright and Stigliani, 2013). New venture growth is generally not linear, sustained, or consistent over time (Derbyshire and Garnsey, 2015; Leitch et al., 2010). The majority of ventures do not experience any significant growth at all while some experience very high growth (Coad et al., 2014; Garnsey et al., 2006). Further, new ventures might utilize different mechanisms of growth at different points in time (Achtenhagen et al., 2016). Growth has also been shown to be discontinuous as ventures can experience periods with stagnation and contraction (Garnsey and Heffernan, 2005).

This dissertation adopts a multidimensional, heterogeneous, and dynamic perspective of growth, inspired by Penrosean thinking having with a stronger emphasis on the internal process of development, including growth modes, processes, and mechanisms. This view provides a range of new opportunities for advancing richer theories of new venture growth. It advocates narrower theoretical development that focuses on specific aspects of growth, with clearer boundary conditions and context specificity (Coad and Guenther, 2014; Leitch et al., 2010; McKelvie and Wiklund, 2010; Shepherd and Wiklund, 2009). This includes new perspectives of growth including the relationship and interactions between different measures of growth (Coad et al., 2013; Delmar et al., 2013; Federico and Capelleras, 2015), the dynamic processes of growth (Achtenhagen et al., 2016; Navarro et al., 2012; Stam, 2010; Wright and Stigliani, 2013), and going beyond the traditional measures of growth (Achtenhagen et al., 2010; McKelvie and Wiklund, 2010).

Growth as Performance. Performance as Growth

Growth has long been a major theme in entrepreneurship research (and vice versa) and the conceptual distinction of when entrepreneurship "ends" and growth "begins" is blurred and more a matter of semantics than being theoretically distinct. In the early stages of venture development, there is so much overlap between the concepts of entrepreneurship and growth that they can be viewed as interchangeable (Davidsson et al., 2006: 20-32). Garnsey (1998) argues that new ventures must access, mobilize, and deploy certain key resources to enable growth. In other words, the entrepreneurial challenge of constructing the initial resource base (Brush et al., 2001) is critical to facilitate growth (Garnsey et al., 2006). From this perspective, entrepreneurship is growth in the initial stages of a venture because growth (in the traditional sense of expansion in size) cannot occur without it. Usually, growth is seen as a distinct dimension of venture performance; a dimension that is particularly relevant for the performance of entrepreneurial ventures (Wright and Stigliani, 2013). The position taken in this dissertation is that the concepts of growth and performance are so conjoined that they cannot be meaningfully separated to understand success in the early (i.e., entrepreneurial) development of RBSOs (Vohora et al., 2004).

This position follows aptly from the refined multidimensional theoretical perspective of growth adopted in this dissertation. Growth is not only understood as expansion in size, but also the outcome of an entrepreneurial process of development. RBSOs are known to have very long development paths when commercializing its technologies, inventions, and scientific

knowledge (Lawton Smith et al., 2008; Mustar et al., 2006; Rasmussen et al., 2015). Hence, RBSOs may invariably spend prolonged periods without expansion in the traditional measures of growth such as revenue (Fini et al., 2016). However, from the perspective of the entrepreneurs, the value of the firm will be increasing (i.e., growing) as a consequence of successfully progressing with, e.g., technological advancements, obtaining VC financing, contracting with pilot customers, and other key milestones (Achtenhagen et al., 2010). According to Davidsson et al. (2006: 7), it is not defensible using growth as the only measure if the true interest is in performance generally. Rather, other relevant measures of performance should be considered in addition to growth (Dahlqvist et al., 2000). This approach also addresses the fact that some new ventures will not experience any growth (Davidsson et al., 2006: 32).

Hence, this dissertation adopts the model in Figure 2-1, which outlines the performance outcomes considered most important in the context of RBSOs. The model is developed in a more technical methodological analysis of performance and growth measures in Section 3.3.

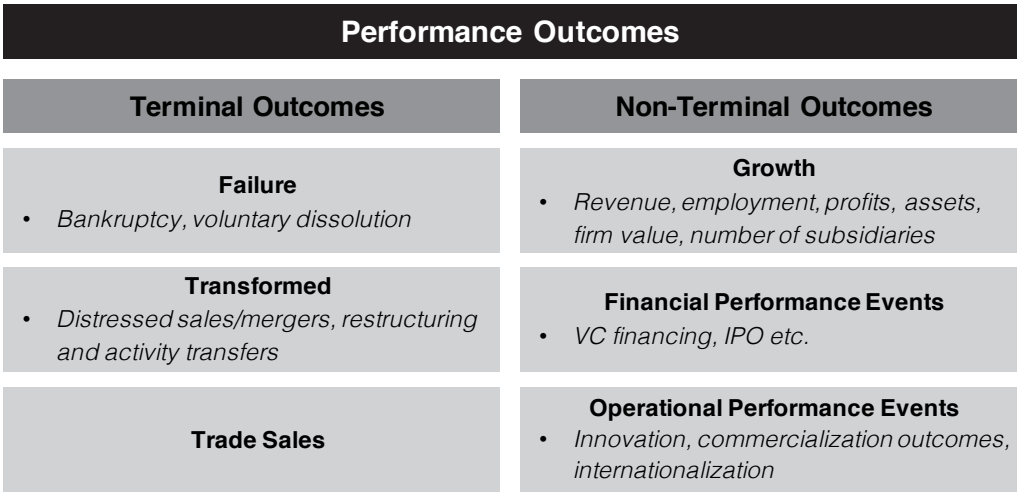


Figure 2-1: Conceptual model of empirical performance outcomes considered in scope of this research.

To clarify, I am not arguing that theoretical development should be done using the composite view illustrated in Figure 2-1 as the only possible performance outcomes. Rather, as discussed earlier, theory should be developed and tested narrowly with specific aspects of growth or performance in mind. For instance, two of the papers in Part 2 specifically focus on trade sales

as a specific and, as it turns out, very influential, performance outcome for RBSOs. Paper 4 aims to contribute with new theoretical insight into how new ventures grow firm value in the context of trade sales. Paper 5 focuses on how the effect of ownership signals by RBSOs affects their propensity to be acquired. Nevertheless, the overall research question of this dissertation is broader and seeks to understand the development and early growth of RBSOs more generally. From this broader perspective, a more contextually relevant view of venture performance, therefore, is endorsed (Venkatraman and Ramanujam, 1986).

2.3 Uncertainty and Knowledge Resources

Uncertainty is a defining theoretical foundation of the analysis of new venture growth because growth inevitably involves expansion into new areas (Coad, 2009: 5). Uncertainty is a particularly prevalent challenge for RBSOs as they have to overcome technological, market, and organizational uncertainty to successfully commercialize their innovations. RBSOs commercialize knowledge resources, which generally are associated with far more uncertainty compared with physical resources (Coff, 1999). Knowledge is a complex resource with unique management challenges, and successful commercialization processes involve transforming the form, content, and structure of the RBSO's knowledge resources.

Knightian Uncertainty

Uncertainty has always been considered a central characteristic of entrepreneurship (Alvarez and Busenitz, 2001; McKelvie et al., 2011), and has inspired the study of concepts like entrepreneurial action (McKelvie et al., 2011), opportunity (Alvarez and Barney, 2007; Sarasvathy et al., 2003) and decision making (Alvarez and Busenitz, 2001; Sarasvathy, 2001). In his seminal contribution, Knight (1921) argued the presence of "true uncertainty" was the theoretical basis for entrepreneurs to earn economic rents, even in the case of perfect competition. Knightian uncertainty is distinct from risk because it cannot be measured or calculated (Cowan, 2016). Uncertain situations are not only unknown, but also unknowable, with unclassifiable instances and a non-existent distribution (Sarasvathy et al., 2003). In other words, whereas risk is linked to probabilistic outcomes, uncertainty is associated with a fundamental lack of information. Decision making under conditions of uncertainty is extremely difficult and entrepreneurs are known to apply creative decision making logic to that end (Fisher, 2012). For instance, entrepreneurs have been found to engage in a socially constructed iterative enactment process when forming opinions and making decisions under conditions of uncertainty (Alvarez et al., 2015).

RBSOs are knowledge-based new ventures and generally commercialize knowledge that is new to the market (Roininen and Ylinenpää, 2009; Walter et al., 2006). As a consequence, RBSOs are known to be particularly associated with uncertainty occurring on several levels (Rasmussen et al., 2011). First, RBSOs typically commercialize early-stage and novel scientific discoveries that initially takes the form of "proofs and prototypes" (Jensen and Thursby, 2001; Shane, 2004: 103). Hence, there is *technological uncertainty* of the feasibility of the technology to function profitability outside the lab and at an industrial scale (Berk et al., 2004; Lubik and Garnsey, 2016). Second, RBSOs typically commercialize innovations that can be characterized as technology push rather than market pull. Because the technology tends to be radical and general purpose (Shane, 2001a), this creates *market uncertainty* as it is not immediately clear which market, if any, (or alternatively if a new market is required) is most attractive (Gruber et al., 2013). Further, RBSOs are known to be remote from the end consumer and must often choose between multiple disparate markets and applications (Lubik and Garnsey, 2016). The combination of these characteristics implies that RBSOs typically have very long development paths and require substantial risk capital to reach the market (Rasmussen and Mathisen, 2017; Wright et al., 2006). Third, the academic origin creates *organizational uncertainty* as the ventures emerge in a non-commercial environment (Vohora et al., 2004). Academia and business have different cultures and access to commercial competencies is often limited in universities (Rasmussen et al., 2011). In addition, RBSOs are usually dependent on interacting with outside organizations, such as industry partners, to access complementary resources (Lubik and Garnsey, 2016; Rasmussen et al., 2015).

In sum, the high level of uncertainty represents a critical challenge to RBSOs because the specifics of the development process are unknown and the eventual outcome will typically be in the distant future. Further, uncertainty is an essential reason for the skewed distribution of entrepreneurship outcomes generally, and for RBSO outcomes in particular, where a few firms are responsible for a disproportionate part of total returns[4]. Please see Section 3.4 for further elaboration of the consequences of such skewed distributions.

Knowledge Resources

The knowledge of the entrepreneurial team is considered the most important resource for new technology-based firms (NTBFs) to achieve growth (Alvarez and Busenitz, 2001; de Boer et al., 1999). This follows Penrosean reasoning of the knowledge of the firm's management being

the key resource facilitating growth (Kor and Mahoney, 2000; Lockett, 2005; Rugman and Verbeke, 2002). This is especially the case for RBSOs established with the objective to create commercial value from new scientific breakthroughs. The RBSO's initial knowledge resources are typically embodied by academic inventors, and are very narrowly oriented around the technology (Clarysse et al., 2007; Knockaert et al., 2011). However, these initial knowledge resources cannot be directly deployed in the market; rather, they must be commercialized into marketable products and services (Widding, 2007). This commercialization process involves transforming the form (i.e., from tacit to explicit), the content (i.e., integrating complementary knowledge), and the structure (i.e., from individual to organizational knowledge) of the RBSO's knowledge resources.

Knowledge can conceptually be divided into tacit and explicit components (Nonaka and Konno, 1998; Polanyi, 1967). Although the exact boundary conditions of tacit knowledge is still debated, it is evident that, in the words of (Polanyi, 1967: 4): *"we can know more than we can tell."* Tacit knowledge is personal, experience-based, intuitive, context-dependent, and cannot easily be expressed or diffused (Gourlay, 2006; Howells, 2002). The characteristics of tacit knowledge make it highly non-scalable and an ill-adapted form of knowledge to facilitate growth alone. Explicit knowledge, on the other hand, can be documented and expressed in the form of, e.g., text, numbers, and figures. In the case of NTBFs, formal intellectual property rights (IPR), such as patents, are examples of potentially valuable and rare explicit knowledge (Clarysse et al., 2011). However, patents alone are often insufficient when commercializing new technology, as critical knowledge needed to develop the technology into commercial products still reside as tacit knowledge with the entrepreneurs (Knockaert et al., 2015; Knockaert et al., 2011; Lowe, 2006).

Scientific and technical knowledge is not sufficient to ensure successful technology commercialization (Criaco et al., 2014; Gurdon and Samsom, 2010). RBSOs usually need a diverse set of manufacturing, distribution, marketing, management, and financial knowledge to succeed in technology commercialization (Widding, 2005; Zahra et al., 2007). RBSOs are characterized by homogeneous management teams consisting of largely scientific expertise (Ensley and Hmieleski, 2005; Franklin et al., 2001) and, thus, are dependent on accessing complementary knowledge and experience. RBSOs able to attract relevant commercial and industry knowledge are found to achieve higher growth (Meyer, 2003; Mueller et al., 2012; Visintin and Pittino, 2014).

However, RBSOs usually sell products and services and not knowledge in its raw form[5]. To grow successfully, the venture's initial tacit and explicit knowledge will need to be embedded into firm knowledge assets such as products, routines, and networks (Alvarez and Busenitz, 2001; Brush et al., 2001; Macpherson and Holt, 2007; Nelson and Winter, 1982; Rasmussen et al., 2015; Stam and Wennberg, 2009). Knowledge-based theories (e.g., Grant, 1996b) suggest that the success of new ventures depend on a continuous and dynamic knowledge conversion process that; 1) enhances knowledge, 2) integrates knowledge, and 3) transforms knowledge to successfully develop new products, services, and processes (Cohen and Levinthal, 1990; Colombo et al., 2010b; Knockaert et al., 2011). Nonaka and Konno (1998) proposed that this process of knowledge conversion takes place through four mechanisms: 1) socialization, where tacit knowledge is shared and interacted within the firm; 2) externalization, where elements of tacit knowledge are transformed into explicit knowledge; 3) combination, where explicit knowledge components are systematized into knowledge systems; and 4) internalization, where the novel knowledge systems are internalized as tacit knowledge in a process closely related to "learning by doing." This process can transform the knowledge resources available at emergence into knowledge assets necessary for growth (Miozzo and DiVito, 2016). Successful knowledge conversion processes are needed to create idiosyncratic set of organizational knowledge assets, or organizational capability (Amit and Schoemaker, 1993; Grant, 1996a; Kogut and Zander, 1992), representing the venture's ability to develop and grow by exploiting its knowledge resources (Lockett et al., 2005; Zahra et al., 2007).

2.4 Conceptual Framework

Figure 2-2 presents a conceptual framework that integrates the theoretical concepts discussed in this chapter.

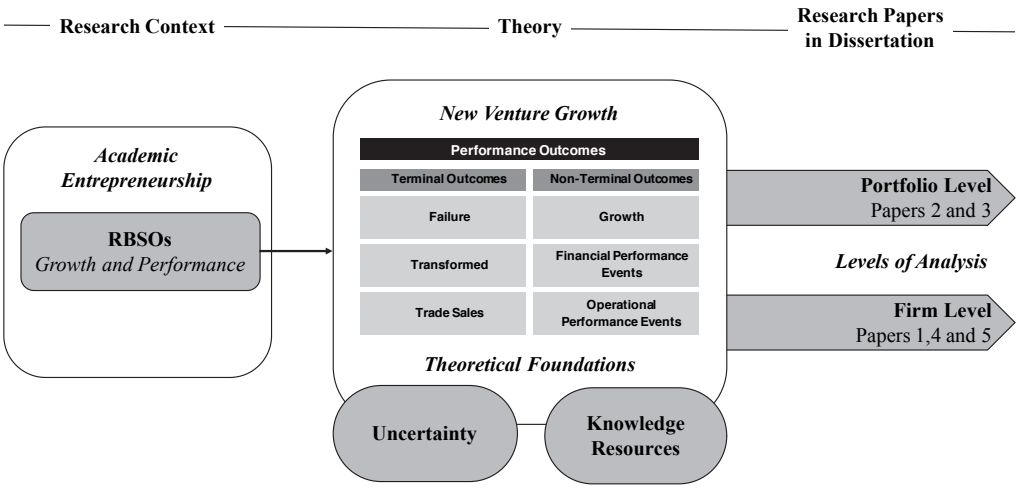


Figure 2-2: Conceptual framework positioning the dissertation, its theoretical foundations, and levels of analysis.

The overall research question of this dissertation *("How do research-based spin-offs develop, grow, and perform?")* is first positioned within the broader literature on academic entrepreneurship. RBSOs represent the research context of the dissertation and all empirical research papers in Part 2 share the research context presented in more detail in Chapter 4. In terms of theory, the dissertation draws on recent advances in the literature of new venture growth to explore the development and growth of RBSOs. The theoretical concepts of Knightian uncertainty and knowledge resources are integrated in the framework to represent the fundamental growth challenges RBSOs face. RBSOs must overcome technological, market, and organizational uncertainty to successfully commercialize their innovations. Further, the initial, and largely tacit, scientific knowledge-base must be transformed into flexible firm assets that can facilitate growth.

Following Davidsson et al. (2006: 32), the growth of RBSOs is studied on two levels: firm-level and portfolio-level. Analyses on the firm-level attempt to advance our theoretical understanding of growth as experienced by individual RBSOs. Implications from firm-level research are primarily directed toward entrepreneurs, investors, and academic institutions involved in the development of RBSOs. The focus of the firm-level studies is *trade sales* as a specific performance outcome. Analyses on the aggregated portfolio-level attempt to advance our understanding of the growth of RBSOs as a category of new ventures. The focus of the

portfolio-level studies is to explore the heterogeneity of RBSOs growth outcomes as well as the quantity/quality relationship. Implications from the portfolio-level research are primarily directed toward policymakers involved in designing framework conditions and support mechanisms for RBSOs.

The research papers in Part 2 respond to gaps and contribute to specific literature. To be clear, not all the research papers are positioned in the literature of new venture growth or draw directly on the concepts of uncertainty and knowledge assets. Rather, each paper is narrowly focused, exploring specific aspects of the overall conceptual framework, often drawing on other theories and literature relevant for the paper's specific research questions. However, all research papers have RBSOs as their research context and analyze the development and growth of RBSOs from a particular perspective. The purpose of the framework in Figure 2-2 is to conceptualize the dissertation's overall theoretical model in light of the overarching research question.

2.5 Gaps and Contributions

Table 2-2 summarizes the literature gaps that each research paper in Part 2 addresses along with its theoretical contributions.

Paper	Research Questions	Level of Analysis	Literature/ Theory	Gaps	Contributions
1. *The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications*	Which factors impact the development, growth, and performance of university spin-offs?	Firm	• Academic entrepreneurship	• Literature treating RBSOs as homogeneous entities, focusing on number of RBSOs created without recognizing later growth and performance • Ignoring skewed distribution of outcomes assuming number of firms is consistent with economic impact • Fragmented literature related to RBSO development, growth, and performance. Current state of knowledge is unclear • No previous literature with this focus	• A conceptual framework capturing the determinants and performance outcomes of RBSOs • Synthesis of the field's state of knowledge into two major research streams • Identification of critical gaps with guidance for further research • Recommendation of using RBSOs as a research context rather than constructing phenomenon-oriented theory
2. *Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study*	How do changes in the institutional framework at national and university levels influence the quantity and the quality of spin-offs from a university?	Portfolio	• Academic entrepreneurship • Entrepreneurship framework conditions • Institutional theory	• The effects of changes in national- and university-level framework conditions on the creation and performance of RBSOs are poorly understood • Literature predominantly focused on RBSO quantity • Limited attention into the quality (i.e., growth and performance) of RBSOs • Paucity of research comparing different countries	• Changes in the institutional framework conditions at both national and university levels are conducive to the creation of more spin-offs, but the increase in quantity is at the expense of the quality of these firms • The effect of these top–down changes in framework conditions on the economic impact from universities seems to be more symbolic than substantive • Study isolates the effects on university and national level, and within and between countries, by comparing national populations of RBSOs in three countries over thirteen years
3. *Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012*	What is the value creation of a national population of science-based entrepreneurial firms?	Portfolio	• Academic entrepreneurship • Uncertainty • Real options	• Limited evidence on the economic impact of RBSOs • Limited evidence on the development and growth paths RBSOs take, and how this relates to economic impact • Lacking conceptual frameworks to assess the development and growth of RBSOs	• A real option framework is appropriate to study impact of a portfolio of RBSOs (and new technology-based ventures in general) • Performance outcomes of RBSOs follow highly skewed distributions, where a few ventures represent a large share of value creation and most ventures have insignificant contributions • Trade sales represent a significant contributor to value creation, but is overlooked in extant research due to methodological oversight • The time span from establishment to successful commercialization is very long

Paper	Research Questions	Level of Analysis	Literature/ Theory	Gaps	Contributions
4. Growing Firm Value: New Venture Growth and Trade Sales of Research-Based Spin-Offs	How do technology-based entrepreneurial ventures grow firm value in the context of trade sales to industry incumbents?	Firm	• New venture growth • Academic entrepreneurship • Technology acquisitions • Uncertainty • Information asymmetry	• Limited theory on growth in firm value in situations of high uncertainty • Firm value overlooked as a measure of growth • Trade sales (i.e., acquisitions) are ignored as an outcome and mode of growth	• Answers calls for more narrow and contextual theorizing of firm growth by developing theoretical propositions of determinants and process of growth in firm value • Identify that growth is not uniform, but occur in irregular bursts • In the context of trade sales, growth in firm value is closely linked to the characteristics of the dyad of buyer and seller • Extend current understanding of growth modes by suggesting that trade sale can act as a distinct mode of growth • Demarcate the boundary of financial valuation theory under conditions of high uncertainty
5. Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions	How does insider ownership provide signals to facilitate transactions in contexts characterized by large information asymmetries? How is the value of insider ownership signals affected by time and other ownership-related signals?	Firm	• Signaling theory • Technology acquisitions • Academic entrepreneurship	• Limited studies and contradictory findings on the signaling effect of insider ownership • Lack of consideration of passage of time, presence of other ownership signals and non-linear effects • Lack of understanding on the role of ownership structures in acquisitions	• Uncover several contingent and temporal situations when insider ownership signals become stronger or weaker • Consider non-linear relationships and negative signals that presumably are sent unintentionally • Considering the signaling effect of insider and professional investor ownership simultaneously

Table 2-2: Summary of identified research gaps and main contributions of research papers in Part 2.

3 METHODOLOGY & RESEARCH DESIGN

3.1 Motivations and Objectives

Driven by theoretical considerations, two methodological objectives were initially particularly important for this doctoral research. The first objective was the empirical representativeness of a *population* of RBSOs. The discourse and attention given to entrepreneurship by politicians, media, and the general public was, and still is, growing notably. I am convinced that the enthusiastic praise of entrepreneurship and its potential impacts on the economy do not sufficiently reflect how extremely difficult the craft of entrepreneurship is, or how many attempts ultimately fail (see e.g., Acs et al., 2016). The expectations of RBSOs, in particular, are formidable, with references to big success stories from the past. Based on personal experiences, my perception was that key stakeholders both overestimate the proportion of research activities that are suitable for commercial exploitation and underestimate the challenges, resources, and time needed to commercialize scientific research. Hence, it was imperative to pursue a methodological strategy that strived to obtain data on an unbiased population of RBSOs. This strategy would allow prospective research to contribute with convincing insights both on the population as well as firm level while simultaneously removing one layer of inference in statistical analyses.

The second objective was that of empirical depth and completeness with respect to tracking RBSO development. A legal entity (i.e., a registered firm with the appropriate governmental agency) is predominantly used to describe the firm in quantitative analyses, but it is not necessarily an accurate representation of "a business." Legal entities are simply formal vehicles used to organize a set of business activities. The fundamental problem is that when a business grows, the legal entity will be the subject of changes, transformations, and amalgamations over time (Coad, 2009: 137; Davidsson et al., 2006: 40-44). It is unreasonable to expect that all of business activities will take place inside the original legal entity forever. For instance, the same business can develop into consisting of several legal entities, probably structured in loose hierarchies. Nevertheless, firms are typically only analyzed on a legal entity basis due to empirical convenience and lack of good alternatives. Although this might not be a serious issue when considering large-scale national samples, or established large firms with consolidated accounts, it will arguably be a greater problem when studying new ventures in a specialized context. Being truly curious on how RBSOs develop, grow, and ultimately end up requires an empirical strategy that follows RBSOs longitudinally on a range of relevant outcomes (Davidsson et al., 2006: 39-41; Venkatraman and Ramanujam, 1986). This includes accounting

for changes to the legal entity that fundamentally alter the understanding of that firm's business activities.

This chapter will present the methodological approach used to examine the research questions of this dissertation, including elaborating on how the two objectives above have been approached. First, philosophical foundations are presented that include a discussion of how my philosophical position impacts the research in practice. Second, I review the methodological challenges of the firm performance construct developing a conceptual framework relevant for this dissertation's research context. Third, I discuss certain methodological influences and positions. Fourth, I introduce the dissertation's overall research design, including central method choices and the empirical research context. This is followed by a description of the data collection process. This chapter concludes with a summary and critical assessment of the methodology.

3.2 Philosophy of Science: Critical Realism

Questions of ontology and epistemology are central for philosophers of science. Ontology, a metaphysical concept, is the study of the ultimate nature of reality and addresses questions of what entities exist, how they can be grouped in categories, and how they relate to each other in hierarchies. A major ontological discourse in the social sciences is whether an independent "real" world exists without human intervention (Benton and Craib, 2011: 4-5). Epistemology represents the theory of knowledge and refers to how knowledge is created (i.e., context of discovery) and relates to truth and beliefs (i.e., context of justification) (Hoyningen-Huene, 1987, discussing the original works of Reichenbach, Popper and others). The Kuhnean notion of "scientific paradigms" (Kuhn, 1962) is used in the philosophy of science to describe a set of concepts, frameworks, and practices adopted by a scientific discipline at any given time when conducting "normal science", including ontological and epistemological positions. Although Kuhn did not consider the concept of paradigms to be directly transferrable to the social sciences as a whole, in part due to the constant flux of social reality, others have argued that disciplines also within the social sciences operate through research programs (Lakatos, 1976) and research traditions (Laudan, 1978) underpinned by distinct cultures, methodologies, and professional practices of a paradigmatic nature.

From my perspective, there are two main reasons why clarifying philosophical influences is important in a doctoral dissertation. First, competing research traditions can co-exist within the

same discipline or field of study (Guba and Lincoln, 1994). As such, researchers studying the same phenomenon will not necessarily agree on how research should be conducted, interpreted, and understood. Second, ontological and epistemological positions are rarely explicit or apparent in published research. Nevertheless, they represent the basis for the social researcher's world view and it is important to understand choices in methods and interpreting knowledge claims. Overall, this dissertation subscribes to and is positioned within the philosophical tradition of Critical Realism (CR). This chapter will present CR in more detail, and how CR has influenced and shaped my research process. It is significantly inspired by the excellent reviews of CR by Buch-Hansen and Nielsen (2005) and Benton and Craib (2011).

Critical Realism

CR as a philosophical tradition evolved in the aftermath of the crisis of classical positivism and is generally regarded as a form of post-positivism. While sharing certain characteristics with positivism, CR critiques and distances itself on fundamental areas, especially those related to the strong form of empiricism adopted in positivism. Similarity, it shares certain characteristics with the hermeneutic, constructivism, and other anti-positivist traditions, but also differs in important ways. On a high level, CR can be viewed as bridging constructivism's account of science being fully social and positivism's view of science having no room for the social practice of science. CR should not be considered one dogmatic movement, as philosophers labelled as critical realists do not fully agree on all facets of the framework (rarely the case in any paradigm). Yet, they do share a family resemblance around fundamental points. Roy Bhaskar is generally regarded as the founder and original architect of CR (Bhaskar, 1975, 1979). Table 3-1 outlines the major concepts and interpretations of CR as initially developed by Bhaskar.

Dimensions of Science	Meaning	Characteristics	Description
Transitive dimension	**Epistemological:** Our knowledge at a given point in time	A Social Outcome	Science is a human activity occurring in social contexts. New knowledge extends and transforms existing knowledge. Critical realists are epistemological relativists but believe in rational judgement.
		Fallible	Knowledge is never certain, absolute, or definitive. Knowledge can always be replaced or extended with new knowledge.
Intransitive dimension	**Ontological:** The reality that exists at a given point in time independent of our knowledge of it	Depth	Reality is structured in three domains. Outside our experiences and observations (the empirical domain) and all possible actual events and phenomena (the actual domain), there is a deeper unobservable world of mechanisms, structures, causal potentials, and tendencies (the real domain). The role of science is to explain the real domain.
		Stratified	Structures and mechanisms in the real domain are stratified in levels. Higher levels (i.e., social) presuppose lower levels (i.e., physical), but cannot be reduced to them.
		Open	As events and phenomena are the result of contingent combinations of many underlying structures and mechanisms, empirical regularities are rare. Reality, therefore, consists of open systems and causality can only be understood as tendencies. Closed systems can generally only be created artificially in the laboratory. Science should primarily be focused on explaining events and phenomena and not on predicting them.
		Complex and Differentiated	Reality contains objects with structures and mechanisms that provide very different causal potentials and tendencies. These causal potentials may or may not materialize in actual events and phenomena depending on the interaction with other conditions and mechanisms.

Table 3-1: Major concepts and characteristics in Critical Realism. Adapted from Buch-Hansen and Nielsen (2005) and Benton and Craib (2011).

Critical realists are ontological realists, but epistemological relativists. Implicit by its name, a fundamental conclusion in CR is that reality exists independent of human perception (ontological realism). However, critical realists consider that surface appearance can be

potentially misleading to their true character. Further, Bhaskar denies the position in classical empiricism that the world is characterized by empirical regularities. Bhaskar uses so-called *transcendental arguments* to demonstrate this point. A transcendental argument takes a supposed accepted experience as granted, and articulates that which must be the case, making the experience possible. Experiments are a fundamental activity in science and Bhaskar asks what the conditions are that make scientific experiments needed. Experiments seek to control for factors that naturally occur in order to isolate the object or mechanism of study. Hence, CR concludes that empirical regularities are rather rare in the actual world and most mechanisms co-exist with many others simultaneously. More generally, Bhaskar separates between two dimensions of science. The **transitive dimension** contains our knowledge of the world and, thus, is the area of epistemological concerns. It includes the theories, models, concepts, descriptions, and methods applied in science. Another fundamental conclusion in CR is that the pursuit of scientific knowledge is a social and historical activity, where new knowledge is constructed and evolves from existing knowledge (epistemological relativism). By supporting such a Kuhnean perspective, CR maintains that science produces knowledge *about something real*. The **intransitive dimension** consists of the real objects, structures, and mechanisms that science attempts to create knowledge about and, thus, is the area of ontological concerns. CR is a realist tradition because it maintains that real objects in the intransitive dimension exist independent of our knowledge of them. Hence, knowledge will be altered, extended, and transformed without that process affecting the real objects in the intransitive dimension.

A distinctive characteristic of CR is that reality is understood to be stratified into three domains: the empirical, actual, and real. CR thus depicts a deep domain of reality not directly observable to us and the focus of scientific activity should be around these underlying structures and mechanisms that create the phenomena and events we can experience. This is why CR, often called “depth realism”, is compared with “empirical realism” in positivism. See Table 3-2 for descriptions of these domains.

Domain	Content
Empirical	Observations and experiences. Necessarily a subset of the actual domain because mechanisms interact and counteract each other.
Actual	All phenomena that exist and events occurring, regardless of being experienced by us or not. Might be produced under experimental conditions in the laboratory or occur in a more complex observable world.
Real	Not directly observable structures and mechanisms that under certain circumstances and conditions can create the phenomena and events in the actual domain.

Table 3-2: Three domains of reality in critical realism. Adapted from Buch-Hansen and Nielsen (2005) and Benton and Craib (2011).

The objects in the real domain, however, are complex and can only be viewed as having causal potential and tendencies, and not deterministic patterns. The real domain contains a wide range of mechanisms and conditions that activate, counteract, and modify each other's consequences. The phenomena and events in the actual domain, therefore, are always a complex result of the combined effect of many mechanisms and conditions. Such a multi-causal and open system world view is radically different from what is assumed in positivism. Consequently, only causal tendencies can be uncovered when studying such open systems. See Figure 3-1 for a visualization of how causality is understood in critical realism.

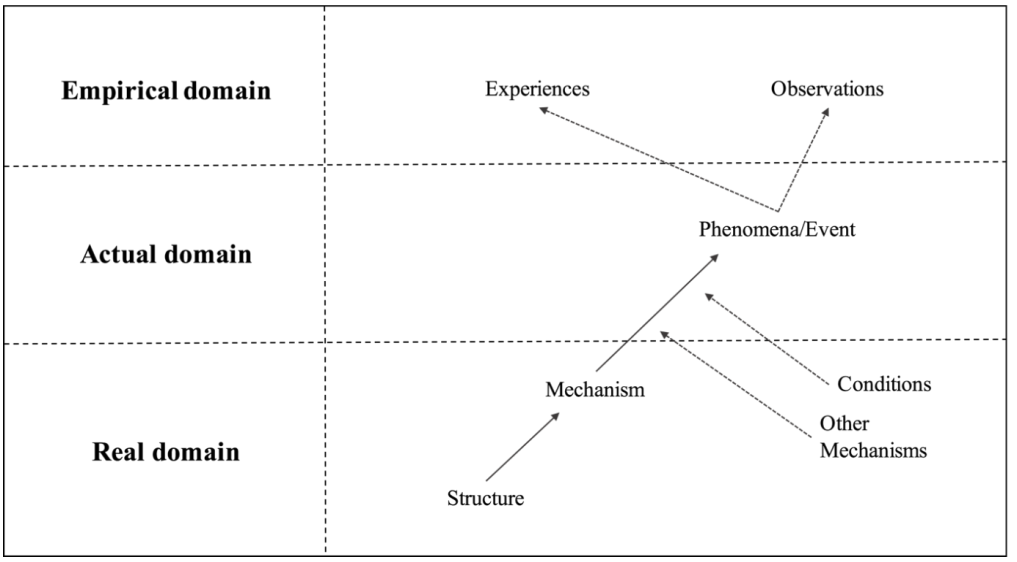


Figure 3-1: Understanding of causality in critical realism. Adapted from Buch-Hansen and Nielsen (2005).

CR assumes that the mechanisms and structures in the real domain are stratified; more specifically, they are hierarchically structured where higher levels presuppose lower levels of reality. Social reality would be placed at the top of such a hierarchy as it assumes a physical world. However, CR has throughout an anti-reductionistic perspective of science. Critical realists argue that the combination of mechanisms on lower levels creates mechanisms on higher levels that have unique causal potentials not achievable to the mechanisms on the lower levels. For instance, the sciences of anatomy and physiology might explain why humans have the capacity to speak, but says nothing about when and how humans will learn to speak, which language they will speak, or what they will say in any given situation.

Research Implications

Although social reality is the highest level in the stratified world view, CR was developed initially with the natural sciences in mind. Bhaskar (and other critical realists) have argued that a naturalistic approach (i.e., studying the social world with similar methods as the natural world) of CR is feasible, extending the same basic principles of CR, as long as certain limitations are imposed (Bhaskar, 1979). The main challenge with the social world is that, in contrast to certain aspects of the natural world, it is constantly changing in different ways. In the terminology of CR, the challenge is whether there exist stable mechanisms and conditions in the real domain. Bhaskar introduces the concept of *critical naturalism*, arguing that certain facets of the social world have relatively durable structures. Specifically, social relations create social structures that can be viewed as equivalent to structures in the natural sciences. Yet, the mechanisms and conditions of the social world are still qualitatively different to the natural world and subject to certain limitations. Please see Table 3-3 for descriptions of the epistemological and ontological limitations.

Area	Limitation	Description and Consequence
Epistemological	Closed systems and experiments	Closed systems can be artificially created using experiments in the natural sciences, but this is never possible in the same way in the social sciences. As such, it is not possible to create conditions where a theory or model can be accurately tested.
	Embeddedness	Social scientists are always part of their own subject matter. Further, new knowledge can have a reverse effect on the original object of study.
Ontological	Activity-dependent	Social structures are maintained only through the activities of agents (e.g., people and institutions).
	Concept-dependent	Social structures are reproduced by actors based on the beliefs they have about what they are doing.
	Space- and time-dependent	While social structures can be relatively durable, changes can and will occur slowly or, sometimes, abruptly. This does not mean that the dividing line between transitive and intransitive dimension is diluted. Rather, social objects will always exist intransitively at one point in time, but due to the nature of the social world will likely be subject to changes.

Table 3-3: Limitations of a naturalistic approach of critical realism in the social sciences. Adapted from Buch-Hansen and Nielsen (2005) and Benton and Craib (2011).

The sort of knowledge that can be achieved in the social sciences will vary based on the subject-matter of the discipline. Bhaskar makes a general point in that due to naturalistic limitations, social scientists should always be critical of own knowledge claims. Benton and Craib (2011: 135) argue that Bhaskar's contrast between the social and natural sciences is too extreme, and that the division is more continuous and blurred than dichotomous. Certain disciplines generally regarded within the realm of the natural sciences; typically studying more open systems (e.g., meteorology, evolutionary biology), share many of the characteristics of social sciences. Similarity, certain disciplines of psychology (e.g., mathematical psychology) have much in common with the natural sciences. Overall, the CR position has several important consequences for research practices, including the research conducted in this dissertation. Please see Table 3-4 for a summary of these implications.

Area	Description
Object of study	Structures and mechanisms in the real domain should be the primary object of study.
Explanation vs. prediction	The real structures and mechanisms only can be observed through the phenomena and events researchers can observe, and they will most likely be observed in open systems with limited ability to conduct experiments. Hence, researchers should primarily be concerned with *explaining* events and phenomena as the future cannot be predicted accurately.
Abductive reasoning	Critical realists support the use of abductive reasoning also associated with philosophical pragmatism. This way of reasoning is closely related to transcendental arguments central in critical realism, where the starting point is the conclusive event and the reasoning is to which necessary casual mechanisms most likely need to exist in order for the event to take place.
Abstraction	Abstraction is viewed as a key methodological tool in CR, where abstractive thought experiments correspond to controlled experiments in the natural sciences. In the process of abstraction, abductive reasoning, metaphors, and analogies are often used to describe emergent mechanisms. Good theorizing in the social sciences often involves both concrete and abstract elements.
Concept clarity	Critical realists are very concerned with concept clarity and emphasize that it is a scientific task in its own right to clarify the definitional boundaries of the concepts under study, and ensure satisfactory and accurate measurements.
Fallibleness	Critical realists are fallible in contrast to idealist and constructivist theories of knowledge that insulate themselves from the possibility from being wrong by denying the idea of a knowable independent reality. Critical realists, therefore, are open to correction in light of new evidence.
Disciplinary approach and method	As a consequence of the CR world view, social science will benefit from multi-disciplinary research practices. CR is generally supportive of qualitative methods and/or mixed method studies

Table 3-4: Implications for practical research activities within the critical realism tradition. Adapted from Buch-Hansen and Nielsen (2005) and Benton and Craib (2011).

In sum, by supporting a critical realist framework, I take a fundamentally different view than the hermeneutic and social constructivist traditions. I emphasize this point specifically because constructivist philosophical influences are quite common in my field. It would, however, be a mistake to consider the relationship between CR and constructivism as fully opposing views. One could argue that critical realism is a moderate form of constructivism maintaining a realistic ontology with room for objective structures, causality, and depth. The objective of social science for critical realists is to acknowledge the vast complexity of the social world, and build models that "cut through" this complexity. In light of this, critical realists are more concerned with identifying useful models that fit reality than attempting to fully understand

reality itself. It also implies that pursuing fully logically coherent models attempting to take into account all variance is considered completely unrealistic and unusable.

Taking this philosophical stance also provides many challenges as the objective of the research activities will be to uncover concepts explaining deep structures not readily observable. The remaining sections in this chapter will outline the methodological choices taken in this dissertation which reflect my critical realist position. Table 3-5 provides a high-level summary of key choices and preferences impacted by CR. Figure 3-2 provides a visual and simplified representation of certain key concepts from my theoretical framework and empirical research, outlining how they are positioned in the three domains of reality in CR.

Area	Choices and Preferences
Mixed methods	• Use of both qualitative and quantitative methods to take advantages of strengths of both methods of inquiry, including representativeness (quantitative) and depth (qualitative).
Triangulated data collection	• Collection of several independent data sources to corroborate and challenge the observations from single sources. Driven by the ambition of approximating the objective reality using several sources.
Complexity of causal relationships	• Focus on explaining and not prediction. • Randomized experiments viewed as the gold standard of social research to isolate mechanisms from confounding effects, although only observational data is feasible in practice. As a replacement, outlining possible counter-factual scenarios is an integral part in all abstraction/theorizing. • Recognize that the phenomena and events under study to a large degree is characterized with uncertainty and power law distributions.
Concept clarity and homogeneous research context	• Choice of very homogeneous research context followed over a long time to enable insight into deep structures. • Significant effort in clarifying and mapping heterogeneity of research objects from their circumstances at the outset.

Table 3-5: Methodological choices and preferences impacted by the author's philosophical position within the tradition of Critical Realism.

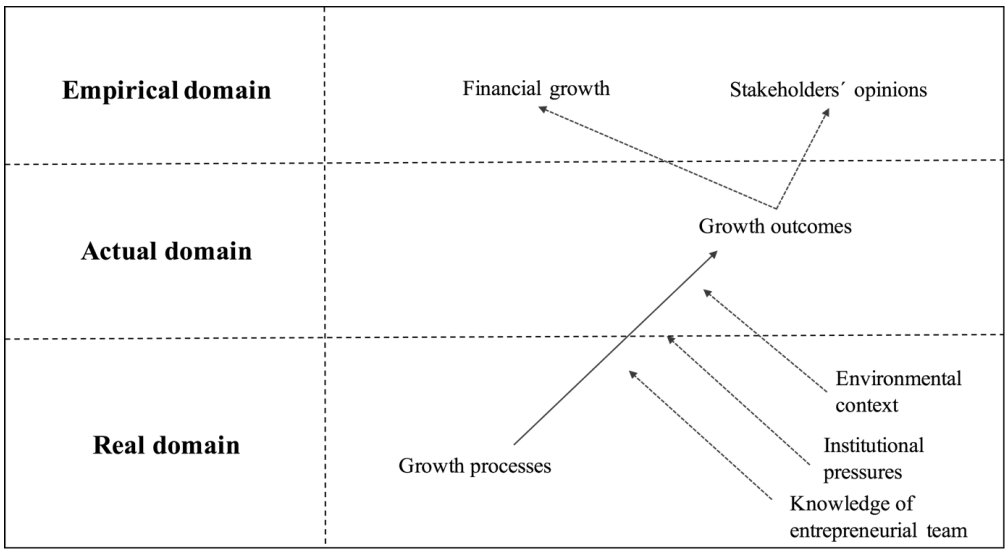


Figure 3-2: Example of causal relationships of relevant theoretical and empirical concepts used in this dissertation.

3.3 Measurement of Performance

Chapter 2 developed a theoretical framework with a multidimensional view of new venture growth in the context of RBSOs. In this section, a more comprehensive justification of this position will be developed based on the challenges in measurement of new venture performance and the theoretical and methodological implications associated with this. The critical realist position necessarily implies questioning the concept of performance. What we can observe and measure of performance occurs in the empirical domain, but the objective is to understand how this is related to the actual and, ultimately, the real domain of firm performance. The section will conclude by proposing a conceptual model of the most relevant performance measures in the context of academic entrepreneurship (which is used in the conceptual framework in Section 2.4).

General Performance

A central objective of organization studies has been to determine what impacts firm performance (Richard et al., 2009). However, the "firm performance" construct appears to have serious unresolved conceptual and empirical problems (Miller et al., 2013). In fact, a recent comprehensive review found almost as many different measures of performance as research papers published (Richard et al., 2009). One could argue, therefore, that the field has made

limited progress since Venkatraman and Ramanujam (1986: 801) stated *"the treatment of performance in research settings is perhaps one of the thorniest issues confronting the academic researcher today."* There are several approaches to this issue. One relates to distinguishing between objective (e.g., collected from archival sources) and subjective (e.g., collected from firms) measures of performance (Brush and Vanderwerf, 1992; Venkatraman and Ramanujam, 1986). Related to this are the goal-based and multiple constituency approaches, suggesting that the evaluation of performance depends on the organization's and its associated stakeholders' goals (Murphy et al., 1996). Goals will clearly matter, especially if the objectives of different stakeholders are not aligned (e.g., the entrepreneur vs. the venture capitalist, Kiviluoto, 2013). Further, aspirations to high performance have been shown to impact actual performance (see e.g., Delmar and Wiklund, 2008; Wiklund and Shepherd, 2003) and comparing the performance of firms with divergent growth ambitions can be problematic for this reason. Nonetheless, the majority of management research on performance has been concerned with objective measures of performance where firms in similar situations can be compared in a meaningful way (Murphy et al., 1996).

Objective measurements of performance has proven difficult in other ways. Miller et al. (2013) argue a critical problem is that researchers use disjunct approaches when conceptualizing firm performance in theory and empirical work. More specifically, a *latent multidimensional* approach in theory building is coupled with a *separate constructs* approach in empirical testing. This implies that theorizing is based on an abstract and general concept of performance, but theories are tested using distinct, and often single, variables. Please see Table 3-6.

	Latent Multidimensional Approach	**Separate Constructs Approach**
Basic description	The construct exists at a deeper level than the dimensions, but it is unobservable directly. It is operationalized as the shared variance among the dimensions.	Separate constructs exist and are only loosely related as members of a domain of firm performance.
Expectations for theory development	Researchers focus their arguments on abstract and general conceptualizations of firm performance.	Researchers focus their arguments on specific aspects of performance.
Expectations for empirical work	Researchers assess performance as the shared variance of dimensions based on factor analyses, reliability analyses, and other similar tools.	Researchers assess distinct variables and use them in separate analyses.

Table 3-6: Two conceptual approaches to the dimensionality of firm performance. Adapted from Miller et al. (2013).

Remarkably, Miller et al. (2013) finds nearly all studies using the latent multidimensional approach of firm performance switch to using separate constructs in empirical testing. This is logically inconsistent as a latent multidimensional understanding should combine several measurements of performance (each describing the abstract concept of performance imperfectly) into a shared variance construct. The key issue, however, is that substantial research shows that different dimensions of performance are not very correlated at all (Miller et al., 2013). This implies that distinct performance variables will have different, and possibly directionally opposite relationships with the theoretical variables of interest. In other words, a general latent performance construct may not exist, at least using the measures we can observe. This seriously questions the construct's validity and the possibility of any rigorous theorizing about a general notion of performance (Combs et al., 2005; Miller et al., 2013; Wiklund and Shepherd, 2003). Many scholars strongly recommend cultivating the separate construct approach in theory development (e.g., Combs et al., 2005; Kiviluoto, 2013; Miller et al., 2013; Murphy et al., 1996). In other words, theoretical development should be undertaken with respect to specific dimensions of performance. Non-convergence in performance measurements is not the end of theoretical work, but rather represents an opportunity as theoretical explanations can be enriched and detailed for specific dimensions of performance.

Many attempts have been made to identify distinct dimensions of firm performance. However, attempts to develop general classification of performance dimensions are characterized not only with disagreement regarding the number of dimensions, but also which measures belong to each dimension (Combs et al., 2005). Further, it is likely that dimensions of performance will overlap and interact. However, there is agreement in that operational and financial performance represent two distinct domains of firm performance (Combs et al., 2005; Venkatraman and Ramanujam, 1986). Operational performance refers to non-financial outcomes tied to *specific* firm activities (e.g., product quality, innovation output, market share). Financial performance refers to indicators reflecting the *interactive* outcome of all firm activities (e.g., size, growth, survival, efficiency). These two domains are linked in the way that operational performance represent factors that may lead to financial performance (Venkatraman and Ramanujam, 1986).

Searching for general categorization schemes of performance dimensions is likely counterproductive. Performance is an exceptionally heterogeneous construct and no single theory likely exist which can explain general performance to a satisfactory degree. Instead,

what constitutes the appropriate theoretical dimensions of performance is dependent on the research question and context (Richard et al., 2009). For instance, small and large firms are likely to perform through different mechanisms. In addition, the research context will determine what measures are meaningful to consider. For instance, financial market measures are generally not applicable for small private firms, whereas they are frequently used in the study of larger public firms (Richard et al., 2009). The broad research context of this dissertation is entrepreneurship and choices of relevant performance measures should be made with that in mind.

Entrepreneurial Performance

Firm growth is a dimension of performance used very frequently in entrepreneurship studies, and a significant literature has emerged that considers firm growth to be a distinct performance construct (Wright and Stigliani, 2013). Firm growth has traditionally been understood as the increase in size or amount over time (Nason and Wiklund, 2015). Size, therefore, is an absolute measure, whereas growth is a relative measure of size over time (Achtenhagen et al., 2010). However, growth should not be equated with success in all circumstances (Kiviluoto, 2013). For instance, unprofitable growth is not sustainable over the long-term (Davidsson et al., 2006: 6). Growth is also found to display further multidimensionality within the construct itself. Table 3-7 summarizes Shepherd and Wiklund (2009) review categorizing the growth literature's use of indicators, formulae, and time spans.

Indicator*	*Sales*	74%
	Employees	16%
	Profit	11%
	Equity/Assets	7%
	Other	18%
Formulae	*Absolute (i.e., $)*	39%
	Relative (i.e., %)	45%
	Other/Not reported	16%
Time span	*1 year*	17%
	2 years	13%
	3 years	6%
	4 years	6%
	5 years	16%
	Other/Not reported	41%

*Table 3-7: The use of indicators, formulae, and time spans based on a review of 82 firm growth studies. Adapted from Shepherd and Wiklund (2009). *22% of the studies used more than one indicator.*

Many possible growth scenarios can be envisioned from different choices of indicator, formulae, and time span. Indicators capture different aspects of growth. For instance, an RBSO developing a new technology might grow employment before achieving any revenue. The initial size will impact the measured level of growth depending on the choice of absolute or relative[6] formulae. Absolute (relative) growth measures are biased toward larger (smaller) firms (Coad et al., 2014). For instance, RBSOs achieving a certain size might have comparatively high growth in absolute, but not relative terms. Finally, if growth is not linear, then measured growth will differ depending on the time span that is applied. RBSOs showing rapid growth after a longer period with technology development will appear to grow quite differently depending on the time span used (Shepherd and Wiklund, 2009).

Similar to general performance, growth research often implicitly assumes concurrent validity between measures (i.e., choice of indicator, formula, and time span does not matter). Shepherd and Wiklund (2009) analyze a population of new ventures in Sweden, investigating concurrent validity across indicators, formulae, and time spans of growth measures. Table 3-8 summarizes this analysis.

Component	Overall Concurrent Validity	Key Exceptions
Across absolute/relative measures of growth	Low	• Employment • Equity
Across indicators of growth	Low	• Absolute employment - Absolute sales • Relative sales growth - Relative assets
Across time spans	High	• Relative assets • Relative profit

Table 3-8: Results of concurrent validity analysis of growth measures for all new ventures in Sweden 1994–1998. Adapted from Shepherd and Wiklund (2009). High concurrent validity between two measures was defined as a correlation above 0.5, and low concurrent validity below 0.3.

The result demonstrates mostly low concurrent validity between both the absolute and relative operationalization of growth, and between indicators. However, there seems to be generally high concurrent validity of growth measures across time spans. Although there are important exceptions, Shepherd and Wiklund (2009) illustrate that the growth construct is complex, and different measures cannot be naively studied as the same phenomena. The theoretical implication, and appropriate remedy, corresponds to recommendations made for the firm performance construct more generally. Theory development should be narrowed to specific aspects of growth (Coad and Guenther, 2014; Leitch et al., 2010; Shepherd and Wiklund, 2009). This will necessarily include new perspectives of growth (viz. the intended contribution of this dissertation).

Growth is not by any means the only performance dimension used in the study of RBSOs. Dichotomous outcomes like survival are often studied in entrepreneurship research because most new ventures fail (Richard et al., 2009; Shane and Venkataraman, 2000). Researchers have argued that survival is a separate dimension of performance (Combs et al., 2005; Murphy et al., 1996). However, there are other relevant terminal outcomes besides failure. Firm exit is often assumed as failure, but not all firm exits are equal or even directionally equivalent (DeTienne and Wennberg, 2016; Richard et al., 2009; Wennberg and DeTienne, 2014). Trade sales are generally viewed as successful outcomes, particularly in contexts where the new venture has obtained VC investors that eventually would want to exit their investment (Coad, 2014; Colombo et al., 2010a; Wright et al., 2006). Further, firms can exit for reasons other than failure or trade sale (Wennberg and DeTienne, 2014). This relates to events like distressed sales/mergers, corporate restructuring, and activity transfers (together labelled in this

dissertation as "transformed outcomes". Please see Section 3.6 for further details on how such events are determined, and Section 4.3 for an analysis of all terminal events in the FORNY portfolio).

In addition to terminal outcomes, a range of non-terminal outcomes can be envisioned. Operational performance was previously discussed and is considered relevant in the entrepreneurship context as well. For instance, innovation outcomes, such as patents and product introductions, are highly relevant for ventures like RBSOs. Similarly, financial performance events, such as VC financing and initial public offerings (IPOs), are also considered very relevant measures in the RBSO context (Colombo et al., 2010a; Fini et al., 2016).

Conceptual Model of Performance

Figure 3-3 summarizes this section by proposing a conceptual model outlining the performance measures considered most important in the context of RBSOs. The term "performance outcome" is introduced as an umbrella term for all aspects of performance, including terminal/non-terminal and continuous/dichotomous outcomes.

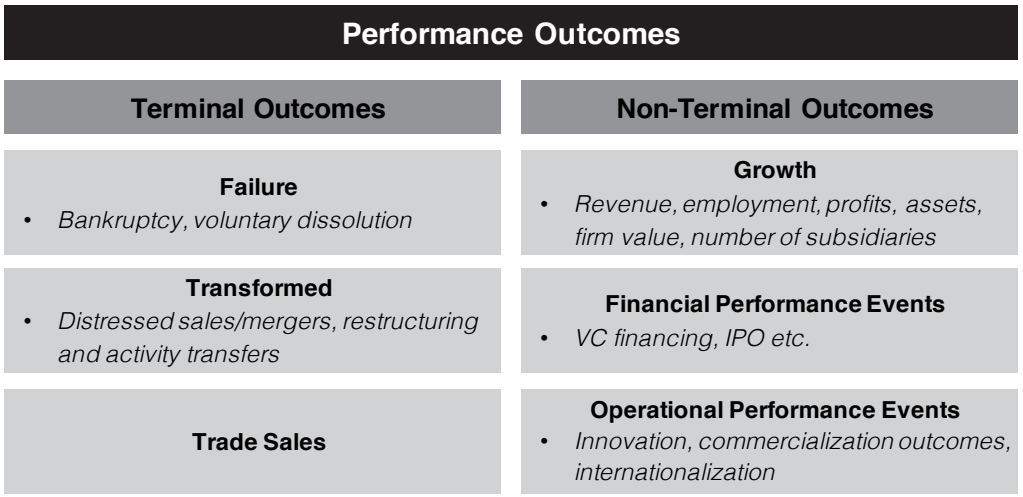


Figure 3-3: Conceptual model of performance outcomes considered relevant for the research context of this dissertation.

This section has advanced a discussion about methodological rigor in the choice and construction of measuring performance. There are several implications to both theoretical and empirical aspect of research. First, choice of performance measures should be relevant for the research context. Figure 3-3 demonstrates that a range of objective performance outcomes are relevant to the RBSO phenomenon. The purpose here is not to construct an exhaustive model, but to focus on the measures considered most relevant for the specific RBSO context. The dissertation will focus on these outcomes in various degrees. Second, specific performance outcomes will describe difference facets of performance. Studies should, therefore, narrowly focus on distinct areas of performance. Third, there is dimensionality of performance outcomes at all levels. The complexity of the growth construct has already been discussed, but this is not a unique scenario. Trade sales represent a terminal performance outcome (dichotomous in nature), but trade sales differ in their valuations (continuous in nature). Paper 5 in Part 2 focuses on the occurrence of trade sales (dichotomous) while Paper 4 focuses on trade sale value (continuous). Still, the theoretical reasoning in the papers is different and tailored to the relevant performance outcome. This illustrates the specificity of theoretical development when applying methodological rigor in the choice of performance outcome.

3.4 Methodology: Influences and Positions

Some argue that elements of classical positivism and empiricism is still alive and well in the field of economics while abandoned in most other disciplines in the social sciences (Buch-Hansen and Nielsen, 2005: 18-19). As a critical realist, I distance myself philosophically from positivism (as do many economists). Yet, I am influenced by certain methodological advances in economics, which I argue is fully in line with a critical realist position. In the first part of this section, I will discuss two such influences, where the first relates to the concept of causality and the second to epistemological consequences of uncertainty and power law distributions. These influences have implications on my research process and results, which will become evident throughout this dissertation. In the last part of the section, I will define the dissertation's main unit of analysis.

Causality

The critical realist perspective acknowledges that phenomena and events in the social world are caused by a range of underlying structures and mechanisms working together simultaneously. Experiments are the ideal research practice to isolate the mechanism(s) of interest. Being pioneered within the medical sciences, randomized control trials (RCTs) have been adopted

also in the social sciences and are increasingly regarded as the research design with highest credibility with respect to knowledge claims of causality. Without going into too much detail, the key advantage of RCTs is that random assignment removes the selection problem being the main challenge in separating between causality and correlation in empirical research (Angrist and Pischke, 2008: 11-24). In the language of critical realism, well-designed RCTs use randomization to isolate a mechanism of interest. Perhaps more importantly, it does so without creating an artificial context of study as in the case of laboratory experiments, which arguably disturbs the naturally occurring mechanisms. That said, there are also many challenges with RCTs, and well planned and executed observational studies can yield as good or better results as RCTs (Deaton and Cartwright, 2016). Additionally, observational data can also take the form of "natural experiments", where some exogenous event has produced an environment akin to a randomized experiment (Angrist and Krueger, 2001). Nevertheless, the RCT is the most convincing approach to ensure identified relationships have a causal interpretation.

However, the objects of study for this dissertation (i.e., RBSOs and their growth processes) cannot feasibly be studied experimentally but have to be based on observational data. Analytical techniques, such as many variants of regression analysis, can control for alternative explanations so that the relationships under study have a causal interpretation, provided no important variables with causal meaning are omitted from the model. The latter is incredibly challenging as important variables might be unknown to the researcher. The main point here, though, is that the planning and design process of scientific research is significantly affected when the RCT is considered the ideal design (even if no research designed as a RCT is actually done). If so, Angrist and Pischke (2008) argue that researchers are able to articulate the hypothetical experiment that would be ideally placed to capture the causal effect of interest. Although it might be fully unrealistic to construct that experiment, the thought process involved provides several advantages. First, it helps to sharpen research questions to those that can be answered scientifically. Second, it increases the ability to cognitively visualize counter-factual outcomes, formulate identification strategies (i.e., identify critical control variables) and mode of inference (i.e., identify the population of which results can be generalized). Together, holding the randomized experiment as the ideal archetype of research is humbling as a researcher, making me critical about my own (and others') knowledge claims and increasing the thought and reflection that goes in to data collection and analysis efforts.

I will provide one relevant example to outline the implications of this position on causality. A very important event in this dissertation's research context was the 2003 legislation change in Norway, which shifted the IPR of inventions from the academic inventors to the universities. Some would study the effect of this institutional change by comparing the entrepreneurial output at universities before or after the legislative change. This is considered a naïve approach, as any causal effect in the changes in entrepreneurial output should be compared with the *counterfactual* scenario, i.e., that no change in legislation occurred. Attempts to isolate the causal impact must, therefore, control for all other important changes between the two time periods. The complexity and uniqueness of the particular social context makes the question of causal impact extremely difficult to answer.

Power Law Distributions

Entrepreneurship outcomes have been found to *not* follow a normal (i.e., Gaussian) distribution (which predictably can be described by its moments), but follow a highly skewed power law distribution (Crawford et al., 2015; Rasmussen and Mathisen, 2017). For technological inventions in particular, Astebro (2003) shows that rates of return are highly skewed with a few inventions representing the majority of total returns. Successful technology-based entrepreneurship arguably follows what Nassim Taleb have coined as a "Black Swan"[7]: it is unpredictable, has major impact, and the determinants of success are often rationalized in hindsight by observers and participants (Taleb, 2007). However, most academic research of entrepreneurial performance still focuses on analytical methods that estimate the mean and statistical inference is performed with the (often implicit) assumption that outcomes of the entrepreneurial phenomenon follow a normal distribution. Outliers are ignored as anomalies fixed by data transformations that squeeze the distribution under a Gaussian curve (Crawford et al., 2015).

Power Law Distributions	Normal (Gaussian) Distributions
A few successful members (outliers) will account for a disproportionate amount of the distribution's total output.	Outliers represent a marginal amount of the distribution's total output.
The most typical member is very small, alternatively no typical member exists. Measurements of averages are not particularly meaningful.	The most typical member is mediocre. Measurements of averages are meaningful.
It typically takes a long time for the form of the distribution to emerge. Development of the distribution is characterized with erratic "jumps."	The form of the distribution emerges quickly. Development of the distribution is characterized with smooth changes.
Outcomes are characterized with uncertainty and wild randomness and, therefore, it is very hard to predict both occurrence and impact.	Outcomes are characterized with risk, and both occurrence and impact can be predicted.

Table 3-9: Power law and Gaussian distributions. Adapted from Taleb (2007).

Table 3-9 illustrates that when venture outcomes are characterized with power law distributions, a few major successes will dominate the total output while most ventures will fail or remain very small. In these circumstances, the distribution's mean is undefined and relatively meaningless. Further, the distribution will be sensitive to "wild randomness", referring to situations when a single event (in this case a venture success) suddenly impacts the total in a highly disproportionate manner, creating a discontinuous shift in the distribution (Mandelbrot, 2013). Please see Paper 3 in Part 2 for specific examples of this from this dissertation's research context.

There are clear implications for research. Although theoretical reasoning has evolved to consider the heterogeneous nature of firm growth, empirical work still focuses on the "average effect for average firms" (Nightingale and Coad, 2014). While significant statistical results might be possible to derive using traditional analytical techniques (such as ordinary least squares regression), it is unlikely to contribute to theoretical progress or produce sound advice for policy and practice. Ignoring outliers for statistical purposes does not reduce the influence of those outliers, and results thus likely lack internal and external validity (Crawford et al., 2015). Transforming data is not helpful either because the key issue is that the average firm is not really not interesting as it grows almost nothing and, hence, not meaningful for theory. Further, the timing of inquiry could have a significant but unknown impact on results, as a major impactful event could be right around the corner (Garnsey, 1998).

Acknowledging the pervasiveness of power law distributions involves embracing outliers as an important part of the entrepreneurship phenomena and not rejecting outliers as analytical nuisance. There are several strategies in research design and analysis that can facilitate this. For instance, new advances in statistics have produced analytical methods that can model other parts of the distribution besides the mean (e.g., quantile regression) (Angrist and Krueger, 2001). Longitudinal research designs also are better able to segregate analysis between, e.g., hyper-growth firms and firms achieving more modest growth (Crawford et al., 2015). More generally, researchers should carefully evaluate if the phenomena under study follow power law distributions and recognize the limitations of traditional analytical techniques. I am influenced by these developments, and dedicate significant time and effort of this dissertation exploring the outliers, rather than average outcomes.

Unit of Analysis

RBSOs as firms represent the overall unit of analysis in this dissertation. However, some of the dissertation's research papers operate with other units of analysis tailored to the papers' specific research objectives. Paper 2 is a multi-level study that has university as the unit of analysis, and also considers effects from the national level. Paper 3 is primarily focused on the value creation output of a portfolio of RBSOs. Paper 4 consider trade sale transactions as the primary unit of analysis. Nevertheless, the firm is the core subject in all papers, used either as an input or output factor. Taking a multi-level perspective on a phenomenon such as the firm is in line with a critical realist approach.

With respect to a more precise definition of the unit of analysis, Paper 1 in Part 2 includes an in-depth discussion on definitional boundaries of the RBSO construct. The general definition of RBSO adopted in this dissertation is a new venture satisfying two key criteria:

- Established to commercialize scientific research results either in the form of explicit inventions/discoveries or more tacit scientific expertise/knowledge.
- The institutional origin is universities (incl. university hospitals), university colleges, or public research institutions (PRIs) (henceforth: collectively referred to as public research organizations (PROs)).

Studies of the RBSO phenomenon have used varied and inconsistent terminology of the unit of analysis. Terms have normally been structured using a juxtaposition of two parts: the first term

refers to the firm's origin (e.g., university, academic, research-based, science-based, etc.) and the second term a description of the new venture (e.g., spin-off, spin-out, entrepreneurial firm, new venture, etc.). It is fair to say that university spin-offs (USOs) and academic spin-offs (ASOs) are the most commonly used terms, but examples of most permutations can be found in the literature. An unequivocal terminology of this phenomenon is likely counterproductive, as the research context and empirical sample will dictate what makes sense[8]. From one perspective, these firms represent certain subsets of NTBFs. In fact, each of the research papers in Part 2 of this dissertation uses different terminologies for its individual purposes. Yet, I generally prefer the RBSO term because it specifically refers to the basis of the new ventures (i.e., scientific research) and its relationship to an academically oriented parent institution[9] (Clarysse and Moray, 2004; Zerbinati et al., 2012).

3.5 Research Design

Mixed Method

This dissertation has a mixed method research design in the sense that it uses both quantitative and qualitative approaches. However, there is great variability between mixed method designs. Decisions on data collection timing, weighting, and data mixing will determine what type of mixed method procedure is adopted (Creswell and Clark, 2007: 206-207). See Table 3-10 for specification of these items for this dissertation.

Aspects	Description
Data collection timing	Data collection is performed **sequentially** in phases starting with quantitative and ending with qualitative data.
Weighting	**Primary weight/priority** given to the **quantitative data** where most time and effort was spent in collection and analysis.
Data mixing	Quantitative and qualitative data are **connected** during the phases of research. More specifically, analysis of the quantitative data inspired the qualitative data collection phase.

Table 3-10: Specification of aspects influencing the type of mixed method design. Adapted from Creswell and Clark (2007).

This specification indicates a procedure that can be labelled a *sequential explanatory design* (Creswell and Clark, 2007: 211). It is commonly used when a largely quantitatively oriented project is connected with a qualitative research phase exploring certain results of interest coming out from the quantitative analysis. See Figure 3-4 for a visualization of this procedure.

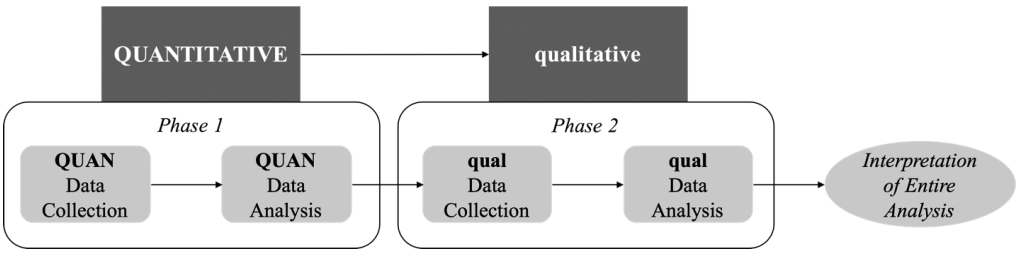


Figure 3-4: Sequential explanatory design. Arrows indicate a sequential form of data collection. Capitalization indicates a weight or priority.

The first phase of this dissertation research process was to construct a quantitative longitudinal database of the population of Norwegian RBSOs established since 1999. While qualitative data sources also were used in the database, these sources were first transformed into quantitative form through a coding process. This population was then analyzed, which inspired a need to collect and analyze deeper and more fine-grained qualitative data on the subset of firms which experienced a trade sale. Therefore, multiple case studies were performed to collect new primary data while at the same time leaning heavily on the comprehensive database constructed. Evidently, this procedure is in accordance with the principles of critical realism, seeking to uncover the deeper structures of reality, which often requires several phases and approaches of data collection and analysis augmenting each other.

As a whole, this dissertation outlines the interpretation of the entire analysis. Yet, this dissertation's research design departs from other mixed method designs in its presentation structure. Although the dissertation overall follows a sequential explanatory design, the results are not presented in a way that coherently integrates the two major phases of the analysis as depicted in Figure 3-4. Rather, while Part 1 presents overall findings, conclusions, and contributions, Part 2 contains several research papers with its own narrower research design. I refer to Chapter 5 for a summary of these research papers as well as Part 2 for the individual research papers in full length. This is an appropriate presentation structure due to research papers being suitable formats for journal publications.

Research Context

The empirical context for this dissertation is the population of RBSOs commercializing research results from PROs in Norway. The population of firms was identified through the FORNY[10] program (acronym meaning research-based innovation), administrated by the Research Council

of Norway (RCN). FORNY was the key governmental policy mechanism for promoting the infrastructure supporting the commercialization of research (for details see Borlaug et al., 2009; Rasmussen et al., 2013; Rasmussen and Gulbrandsen, 2012; Spilling et al., 2015). The program was established in 1995[11] and operated until 2012, with certain adjustments in its structure as the program evolved over time. In 2012, FORNY was replaced by the new FORNY2020 program having similar objectives, but more aligned with the increasingly mature infrastructure for commercialization of research in Norway. The budget for FORNY increased from short of €5 million in 2000 to close to €20 million in 2015 (FORNY2020) (Borlaug et al., 2009; Spilling et al., 2015), indicating increased attention given to academic entrepreneurship also seen generally in Europe (Fini et al., 2016).

FORNY's objective was to facilitate the commercialization of research results with considerable market potential. To achieve this objective, the program's activities aimed to:

- Raise awareness and enhance the attitudes and behavior of research communities, making the commercialization of research results an integrated and prioritized task at research institutions;
- Assist in establishing professional organizations and systems for commercialization of research results, including developing competent support mechanisms for scientists having made scientific discoveries with commercial potential;
- Increase number of science-based business ideas with sufficient value creation potential, and ensure efficient realization of these potential business opportunities through new ventures or licenses; and
- Encourage and contribute to increased cooperation between research communities, entrepreneurs, investors, industry and commerce, and public authorities.

The FORNY program worked primarily through the technology transfer offices (TTOs) or equivalent organizations, such as incubators and science parks (henceforth: collectively referred to as TTOs), connected to PROs (Gulbrandsen and Rasmussen, 2012). Within FORNY, commercialization was viewed as either licensing agreements[12] to established industry, or the establishment of new ventures. As in many other European countries, Norway passed changes in legislation in 2003 related to intellectual property (IP) developed at universities. Influenced by the Bayh-Dole Act (see e.g., Grimaldi et al., 2011) in the US, this new legislation essentially transferred the control of IP ownership from the scientific staff (called the professor's privilege, see e.g., Bourelos et al., 2012; Damsgaard and Thursby, 2013) to the university. The implication

of the new IP legislation was that all scientific staff pledge to report all research results they believe have commercial potential. Under the earlier professor's privilege scheme, no Norwegian universities operated with internal TTOs and allowed external organizations to assist faculty in their commercial exploits. However, the legislative changes in 2003 essentially led to the establishment of TTOs at all major universities in Norway, taking the responsibility for commercialization processes at its associated PRO. While the number and composition of TTOs has changed throughout the program, all major PROs have been connected to a TTO at all times. It should be noted that PRIs were not directly affected by the legislative change as they never operated with an equivalent system to the professor's privilege.

The program was the primary source of funding for TTOs, both to finance their internal operations and to provide financial support to specific commercialization projects. The program operated with an incentive-pay model directed at the TTOs, where bonuses were awarded for successful establishment of each new RBSO (Gulbrandsen and Rasmussen, 2012). The bonuses constituted approximately 10% of the total funding in the program (Borlaug et al., 2009). This model ensured that the TTOs were highly incentivized to report all new RBSOs in any way connected to the institutions they supervised. I will label the collection of all reported RBSOs as the "FORNY portfolio".

This structure of FORNY is vital for my research for two reasons. First, the FORNY portfolio approximates the full population of such firms in Norway in the focal period, given the reporting incentives and the program's critical financial importance for the TTOs. Second, the continuous reporting of RBSOs in real time limits survivorship bias typically associated with retrospective entrepreneurship studies (Davidsson and Honig, 2003; Delmar and Davidsson, 2000). FORNY is not the only policy mechanism or program that RBSOs can access for funding and support. However, it is unique and essential for this dissertation because its structure provides an unbiased and full identification of the population of RBSOs in Norway.

3.6 Data Collection

Empirical data for this thesis have been collected as part of a research project between NTNU and Nord University. Managed by Professor Einar Rasmussen, a small team of faculty and doctoral students have gathered data on the FORNY portfolio from a wide range of sources. Personally, I have been responsible for data collection efforts in primarily three areas. First, a coding template was developed to integrate and code several quantitative and quantitative data

sources into a coherent quantitative framework documenting details of the origin, development, and outcomes of growth processes of the RBSOs. Second, access to official corporate announcements was obtained from the public registry, which subsequently were extended and manipulated into functional formats for analysis. Third, 52 interviews were conducted with four groups of stakeholders in nine trade sales in the portfolio.

Data were systematically collected on 373 RBSOs reported into the FORNY portfolio in the 1999–2011 period and tracked until the end of 2015. Firms reported prior to 1999 (72 firms) were generally excluded from my data collection efforts[13], because many of key data sources were not available prior to this[14]. Firms reported after 2011 were removed as the key incentive structure embedded in the program was abandoned and the program was approaching completion in its current design. Finally, entities not incorporated as limited liability firms (e.g., sole proprietorships) were excluded (four firms). Table 3-11 summarizes the data collection process, which will be described in more detail in the following. A cohort approach like this, where firms with the same vintage are tracked longitudinally over time, is a recommended design to study the development and growth of new ventures (Coad, 2009: 144; Garnsey et al., 2006). It also addresses the fact that many growth studies draw inappropriate inferences in cross-sectional samples by excluding firms that have failed (Garnsey et al., 2006).

Area	Category	Type	Sources
Secondary data	*Financial data*	Register data (mostly quantitative)	Downloaded from the PROFF company database
	Corporate announcements	Register data (mostly qualitative)	Downloaded from The Brønnøysund Register Centre
Coded data	*Coding template*	Coding qualitative and quantitative sources into structured variables	Many, including annual reports, business plans, news articles and press releases, register data, web resources (LinkedIn, websites, etc.)
Primary data	*Case studies*	Qualitative data	Interviews supported by quasi-primary and secondary data

Table 3-11: Summary of empirical data collected in the dissertation.

Within my areas of responsibility, I supervised 17 graduate students from the NTNU School of Entrepreneurship and Nord University assisting in various degrees with data collection work from 2013-2016, typically in relation to their master's thesis work. At least 4,000 hours of coding and data structuring work have been completed directly related to this dissertation. This

section will describe the data sources and collection processes I have administrated to obtain and structure the core data used in this dissertation. In addition, supplementary and specialized data were often collected as part of the individual research papers. I refer to the specific research papers in Part 2 for details regarding this.

Sources

Annual Reports

All limited liability companies in Norway are obligated to submit an annual report to The Brønnøysund Register Centre[15] (BRREG) every year. BRREG is the national agency managing the Register of Company Accounts, among several other national registers. Overall, more than 3,500 annual reports were accessed through BRREG directly and the PROFF database (www.proff.no), encompassing the complete annual report history of each RBSO until 2014. Each annual report has three main components:

1. The financial statements, including the profit and loss statement (P&L) and balance sheets (B/S).
2. Notations to the financial statements outlining detailed information on items such employees and salaries, auditor, ownership, tax and tax credits, R&D project specifications, changes in fixed assets (e.g., depreciations), and changes in equity.
3. A qualitative statement from the board of directors (BOD), which typically includes overall descriptions of the business activities, key events in the reporting year, financial situation (e.g., liquidity, solidity, growth) and going concern assessment, working conditions for employees, gender equality in the organization, and the firm's impact on the environment.

In addition to the annual report document, the quantitative financial statements for the RBSOs were downloaded in structured spreadsheets. The financial data available for small firms in Norway include P&L and B/S information with extraordinary levels of detail, comparable to public firms in many other countries. The financial data is structured in a hierarchy of sub-levels, but the more detailed levels were not particularly meaningful for the purposes of this dissertation. Rather, aggregated financial measures were primarily used. In addition to the traditional P&L and B/S figures, the financial statements include data on the number of employees (absolute or full-time equivalents) and management compensation.

Corporate Announcements

Corporate announcements (Norwegian: "kunngjøringer") are mandatory notices to creditors and the general public that report significant events in the firm. All corporate announcements registered by the RBSOs were obtained from BRREG, totaling more than 10,000 observations across fifty different categories of announcements. The most important categories for this dissertation's purposes include initial registration, name changes, capital changes, mergers, divestments, CEO and BOD changes, as well as terminal events such as bankruptcy proceedings and dissolutions.

The announcements were received as individual computer files (XML format) per firm, with unique formats to each announcement type. Hence, a computer script was written to consolidate all individual files into a comprehensive data structure. However, because BRREG changed the structure of its internal database over time, all observations from 1999 to approximately 2003[16] were not available in a structured format. Therefore, these observations were added manually by a student assistant.

Corporate announcements could represent one-off events, such as date of establishment, but the vast majority relate to recurring corporate changes. However, these corporate events do not occur necessarily in regular intervals. In other words, a specific corporate event could occur zero, once, or several times. The announcements register events the day of occurrence, meaning that for each change we can identify the day when the change was registered. For each event, we also get unique information relevant to that specific type. As an example, firms change their board composition quite often, but without regular frequency. We can identify each change in the board as well as track the names of individuals on the board.

Business Plans and News Articles

As part of the reporting process to FORNY, TTOs were incentivized to submit business plans describing the new RBSO established. The FORNY administration provided access to this business plan archive of which all documents were scanned and organized into folders. We had access to the original business plans for approximately two-thirds of the RBSOs. While varying greatly on quality, scope, and depth, the business plans generally provided details on factors such as the technology, venture team, and industry in addition to business models, strategies, and market segments the firm intended to pursue.

We also developed a comprehensive news archive containing press releases and all print and online news bulletins referencing the name(s) of the RBSOs. More than 4,000 individual bulletins were downloaded and organized into folders. The news archive was constructed using Retriever, the largest media surveillance provider in the Nordic region (http://www.retriever-info.com/). Searches were conducted using the same approach and methodology and the results is expected to reasonably represent the media coverage that the RBSOs have received. Both the business plans and news articles are primarily used as supporting documentation for coding other primary data sources, as well as used when conducting case studies.

Coding Template

Objectives and Design

Combined, the data sources used in this dissertation provide rich details on various facets of RBSO development and growth, but many do so in a fragmented and qualitative manner. This refers specifically to business plans, news article archives, and annual reports. Accordingly, there was a need to codify information into more structured formats. A coding template was developed to capture relevant variables. An essential principle was to follow the development and growth of an RBSO's business activities from inception and throughout its life cycle, regardless if it is extended into several legal entities over time. Further, we often included variables well covered in other structured sources in order to cross-check data reliability. See Table 3-12 for more details on the key objectives of the coding template.

Origin	Document main characteristics of the RBSO's origin, including institutional relationships, technological foundations, and individuals involved in establishing the firm.
Legal entity changes	Document all events, transformations and amalgamations impacting the structure of the legal entity(ies) or fundamentally extending or changing the nature of business activities.
Milestones and events	Document key developmental milestones and performance events.
Terminal outcomes	Document qualitatively different terminal outcomes when the RBSO's business activities cease to exist in its current structure.
Ownership structure	Document the annual ownership structure.

Table 3-12: Objectives of the coding template.

As most sources were qualitative in nature, it was apparent that variables to be considered in the template needed to satisfy two criteria:

1. Consistency: Information needed to consider the value of a variable was not only required to have high coverage, but also demonstrate consistency. The latter refers to the information always being available, regardless of firm choices and characteristics.
2. Objectivity: Determination of variable values should be based on objective criteria and not influenced by the subjective judgement of the coder.

As an example, a variable capturing material change in an RBSO's business model was initially considered to be included in the template. However, this variable satisfied neither of the criteria. It seemed arbitrary when the RBSOs commented on their business model in either the annual reports or news articles. Further, what constituted a "material change" was not possible to define objectively and, thus, was influenced by the coder's subjective judgement. In contrast, a variable capturing when RBSOs established (or acquired) new subsidiaries was included in the final template. This information is consistently and objectively available in the annual report due to legal reporting requirements.

To reach a stable version of the template, an initial version was tested on a training sample of RBSOs where I personally had particularly good prior insight (all having their institutional origin at my home university). During this period, the template was altered continuously by removing and adding variables to match the realities in the data. The final template was decided upon when additional coding did not create a need for additional changes. The template was supplemented with detailed coding instructions outlining, e.g., the description of the variable and corresponding admissible values, which data sources should be used for each variable, and how information should be interpreted. In addition, all variables were accompanied by comment fields where coders entered the rationale behind their decision and other comments useful to interpret that variable. Finally, the template included the responsible coder to write a synopsis highlighting key points concerning the RBSO's development and growth, and a description of information gaps that could be investigated further.

In terms of content, the final coding template covers five major areas: Institutional Origin, Technological Origin, Significant Events, Terminal Outcomes, and Firm Development. Table 3-13 presents an overview of the variable categories within each area. "Institutional Origin" consists of time-invariant variables related to the parent PRO and TTO, presence of student involvement and industry partners as well as where and when the RBSO was established. "Technological Origin" refers to time-invariant variables describing the scientific basis and

technological domain of the RBSO. “Significant Events” are time-varying variables tracking the life cycle of the RBSO through key milestones such as VC investments, commercial breakthroughs, internationalizations, and changes to the company structure. “Terminal Outcomes” specifies if, how, and when the RBSO reached a terminal outcome, separating between failure, trade sale, and transformed outcomes. The latter refer to two types of special outcomes. First, the firm could cease to exist because it merges with another firm, but not like a trade sale where a larger industry incumbent acquires the firm with the motive of obtaining valuable strategic resources possessed by the RBSO (Coff, 1999; Puranam et al., 2006; Ranft and Lord, 2002). Second, an RBSO might go through a major company restructuring leaving the firm unrecognizable with respect to its original business activities. One example here is when the “real” business activities are moved into a new company and the original legal entity is used for other purposes (please see Section 4.3 for further details). Finally, “Firm Development” refers to time-varying variables specifying the RBSO’s degree of R&D activity, going concern statements (relating to financial solidity), and the ownership structure. With respect to the latter, we take advantage of the legal requirement in Norway that all firms must disclose in the annual report the ten largest owners controlling more than 5% ownership[17]. We did extensive research on each owner and classified them into twenty-three distinct categories constructed by the juxtaposition of relevant dimensions, i.e., individual/organization, insider/external, domestic/international, financial holding/operating, and private/public. As an example, this granular approach gives the unique ability to identify shares held by individuals, irrespective of whether these shares are directly held by individuals or through financial holding companies established for tax or legal reasons.

Area	Variable Categories	Type
Institutional Origin	Parent academic institution	Time-invariant
	Reporting TTO	
	Industry partner	
	Student involvement	
	Link to other FORNY entities	
	Reporting and incorporation dates	
	Original geographic location	
Technological Origin	Scientific basis (explicit invention or tacit knowledge)	Time-invariant
	Social science	
	Technological domain	
	Biotechnology	
	Software	
Significant Events	VC investments	Time-varying
	First commercial sale	
	First international sale	
	New subsidiaries	
	Mergers and divestments	
	Name changes	
	Major company restructuring	
	Major ownership transfers	
	Initial public offerings (IPO)	
	Bankruptcy proceedings	
	Recycling legal entity	
Terminal Outcomes	Failure	Time-varying
	Trade sale	
	Transformed	
Firm Development	R&D activity	Time-varying
	Financial solidity and funding need	
	Ownership structure (ten largest owners)	

Table 3-13: Description of variable categories included in the coding template.

The actual template computer file was prepared with MS Excel and all variables were formatted so that admissible values were listed ex-ante using drop-down menus. This was enacted to improve coding efficiency and consistency. The MS Excel file is available from the author on request.

Process and Sources

The 373 RBSOs were coded with the assistance of graduate students starting in late 2013 and concluding in mid-2016, typically organized in intense two- to three-month periods where a

team of students cooperated on a dedicated part of the FORNY portfolio. The main data sources were the business plans, news article archive, corporate announcements, and annual reports. Supporting sources were employment-oriented social networking service LinkedIn (www.linkedin.com), the PROFF company database (www.proff.no), and general Google searches. LinkedIn was used to obtain education and professional experience data on founders, board members, and other individuals involved in the RBSO. The PROFF database was used to investigate ownership structure of the RBSOs' corporate owners to code these with appropriate categories, and observe any formal connections (e.g., ownership, management roles, or BOD position) of identified individuals to other companies. Google web searches were used as a supplementary source of information when needed.

All students went through comprehensive training and coded multiple example firms before coding new firms. Further, all completed templates were reviewed by me and approved with necessary revisions. Certain changes to the coding process were required over this prolonged period. First, experience managing the coding process induced insight into improvement areas. Most prominently, this involved enhancing and refining the admissible values that certain variables could take. For example, the initial template specified twelve owner categories (e.g., founder, university, VC investor, etc.). This was later expanded to the current, and more granular, twenty-three categories[18]. Second, as time passed, we obtained access to additional data. When the initial coding work commenced, we only had access to the annual reports up to 2012; however, we later gained access to the 2013 and 2014 annual reports. In both cases, the entire population of RBSOs was re-coded to consistently reflect these changes.

Case Studies

One objective of the dissertation was the capacity to separate between qualitatively different outcomes. Trade sales are one type of outcome and an initial analysis of the FORNY portfolio revealed that this was a common outcome for promising RBSOs. Chapter 4 demonstrates in more detail that trade sales represent an essential aspect of success for the FORNY portfolio as a whole. I increasingly came to realize that trade sales are an important, but very understudied aspect of RBSOs' growth processes. Earlier research supports this in two ways. First, RBSOs are technology-oriented new ventures often backed by VC investors. VC investors ultimately want to exit their investments and a trade sale is the most common liquidity event for such investors (Schwienbacher, 2005; Wright et al., 2006), especially in small countries like Norway with poorly developed public markets for NTBFs. Second, RBSOs can be motivated to pursue

a trade sale in order to obtain access to critical complementary assets controlled by industry incumbents, such as manufacturing or marketing capabilities (Lubik et al., 2013; Zahra et al., 2007).

While the coding process identified when trade sales occurred, it revealed limited details on the micro-level mechanisms of these transactions despite the rich data at our disposal. This is caused by no formal reporting requirements combined with the confidential aspects associated with such transactions. In essence, we did not have a clear understanding of the reasons and processes leading up to RBSOs being acquired and lacked insight into events occurring after the trade sale was completed. The case study method is recommended as an appropriate design to obtain a deep understanding of processes, contexts, and causal mechanisms, and is especially suitable to study complex situations such as trade sales (Miles and Huberman, 1994; Schweizer, 2005). Further, conducting case studies within a larger research project has been found to be a benefit due to the depth of available data and the longer anticipated research horizon (Gephart, 2004). Hence, the database and rich data sources already collected provided ample opportunities both for the sampling of cases and primary data collection. Accordingly, I decided to conduct qualitative multiple case studies of the trade sales in the FORNY portfolio. Paper 4 in Part 2 carefully outlines the details of this qualitative study; therefore, here I will only emphasize certain key points that speak more generally to my methodological choices.

Compared with single case studies, multiple case studies provide a stronger base from which to develop theory (Yin, 1994). I view cases as a series of "experiments" which serve as replications that enable contrasting and comparisons between cases when constructing emerging theory (Eisenhardt and Graebner, 2007; Yin, 1994). The selection of cases is a critical step. Representative samples are an important criterion in quantitative studies to ensure reliable statistical inference to the larger population. In case studies, however, it is more appropriate to employ *theoretical sampling* with the objective of selecting cases that are particularly relevant and suitable to generate theoretical insights (Eisenhardt and Graebner, 2007). Still, it is important to make the sampling criteria explicit, allowing for accessible interpretation of findings and facilitating replication of the study in other settings (Neergaard and Ulhøi, 2007, chapter 9). The FORNY portfolio offers an opportunity to conduct theoretical sampling in a uniquely systematic and controlled manner. The portfolio approximates the full RBSO population in Norway, and the available database contains a range of variables of the firm's origin, development, and ultimate outcome. A reasonable impression of a "common" trade sale,

therefore, could be formed in addition to visibility to important outliers. We applied a sampling approach using "polar types" (Eisenhardt and Graebner, 2007), selecting both low and high value transactions. Further, we aimed for the sample to be varied on other dimensions that could potentially impact acquisition dynamics (Eisenhardt, 1989). We therefore selected firms with varied origins (i.e., type of PRO, technical domain, and presence of industry partner), development process (i.e., growth and VC-backing), time period and structure of the transaction. Trade sales evaluated as not representative more generally and, thus, unsuitable as a basis to generate theory, were excluded. One example of this was a trade sale where the original owners re-purchased the firm a short period after the initial transaction. We also avoided trade sales taking place more than ten years ago as these would be especially prone to recollection bias by the informants (Miller et al., 1997). Lastly, priority was given to trade sales where my personal relationships enabled generous and open access to information. Initially, eleven cases were selected from the total of thirty-two trade sale in the FORNY portfolio. This is not only a substantial number of cases (Eisenhardt, 1989), but also about one-third of all trade sales in the portfolio. However, two cases were later dropped after data collection had begun. In one case, the buyer refused all relevant individuals to participate in the study due to unwillingness to share confidential information. In another case, we were not able to agree interviews with sufficiently many informants.

The primary data source for the case studies was 52 semi-structured interviews. Interviews are an especially helpful source of data when studying episodic but significant events such as trade sales (Eisenhardt and Graebner, 2007). The design and selection of interviews were clearly influenced by my critical realist standpoint. The objective of the interviews was to infer the "reality" of the development processes leading up to the trade sales based on the subjective opinions and meanings attached to the experience among participants (Yin, 1994). However, it was a priority to ensure numerous informants having diverse perspectives of the process as the subjective statements of the informants are prone to be biased by retrospective sense-making (Eisenhardt and Graebner, 2007). Consequently, four groups of stakeholders were defined: founders/employees, buyer representatives, investor representatives, and external board members/advisors. These groups do not necessarily have aligned interests or equal access to information. This is a benefit for the researcher because it promotes varied and balanced perspectives of the process. We identified and selected informants among these groups carefully. The existing database provided access to the names and backgrounds of the founders, owners, board members, and CEOs. We initially approached the individuals we believed were

most involved in the acquisition process. The original founders were always the starting point from where we moved on chronologically following the life cycle of the firm, concluding with the buyers. We also approached other individuals in possession of vital information, identified through interactions with existing informants. We stopped targeting new informants when we did not foresee gaining significant novel information from additional interviews.

The development of the interview guide was assisted by a comprehensive review of relevant literature. A literature review helps focus the empirical work and enables evaluation of the applicability of constructs identified *a priori* (Eisenhardt, 1989). The interview guide was comprised of one generic section and four sections specifically tailored to each stakeholder group (the interview guide is available from the author on request). In practice, the interviews took a semi-structured and conversational form. We strived to let the informants speak freely and allowed them to focus on areas they were most knowledgeable about (Suddaby, 2006). The database and all secondary sources were consulted prior to all interviews in order to know as much as possible about the case and the role of the specific informant (Yin, 1994). Typically, we first covered the development of the firm from its founding up to the trade sale. For this part, we leaned heavily on our documented history of the firm and time with informants was spent primarily on corroborating and extending the narrative with richer details. We then focused on the intricate details of the acquisition process.

3.7 Summary and Limitations

This chapter has presented the dissertation's overall research methodology. In the aggregate, the dissertation has applied a mixed method approach with a sequential explanatory design, where findings are presented primarily through five research papers. As a consequence of this design, no single modeling approach or analytical technique is used. The research papers in Part 2 use tailored methods and analytical approaches appropriate for each research context, utilizing some parts of the comprehensive data collected. Table 3-14 provides a summary of the methods used in each research paper. The four empirical papers all use data from the FORNY portfolio.

Paper	Type	Data and Sample	Modeling and Analysis
1	Literature Review	105 research papers in peer-reviewed journals	Conceptual analysis and synthesis of the literature.
2	Empirical - Quantitative	2,323 RBSOs from 185 universities in Italy, UK, and Norway	Dependent variables are count-based (i.e., number of RBSOs established and number of RBSOs receiving first round VC investment), and independent variables occur on both university-level and country-level. Thus, multi-level negative binomial regression was applied.
3	Empirical - Quantitative	471 RBSOs from the FORNY portfolio (1995-2012) in Norway	Descriptive analysis of the value creation in the portfolio segregated on outcome categories.
4	Empirical - Qualitative	Nine trade sales in the FORNY portfolio	Qualitative case-study adopting the Gioia analytical approach (Gioia et al., 2013).
5	Empirical - Quantitative	370 RBSOs from the FORNY portfolio (1999-2011) in Norway	The dependent variable is an acquisition event, e.g., a time-to-event variable exposed to right-censoring. Hence, discrete time event history analysis is the pertinent procedure to analyze the data.

Table 3-14: Summary of methods and analyses applied in the five research papers in Part 2.

The methodology presented in this chapter has a number of limitations and areas of improvement. First, in retrospect, too much time and effort was likely spent on generic compared with theory-driven data collection. The objective of empirical completeness led to the desire to collect as many relevant data sources as possible. While the resulting database contains a large amount of data on a range of areas, the variables can mostly be put in two categories. The first category describes firm heterogeneity at origin. This relates to areas such as characteristics of the spawning institution and technical domain. These types of variables are often used as control variables. The second category of variables describes firm outcomes in various ways, such as firm milestones, financial performance, and terminal outcomes. These are often used as dependent variables. In sum, the database lacked a range of variables that can *explain* such firm outcomes and events. While this is not a pervasive issue for the entire database, a stronger theoretical position upfront would probably have resulted in more focused data collection of theoretically relevant variables. For instance, the database does not contain variables on the individual level to any large extent. Insight into type of entrepreneurs, their behavior, and actions would have enabled studies linking these characteristics to firm outcomes. While the data collected for this dissertation has many strengths, these weaknesses limit the type of theoretical questions that can be addressed. Second, all the data coding was both supervised and ultimately approved by me. The empirical data can be influenced by my own

subjective biases and errors. Third, all data are contextually embedded in Norway. The extent to which the findings of this dissertation can be generalized to other contexts remains unclear, and represents an area for further research. Fourth, although the dissertation advocates for the use of quantile regressions and similar advanced statistical techniques and research designs, such techniques have not been applied. Finally, although the constructed database approximates a national population of NTBFs, the sample size is, in fact, quite small. Further, no matched sample of comparative independent NTBFs or corporate spin-offs (CSOs) was developed as part of this dissertation. Hence, there are limited possibilities to conduct comparative studies and map differences between RBSOs and other NTBFs. This includes investigating whether certain factors have differential effects on RBSOs and NTBFs (for examples of this see e.g., Clarysse et al., 2011; Ensley and Hmieleski, 2005; Wennberg et al., 2011; Zahra et al., 2007).

Notwithstanding these limitations, my hope is that other researchers can take advantage of and extend the database that has been developed so far. As the quantitative data systematized during this research contains far more data than required for the scope of this dissertation, it provides an ample opportunity to exploit the database for other uses.

4 EMPIRICAL CONTEXT

This chapter provides a mostly descriptive analysis of the portfolio of RBSOs that constitutes the empirical context for this dissertation. The analysis follows the RBSOs in the FORNY portfolio established in the 1999-2011 period. Each venture is tracked longitudinally from founding until reaching a terminal outcome, or right-censored in 2015 if survived. The purpose of this analysis is twofold. First, it gives a tangible depiction of the empirical context of this dissertation and illustrates the breadth and depth of the data presented in Section 3.6. The empirical research papers in Part 2 all make use of certain parts of this data. Second, it will provide a general overview of the RBSO phenomenon in Norway.

As discussed in Section 3.5, the bonus model embedded in the FORNY program incentivized the TTOs to report all new ventures associated with their institutions. This ensures that the vast majority of the full population of RBSOs in the period were reported to the FORNY administration. However, certain firms are included that "stretch" the boundaries of the RBSO concept (as defined in Section 3.4). This relates particularly to two issues. First, some RBSOs are based on research in the social sciences (17 ventures, 5% of portfolio), which arguably face very different growth challenges compared with RBSOs commercializing technology. Second, certain RBSOs are based on inventions or expertise that are only partly connected to a PRO. For instance, spin-offs from the research division of Telenor[19] were originally included in the FORNY program (nine ventures, 2% of portfolio). In other cases, outside corporations or individuals appear be the primary source of knowledge, with the PRO only playing a supportive role (32 firms, 9% of portfolio). For the purposes of this analysis, these 58 RBSOs are removed from the portfolio of 373 RBSOs[20], leaving a total sample of 315. The analysis presented here is in its entirety based on the data sources presented in Section 3.6.

Figure 4-1 below provides an overview of the different elements the analysis will cover. First, institutional, technological, and partnership characteristics of the sample will be analyzed. Second, a variation of the conceptual framework developed for performance outcomes in Section 3.3 is adopted, focusing on both terminal and non-terminal outcomes. Development of ownership structures are included as part of financial performance events.

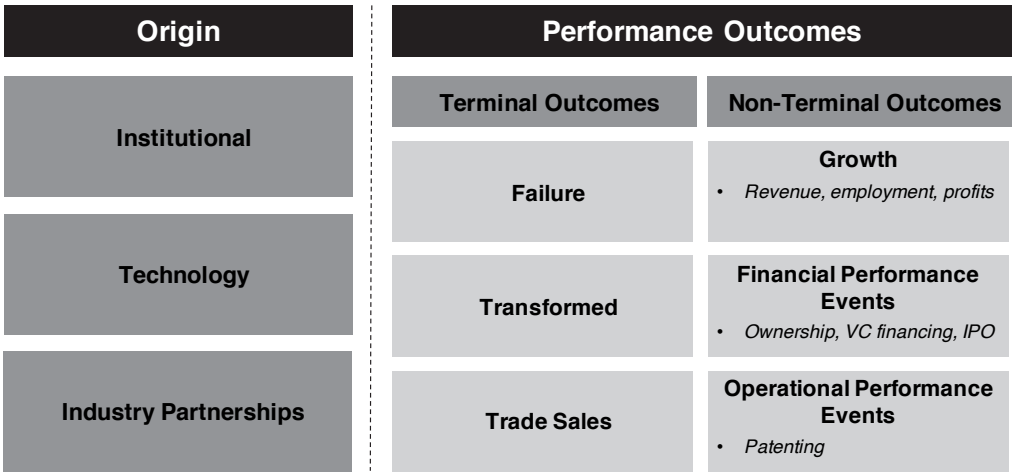


Figure 4-1: Elements of empirical analysis based on conceptual model developed in Section 3.3.

4.1 Firm Origins

Institutional

At the start of the sample time period (i.e., 1999), Norway only had four universities[21], which are prestigious, long-established, and research-intensive (hereafter: traditional universities). During a period of reform in the higher education sector in Norway, four former university colleges were approved as new universities[22] in the 2000s (hereafter: new universities). In addition, the RBSOs in the FORNY portfolio can have their origin at university colleges or PRIs. Please see Figure 4-2 and Figure 4-3 for spin-off activity distributed by type of parent institution.

The four oldest universities are the most important institutions with respect to establishing RBSOs, followed closely by PRIs. The academic entrepreneurship literature is predominantly concerned with universities, often overlooking PRIs as a source of RBSOs (for notable exceptions see e.g., Clarysse and Moray, 2004; Clarysse et al., 2005; Heirman and Clarysse, 2004; Moray and Clarysse, 2005). This analysis shows that PRIs represent one-third of the FORNY portfolio. Hence, not taking PRIs into account would miss a significant part of total commercialization activities. PRIs absorb about 25% of total public R&D spending in Norway and are important contributors to national R&D activity. However, this is not unique to Norway as most European countries have a large number of PRIs (Gulbrandsen, 2011).

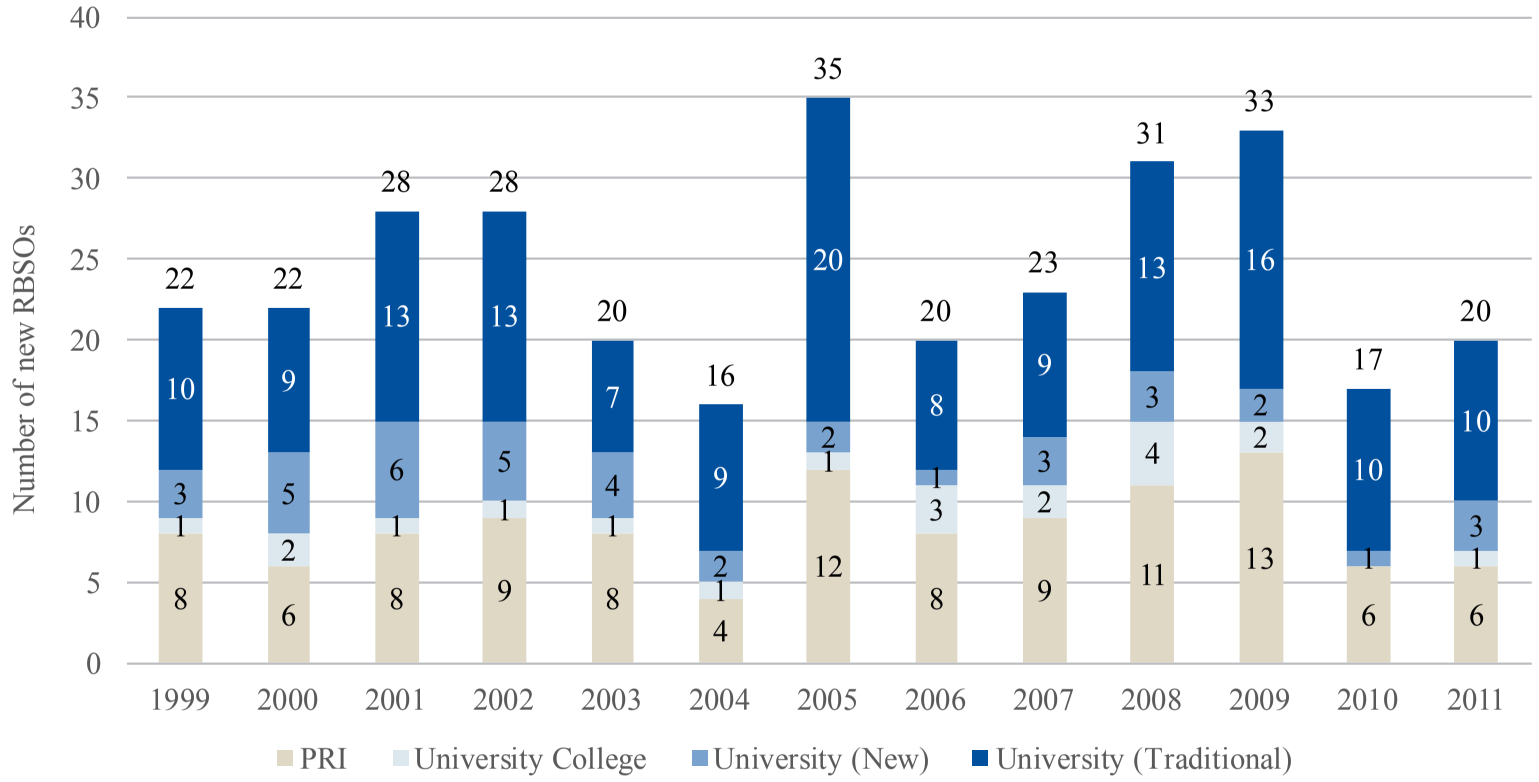
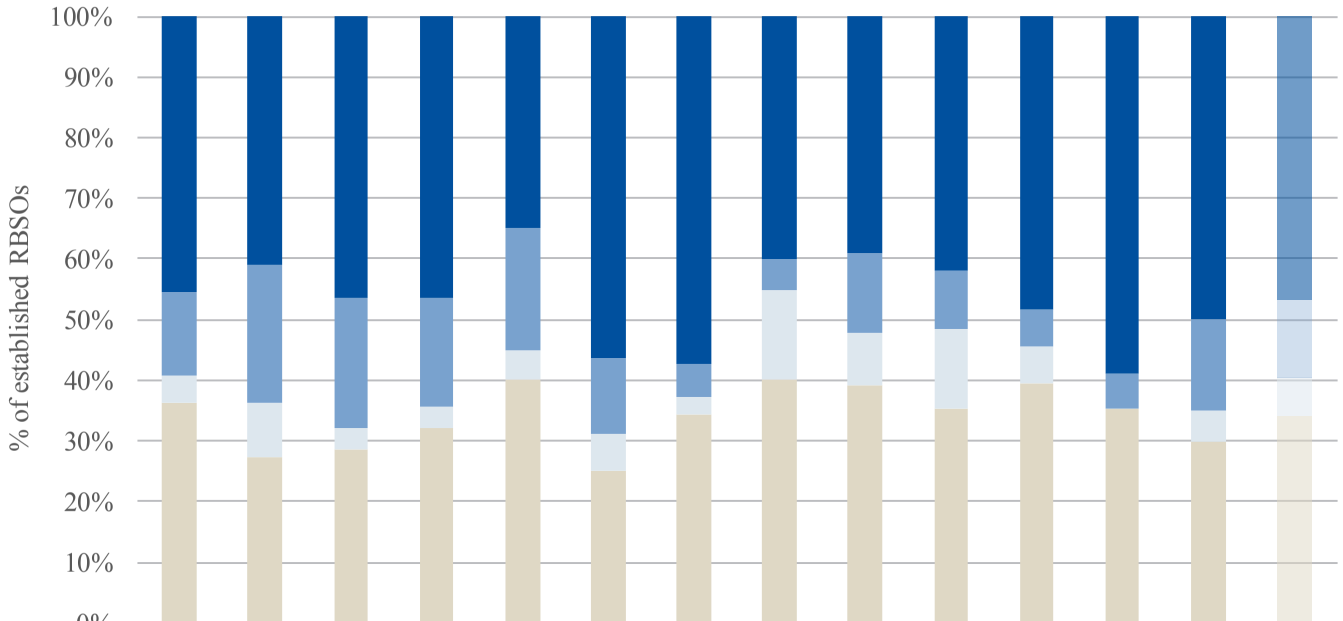


Figure 4-2: Absolute number of new RBSOs reported to FORNY per year (1999-2011) distributed by type of academic parent institution.



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
University (Traditional)	45%	41%	46%	46%	35%	56%	57%	40%	39%	42%	48%	59%	50%	47%
University (New)	14%	23%	21%	18%	20%	13%	6%	5%	13%	10%	6%	6%	15%	13%
University College	5%	9%	4%	4%	5%	6%	3%	15%	9%	13%	6%	0%	5%	6%
PRI	36%	27%	29%	32%	40%	25%	34%	40%	39%	35%	39%	35%	30%	34%

Figure 4-3: Relative shares of new RBSOs reported to FORNY per year distributed by type of academic parent institution.

The university colleges and new universities together play a quite limited role in commercialization activities. This is somewhat expected due to being significantly less research-intensive institutions. Going deeper, it also becomes evident that a few institutions are dominant within the traditional university category. NTNU represents 46% of RBSOs from traditional universities (21% of the total portfolio). A total of 17 PRIs are represented and the concentration of spin-off activity among these is somewhat less pronounced compared with traditional universities. SINTEF[23] is the largest contributor, with 24% of the PRI category, followed by International Research Institute of Stavanger (IRIS[24]) at 14% and Institute for Energy Technology (IFE[25]) at 12%. These three institutions represent half of the RBSOs established from PRIs. SINTEF is by far the largest PRI in Norway and, thus, could be expected to establish the largest number of RBSOs. SINTEF is also very closely linked to NTNU and these two institutions together represent 30% of all RBSOs in the portfolio[26]. NTNU is an engineering-oriented university with the national responsibility for higher education in technology. In addition, NTNU and SINTEF have a rich history of quite successful commercialization activities, especially within the electronics, information and communication technology (ICT), and maritime technical areas. The analysis confirms that NTNU and SINTEF have a central position in commercializing research in Norway (at least with respect to the number of ventures).

Technology

While industry is a common control variable in management research, it is a challenging concept in the context of academic entrepreneurship. RBSOs are known to commercialize radical and general purpose technology, which can be exploited in several industries through multiple application areas (Shane, 2001a, b). Hence, it is arguably more informative to segregate the portfolio based on the type of technologies the RBSOs are commercializing. Biomedical and software technologies have generally been found to be the most common technical fields for academic entrepreneurship (e.g., Golob, 2006; Lundqvist, 2014; Shane, 2004: 139-149). Figure 4-4 illustrates that this is also the case in Norway, where close to two-thirds of the RBSOs are significantly based on biomedicine and/or software.

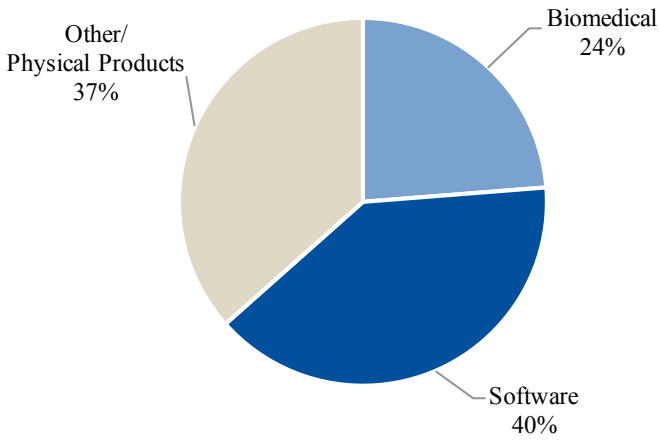


Figure 4-4: Distribution of RBSOs in the FORNY portfolio by technological field.

Figure 4-4 is somewhat misleading because, e.g., software technologies can be used for purposes outside what is usually considered as the ICT industry. There is also limited insight into what the *Other/Physical Products* category contains. Figure 4-5[27], supported by Table 4-1, provides a classification of into technical domains and more detailed application areas[28].

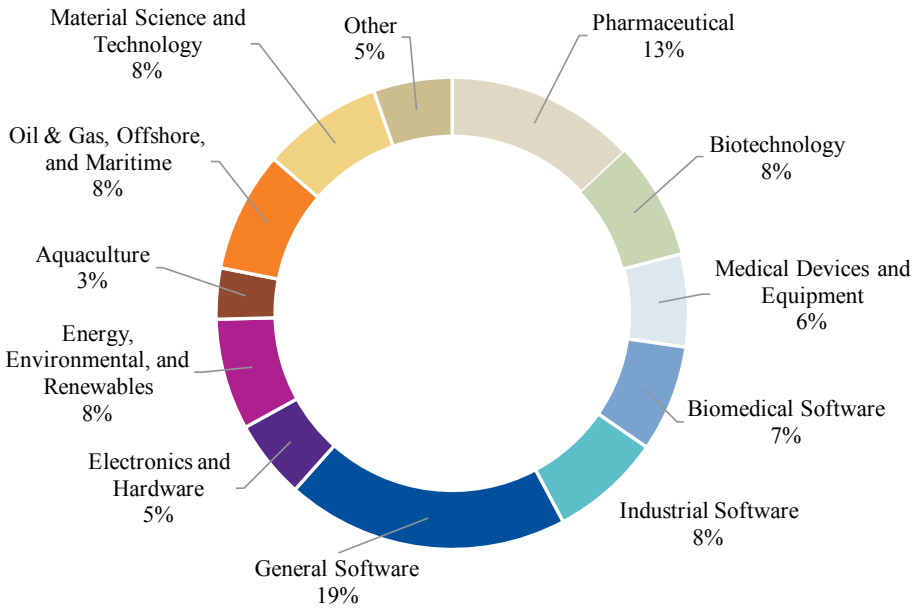


Figure 4-5: Distribution of RBSOs in the FORNY portfolio by application areas.

Technical Domain	Application Area	Description
Medical & Life Sciences	*Pharmaceutical*	Pharmaceutical technology, incl. drug development, vaccines, diagnostic kits, etc.
	Biotechnology	Biotechnology, incl. agricultural sciences, food science, animal and marine bioscience, etc.
	Medical Device	Medical devices and equipment
ICT & Electronics	*Biomedical Software*	Software specifically developed for medical applications
	Industrial Software	Software specifically developed for industrial applications, mostly in the energy, petroleum, and maritime industries
	General Software	Other software technologies not for industrial or medical applications
	Electronics & Hardware	Physical ICT devices, equipment, and systems based on electronics
Engineering & Physical Products	*Energy, Environmental, & Renewables*	Energy production components, renewable energy systems, and environmental technologies
	Aquaculture	Physical solutions and technology for aquaculture applications
	Oil & Gas, Offshore, and Maritime	Physical solutions, equipment, and components for use in oil & gas, offshore, and maritime applications
	Material Science and Technology	New or improved materials and compounds, or physical products developed on the basis of material advances

Table 4-1: Descriptions of technical domains and application areas.

The 11 application areas in Figure 4-5 can be grouped roughly into three technical domains: *Life Sciences, ICT and Electronics*, and *Physical Products*. This view provides some interesting new details. For instance, the *Medical Device* and *Biomedical Software* application areas together represent around 13% of the portfolio. While these technologies are not based on the chemical or biological sciences, they still represent a significant proportion of the RBSOs targeting what could be considered the medical industry. Overall, the distribution into technical domains is in line with previous academic entrepreneurship research (see e.g., Lundqvist, 2014; Shane, 2004: 139-140). However, the influence of the industry structure idiosyncratic to Norway is also evident. The *Oil & Gas*, *Offshore and Maritime,* and *Aquaculture* application areas are associated with major industries in Norway and RBSOs commercializing physical products and solutions within these application areas represent 11% of all RBSOs. Further, this is likely an understatement, as RBSOs in other categories also target these industries. For

instance, a substantial amount of RBSOs commercializing *Industrial Software* are targeting the oil and gas and maritime industries.

Further, the RBSOs' technological focus is strongly linked to the research activity of the parent institution. PRIs tend to have a narrow scientific focus and RBSOs created by PRIs overwhelmingly inherit and share the technical domain of their parent. Albeit having a much broader scientific research base, a similar situation exists with universities. The University of Oslo (UiO) represents over 40% of the RBSOs in the *Pharmaceutical* and *Medical Device* application areas, reflecting their leading scientific position in Norway within the medical area. In contrast, NTNU represents only around 10% of RBSOs in this area, albeit being the most important university overall.

The literature has mostly assumed that RBSOs are commercializing specific inventions (Karnani, 2013). However, RBSOs can also be based on non-formalized scientific expertise and tacit knowledge (Pirnay et al., 2003). Figure 4-6 shows that 26% of the RBSOs are established based on scientific expertise rather than specific inventions.

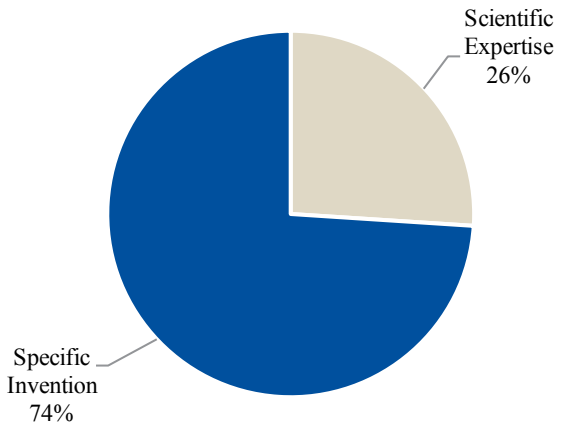


Figure 4-6: Distribution of RBSOs in the FORNY portfolio based on specific invention vs. scientific expertise.

RBSOs commercializing specific inventions can opt to legally protect their IP through patents. In certain areas, such as drug development, patenting is extremely common (Thumm, 2004). In other areas, RBSOs may favor secrecy and speed over formal IPR (Hall et al., 2014). For

instance, software code can be difficult to patent effectively and trade secrets are often viewed as a better strategy (Hurmelinna-Laukkanen and Puumalainen, 2007). Overall, 26% of the RBSOs commercializing specific inventions had applied for a patent(s)[29]. However, this figure is pushed downwards by the presence of software firms, where only 6% have patented inventions. As expected, less than 5% of the RBSOs based on scientific expertise have pursued patenting.

Industry Partnerships

RBSOs are established in academic environments and face the challenges of developing into a commercial enterprise. During the development process, early-stage technology must be transformed into marketable products or services. Some RBSOs are established as joint ventures with industry, presumably providing greater access to commercial skills and market capabilities (Munari and Toschi, 2011; Wright et al., 2004). Figure 4-7 shows the proportion of RBSOs established in cooperation[30] with industry incumbents.

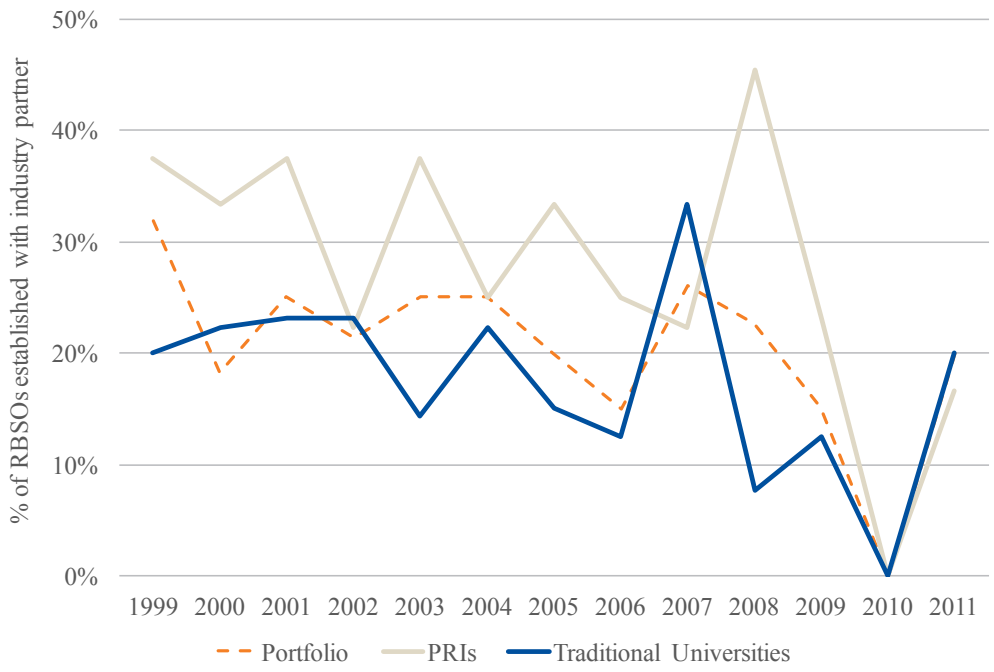


Figure 4-7: Percentage of new RBSOs reported to FORNY per year established in cooperation with industry incumbents.

PRIs are more active than universities at establishing RBSOs in partnership with industry. This is expected as PRIs conduct more applied research, often sponsored by industry (Gulbrandsen, 2011). It is more surprising that the degree of industry partnerships seems to be decreasing in recent years. Commercial skills and market competencies are critical resources for RBSOs to complement the often homogeneous management team (Hayter, 2015; Vanaelst et al., 2006; Widding, 2007). Partnerships with industry have been found, therefore, to be important for RBSO success (Lubik et al., 2013). While the effects of reduced use of industry joint venturing is unclear, one possible explanation for this is the changes in IPR legislation in Norway in 2004. This policy created the TTOs and other support mechanisms, which might act as a substitute for the services previously rendered from industry partners.

4.2 VC-Financing and Ownership

The academic entrepreneurship literature generally finds that many, if not most, RBSOs are reliant on attracting risk capital from venture capitalists (VCs) to finance firm development (Mustar et al., 2006). Figure 4-8 shows the cumulative incidence (for a formal description of cumulative incidence functions please see Scrucca et al., 2007) of VC investments in the FORNY portfolio.

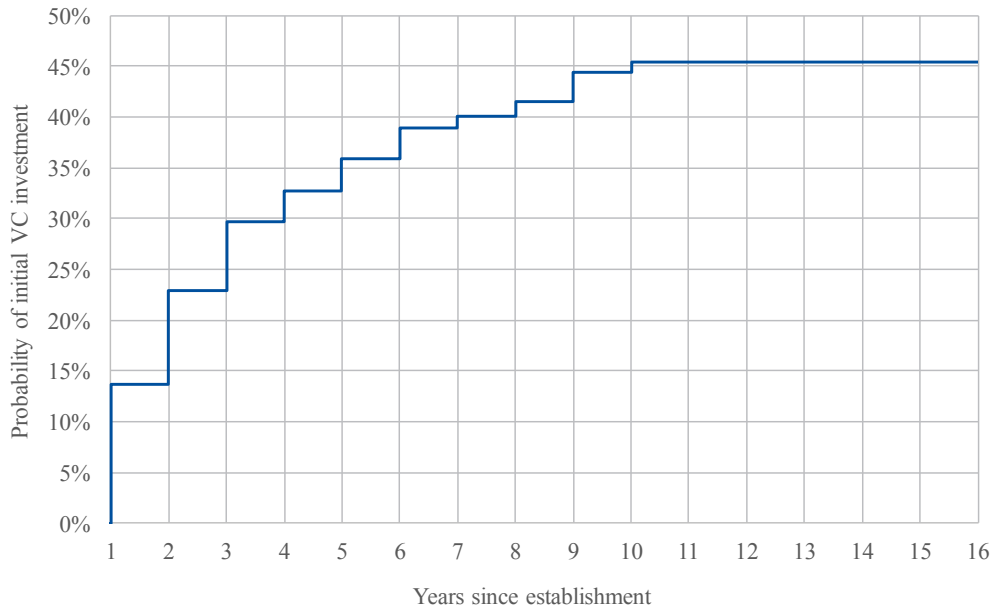


Figure 4-8: Cumulative incidence plot estimating the probability of initial VC investment.

Figure 4-8 essentially estimates the cumulative incidences of initial VC investment[31] in the FORNY portfolio, taking into account the timing of occurrences with respect to venture age. About 45% of the RBSOs are expected to eventually raise VC funding, and most do so quite early in development. After four years, one-third of the RBSOs had raised some form of VC-financing[32] and no RBSO raised initial VC-financing after ten years. Together these findings indicate that RBSOs are very frequent beneficiaries of VC funding, but that the possibility to raise VC funding declines dramatically after around four to six years.

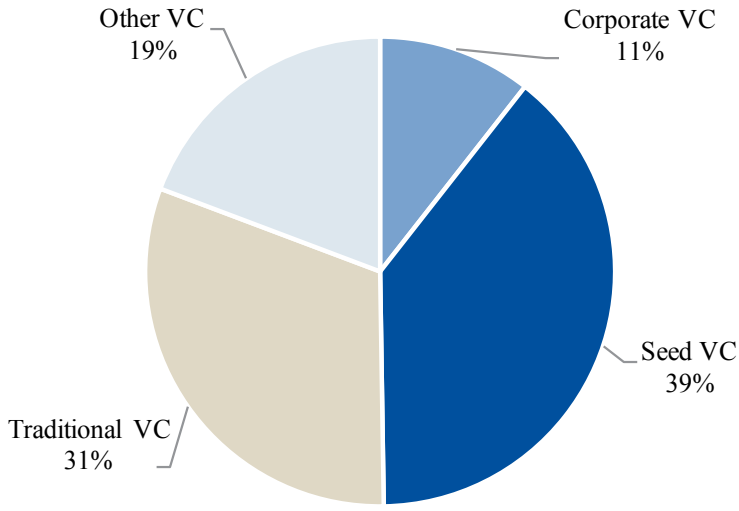


Figure 4-9: Detailed distribution of types of VCs active in the FORNY portfolio.

Figure 4-9 shows the distribution[33] of VC investments in more detailed categories. The most common type is VC investors specifically focused on seed investments (i.e., the earliest stage of investment). Most of the seed VCs active in the FORNY portfolio manage government-sponsored funds (see e.g., Brander et al., 2014), where the Norwegian government is an investor and/or provides risk adjustments to the private investors. Traditional VCs (mostly private and early-stage[34] funds) represent about 31% while corporate VCs backed fully by a corporate incumbent represent 11%. The remaining 19% are a group of VCs that invests in a portfolio structure similar to more traditional VCs, but, in fact, are fully funded by high-net worth individuals[35] or families.

More broadly, professional investors like VCs are not the only external owners in RBSOs. PROs are often initial owners in the venture and other individuals and companies will invest in the firm over time. Figure 4-10 shows the evolution of ownership between four major owner groups[36].

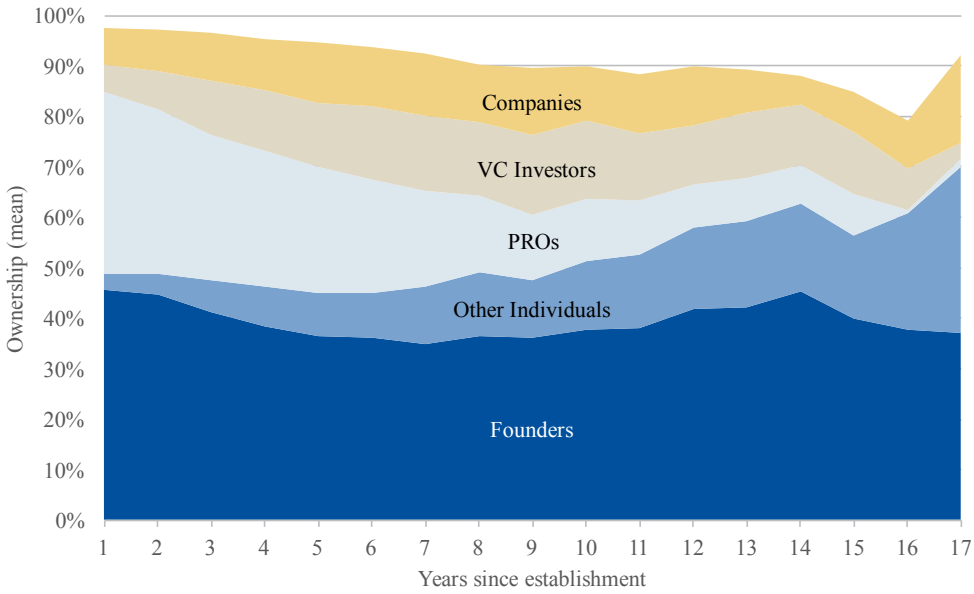


Figure 4-10: Evolution of ownership structures for RBSOs in the FORNY portfolio.

Founders[37] are the largest owner category in the RBSOs and maintain 35-45% ownership over time on average. Together with other individuals (i.e., other private owners such as employees and private investors), individual owners control 45-60% of the RBSOs over time. Individuals other than the original founders become relatively more important over time, although the founders still remain the largest group. The distribution of private ownership is rather bi-modal, where very low (below 5%) and very high (above 95%) ownership is the most frequent. For instance, the increase in individual ownership in the oldest firms is primarily due to the relatively higher proportion of RBSOs fully owned by individuals at that time.

The parent academic institutions (i.e., PROs) are typically quite large owners in the early years, but decrease their ownership significantly over time. This is likely because these stakeholders receive equity primarily as compensation for transferring IPR into the RBSO, but typically have limited ability to invest new capital going forward. In addition, there are notable examples in

Norway of TTOs selling shares in RBSOs to external investors[38]. More detailed analyses reveal two interesting findings. First, the initial ownership by academic institutions is substantially higher in RBSOs established more recently, but the same pattern of decreasing ownership is present. This could be expected from the changes in IPR legislation in 2004. Second, academic ownership has a skewed distribution (and increasingly so over time), illustrated by the median academic ownership being zero already in year six. At this point, the clear majority of RBSOs does not have any academic owners and average ownership is affected by a few RBSOs with very high academic ownership (dominantly from PRIs).

VCs and company owners (i.e., public and privately held companies with operational business activities) seem to be of about equal importance. These two groups essentially represent financial and industrial investors, respectively, and together these investors increase RBSO ownership over time to around 25-30% on average (peaking at around ages seven to nine years). However, VC and company ownership have quite different distributions. Both share a skewed distribution where zero ownership clearly is the modal condition. However, significant differences arise in the cases when either VC and company owners are present. VC investors typically maintain ownership of around 30-50% and very low/high ownership is uncommon. In contrast, moderate company ownership is quite uncommon and full ownership becomes the modal condition over time. The latter refers to scenarios where a company has acquired an RBSO, but operates the business independently. Paper 4 in Part 2 deals with trade sale processes in more detail.

Of course, ownership structure will differ significantly based on many factors. This will include circumstances from its origin, but also how resource-demanding and successful the RBSO's development process has been. Paper 5 in Part 2 deals with the effect of ownership structures in more detail.

4.3 Survival and Trade Sales

In Section 3.3, terminal outcomes of RBSOs were categorized as either failure, transformed[39], or acquired (i.e. experiencing a trade sale). By definition, surviving RBSOs have not achieving either of these outcomes (during the observation period). Figure 4-11 illustrates the evolution of these outcomes, with cumulative incidence curves modeling the three outcomes as competing events[40] (Scrucca et al., 2007).

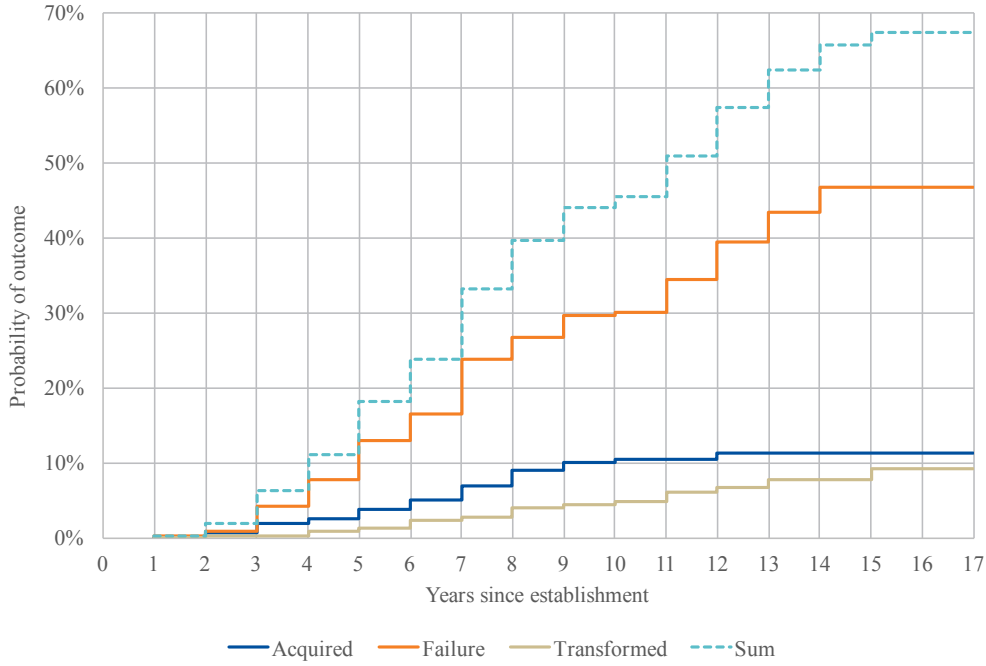


Figure 4-11: Cumulative incidence plot estimating the probability of competing terminal outcomes.

In sum, one-third of the RBSOs are expected to survive (i.e., exist independently) after fifteen years. The survival rate appears to be quite high in the FORNY portfolio, supporting other academic entrepreneurship research (see e.g., Rothaermel and Thursby, 2005; Zhang, 2009). After ten years, only 30% of RBSOs are expected to fail. Contrary to what could be expected, failure by bankruptcy is actually quite rare. Only 23% of failures are due to bankruptcy (or other forced dissolution), implying that most RBSO failures are voluntary dissolutions of the firm. This is in line with other research on voluntary vs. involuntary exits (DeTienne and Wennberg, 2016). The failure curve does not seem to really flatten out at any point, with failures occurring at fourteen years and beyond. However, only the oldest cohorts in the portfolio had the opportunity to mature to such an age. Consequently, interpretation is somewhat difficult beyond ten to twelve years due to the limited number of observations. Nevertheless, the analysis indicates that RBSOs have very long development processes before reaching terminal outcomes. Please see Paper 3 in Part 2 for a more in-depth discussion of this.

Trade sales seem to be a very important outcome, with about 10% of RBSOs expected to be acquired within ten years. A trade sale is defined here by two criteria adopted from the technology acquisition literature (Puranam et al., 2003): (1) the buyer is an industry incumbent significantly larger than the new venture, and (2) the buyer assumes 51% or more ownership (stock sale) or all productive assets (asset sale). Perhaps surprisingly, Figure 4-11 illustrates that trade sales occur quite steadily from a very young age. Closer qualitative inspection reveals the following conditions at the time of the trade sale:

- The majority of RBSOs are very small: 72% have five employees or less. 55% have less than 3 MNOK (approx. €330,000) in revenue. 80% are unprofitable.
- Only four firms have over ten employees and three firms have above 20 MNOK (approx. €2.2M) in revenue. One firm (incidentally, the oldest) represents about 43% of all revenue and employees.
- Seven firms have an acquisition valuation above 50 MNOK (approx. €5.5M) and one firm represents more than half the (known[41]) acquisition value in the portfolio (valuation of approx. 500 MNOK or €55M).

In fact, only about one-third of the trade sales can be understood as having a substantial value exchange between buyer and seller. The majority of RBSOs pursuing a trade sale seem to use it as a mechanism to further develop their technology and business concept in an industrial context. Please see Paper 3 in Part 2 for a more elaborate analysis of this.

An initial public offering (IPO) is a non-terminal outcome and is often viewed as a financial performance event. IPOs are rare outcomes of academic entrepreneurship in Norway, but still represent a major source of firm value in the FORNY portfolio. Four RBSOs have gone public on the Oslo Stock Exchange (http://www.oslobors.no/), where three are pharmaceutical drug development companies. Two RBSOs have later been delisted and remain privately owned with modest valuations. The remaining two RBSOs have current[42] valuations of approximately 5 billion NOK (approx. €550M), where one firm (*Nordic Nanovector*) represents 90% of the total value. Again, a very skewed distribution is observed. More importantly, the valuation of *Nordic Nanovector* grew around 700% in 2016 as the market responded to positive results from the firm's clinical trials. This is an illustration of the effect of Mandelbrotian wild randomness discussed in Section 3.4. As commonplace in the pharmaceutical context, *Nordic Nanovector* still has not experienced any significant commercial revenue (Gilbert et al., 2006).

4.4 Firm Growth

Revenue

Firms that fail cannot grow, but survival is not necessarily evidence for growth in the context of academic entrepreneurship. Looking first at revenue, Figure 4-12 shows the development in revenue from founding (RBSOs are included in the analysis until reaching a terminal outcome).

The mean is always higher than the median revenue, indicating that the distribution of revenue is skewed to the right. The bars show the share of the largest firms over time, illustrating that a small number of RBSOs are responsible for a large share of total revenue. Over time, the distribution becomes more skewed and, after ten years, the highest grossing firm represents over one-quarter of total revenue. More detailed investigation of the distribution finds that very low revenues (i.e., below NOK 500,000 or €55,000) are most common, regardless of firm age. Three RBSOs have experienced revenues above 100 MNOK (approx. €11M) and four additional firms above MNOK 50 (approx. €5.5M).

While it seems clear that a few RBSOs over time will dominate total revenue generated, it does not provide insight into how growth occurs on the firm level. Correlation analysis indicates that growth exhibits mild serial correlation, as annual revenue growth is correlated with its lagged value ($r = 0.28$, strongly statistically significant). Figure 4-13 illustrates the average (mean and median) and extremes (max/min) of annual revenue growth. We focus on absolute growth rates, which is appropriate in the context of very small firms (Coad, 2009: 10).

Most RBSOs do not seem to grow at all, but growth spurts from certain firms ensure that the average annual growth remains positive. However, Figure 4-13 also shows that growth setbacks also occur. Together, this indicates that "stasis" (Derbyshire and Garnsey, 2014), i.e., no growth, may be a common growth scenario accompanied by discontinuous and erratic growth events in certain RBSOs (Coad, 2007, 2010; Garnsey and Heffernan, 2005). To investigate this in more detail, each annual growth period was coded[43] as *Growth*, *Stasis*, or *Setback* according to the method outlined by Coad et al. (2015).

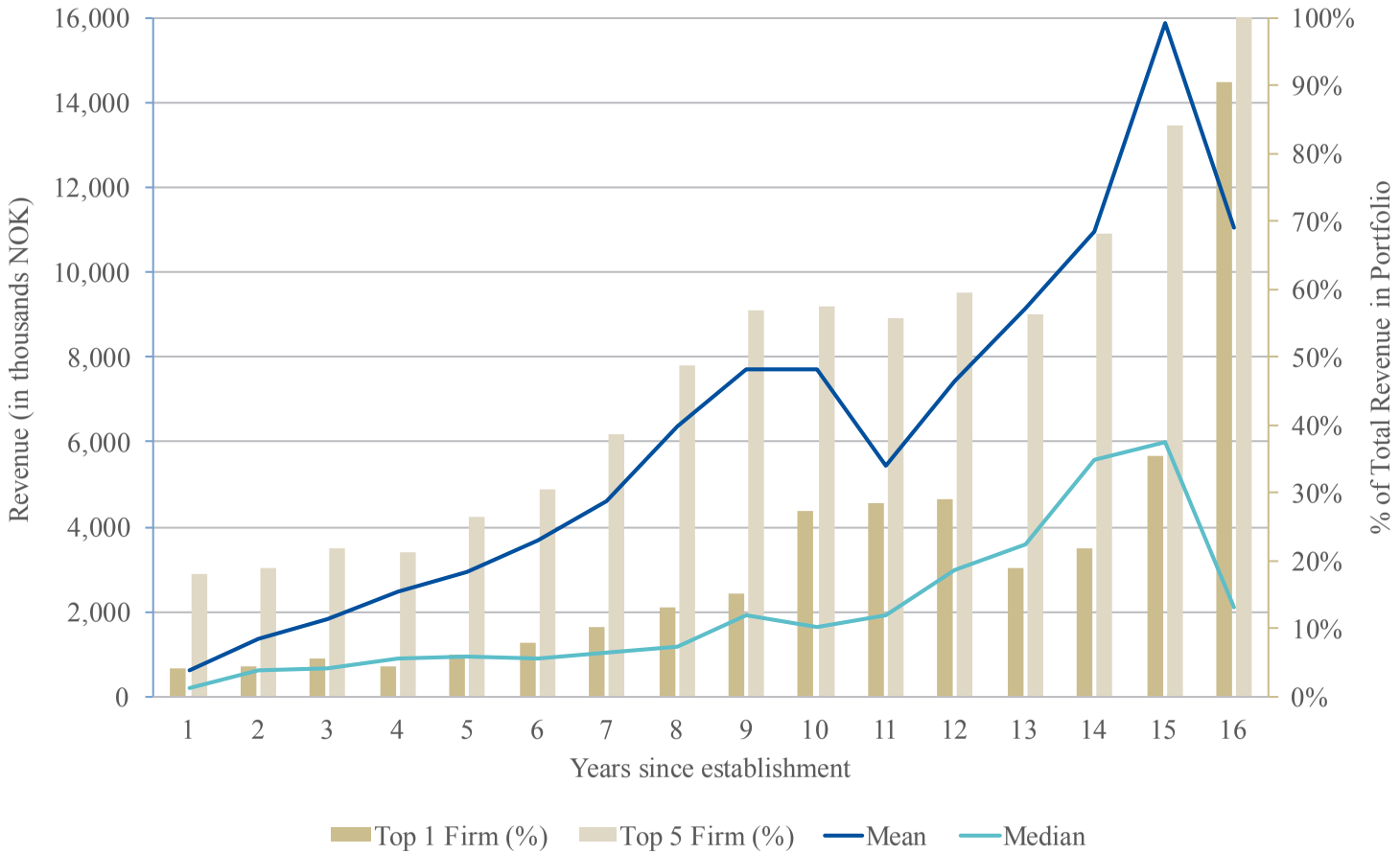


Figure 4-12: Development in revenues (mean and median; thousands NOK) in years since establishment (lines; measured on left axis). Share of total represented by the largest and five largest firms (bars; measured on right axis).

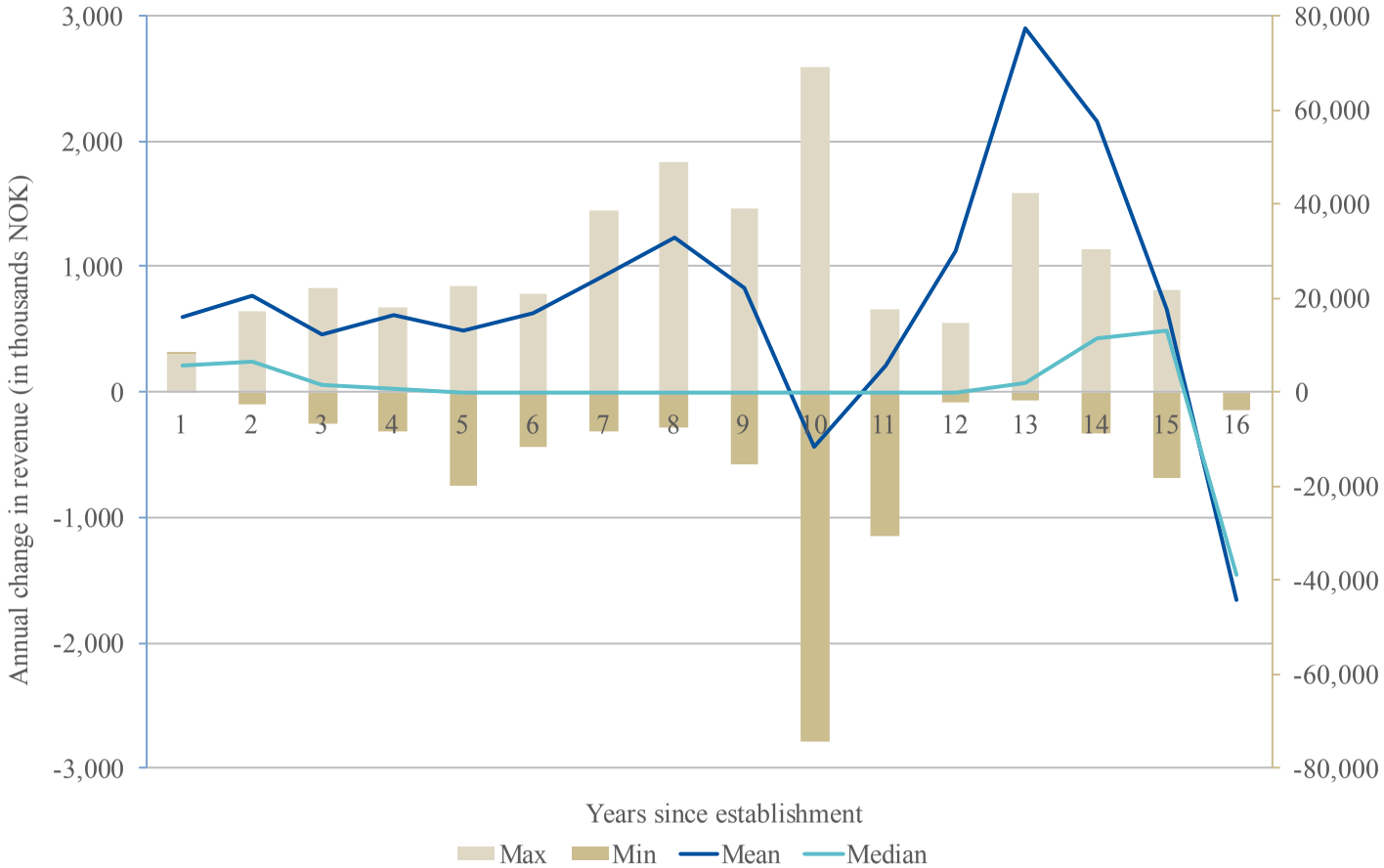


Figure 4-13: Development in revenue growth (mean and median) in years since establishment (lines; measured on left axis). The maximum and minimum growth per vintage year (bars; measured on right axis). All numbers in thousands NOK.

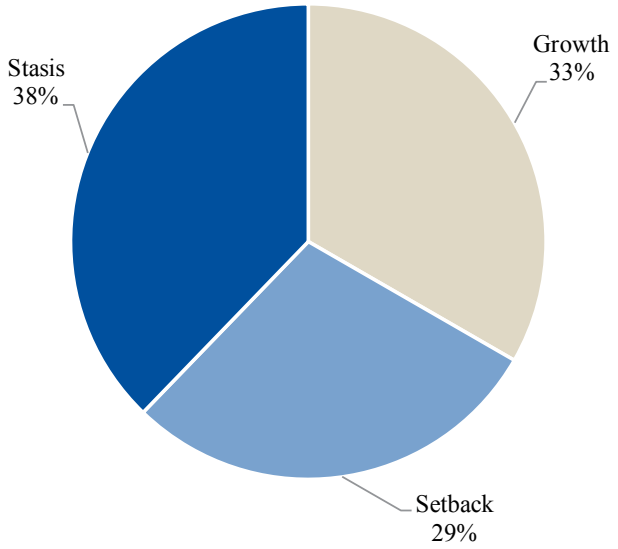


Figure 4-14: Distribution of growth type on annual basis in the FORNY portfolio.

Figure 4-14 shows that all three types of annual growth are approximately as frequent, with *Stasis* being slightly more frequent at 38%. A more detailed analysis was conducted, tracking the growth paths of each RBSOs the first five years. This gives 243 possible growth paths for the RBSOs that survived to this point (244 firms[44]). Table 4-2 shows the most frequent growth paths, which together represent 30% of the growth paths taken for all RBSOs.

Growth Path	Primary Pattern	% per path
Stasis-Setback-Stasis-Stasis-Stasis	Stasis	7.0%
Stasis-Stasis-Setback-Stasis-Stasis	Stasis	3.7%
Growth-Growth-Setback-Growth-Growth	Growth	3.3%
Growth-Growth-Growth-Growth-Growth	Growth	
Stasis-Stasis-Stasis-Setback-Stasis	Stasis	2.5%
Growth-Growth-Growth-Growth-Setback	Growth	
Stasis-Stasis-Stasis-Stasis-Stasis	Stasis	
Stasis-Setback-Stasis-Setback-Stasis	Stasis	
Stasis-Growth-Setback-Growth-Setback	Mixed	
SUM		*29.5%*

Table 4-2: Most frequent revenue growth paths (first five years).

Table 4-2 indicates that the most frequent growth paths are generally associated with *Stasis*. Only 40 RBSOs (16%) experienced at least three consecutive periods of growth within the first five years and only 8 RBSOs (3%) had continuous growth throughout this five-year period. Overall, that analysis concurs with other research (Coad et al., 2015; Garnsey et al., 2006) in the paradox that while so much of the small firm growth literature is concerned with prolonged growth, this seem to rarely occur in practice in the new venture context.

Employment

In certain new venture scenarios, employment will precede revenue growth and, thus, be a more useful indicator of growth (Delmar et al., 2003; Knockaert et al., 2011). For instance, RBSOs commercializing new pharmaceutical drugs often go many years without any sales (Gilbert et al., 2006). Figure 4-15 shows the development in labor cost in the FORNY portfolio. Labor cost is preferred here over number of employees because of its more granular nature and automatically accounting for part-time positions[45].

It is fair to say that employment follows a similar development as revenue, where a few RBSOs go on to represent the majority of employment over time. Revenue and labor cost are also highly correlated ($r = 0.85$, strongly statistically significant), indicating that the biggest employers are, to a large extent, the same RBSOs with the highest revenues (similar result as Shepherd and Wiklund, 2009). Most RBSOs have very few employees (median increase from one to four employees for the oldest firms) and only seven RBSOs have more than 30 employees at any time. The largest number of employees observed for any RBSO was 78.

Figure 4-16 illustrates the average (mean and median) and extremes (max/min) of annual growth in labor cost. Comparable to revenues, most RBSOs have no growth in employment, but large outliers do occur here as well.

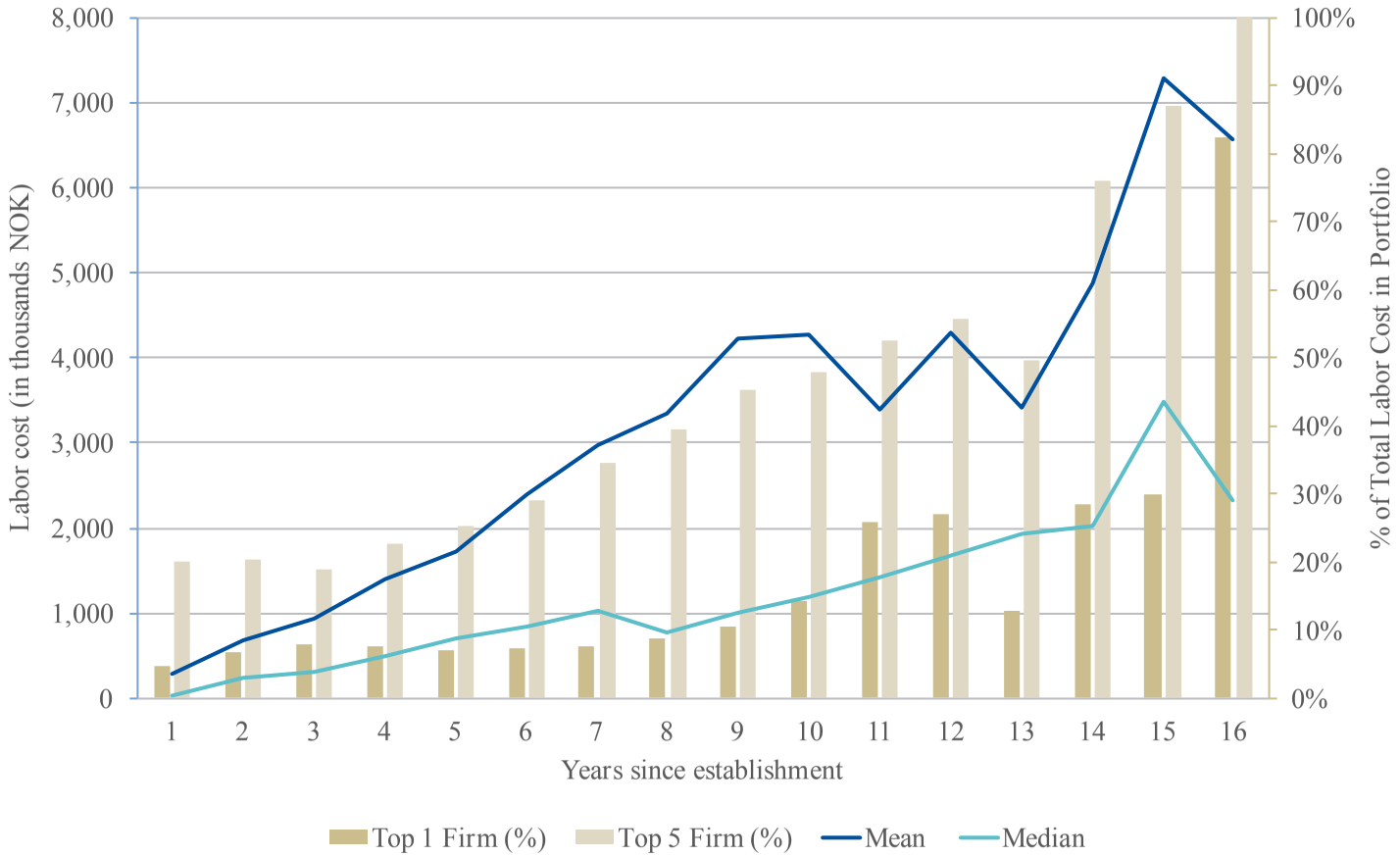


Figure 4-15: Development in labor cost (mean and median; thousands NOK) in years since establishment (lines; measured on left axis). Share of total represented by the largest and five largest firms (bars; measured on right axis).

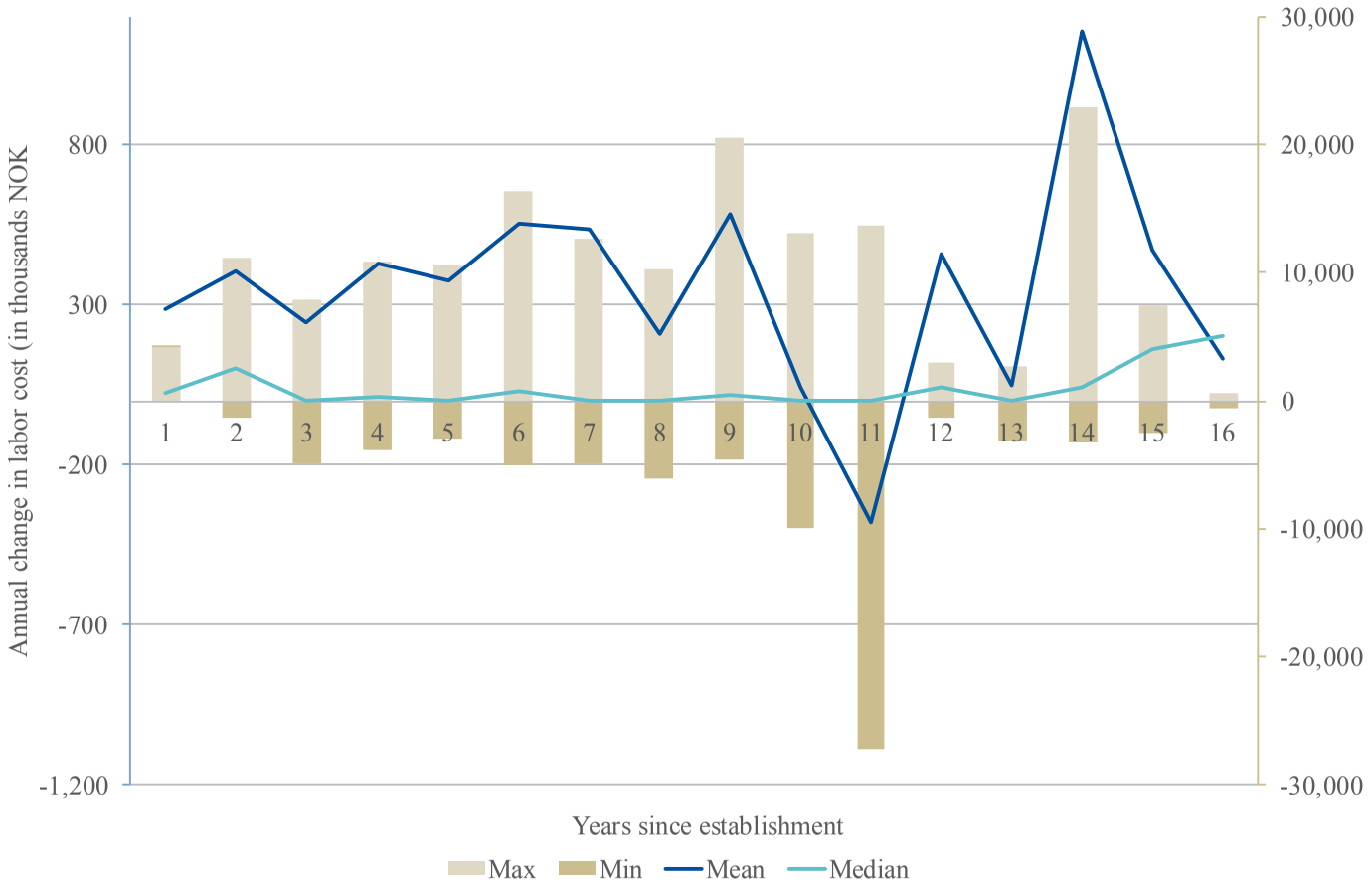


Figure 4-16: Development in labor cost growth (mean and median) in years since establishment (lines; measured on left axis). The maximum and minimum growth per vintage year (bars; measured on right axis). All numbers in thousands NOK.

Employment and revenue, however, differ with respect to the dynamics of growth. Labor cost exhibits very strong serial correlation ($r = 0.94$, strongly statistically significant). This indicates that growth in employment is highly path-dependent, with less variability and erratic patterns compared with revenue growth. Applying the same growth path analysis as revenue growth, Table 4-3 shows the most frequent growth paths with respect to labor cost. Together, this represents 40% of the employment growth paths taken for all RBSOs surviving the first five years.

Growth Path	Primary Pattern	% per path
Stasis-Stasis-Stasis-Stasis-Stasis	Stasis	13.9%
Growth-Growth-Growth-Growth-Growth	Growth	5.3%
Stasis-Stasis-Setback-Stasis-Stasis	Stasis	4.5%
Stasis-Stasis-Growth-Growth-Growth	Mixed	3.3%
Stasis-Growth-Growth-Growth-Growth	Growth	2.9%
Stasis-Stasis-Stasis-Growth-Growth	Mixed	2.5%
Stasis-Stasis-Stasis-Stasis-Setback	Stasis	2.0%
Growth-Growth-Growth-Setback-Setback	Mixed	
Stasis-Setback-Stasis-Stasis-Stasis	Stasis	
Stasis-Stasis-Growth-Growth-Stasis	Mixed	
SUM		*40.6%*

Table 4-3: Most frequent labor cost growth paths (first five years).

Analysis of employment growth paths confirm its more persistent nature, where the two most common paths are continuous Stasis and Growth.

Profitability

The objective of all independent firms, sooner or later, is to make a profit. However, losses frequently occur in the period when technologies are developed into marketable products and services. Figure 4-17 shows the development in operating result (earnings before interest and taxes, EBIT) from founding.

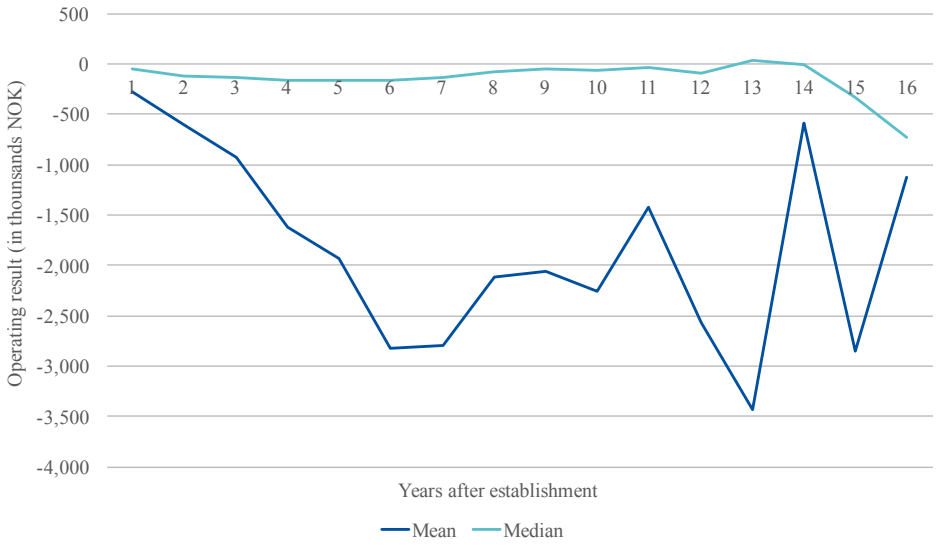


Figure 4-17: Development in operating result (mean and median) in years since establishment (thousands NOK).

Most RBSOs sustain consistent negative, but very small losses. The major difference between the mean and median indicates a skewed distribution and that some RBSOs run major operational losses. Figure 4-18 shows the extreme values (max/min) of operating result at each firm age.

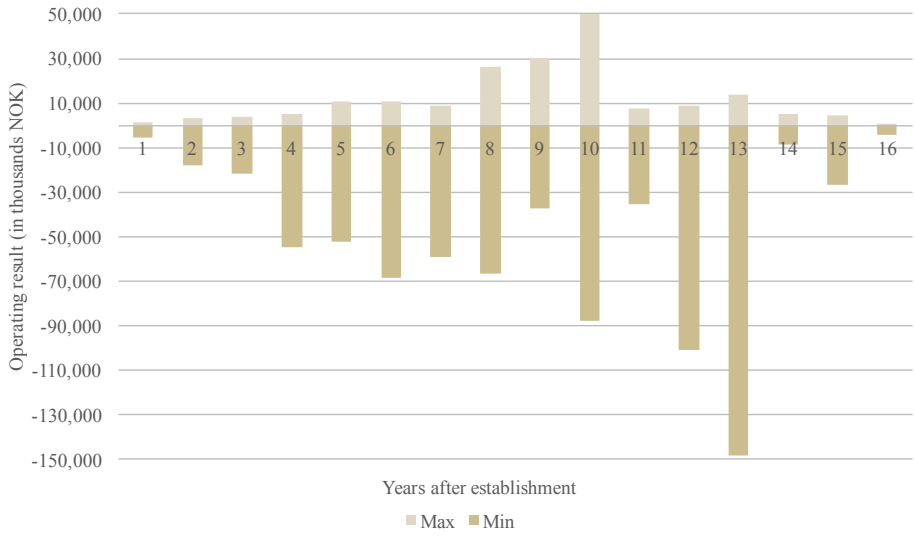


Figure 4-18: Maximum and minimum operating result (thousands NOK).

While profits above 10 MNOK (approx. €1.1M) occur from around year five, losses are far more frequent and substantial. Starting at year four, the activities of certain RBSOs generate losses in excess of 50 MNOK (approx. €5.5M). More detailed insight was obtained from analyzing the RBSOs at both ends of the profitability extremes. First, the RBSOs achieving the highest profits generally do so after running losses (and often quite substantial ones) in earlier years. These RBSOs have successfully commercialized their technology and have been able to grow revenues to a point where sustainable profitable operations have commenced. In particular, one RBSO has the three highest years of operating result observed[46] in the portfolio, supporting earlier findings of the large impact of a few RBSOs.

Further analysis of operating results over time reveals that several growth trajectories can lead to profitability. Since their founding, two of the most profitable RBSOs (in accumulative terms) have created consistent, but moderate, positive profits for the last fifteen years. Interestingly, both RBSOs offer consulting services based on unique scientific expertise. In other words, these RBSOs are not only commercializing specific inventions. Hence, while the highest profits are not generated from these service-based business models, profitability can be achieved much quicker.

Second, the RBSOs generating the highest losses generally have major operating costs other than employment. Many of these RBSOs are developing new pharmaceutical drugs and these costs presumably relate to clinical trials and other development expenses. To be clear, employment costs are always present, but they are not the main contributor to the high operating costs in these cases. The RBSOs in question are obviously able to sustain such losses because of success in raising substantial VC capital. Thus, from one perspective, these are highly unprofitable firms. But from another perspective, these are the same firms receiving high valuations[47] and viewed as the most promising new ventures in the portfolio. The ambition of both entrepreneurs and investors is future high profits or high value IPOs and/or trade sales. This counterintuitive fact is a distinctive characteristic of this portfolio of RBSOs (Rasmussen and Mathisen, 2017).

4.5 Conclusion

This chapter has presented a comprehensive analysis of the FORNY portfolio, investigating the origins, development, growth, and ultimate outcomes of RBSOs in Norway. In conclusion, three areas seem particularly important for this dissertation as a whole. First, commercialization can

occur through qualitatively different outcomes; therefore, focusing only on one performance outcome will likely have major limitations. For instance, several trade sales with high valuations have occurred and, more generally, trade sales seem to be an important mechanism to access the necessary resources to successfully scale-up commercialization processes. Assuming survival as an independent firm as a precondition for success is, thus, misguided. Further, while a firm might appear to be unsuccessful in one facet of performance (e.g., profits), it might simultaneously be highly successful in another (e.g., firm value).

Second, skewed distributions and the extreme impact of outliers appear to be the norm across most dimensions of the RBSO phenomenon. Under these circumstances, interpreting average values should be done with care as they can be directly misleading. A meaningful evaluation of a portfolio of RBSOs must, therefore, pay particular attention to the portfolio's outliers and not only its most common members. Finally, the time needed for the commercialization of research is very long and development and growth can be discontinuous and erratic. Timing matters as the status and prospects of RBSOs can be dramatically changed over short periods. These findings are fully compatible with the theoretical and methodological framework developed in this dissertation.

This has been a limited descriptive analysis, without systematic inquiry on causal relationships. The research papers in Part 2 are more theoretically oriented studies that go much deeper into certain aspects of growth and performance of RBSOs. The next chapter will summarize all the research papers in Part 2. Nevertheless, two limiting features of this analysis are important to keep in mind. Many of the individual analyses presented have been so-called "cohort analysis", distinguishable by tracking the variable of interest based on number of years since founding of the RBSOs. In this approach, the RBSOs established more recently have not had the opportunity to mature to advanced ages. In addition, firms that exit (for any reason) fall out of the analysis continuously. Hence, the further out in firm age the fewer observations to form the basis of the results and, in certain cases, findings will be skewed toward "surviving" firms.

5 SUMMARY OF RESEARCH PAPERS

This chapter presents brief synopses of the five research papers included in this dissertation. The focus is on outlining the research questions, theoretical frameworks, methods, and key contributions of each paper. To conserve space, citations have been omitted. Further, the terminology applied in the individual papers has been preserved in these summaries. In some cases, this implies a divergence with what has been used thus far (e.g., USOs, ASO, and SBEF may be used in lieu of RBSOs and "acquisition" may be used in place of "trade sale"). Paper 1 is a structured literature review of the academic entrepreneurship literature. The remaining four papers are empirical, using data developed from the FORNY portfolio presented in previous chapters. All papers are stand-alone contributions, written in a format suitable for publication in peer-reviewed journals. Still, each paper offers a detailed investigation of one particular aspect relevant to the general theme of the dissertation. Table 5-1 provides an overview of the papers and their publication status.

5.1 Paper 1: The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications

Introduction and research question

Several comprehensive literature reviews have recently been published, focusing on different areas in the academic entrepreneurship literature. The few reviews focused on USOs only consider the antecedents of spin-off activity; more specifically, how individual, institutional, and environmental conditions impact spin-off creation at universities. The key theoretical problem with this approach is that distribution of USOs outcome is highly skewed, and number of firms, therefore, does not necessarily correspond with performance. There is an increasing literature related to the development, growth, and performance of USOs. However, this literature is fragmented and the current state of knowledge remains unclear. This gap seriously hinders theoretical progress and this paper seeks to answer the following research question: *Which factors impact the development, growth, and performance of USOs?*

Title	Authors	Research Questions	Theoretical Approach	Methods	Focus	Publication Status
The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications	Mathisen, M.T.	Which factors impact the development, growth, and performance of university spin-offs?	Structured literature review of the academic entrepreneurship literature based on 105 papers published since 2000.	Conceptual	• Conceptual framework for analysis is developed by juxtaposing the determinants and outcomes of development, growth, and performance of university spin-offs. • Contribute with comprehensive overview of the state of knowledge in the field and recommended directions for future research.	• Currently in review in *The Journal of Technology Transfer*
Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study	Fini, R. Fu, K. Mathisen, M.T. Rasmussen, E. Wright, M.	How do changes in the institutional framework at national and university levels influence the quantity and quality of spin-offs from a university?	Hypotheses derived from institutional theory of how changes in formal structures result in symbolic (i.e., quantity) rather than substantive (i.e., quality) effects on operational efficiency.	Quantitative	• Longitudinal and multi-level analysis of populations of university spin-offs across three European countries (Norway, Italy, UK) with different approaches to university support structures (i.e., TTOs) and changes in national legislation regarding intellectual property at universities (i.e., "professor privilege"). • Comparing effects on quantity and quality.	• Presented at the Academic of Management Annual Meeting 2015 • Published in Special Issue of *Small Business Economics* (2017, 48:2)
Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012	Rasmussen, E. Mathisen, M.T.	What is the value creation of a national population of science-based entrepreneurial firms?	Real option framework considering the uncertainty and highly skewed distribution of firm outcomes.	Quantitative	• Longitudinal analysis of firms with respect to value creation (gross value added). • Detailed analysis into qualitative categorization of firm outcomes, including identification of real options.	• Published as a book chapter in *Process Approach to Academic Entrepreneurship: Evidence from the Globe* (Volume 4 of The World Scientific Reference on Entrepreneurship)

Title	Authors	Research Questions	Theoretical Approach	Methods	Focus	Publication Status
Growing Firm Value: New Venture Growth and Trade Sales of Research-Based Spin-Offs	Mathisen, M.T. Widding, Ø.	How do technology-based entrepreneurial ventures grow firm value in the context of trade sales to industry incumbents?	Integration of Knightian uncertainty and information asymmetry as determinants of firm value.	Qualitative	• Multiple case study inductively developing theoretical propositions on the mechanisms new ventures use to reduce uncertainty and information asymmetry to grow firm value in the context of trade sales	• Rejected after review in *The Journal of Management Studies* • Presented at ACERE 2017 conference and awarded "Best Qualitative Paper" • Currently preparing submission to new journal.
Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions	Leunback, D. Mathisen, M.T. Johnson, A.R. Knockaert, M.	How does insider ownership provide signals to facilitate transactions in contexts characterized by large information asymmetries? How is the value of insider ownership signals affected by time and other ownership-related signals?	Hypotheses derived from signaling theory of how insider ownership signals affect acquisition propensity.	Quantitative	• Event history analysis of acquisition events, studying how different levels of insider ownership convey positive/negative signals and how this interacts with passing time and other ownership signals.	• Accepted for presentation at the Academic of Management Annual Meeting 2017, and as "Best Paper" for the Academic of Management Proceedings.

Table 5-1: Summary of research papers in Part 2.

Methods

A search for relevant literature was completed using the ISI Web of Science citation indexing service. Prior to this, all previous literature reviews and special issues related to the core topic were examined. A structured and comprehensive search process was conducted through five steps, condensing 4,000 initial results down to 105 research papers published in renowned peer-reviewed journals. Based on these results, a conceptual framework was developed, which provided the structure of the review. The framework outlines that the objective of prior studies has been focused on determinants of USOs outcomes; more specifically, on the individual, firm, and institutional/ecosystem levels of analysis.

Key findings and contributions

The results reveal that the literature can be structured in two distinct streams. One stream contains comparative studies between USOs and other NTBFs, and takes place in varied contexts. The second stream is devoted to the development, growth, and performance of USOs specifically. With respect to the first stream, the analysis finds that fundamental factors other than the institutional origin that separate USOs and NTBFs are more important to explain firm outcomes. In the second stream, the analysis shows that aspects related to individuals and teams involved in USOs have received the most attention. This is the area where most knowledge has accumulated and stylized facts have emerged. In contrast, limited progress has been done in understanding the institutional and environmental conditions that impact how USOs grow. Case in point, the impact of factors such as university collaboration, VC and capital market conditions, national legislature, and economic structure on USOs remain unclear. Finally, the review suggests that its lack of presence in the most prestigious journals within economics, strategic management, and organization studies is largely because the literature is too phenomenon-driven. In conclusion, the paper recommends academic entrepreneurship scholars in the future to take advantage of their research subject as the unique empirical context it is and explore broader theoretical questions, rather than constructing narrow phenomenon-oriented theory.

Relevance to overall dissertation

First, the paper provides the most comprehensive overview available of the literature specifically focused on USOs from a development and growth perspective. Without appreciation of what the field has found already, this study would risk only rediscovering old insights. Hence, it provides the fundamental backdrop for the dissertation. Second, the findings

from the review led to research questions that motivated the empirical work in the dissertation. For instance, identifying that very limited work had been done on institutional and environmental characteristics inspired Paper 2. Further, finding that the literature essentially ignores acquisitions and that USO outcomes are highly skewed with extreme impact from outliers in part inspired Papers 3, 4, and 5. Finally, the review identified that the literature had made very limited contributions to more general theoretical discourses. Consequently, the overall theoretical position of the dissertation is that a deep understanding of the USO phenomenon is important for policy and practice; however, for the purposes of theory development, USOs should be viewed as an excellent empirical context and not primarily as a theoretical field in its own right.

5.2 Paper 2: Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study

Introduction and research question

Governments and universities are seeking framework conditions that are conducive to university spin-off creations and their subsequent growth. The most important of such initiatives are national legislative changes and the establishment of TTOs at universities. The former refers more specifically to governments ending the so-called professor's privilege, following the example of the US Bayh-Dole Act from 1980. This legislative change assigns ownership of intellectual property rights (IPR) to the university rather than being held by academics. The rationale for both types of initiatives is to increase the commercial output from university research. However, the effectiveness of such initiatives is debated and empirical evidence is limited. This paper analyzes the full population of universities in Italy, Norway, and the UK; three countries adopting differing approaches to framework conditions, and investigates how changes in the institutional framework at national and university level affect the number of spin-offs created and the quality of these spin-offs.

Theoretical framework

The institutional context where entrepreneurs operate both constraints and facilitates entrepreneurial opportunities, and institutional theory is particularly helpful in understanding entrepreneurship in organizational contexts. One example is how scientists conform to the behavior of their superiors and peers when deciding to engage in the commercialization of research. Using institutional theory, the paper argues that the number of spin-offs will increase

as a result of institutional pressures upon universities to produce more spin-offs. However, since spin-off performance is likely more dependent on individual- and university-level characteristics, the quality of spin-offs will not increase at the same pace. The rationale for this is that scientists, universities, TTOs, and other stakeholders will tend to strategically conform to new frameworks and incentives.

Methods

A unique dataset was constructed by pooling country-level, regional-level, university-level, and firm-level data from several sources in Italy, Norway, UK, and the EU. USO quantity and quality were used as dependent variables, where the latter was operationalized as the ability to raise VC- financing. As the data feature a hierarchical structure at multiple levels, a multilevel modeling approach was adopted to test the hypotheses. Multilevel modeling accounts for data interdependence by capturing residuals at different levels and to specify country-year fixed effects. As both dependent variables in the analyses are measured by count data with over-dispersion, multilevel negative binomial regressions were used, nesting university-level into country-level data.

Key findings and contributions

The findings show that changes in the institutional framework conditions at both the national and university level are conducive to the creation of more spin-offs, but that the increase in quantity is at the expense of the quality of these firms. Any substantive impact on spin-off firm quality needs a much longer time to manifest because founding new firms is easier than the long-term involvement required for firm success. Hence, the effect of such top-down changes in framework conditions on the economic impact from universities seems to be more symbolic than substantive. These findings make a key contribution to the policy literature on academic entrepreneurship especially considering the study integrates both spin-off quality and quantity and has a cross-country design with national populations of USOs followed over a long period.

Relevance to overall dissertation

This study illustrates that an increase in USOs does not necessarily, or even likely, result in more successful USOs overall. Since top-down policies and initiatives face the risk of symbolic conformance, such initiatives must be complemented by bottom-up initiatives, appreciating that successful commercialization is a complex and resource demanding process. To increase spin-off quality, entrepreneurs, support providers, and policymakers need to understand the

commercialization process including its challenges. This motivates the study of development and growth of USOs.

5.3 Paper 3: Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012

Introduction and research question

Studies following the growth of science-based entrepreneurial firms (SBEFs) provide rather disappointing results concerning impact. However, most of these studies use quite short time periods and studies with time frames over decades conclude that SBEFs play a key role for economic growth at both the regional and national level. However, there is limited evidence on how SBEFs create impact, including the development paths taken. This paper uses a portfolio perspective to assess the value creation of the national population of SBEFs established between 1995 and 2012 in Norway. We also untangle how different categories of outcomes contribute to the overall value creation of the portfolio.

Theoretical framework

SBEFs can be seen as an extreme type of entrepreneurial venture due to their high degrees of uncertainty across several dimensions, including technology, market, and organization. For SBEFs, the high level of uncertainty is challenging because the possible returns from investing in such ventures are unknown and will typically be in a distant future. Hence, equity investors and other resource providers can be reluctant to support these ventures. Seen from a macro perspective, this potentially leads to underinvestment in such ventures and provides a rationale for governments to support the creation and early development of SBEFs. The trade-off between projects with lower and higher levels of uncertainty is often between more incremental or more radical innovation projects. The innovation literature often points at the long-term benefits of investing in radical innovation. The high level of uncertainty associated with SBEFs makes real options theory a well-suited framework to assess the portfolios of such firms. In an SBEF portfolio, firms can be characterized as either being a real option or as having reached an unsuccessful or successful outcome.

Methods

The FORNY portfolio is the empirical context of the study. Applying a real options approach, the portfolio is segmented into outcome categories separating between negative outcome

(abandoned commercialization), positive outcome (realized commercialization), and uncertain outcome (real option). The two latter categories are categorized further, so that positive outcome can either be through acquisition or as independent firms, and uncertain outcomes are either dormant of potential (active) firms. A dataset is then constructed with annual financial data for each firm, which enables an estimation of value creation (i.e., gross value added) across the different categories. The dataset is analyzed and value creation is tracked in each category over time.

Key findings and contributions

The results show that surviving independent SBEFs represent the main share of value creation in the portfolio. However, a few successes dominate the total value creation within this category. Further, value creation grows over time, making the current estimates conservative because large shares of the portfolio firms are still very young. Next, the analysis finds that acquired SBEFs have a marginal contribution in value creation. This is very misleading, however, as acquisition prices reveal these are highly valuable firms. With respect to the uncertain outcomes (i.e., real options), the results indicate that dormant firms have insignificant value creation, whereas potential firms have a large negative contribution to value creation. The latter is driven by SBEFs running major operating losses while developing a technology and business. These firms represent the future successes (either as independent firms or acquisitions), and illustrate that value creation is not necessarily a useful measure in this context. Overall, this study contributes with a rare analysis of a national population of SBEFs over a long time.

Relevance to overall dissertation

While mainly descriptive analysis, the analysis in this paper contributes with insights into the necessity of understanding qualitatively different outcomes of SBEFs, and looking beyond financial and employment growth measures applied only to surviving firms. While the latter clearly are important, the paper illustrates that it is inadequate to fully appreciate the impact and general growth processes of SBEFs. Related to this, the study confirms that the time span from research to successful commercialization is very long and that the impact of outliers can be extreme. More theoretically, the paper inspired the notion that uncertainty is a fundamental characteristic with SBEF development and growth.

5.4 Paper 4: Growing Firm Value: New Venture Growth and Trade Sales of Research-Based Spin-Offs

Introduction and research question

We still have a limited theoretical understanding of new venture growth and existing research has been largely unsuccessful in developing theory explaining total rate of growth. This paper adopts a Penrosean perspective of growth by viewing it as a multidimensional, heterogeneous, and complex process of development. Three critical gaps are addressed. First, extant research has called for more research into dynamic growth processes and trajectories. Second, growth in firm value has been neglected, despite being highly relevant and important for both theory and practice. Third, trade sales have been ignored as distinct modes of growth, which is problematic in the context of NTBFs that may use trade sales as a mechanism to obtain access to critical complementary assets under the control of incumbents. The paper addresses these gaps through the following research question: *How do new technology-based firms grow firm value in the context of trade sales?"*

Theoretical framework

The paper develops a conceptual framework based on uncertainty and information asymmetry being the fundamental obstacles NTBFs must overcome to grow firm value. First, the ability of NTBFs to achieve growth is linked to successfully exploiting the knowledge and technologies the venture possesses. However, the value of these knowledge resources is associated with uncertainty. For RBSOs in particular, there is *technological uncertainty* regarding the feasibility of the technology to function profitability outside the lab and at an industrial scale. Further, there is *market uncertainty* as it is not immediately clear which market is most attractive for the technology. The extent of these uncertainties is in part linked to the firm's knowledge resources as the venture's initial tacit and explicit knowledge resources will need to be transformed and embedded into firm knowledge assets such as products, routines, and networks to promote growth. Second, information asymmetry arises because the quality and value of the firm is especially hard to appraise for external partners. Information asymmetry is especially high for NTBFs because it is more difficult to assess the quality of knowledge-based resources than tangible assets. Signaling, screening, and strategic partnerships have been suggested as possible strategies to combat information asymmetry. In sum, to grow value in the context of trade sales, NTBFs need to overcome: (1) the intrinsic technical and market uncertainty linked to the tacit and explicit knowledge resources of the venture, and (2) the information asymmetries arising

between the NTBF and potential buyers based on the difficulties of the latter to appraise the value of venture's knowledge resources. However, although several options and strategies have been suggested for NTBFs to cope with these growth challenges, we still lack a detailed understanding of which mechanisms are selected, the process and context of under which these choices are made, and the impacts and interactions of these mechanisms.

Methods

The research design is an inductive multiple case study of nine trade sales from the FORNY portfolio. As firm value was the primary concern, a sampling approach using "polar types" was applied securing both low and high value trade sales. The primary data were 52 semi-structured interviews from four stakeholder groups: founders/employees, buyer representatives, investor representatives, and external board members/advisors. These data were triangulated with an expansive array of secondary archival and qualitative sources documenting the growth process of the ventures since founding. The analysis follows the Gioia methodology, working iteratively from informant-centric data to higher order theoretical dimensions. The final theoretical concepts and relationships were settled upon after reaching theoretical saturation.

Key findings and contributions

This paper contributes to three streams of literature. First, contributions are made to the new venture growth literature through more narrow and contextual theorizing of the growth construct. The inductive analysis pinpoints the three theoretical dimensions of uncertainty attrition, synergy potential, and credible alternatives as the key determinants of growth in firm value. Propositions are developed that outline the key mechanisms affecting each of these dimensions over time and how they interact and vary in magnitude under different circumstances. The analysis reveals that the early growth of new ventures is not uniform and regular, but rather occurs in irregular bursts caused by technological and market breakthroughs. Further, firm value growth is linked to the dyad of the venture and its potential buyers and, thus, is a relative concept that cannot be fully understood by only taking into account the growth of the focal firm. This illustrates that there are important mechanisms affecting growth in firm value that occur specifically in the context of trade sales. Second, the paper contributes to the academic entrepreneurship literature with a rare study of trade sales. Trade sales have received marginal attention in this literature, despite being a very common and important event for RBSOs. The paper also broadens current conceptualization of growth modes by demonstrating how trade sales can be used to fulfil commercialization processes. Finally, the paper contributes

to the technology acquisition literature with insights into the underexplored area of trade sales from the perspective of the acquired firms, focusing on how new ventures become valuable acquisition targets.

Relevance to overall dissertation

This paper focuses on the dynamic elements of the development processes of RBSOs that significantly affect growth in firm value in trade sales. In the context of the overall dissertation, it offers a fine-grained qualitative approach that complements the largely quantitative focus in other papers. The paper draws attention to firm value being an overlooked measure of growth, but still highly relevant in the context of knowledge-based entrepreneurship. When considering firm value, growth cannot be explained fully by only considering internal factors and the environment the firm operates within. Rather, growth in firm value is contextually embedded and is linked to the idiosyncratic dyads between the firm and its potential buyers. Further, the study argues that trade sales are not necessarily the end of RBSOs, but can be a specific mode of growth important to facilitate successful commercialization processes. This view supports a multidimensional and heterogeneous perspective of growth, where growth transcends the boundaries of the firm as formal legal structures. With respect to academic entrepreneurship, the paper supports the conclusions in Paper 3 of trade sales being an important mechanism when considering technology transfer from PROs.

5.5 Paper 5: Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions

Introduction and research question

Large information asymmetries exist between new ventures and actors in the environment of the firm. Signaling mechanisms may help distinguish high-quality companies from their low-quality counterparts. The literature has examined the impact of signals used by new ventures, including signals related to characteristics of the entrepreneur(s), the management team, and the venture itself. This study focuses on providing an in-depth understanding of the impact of insider ownership, i.e., the extent to which the new venture team owns the firm, as a signal in early stage venture context. Despite that insider ownership is assumed to provide meaningful signals, studies in several contexts have provided inconclusive results. This paper contends that the lack of agreement on this signal is caused by contingency and time effects that have been largely neglected in the literature. The study contributes to closing these research gaps by the

following research question: *"How does insider ownership provide signals to facilitate transactions in a context characterized by large information asymmetries and how is the value of insider ownership signals affected by time and other ownership-related signals?"*

Theoretical framework

Assessing the value of potential knowledge-intensive acquisition targets is inherently difficult for buyers due to information asymmetry. Two forms of information asymmetry occur between buyers and sellers: information asymmetry related to *quality* and information asymmetry related to *behavior* or *behavioral intent.* Information asymmetry about quality occurs because sellers often have superior information about the intrinsic quality of the firm's technology than buyers. Similarly, it occurs with behavioral intent because buyers may lack information to assess the future intended actions of key individuals in the target firm. Signaling has been proposed as one way of reducing the uncertainty associated with information asymmetries and signals are considered efficacious when they are observable, costly to obtain, and originate from firm insiders. Using signaling theory, a theoretical framework is developed hypothesizing that the relation between insider ownership and an acquisition event is inverse U-shaped, with moderate insider ownership being most favorable. Further, this relationship is expected to strengthen over time and when coupled with the presence of professional VC investors.

Methods

The FORNY portfolio acts as the empirical context for this study. Event history analysis is an appropriate procedure when both the occurrence and timing of events are of interest. As the dependent variable is the occurrence of an acquisition, discrete time event history is used to specify a model containing a set of covariates to explain the number of years to reach an acquisition event. In addition to the variables of primary interest, the model controls for firm size, patents, industry, and parent institution.

Key findings and contributions

The analysis finds support for the curvilinear relationship for insider ownership. In particular, moderate insider ownership seems to be a superior signal compared with high insider ownership. However, there is only marginal support for this relationship becoming stronger over time. There is also no support for the notion that the presence of professional owners strengthens the insider ownership signal. However, there is considerable support for the effect of time and professional ownership together. This three-way interaction effect suggests that

signal effect of insider ownership on acquisition becomes stronger with time when professional investors have backed the firm. Overall, the study answers calls in the signaling literature to study contingency and time effects of signals. The findings point to the fact that parties engaging in important transactions with high levels of information asymmetry, such as acquisitions, do not attend to one signal at a time, but combine different signals when considering potential transactions, thereby attaching more or less value to specific signals depending on the moment at which the signal is received.

Relevance to overall dissertation

Following Paper 4, this paper also focuses on trade sales (i.e., acquisitions) of RBSOs and, specifically, how the development of ownership structures impact the ability to be acquired when the venture grows. In the context of the overall dissertation, the paper concentrates on explaining key aspects of one particularly important RBSO outcome. It provides valuable implications for all stakeholders involved in commercialization of research results. This paper also uses academic entrepreneurship as a research *context* rather than contributing with findings only relevant for narrow phenomenon of academic entrepreneurship, thereby following the recommendation in Paper 1 of using academic entrepreneurship as a context for theoretical development more broadly.

6 CONCLUSIONS AND IMPLICATIONS

This dissertation has explored growth processes and performance outcomes of RBSOs, responding to the dissertation's overall research question: "*How do research-based spin-offs develop, grow and perform?"* Figure 6-1 and Table 6-1 recapitulates the conceptual framework developed in Chapter 2, and the theoretical gaps addressed and contributions made in each research paper in Part 2, respectively. These act as references upon which the discussion in this chapter can be compared with.

This chapter is organized in three parts. First, I will summarize and discuss the key findings and theoretical contributions from the research papers. Five research papers have been developed which address the dissertation's research question on both the aggregated portfolio level and the firm level. The discussion will focus on the linkages and interactions between the papers, how they together contribute to the dissertation's research question and the theoretical implications emerging from the papers. Emphasis will be given to the four empirical papers (Papers 2-5). Overall, the empirical studies build on the theoretical framework developed in Chapter 2, adopting a Penrosean conceptualization of growth being an internal process of development manifested through multidimensional, heterogeneous, and complex performance outcomes. The contributions on the aggregated portfolio level will be discussed first, followed by the firm level. Second, major limitations and important areas for further research will be discussed. Finally, the dissertation's practical implications for entrepreneurs, PROs, and policymakers will be presented.

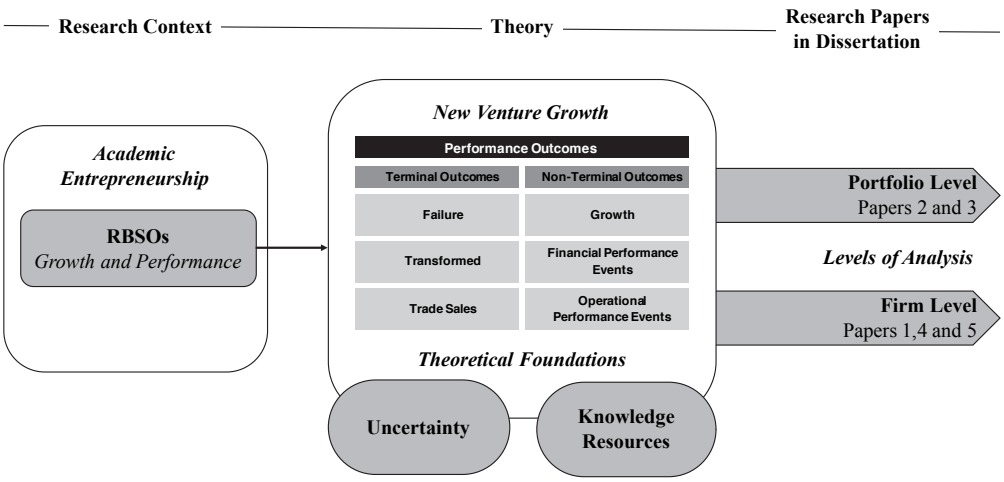


Figure 6-1: The dissertation's overall conceptual framework.

Paper	Research Questions	Level of Analysis	Literature/ Theory	Gaps	Contributions
1. *The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications*	Which factors impact the development, growth, and performance of university spin-offs?	Firm	• Academic entrepreneurship	• Literature treating RBSOs as homogeneous entities, focusing on number of RBSOs created without recognizing later growth and performance • Ignoring skewed distribution of outcomes assuming number of firms is consistent with economic impact • Fragmented literature related to RBSO development, growth, and performance. Current state of knowledge is unclear • No previous literature with this focus	• A conceptual framework capturing the determinants and performance outcomes of RBSOs • Synthesis of the field's state of knowledge into two major research streams • Identification of critical gaps with guidance for further research • Recommendation of using RBSOs as a research context rather than constructing phenomenon-oriented theory
2. *Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study*	How do changes in the institutional framework at national and university levels influence the quantity and the quality of spin-offs from a university?	Portfolio	• Academic entrepreneurship • Entrepreneurship framework conditions • Institutional theory	• The effects of changes in national- and university-level framework conditions on the creation and performance of RBSOs are poorly understood • Literature predominantly focused on RBSO quantity • Limited attention into the quality (i.e., growth and performance) of RBSOs • Paucity of research comparing different countries	• Changes in the institutional framework conditions at both national and university levels are conducive to the creation of more spin-offs, but the increase in quantity is at the expense of the quality of these firms • The effect of these top–down changes in framework conditions on the economic impact from universities seems to be more symbolic than substantive • Study isolates the effects on university and national level, and within and between countries, by comparing national populations of RBSOs in three countries over thirteen years
3. *Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012*	What is the value creation of a national population of science-based entrepreneurial firms?	Portfolio	• Academic entrepreneurship • Uncertainty • Real options	• Limited evidence on the economic impact of RBSOs • Limited evidence on the development and growth paths RBSOs take, and how this relates to economic impact • Lacking conceptual frameworks to assess the development and growth of RBSOs	• A real option framework is appropriate to study impact of a portfolio of RBSOs (and new technology-based ventures in general) • Performance outcomes of RBSOs follow highly skewed distributions, where a few ventures represent a large share of value creation and most ventures have insignificant contributions • Trade sales represent a significant contributor to value creation, but is overlooked in extant research due to methodological oversight • The time span from establishment to successful commercialization is very long

Paper	Research Questions	Level of Analysis	Literature/ Theory	Gaps	Contributions
4. Growing Firm Value: New Venture Growth and Trade Sales of Research-Based Spin-Offs	How do technology-based entrepreneurial ventures grow firm value in the context of trade sales to industry incumbents?	Firm	• New venture growth • Academic entrepreneurship • Technology acquisitions • Uncertainty • Information asymmetry	• Limited theory on growth in firm value in situations of high uncertainty • Firm value overlooked as a measure of growth • Trade sales (i.e., acquisitions) are ignored as an outcome and mode of growth	• Answers calls for more narrow and contextual theorizing of firm growth by developing theoretical propositions of determinants and process of growth in firm value • Identify that growth is not uniform, but occur in irregular bursts • In the context of trade sales, growth in firm value is closely linked to the characteristics of the dyad of buyer and seller • Extend current understanding of growth modes by suggesting that trade sale can act as a distinct mode of growth • Demarcate the boundary of financial valuation theory under conditions of high uncertainty
5. Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions	How does insider ownership provide signals to facilitate transactions in contexts characterized by large information asymmetries? How is the value of insider ownership signals affected by time and other ownership-related signals?	Firm	• Signaling theory • Technology acquisitions • Academic entrepreneurship	• Limited studies and contradictory findings on the signaling effect of insider ownership • Lack of consideration of passage of time, presence of other ownership signals and non-linear effects • Lack of understanding on the role of ownership structures in acquisitions	• Uncover several contingent and temporal situations when insider ownership signals become stronger or weaker • Consider non-linear relationships and negative signals that presumably are sent unintentionally • Considering the signaling effect of insider and professional investor ownership simultaneously

Table 6-1: Theoretical gaps addressed and contributions made in the research papers in Part 2.

6.1 Key Findings and Theoretical Development

Aggregate Portfolio Level

Research papers 2 and 3, supported by the empirical analysis of the FORNY portfolio in Chapter 4, address the dissertation's research question mainly on the aggregated portfolio level. Paper 2 concludes that changes in national- and university-level framework conditions has differential impacts on the creation and subsequent growth of RBSOs. More specifically, we find that certain institutional changes in framework conditions have more symbolic than substantive effects, in the sense that quantity of firms was positively affected, at the expense of firm quality which was negatively affected. This result suggests that any real effects from policy interventions on spin-off quality likely needs a much longer time to manifest. Creating new firms is more straightforward to implement than changing the culture, abilities, and intentions inside a PRO which is needed to create successful firms in the long-run (Clarysse et al., 2005). Further, it is expected that bottom-up initiatives (Goldfarb and Henrekson, 2003) targeted directly at the RBSOs and their entrepreneurs, will have a stronger impact on firm success than policy changes at national level (Gilsing et al., 2010). These contributions support the theoretical premise of this dissertation, confirming that the growth and performance of RBSOs are entirely different issues compared to spin-off creation as measured in number of firms (Meoli et al., 2013). Creation is of course a requirement for growth, yet the findings suggest that emphasis should be on venture performance, and not creation, when considering the economic impact of RBSOs. This has in part motivated the other research papers in this dissertation, which address the growth processes and outcomes of RBSOs in more detail. Moreover, Paper 2 contributes with evidence based on a cross-country, multi-level, and longitudinal analysis of RBSO populations. Such evidence is rare, and address, among others, calls in the literature to study RBSOs across countries (e.g., Clarysse et al., 2007; Fini and Grimaldi, 2016; Kochenkova et al., 2016) and considering quantity and quality of firms simultaneously (e.g., Kirchberger and Pohl, 2016; Kochenkova et al., 2016; O'Shea et al., 2008). Most RBSO research comprises a few PROs or single countries, and the vast majority of studies rely on cross-sectional research design. The theoretical implication emerging from these contributions is that policy studies should to a greater degree consider RBSO performance outcomes (i.e., the quality of firms), supplementing the current primary focus on spin-off activity in numbers.

Paper 3, supported by the empirical analysis in Chapter 4, builds on the contributions in Paper 2, and delves deeper into the structure of growth and performance for RBSOs on the aggregated

level. First, the findings suggest that growth and performance outcomes of RBSOs are highly skewed, where a small minority of ventures represent a large share of the total, while most RBSOs have quite insignificant impact. This skewness is pervasive also within certain performance events often considered dichotomous, and thus of assumed equivalent magnitude. For instance, trade sales and IPOs are found to be highly skewed in terms of firm valuations, where a few, or even single, observations dominate the total. Section 3.4 discusses the theoretical implications of such skewed distributions in more detail. In brief, traditional statistical analyses estimating the mean is unlikely to contribute to theoretical progress, because the average outcome is not particularly meaningful when performance is highly skewed (Crawford et al., 2015). In other words, research ignoring skewed distributions are in danger of estimating attributes for firms that are not representative or might not exist in practice. However, the literature review in Paper 1 reveals that most research on RBSOs still ignore the presence of skewed outcomes. This mirrors entrepreneurship research more broadly (Crawford et al., 2015), and the new venture growth literature specifically where empirical work still tends to focus on "the average effect for average firms" (Nightingale and Coad, 2014). In sum, the theoretical implications of these findings are an increased appreciation of outliers being very important to theoretically understand the growth of RBSOs, and new ventures more generally, at the aggregated level.

Second, the findings suggest that growth can occur through several qualitatively different performance outcomes. Hence, focusing on only one performance outcome will limit our theoretical understanding of the complexity of academic entrepreneurship. This follows and supports the conceptual framework in Figure 6-1. While research has matured to acknowledge the heterogeneity of RBSOs at origin, this dissertation contributes with recognizing the heterogeneity with respect to outcomes. In particular, the results indicate that trade sales represent very important performance outcomes. Trade sales appear to be far more common in the context of RBSOs compared to entrepreneurial firms more generally (cf., Coad et al., 2013). Close to 10% of the FORNY portfolio tend to be acquired at some point. Previous research has found that RBSOs having already gone public, are more likely to be acquired (Bonardo et al., 2010; Cattaneo et al., 2015) and reach higher valuations (Meoli et al., 2013) than comparable independent firms. We contribute with extending this stream of research by considering RBSOs when they are private. The vast majority of RBSOs remain private, and trade sales of private firms are a far more common phenomenon than trade sales of public firms (although less visible and thus more difficult to observe empirically) (Capron and Shen, 2007; Shen and Reuer, 2005).

Further, our analysis shows that RBSOs are very frequent beneficiaries of risk capital from VCs, and thus have owners ultimately eager to exit their investments (Wright et al., 2006). Private trade sales are more common, as well as increasingly preferred by VCs, as a route to exit compared with an IPO (Achleitner et al., 2012; Clarysse et al., 2013; Gerasymenko and Arthurs, 2014; Mason and Brown, 2013; Schwienbacher, 2005). Not all RBSOs that experience initial success were acquired, but relatively few experienced significant growth and reached firm sizes which resulted in sustainable profitable returns (Vohora et al., 2004). Also, several of the RBSOs reaching profitable operations tend to operate with business models which are difficult to scale to support high growth (i.e., consulting and contract research services). The theoretical implication of these findings is that evaluating RBSOs at the aggregate portfolio level should account for the presence of trade sales in some way. This is especially important because RBSOs oriented towards high-growth may be sold with high firm value, while still having experienced very limited growth in traditional financial measures such as revenues, employment, and profitability.

Finally, the study support existing research in that the time span from establishment to successful commercialization generally is very long, where five to ten years of development might be needed before revenues can grow significantly (e.g., Lubik and Garnsey, 2016; Miozzo and DiVito, 2016; Rasmussen et al., 2015). Further, the analysis of the aggregated portfolio level suggests that RBSO growth is not uniform and consistent, but rather characterized as discontinuous and erratic. Only a few firms achieve consistent growth, and growth setbacks and stasis (i.e., no growth) is equally frequent as positive growth in any given period (Coad et al., 2015; Derbyshire and Garnsey, 2014; Garnsey et al., 2006). In fact, stasis is very common which supports earlier research that RBSOs are often subject to the so-called "living dead" phenomenon, where firms have high survival rates but very limited activity and growth (Clarysse et al., 2007; Coad et al., 2013; Hayter, 2011, 2015; Leitch and Harrison, 2005). In addition, growth in revenue is characterized with more volatility than in employment, suggesting that growth in employment can be more consistent. Discontinuous growth is also supported on the firm-level by Paper 4, finding that technological and commercial breakthroughs facilitate growth. This indicates that new venture growth is influenced by erratic jumps from key events occurring during the process of development.

These complex patterns of growth, combined with long development cycles and dramatic impact of outliers (i.e., skewed distributions), indicate that evaluating a portfolio of RBSOs on

the aggregate level is sensitive to the timing of inquiry. At any given point, there will be a range of uncertain outcomes (i.e., real options) which all of a sudden can achieve growth spurts and performance events that significantly shift the total impact of the portfolio. The theoretical implication from this finding is that studies of RBSOs at the aggregate portfolio level should be done at least ten years after the last cohort was established. In particular, cross-sectional studies should be careful in extrapolating historical events into the future. This is especially the case when considering profitability and wealth creation which takes longer to manifest itself than growth in revenues and employment.

Firm Level

The focus of the empirical firm-level studies in Paper 4 and 5 are trade sales, which are motivated by the two linkages to the other research papers: (1) the literature review in Paper 1 revealed that trade sales had received marginal treatment as a performance outcome in the academic entrepreneurship literature. This is surprising given the expected prevalence of trade sales as a means of exit for investors and entrepreneurs (e.g., Clarysse et al., 2013). More broadly, studies on exit events has traditionally seen far less attention in the entrepreneurship literature compared with creation and growth (DeTienne and Wennberg, 2016); (2) studies on the aggregated portfolio level contributed with the recognition that trade sales was an influential performance outcome for RBSOs overall.

Paper 4 focuses specifically on how RBSOs grow firm value in the context of trade sales, and makes a number of contributions of relevance to this dissertation's overall research question. First, it contributes with extending the notion of firm value being a particularly relevant measure of growth for new ventures (Achtenhagen et al., 2010). This links back to Penrose (1959: 22) who considered firm value as the most appropriate measure of growth. Further, an emphasis on firm value supports the theoretical position argued in Chapter 2, where the concepts of growth and performance are conjoined in understanding entrepreneurial success. More specifically, with respect to the conceptual framework in Table 6-1, the measure of firm value permeates through all performance outcomes for RBSOs. Growth in revenue, employment, and assets are, at least from the perspective of many entrepreneurs (Achtenhagen et al., 2010), intermediary steps with the objective of growing firm value. Further, operational performance events such as innovation and internationalization can also be linked to firm progress. Such activities will contribute to growth in firm value when they are successful. Further, firm value is discovered by the market through terminal outcomes such as trade sales (or failure, when firm value is

essentially zero), or financial performance events such as IPOs or equity investments. While firm value is generally difficult to observe empirically (Capron and Shen, 2007), it by no means it is any less important theoretically. Hence, this dissertation contributes with positioning growth in firm value as a measure of growth that is particularly relevant in the context of knowledge-intensive entrepreneurship. This does not imply that it replaces other measures of growth, but rather that in certain contexts it is more theoretically meaningful to consider growth in firm value.

Second, Paper 4 contributes to extending current understanding of growth modes (McKelvie and Wiklund, 2010). The RBSOs in this study generally pursued trade sales to obtain access to critical resources and complementary assets. This can be illustrated by the fact that the only original (technical-oriented) founders did exit the firm as a direct consequence of the trade sale in only two out of the nine case firms. Hence, trade sales do not necessarily represent the end of the venture, but a specific mechanism of growth made consciously by the firm (Mason and Brown, 2013). While trade sales often involve the exit of entrepreneurs (DeTienne et al., 2015) and investors (Clarysse et al., 2013), this study contributes with identifying the circumstances when trade sale are better understood as a growth mode than exit. Specifically, trade sales act more as a growth mode when the new venture's business activities are still associated with technological and market uncertainty. Hence, trade sales represent a potential mechanism of growth quite early in the development cycles in the case of RBSOs. In fact, many of the case firms were sold at a very young age. This relates to RBSOs often commercializing technologies that are general purpose and positioned upstream in industry value chains (Lubik and Garnsey, 2016). Hence, it is a mechanism that can be a step in completing commercialization processes (Meoli et al., 2013). Trade sales therefore share many of the same characteristics as the hybrid growth mode of strategic alliancing (McKelvie and Wiklund, 2010). However, trade sales will theoretically be a superior mode of growth compared with strategic alliancing when integration of the new venture into the larger incumbent's organization is necessary to efficiently scale-up the venture's business activities (Clarysse et al., 2007; Penrose, 1959: 142). In sum, this dissertation contributes to broaden the current conceptualization of growth modes.

Finally, Paper 4 contributes with a novel perspective of the extent of firm growth being dependent on the idiosyncratic dyad of the firm and its potential partners. This perspective is linked to the notion that firms can access and leverage external resources (i.e., without owning the resources) through partnerships (Haeussler et al., 2012; Lavie, 2007). Accessing external

resources is theoretically more related to growth in firm output (e.g., revenues and value) compared with growth in firm input (assets and employment), because it can facilitate growth without the firm internalizing resources acquired in strategic factor markets (Barney, 1986; Nason, 2014: 77-112). The trade sale is a very close form of partnership, and the findings suggests that extent of growth is dependent of the strategic match with potential buyers. When a particularly beneficial synergetic match with a potential buyer is located, growth in firm value can be much higher compared with continuing to operate as an independent firm. This illustrates that new venture growth not only is dependent on the resources the firm controls and the competitive environment it operates within (Wiklund et al., 2009), but also on its strategic match with potential partners in that environment.

The literature review in Paper 1 concluded that most studies of RBSOs are phenomenon-driven, and recommended that future research takes advantage of RBSOs as a particularly productive context to explore broader theoretical questions, rather than constructing narrow phenomenon-oriented theory. Paper 5 is an example of this, using RBSOs as the empirical context to test and extend signaling theory. Further, the link between Paper 4 and Paper 5 is that the former investigates the magnitude of growth achieved through trade sales, while the latter focuses on the *ability* to achieve a trade sale in the first place. Paper 5 contributes with new insights into the signal value of insider ownership (i.e., ownership controlled by entrepreneurs and other individuals directly involved in the management of the firm) in important transactions subject to information asymmetry (such as trade sales). The study finds the relationship between insider ownership and trade sales to be inverse U-shaped, with likelihood of a trade sale becoming particularly high when insiders hold moderate rather than high ownership in their venture. Further, the study finds that strength of the signal is contingent on firm age and presence of professional investors as owners. This illustrates that signals are not interpreted one at the time, but rather in combination hereby attaching more or less value to specific signals depending on the circumstances and moment at which the signals are sent.

6.2 Limitations and Further Research

This dissertation has several limitations, where some of the areas providing salient opportunities for further research will be presented below. I refer to Section 3.7 for a specific discussion concerning methodological limitations.

This dissertation is primarily based on empirical data describing RBSOs from Norway. The degree of transferability of the dissertation's findings to other country- and regional contexts is unclear. To corroborate the international representativeness of the findings, further research with similar focus might be conducted in other countries and regions. For instance, Norway has a very limited public market for small knowledge-intensive firms. This is likely an important reason for why trade sales are so prevalent compared to IPOs for NTBFs in Norway. Although trade sales generally have increased in popularity compared to IPOs (Achleitner et al., 2012; Clarysse et al., 2013; Gerasymenko and Arthurs, 2014; Mason and Brown, 2013; Schwienbacher, 2005), it is entirely likely that IPOs are more frequent and desired among RBSOs in other countries. Context will influence the robustness of the findings in other ways also. Norway is a very small economy, with a limited domestic market for the product and services RBSOs are commercializing. The inability to rely on a domestic market might entice a greater incentive to pursue growth modes such as trade sale to easier achieve access to an international market.

Further, the findings of this dissertation are considered to have relevance outside the specific context of academic entrepreneurship, but they are not universally valid. The theoretical framework and research papers in this dissertation support the notion that RBSOs are different on several dimensions compared with average entrepreneurial firms. However, I believe the many of the dissertation's overall findings can be generalized to the more comparable firm categories of NTBFs and CSOs. These firms face similar, albeit not identical, growth challenges, and future research might explore possibilities for comparative studies between RBSOs and other NTBFs. This could include investigating whether factors discussed in this dissertation have differential effects on RBSOs and NTBFs (for examples of this see e.g., Clarysse et al., 2011; Ensley and Hmieleski, 2005; Wennberg et al., 2011; Zahra et al., 2007).

This dissertation has adopted a multidimensional perspective of growth with greater emphasis on qualitatively different growth modes (e.g., Achtenhagen et al., 2016; McKelvie and Wiklund, 2010; Navarro et al., 2012). Applying this perspective, the dissertation contributes with a more complex comprehension of growth and performance outcomes for RBSOs. However, limited attention has been given to the relationships *between* different dimensions of growth and venture performance. This warrants further study, as a better understanding of the complex relationships between growth measures will give deeper insights into growth patterns and trajectories of RBSOs. Recent advances in the growth literature has investigated such

relationships, including: co-evolution of growth measures (e.g., Coad, 2010; Coad and Broekel, 2012; Delmar et al., 2013); acquisitive and organic growth (e.g., Burghardt and Helm, 2015; Lockett et al., 2011); survival and growth (e.g., Coad et al., 2013); innovation performance and growth (e.g., Audretsch et al., 2014; Capasso et al., 2015; Coad and Guenther, 2014; Coad et al., 2016b; Stam and Wennberg, 2009); size, profitability, and growth (e.g., Coad et al., 2016a; Federico and Capelleras, 2015); and consistency and patterns of growth (e.g., Achtenhagen et al., 2016; Coad, 2007; Coad and Guenther, 2013; Daunfeldt and Halvarsson, 2015). I believe that the database of the FORNY portfolio constructed in this dissertation is ideal for such research, as it maps a range of growth, development, and performance outcomes (see Figure 3-3).

While the choice of focusing on trade sales is warranted for a number of reasons previously discussed, it leaves a gap with respect to the growth of independent RBSOs. This provides a compelling opportunity for further research. For instance, the analysis in Chapter 4 suggests that RBSOs operating with business models accentuating services (e.g., consulting and contract research) are associated with more consistent growth in sales and profits at a younger age. However, when maturing, these firms are less likely to achieve rapid growth compared with RBSOs following more product-oriented business models. This suggests that growth patterns and business models are related (see e.g., Helm and Mauroner, 2011). RBSOs have been found to change and adapt their business models as a consequence of resource requirements, technological characteristics, and long development horizons (Bigdeli et al., 2016; Fisher et al., 2016; Lubik and Garnsey, 2016). Further, the entrepreneurs' growth aspirations and the firm's entrepreneurial orientation has been found to be related to actual growth (Delmar and Wiklund, 2008; McKelvie et al., 2017; Wiklund et al., 2009; Wiklund and Shepherd, 2003). Low growth aspirations and entrepreneurial orientation is likely related to the choice of business models, suggesting that business models might mediate such relationships. In short, the relationship between business models and growth of RBSOs represent a fruitful avenue for future research.

This dissertation has purposefully focused on RBSOs as one distinct facet of academic entrepreneurship. Relevant emerging perspectives in academic entrepreneurship include looking beyond the commercialization of research, and focus more on the much more frequent phenomenon of student entrepreneurship (Astebro et al., 2012). Student entrepreneurship has received far less attention that it likely deserves (Grimaldi et al., 2011). Student and academic entrepreneurship overlap when students are part of the entrepreneurial team in a new RBSO.

Future research might explore the role of student entrepreneurs in RBSOs (see e.g., Boh et al., 2016; Hayter et al., 2016; Lundqvist, 2014). Further, new forms of support structures like accelerators challenge the conventional property-based structures like TTOs, science parks, and incubators (Siegel and Wright, 2015). Paper 1 illustrated that a fair amount of research has been done on how conventional support structures affect the growth processes of RBSOs (e.g., Jong, 2006; Leitch and Harrison, 2005; Moray and Clarysse, 2005; Patzelt and Shepherd, 2009; Rasmussen and Borch, 2010; Rasmussen et al., 2014; Steffensen et al., 2000; Treibich et al., 2013). However, much less is known about how these more recent support structures might impact spin-off development and growth.

This dissertation has to a large extent ignored the effect of the environment on growth and performance. This is not because I do not recognize that the environment can be both a source of opportunities and constraints on RBSO growth. Rather, I follow Penrose (1959: 38) in that the environment shapes growth opportunities and firm behavior by how it is perceived by entrepreneurs. Environmental conditions and changes will undoubtedly affect growth. Yet, the position of this dissertation is that entrepreneurial agency and the internal factors of the firm can uncover the most interesting and helpful theoretical insights related to development and growth of RBSOs. For instance, the industrial composition of a geographical area might have negative effects (cf., Shane, 2004: 100), but this fact is not particularly helpful for an entrepreneur launching an RBSO in that area. Further, as RBSOs typically are searching for a market for its technologies (i.e., technology push), success might require *changing* the environment. Hence, this dissertation take a Penrosean approach, with emphasis on the internal resources of a firm, particularly the productive services available from the knowledge resources of the firm. The limitation of this approach is that I risk overemphasizing internal mechanisms, and fail to recognize or downplay other important factors in the environment.

6.3 Implications for Practice and Policy

Implications for Entrepreneurs

The skewed distribution of successful outcomes and long development times this dissertation has pointed to indicate that the growth challenges facing RBSOs are substantial. The lacking effects of national- and university policy changes discovered in Paper 2, sends a clear message to entrepreneurs; their knowledge and actions are the deciding ingredients for success. The literature review in Paper 1 summarizes a body of research which in part has investigated how

entrepreneurs may overcome these challenges. However, I will concentrate on key implications for entrepreneurs based on the results of the empirical studies in this dissertation.

First, Paper 4 reveals that entrepreneurs need to be attentive to dependence on individual tacit knowledge. Academic inventors will in all likelihood possess technical expertise that is necessary to successfully industrialize the firm's technology. The creation of firm capabilities requires sustained efforts over time and entrepreneurs should emphasize building processes, routines, and internal structures which gradually can operate independent of them. This is important not only to develop products and services that are marketable commercially, but will also contribute to grow the value of the firm. Further, if the firm has aspirations for high growth, entrepreneurs should strive to make their knowledge assets as scalable as possible. Rapid growth is challenging to accomplish if significant human interaction is needed in the delivery of the firm's products.

Second, the results in Chapter 4 indicates that IPOs are very rare (at least in countries with poorly developed public markets for small firms), and only seem likely for RBSO commercializing new pharmaceutical technologies. In contrast, trade sales are identified in Paper 3 as a much more frequent venture outcome, important both with respect to exit opportunities but also as a mechanism to grow. Paper 4 shows that RBSOs achieve the highest growth in firm value when maximizing the synergy potential with potential buyers. This is in part caused by synergy potential being crucial to enable growth in sales and profits after the trade sale has been completed, and when business activities are conducted under the new governance structure of the buyer. Entrepreneurs tend to focus on partnerships with organizations they already know or are comfortable with. However, this dissertation points to this as a suboptimal approach, as the highest synergy potential might be with a partner unknown to the entrepreneur ex ante. Hence, entrepreneurs should actively seek out potential partners where they can maximize the idiosyncratic synergy potential.

Third, entrepreneurs should carefully consider the consequences of bringing professional VC-investors on board. As Paper 5 illustrates, investors contribute with necessary financial resources and signal venture quality, but entrepreneurs must realize they are temporary owners and will always seek to successfully exit their investment in the medium term. Conflicts between investors and entrepreneurs were observed in the qualitative field work of this dissertation. These conflicts were largely concerned with decisions related to exit timing and

opportunities. These conflicts could to a large extent be avoided if the communication between the entrepreneurial team and investors were more intelligible. Further, entrepreneurs should be aware that the level of ownership they control sends important signals to potential partners, both with respect to their commitment and the quality of the venture. It will be in the best interest of all parties that the entrepreneurs own a reasonable share of the firm, obviously seen in light of the resources invested in the firm.

Finally, entrepreneurs should be aware of both the benefits and risks of strategic partnerships with larger industry firms. RBSOs should early on start to interact with potential customers, users and strategic partners. This is especially the case for RBSOs commercializing technologies that has upstream applications in industry value chains. In this scenario, it is unlikely that the RBSO will be able to successfully commercialize the technology without assistance and support from the industry. However, while partnerships can be a critical source for resources, specific cooperative arrangements such as minority equity involvement can reduce the firm's ability to generate alternative courses of action further down the line. In general, entrepreneurs should maintain a sensible level of independence, while pursuing a restricted number of high impact strategic partnerships. More generally, entrepreneurs who develop several alternative courses of actions, enjoy flexibility which may prove valuable later.

Implications for Public Research Organizations

The results from Paper 2 provide a skeptical perspective on the effect of "top-down" policy changes on the growth and performance of RBSOs. This implies that universities should develop support mechanisms to improve spin-off success separately from responding to policies aimed at increasing spin-of activity (Gilsing et al., 2010). It seems important that PROs and TTOs launch "bottom-up" initiatives which develop capabilities within their entire organization and surrounding ecosystem that can provide the necessary support to make RBSOs ready for growth. Further, support mechanisms should specifically assist RBSOs in reducing technological, market, and organizational uncertainty. Support to reduce technological uncertainty could include sabbaticals for technical inventors, access to laboratories and equipment, and research funds. Support to reduce market uncertainty could include facilitating market research, taking responsibility for patenting activities, and providing networks to relevant industry players. In particular, this research has revealed the importance of networks with industrial incumbents and TTOs should, therefore, have programs in place which facilitate interaction between their spin-off projects and industry. Support to reduce organizational

uncertainty could include access to appropriate office space, assisting with recruitment of surrogate entrepreneurs with commercial experience, and assembling a board of directors or advisory boards.

RBSOs have high survival rates, but this dissertation has also shed light on the "living dead" phenomena, where many firms seem to exist with limited indications of development and growth. The intention of support mechanisms and entrepreneurship policy should be to implement policy interventions that correct market failures for the net benefit of society (Acs et al., 2016). RBSOs that survive principally through access to funding from public support programs are not in alignment with this intention. From a real options perspective (see Paper 3 in Part 2), engaging in productive activities will accelerate clarification of outcomes. PROs and TTOs should, therefore, provide incentives for RBSOs to engage in necessary development activities which can resolve and clarify whether the venture is viable. For example, programs which provide access to funding should be coupled with requirements to utilize such funds specifically for productive development activities.

Implications for Policymakers

A number of implications arise from this research which are relevant for policymakers at national and regional level. First, this dissertation has shown that top-down policies face the risk of being met by strategic responses at the lower levels. Our results provide a general indication across countries that the effects of policy changes may not lead to the intended increase in the creation of high-performing RBSOs. Hence, policies developed specifically toward the commercialization of university research needs to be connected closely to entrepreneurship policies and funding programs more generally to be successful. RBSOs are heterogeneous new ventures where different growth trajectories can lead to profitability. For instance, not all spinoffs are established with the intention to maximize growth, and rather wish to operate as lifestyle companies offering consulting services. Such RBSOs should not be the primary target for policy instruments specifically designed with the objective to commercialize research results. Further, the outcomes of RBSOs follow highly skewed distributions and only a few firms will be a source of significant value creation. Hence, dedicated policy instruments for commercialization of research should, therefore, be prioritized and focused toward the RBSO which have the ambitions and abilities to achieve high growth. As the analysis in Chapter 4 illustrates, these are the firms investing in large deficits in the period when technologies are

developed, and thus might be subject to the "funding gap" which policy and support mechanisms can address (Munari and Toschi, 2011; Widding et al., 2009).

Second, trade sales are an important mechanism to facilitate commercialization of research. Trade sales often have unfavorable connotations in policy circles because of the fear that technologies and firms partly financed by governmental resources and tax dollars will be "sold of the country", thus surrendering the new knowledge-based employment opportunities which would be created locally. Although acquisitions by large foreign companies do occur in the FORNY portfolio, the majority of buyers were domestic firms. Further, many of the RBSOs acquired by foreign companies remained domestically and even increased the scope of their business activities locally. Also, very successful trade sales provide high returns for entrepreneurs and VC investors which can be re-invested into new ventures. For these reasons, I recommend policymakers to keep an open mind with respect to trade sales. More specifically, policymakers should facilitate for large foreign industry incumbents to interact with domestic PROs for the mutual benefit of both parties.

Finally, policymakers need to be attentive to the skewed distribution of outcomes and the long timespans involved in the commercialization of research results when designing and evaluating policy instruments and support programs. In particular, evaluations of the economic impact of a portfolio of RBSOs needs to allow enough time to pass before the analysis should be conducted. At least ten years after the last cohort was established seems sensible before any robust conclusions can be settled upon (Rasmussen and Mathisen, 2017). Further, a comprehensive approach to how impact is measured should be applied, as economic impact can occur through different channels. For instance, the "full" economic impact of trade sales is likely not visible through analysis of financial statements because many RBSOs are acquired while still being unprofitable. Further, some researchers have argued that the majority of economic impact from RBSOs are indirect through their indirect role of translating scientific findings into application in society (Rasmussen et al., 2016). The value of these indirect effects is clearly difficult to quantify, but should still be considered when evaluating policy programs.

7 REFERENCES

Achleitner A., Braun R., Lutz E., Reiner U. Venture capitalist firm returns from acquisitions exits. Working paper, 2012-01, Technical University of Munich; 2012.

Achtenhagen L., Brunninge O., Melin L. Patterns of Dynamic Growth in Medium-Sized Companies: Beyond the Dichotomy of Organic Versus Acquired Growth. *Long Range Planning* 2016.

Achtenhagen L., Naldi L., Melin L. "Business Growth"-Do Practitioners and Scholars Really Talk About the Same Thing? *Entrepreneurship Theory and Practice* 2010; 34(2): 289-316.

Acs Z., Åstebro T., Audretsch D., Robinson D.T. Public policy to promote entrepreneurship: a call to arms. *Small Business Economics* 2016; 47(1): 35-51.

Agrawal A. University-to-industry knowledge transfer: literature review and unanswered questions. *International Journal of Management Reviews* 2001; 3(4): 285-302.

Allison P.D. Event History and Survival Analysis. 2nd ed.: Sage; 2014.

Alvarez S.A., Barney J.B. The entrepreneurial theory of the firm. *Journal of Management Studies* 2007; 44(7): 1057-1063.

Alvarez S.A., Busenitz L.W. The entrepreneurship of resource-based theory. *Journal of Management* 2001; 27(6): 755-775.

Alvarez S.A., Young S.L., Woolley J.L. Opportunities and institutions: A co-creation story of the king crab industry. *Journal of Business Venturing* 2015; 30(1): 95-112.

Ambos T.C., Birkinshaw J. How Do New Ventures Evolve? An Inductive Study of Archetype Changes in Science-Based Ventures. *Organization Science* 2010; 21(6): 1125-1140.

Amit R., Schoemaker P.J.H. Strategic Assets and Organizational Rent. *Strategic Management Journal* 1993; 14(1): 33-46.

Angrist J., Krueger A.B. Instrumental variables and the search for identification: From supply and demand to natural experiments. National Bureau of Economic Research; 2001.

Angrist J.D., Pischke J.-S. Mostly harmless econometrics: An empiricist's companion. Princeton university press; 2008.

Anyadike-Danes M., Bonner K., Hart M., Mason C. Measuring business growth: high growth firms and their contribution to employment in the UK. 2009.

Astebro T. The return to independent invention: Evidence of unrealistic optimism, risk seeking or skewness loving? *Economic Journal* 2003; 113(484): 226-239.

Astebro T., Bazzazian N., Braguinsky S. Startups by recent university graduates and their faculty: Implications for university entrepreneurship policy. *Research Policy* 2012; 41(4): 663-677.

Audretsch D.B., Coad A., Segarra A. Firm growth and innovation. *Small Business Economics* 2014; 43(4): 743-749.

Barney J. Strategic Factor Markets - Expectations, Luck, and Business Strategy. *Management Science* 1986; 32(10): 1230-1241.

Bathelt H., Kogler D.F., Munro A.K. A knowledge-based typology of university spin-offs in the context of regional economic development. *Technovation* 2010; 30(9-10): 519-532.

Benton T., Craib I. Philosophy of social science: The philosophical foundations of social thought. Palgrave Macmillan; 2011.

Berk J.B., Green R.C., Naik V. Valuation and return dynamics of new ventures. *Review of Financial Studies* 2004; 17(1): 1-35.

Bhaskar R. A Realist Theory of Science. Routledge; 1975.

Bhaskar R. The Possibility of Naturalism: A Philosophical Critique of the Contemporary Human Sciences. Routledge; 1979.

Bigdeli A.Z., Li F., Shi X.H. Sustainability and scalability of university spinouts: a business model perspective. *R & D Management* 2016; 46(3): 504-518.

Boh W.F., De-Haan U., Strom R. University technology transfer through entrepreneurship: faculty and students in spinoffs. *Journal of Technology Transfer* 2016; 41(4): 661-669.
Bonardo D., Paleari S., Vismara S. The M&A dynamics of European science-based entrepreneurial firms. *Journal of Technology Transfer* 2010; 35(1): 141-180.
Borlaug S.B., Grunfeld L., Gulbrandsen M., Rasmussen E., Rønning L., Spilling O.R. et al. Between entrepreneurship and technology transfer: Evaluation of the FORNY programme. NIFU STEP; 2009.
Bourelos E., Magnusson M., McKelvey M. Investigating the complexity facing academic entrepreneurs in science and engineering: the complementarities of research performance, networks and support structures in commercialisation. *Cambridge Journal of Economics* 2012; 36(3): 751-780.
Bozeman B. Technology transfer and public policy: a review of research and theory. *Research Policy* 2000; 29(4-5): 627-655.
Bozeman B., Fay D., Slade C.P. Research collaboration in universities and academic entrepreneurship: the-state-of-the-art. *Journal of Technology Transfer* 2013; 38(1): 1-67.
Brander J.A., Du Q., Hellmann T. The effects of government-sponsored venture capital: international evidence. *Review of Finance* 2014: rfu009.
Brush C.G., Greene P.G., Hart M.M. From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base. *Academy of Management Executive* 2001; 15(1): 64-78.
Brush C.G., Vanderwerf P.A. A Comparison of Methods and Sources for Obtaining Estimates of New Venture Performance. *Journal of Business Venturing* 1992; 7(2): 157-170.
Buch-Hansen H., Nielsen P. Kritisk realisme. Roskilde: Roskilde Universitetsforlag; 2005.
Burghardt D., Helm M. Firm growth in the course of mergers and acquisitions. *Small Business Economics* 2015; 44(4): 889-904.
Capasso M., Treibich T., Verspagen B. The medium-term effect of R&D on firm growth. *Small Business Economics* 2015; 45(1): 39-62.
Capron L., Shen J.C. Acquisitions of private vs. public firms: Private information, target selection, and acquirer returns. *Strategic Management Journal* 2007; 28(9): 891-911.
Cattaneo M., Meoli M., Vismara S. Cross-border M&As of biotech firms affiliated with internationalized universities. *Journal of Technology Transfer* 2015; 40(3): 409-433.
Chiesa V., Piccaluga A. Exploitation and diffusion of public research: the case of academic spin-off companies in Italy. *R & D Management* 2000; 30(4): 329-339.
Clarysse B., Bobelyn A., Aguirre I.D. Learning from own and others' previous experience: the contribution of the venture capital firm to the likelihood of a portfolio company's trade sale. *Small Business Economics* 2013; 40(3): 575-590.
Clarysse B., Moray N. A process study of entrepreneurial team formation: the case of a research-based spin-off. *Journal of Business Venturing* 2004; 19(1): 55-79.
Clarysse B., Wright M., Lockett A., Mustar P., Knockaert M. Academic spin-offs, formal technology transfer and capital raising. *Industrial and Corporate Change* 2007; 16(4): 609-640.
Clarysse B., Wright M., Lockett A., Van de Velde E., Vohora A. Spinning out new ventures: a typology of incubation strategies from European research institutions. *Journal of Business Venturing* 2005; 20(2): 183-216.
Clarysse B., Wright M., Van de Velde E. Entrepreneurial Origin, Technological Knowledge, and the Growth of Spin-Off Companies. *Journal of Management Studies* 2011; 48(6): 1420-1442.
Clausen T.H., Rasmussen E. Parallel business models and the innovativeness of research-based spin-off ventures. *Journal of Technology Transfer* 2013: 1-14.

Coad A. A closer look at serial growth rate correlation. *Review of Industrial Organization* 2007; 31(1): 69-82.
Coad A. The growth of firms: A survey of theories and empirical evidence. Edward Elgar Publishing; 2009.
Coad A. Exploring the processes of firm growth: evidence from a vector auto-regression. *Industrial and Corporate Change* 2010; 19(6): 1677-1703.
Coad A. Death is not a success: Reflections on business exit. *International Small Business Journal* 2014; 32(7): 721-732.
Coad A., Broekel T. Firm growth and productivity growth: evidence from a panel VAR. *Applied Economics* 2012; 44(10): 1251-1269.
Coad A., Daunfeldt S.O., Holzl W., Johansson D., Nightingale P. High-growth firms: introduction to the special section. *Industrial and Corporate Change* 2014; 23(1): 91-112.
Coad A., Frankish J., Roberts R.G., Storey D.J. Growth paths and survival chances: An application of Gambler's Ruin theory. *Journal of Business Venturing* 2013; 28(5): 615-632.
Coad A., Frankish J.S., Roberts R.G., Storey D.J. Are firm growth paths random? A reply to "Firm growth and the illusion of randomness". *Journal of Business Venturing Insights* 2015; 3: 5-8.
Coad A., Frankish J.S., Roberts R.G., Storey D.J. Predicting new venture survival and growth: Does the fog lift? *Small Business Economics* 2016a; 47(1): 217-241.
Coad A., Guenther C. Diversification patterns and survival as firms mature. *Small Business Economics* 2013; 41(3): 633-649.
Coad A., Guenther C. Processes of firm growth and diversification: theory and evidence. *Small Business Economics* 2014; 43(4): 857-871.
Coad A., Rao R. Innovation and firm growth in high-tech sectors: A quantile regression approach. *Research Policy* 2008; 37(4): 633-648.
Coad A., Segarra A., Teruel M. Innovation and firm growth: Does firm age play a role? *Research Policy* 2016b; 45(2): 387-400.
Coff R.W. How buyers cope with uncertainty when acquiring firms in knowledge-intensive industries: Caveat emptor. *Organization Science* 1999; 10(2): 144-161.
Cohen W.M., Levinthal D.A. Absorptive-Capacity - a New Perspective on Learning and Innovation. *Administrative Science Quarterly* 1990; 35(1): 128-152.
Colombo M., Mustar P., Wright M. Dynamics of Science-based entrepreneurship. *Journal of Technology Transfer* 2010a; 35(1): 1-15.
Colombo M.G., D'Adda D., Piva E. The contribution of university research to the growth of academic start-ups: an empirical analysis. *Journal of Technology Transfer* 2010b; 35(1): 113-140.
Combs J.G., Russell Crook T., Shook C.L. The dimensionality of organizational performance and its implications for strategic management research. Research methodology in strategy and management. Published: Emerald Group Publishing Limited; 2005. p. 259-286.
Conceicao O., Fontes M., Calapez T. The commercialisation decisions of research-based spin-off: Targeting the market for technologies. *Technovation* 2012; 32(1): 43-56.
Cooney T.M. Editorial: What is an entrepreneurial team? *International Small Business Journal* 2005; 23(3): 226-235.
Cowan D. Knightian Uncertainty. Frank H Knight: Prophet of Freedom. Published: Palgrave Macmillan UK; 2016. p. 27-74.

Crawford G.C., Aguinis H., Lichtenstein B., Davidsson P., McKelvey B. Power law distributions in entrepreneurship: Implications for theory and research. *Journal of Business Venturing* 2015; 30(5): 696-713.
Creswell J.W., Clark V.L.P. Designing and conducting mixed methods research. 2007.
Criaco G., Minola T., Migliorini P., Serarols-Tarrés C. "To have and have not": founders' human capital and university start-up survival. *Journal of Technology Transfer* 2014: 1-27.
Dahlqvist J., Davidsson P., Wiklund J. Initial conditions as predictors of new venture performance: A replication and extension of the Cooper et al. study. *Enterprise and Innovation Management Studies* 2000; 1(1): 1-17.
Damsgaard E.F., Thursby M.C. University entrepreneurship and professor privilege. *Industrial and Corporate Change* 2013; 22(1): 183-218.
Daunfeldt S.O., Halvarsson D. Are high-growth firms one-hit wonders? Evidence from Sweden. *Small Business Economics* 2015; 44(2): 361-383.
Davidsson P., Delmar F., Wiklund J. Entrepreneurship and the Growth of Firms. 2006.
Davidsson P., Honig B. The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing* 2003; 18(3): 301-331.
de Boer M., Van den Bosch F.A.J., Volberda H.W. Managing organizational knowledge integration in the emerging multimedia complex. *Journal of Management Studies* 1999; 36(3): 379-398.
Deaton A., Cartwright N. Understanding and misunderstanding randomized controlled trials. National Bureau of Economic Research; 2016.
Delmar F., Davidsson P. Where do they come from? Prevalence and characteristics of nascent entrepreneurs. *Entrepreneurship & Regional Development* 2000; 12(1): 1-23.
Delmar F., Davidsson P., Gartner W.B. Arriving at the high-growth firm. *Journal of Business Venturing* 2003; 18(2): 189-216.
Delmar F., McKelvie A., Wennberg K. Untangling the relationships among growth, profitability and survival in new firms. *Technovation* 2013; 33(8-9): 276-291.
Delmar F., Wiklund J. The effect of small business managers' growth motivation on firm growth: A longitudinal study. *Entrepreneurship Theory and Practice* 2008; 32(3): 437-457.
Derbyshire J., Garnsey E. Firm growth and the illusion of randomness. *Journal of Business Venturing Insights* 2014; 1: 8-11.
Derbyshire J., Garnsey E. Are firm growth paths random? A further response regarding Gambler's Ruin Theory. *Journal of Business Venturing Insights* 2015; 3: 9-11.
DeTienne D., Wennberg K. Studying exit from entrepreneurship: New directions and insights. *International Small Business Journal* 2016; 34(2): 151-156.
DeTienne D.R., McKelvie A., Chandler G.N. Making sense of entrepreneurial exit strategies: A typology and test. *Journal of Business Venturing* 2015; 30(2): 255-272.
Djokovic D., Souitaris V. Spinouts from academic institutions: a literature review with suggestions for further research. *Journal of Technology Transfer* 2008; 33(3): 225-247.
Dobbs M., Hamilton R. Small business growth: recent evidence and new directions. *International journal of entrepreneurial behavior & research* 2007; 13(5): 296-322.
Druilhe C., Garnsey E. Do academic spin-outs differ and does it matter? *Journal of Technology Transfer* 2004; 29(3-4): 269-285.
Eisenhardt K.M. Building Theories from Case-Study Research. *Academy of Management Review* 1989; 14(4): 532-550.
Eisenhardt K.M., Graebner M.E. Theory building from cases: Opportunities and challenges. *Academy of Management Journal* 2007; 50(1): 25-32.

Ensley M.D., Hmieleski K.A. A comparative study of new venture top management team composition, dynamics and performance between university-based and independent start-ups. *Research Policy* 2005; 34(7): 1091-1105.
Etzkowitz H., Leydesdorff L. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research Policy* 2000; 29(2): 109-123.
Etzkowitz H., Webster A., Gebhardt C., Terra B.R.C. The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research Policy* 2000; 29(2): 313-330.
Federico J.S., Capelleras J.L. The heterogeneous dynamics between growth and profits: the case of young firms. *Small Business Economics* 2015; 44(2): 231-253.
Fini R., Fu K., Mathisen M.T., Rasmussen E., Wright M. Institutional determinants of university spin-off quantity and quality: a longitudinal, multilevel, cross-country study. *Small Business Economics* 2016; 48(2): 361-391.
Fini R., Grimaldi R. Process Approach to Academic Entrepreneurship: Evidence from the Globe. World Scientific Publishing; 2016.
Fini R., Lacetera N., Shane S. Inside or outside the IP system? Business creation in academia. *Research Policy* 2010; 39(8): 1060-1069.
Fisher G. Effectuation, Causation, and Bricolage: A Behavioral Comparison of Emerging Theories in Entrepreneurship Research. *Entrepreneurship Theory and Practice* 2012; 36(5): 1019-1051.
Fisher G., Kotha S., Lahiri A. Changing with the times: An integrated view of identity, legitimacy, and new venture lifce cycles. *Academy of Management Review* 2016; 41(3): 383-409.
Fontes M. The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-offs. *Technovation* 2005; 25(4): 339-347.
Franklin S.J., Wright M., Lockett A. Academic and surrogate entrepreneurs in university spin-out companies. *Journal of Technology Transfer* 2001; 26(1-2): 127-141.
Gans J.S., Stern S. The product market and the market for "ideas": commercialization strategies for technology entrepreneurs. *Research Policy* 2003; 32(2): 333-350.
Garnsey E. A theory of the early growth of the firm. *Industrial and Corporate Change* 1998; 7(3): 523-556.
Garnsey E., Heffernan P. Growth setbacks in new firms. *Futures* 2005; 37(7): 675-697.
Garnsey E., Stam E., Heffernan P. New firm growth: Exploring processes and paths. *Industry and Innovation* 2006; 13(1): 1-20.
Gephart R.P. Qualitative research and the Academy of Management Journal. *Academy of Management Journal* 2004; 47(4): 454-462.
Gerasymenko V., Arthurs J.D. New insights into venture capitalists' activity: IPO and time-to-exit forecast as antecedents of their post-investment involvement. *Journal of Business Venturing* 2014; 29(3): 405-420.
Gibrat R. Les inégalités économiques. Recueil Sirey; 1931.
Gilbert B.A., McDougall P.P., Audretsch D.B. New venture growth: A review and extension. *Journal of Management* 2006; 32(6): 926-950.
Gilsing V.A., van Burg E., Romme A.G.L. Policy principles for the creation and success of corporate and academic spin-offs. *Technovation* 2010; 30(1): 12-23.
Gioia D.A., Corley K.G., Hamilton A.L. Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods* 2013; 16(1): 15-31.

Goldfarb B., Henrekson M. Bottom-up versus top-down policies towards the commercialization of university intellectual property. *Research Policy* 2003; 32(4): 639-658.
Golob E. Capturing the regional economic benefits of university technology transfer: A case study. *Journal of Technology Transfer* 2006; 31(6): 685-695.
Gourlay S. Conceptualizing knowledge creation: A critique of Nonaka's theory. *Journal of Management Studies* 2006; 43(7): 1415-1436.
Grant R.M. Prospering in dynamically-competitive environments: Organizational capability as knowledge integration. *Organization Science* 1996a; 7(4): 375-387.
Grant R.M. Toward a knowledge-based theory of the firm. *Strategic Management Journal* 1996b; 17: 109-122.
Grimaldi R., Kenney M., Siegel D.S., Wright M. 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy* 2011; 40(8): 1045-1057.
Gruber M., MacMillan I.C., Thompson J.D. Escaping the Prior Knowledge Corridor: What Shapes the Number and Variety of Market Opportunities Identified Before Market Entry of Technology Start-ups? *Organization Science* 2013; 24(1): 280-300.
Guba E.G., Lincoln Y.S. Competing paradigms in qualitative research. *Handbook of qualitative research* 1994; 2(163-194): 105.
Gulbrandsen M. Research institutes as hybrid organizations: central challenges to their legitimacy. *Policy Sciences* 2011; 44(3): 215-230.
Gulbrandsen M., Rasmussen E. The use and development of indicators for the commercialisation of university research in a national support programme. *Technology Analysis & Strategic Management* 2012; 24(5): 481-495.
Gurdon M.A., Samsom K.J. A longitudinal study of success and failure among scientist-started ventures. *Technovation* 2010; 30(3): 207-214.
Haeussler C., Patzelt H., Zahra S.A. Strategic alliances and product development in high technology new firms: The moderating effect of technological capabilities. *Journal of Business Venturing* 2012; 27(2): 217-233.
Hall B., Helmers C., Rogers M., Sena V. The Choice between Formal and Informal Intellectual Property: A Review. *Journal of Economic Literature* 2014; 52(2): 375-423.
Harrison R.T., Leitch C. Voodoo Institution or Entrepreneurial University? Spin-off Companies, the Entrepreneurial System and Regional Development in the UK. *Regional Studies* 2010; 44(9): 1241-1262.
Hayter C.S. In search of the profit-maximizing actor: motivations and definitions of success from nascent academic entrepreneurs. *Journal of Technology Transfer* 2011; 36(3): 340-352.
Hayter C.S. Social Networks and the Success of University Spin-offs: Toward an Agenda for Regional Growth. *Economic Development Quarterly* 2015; 29(1): 3-13.
Hayter C.S. Constraining entrepreneurial development: A knowledge-based view of social networks among academic entrepreneurs. *Research Policy* 2016a; 45(2): 475-490.
Hayter C.S. A trajectory of early-stage spinoff success: the role of knowledge intermediaries within an entrepreneurial university ecosystem. *Small Business Economics* 2016b; 47(3): 633-656.
Hayter C.S., Lubynsky R., Maroulis S. Who is the academic entrepreneur? The role of graduate students in the development of university spinoffs. *The Journal of Technology Transfer* 2016: 1-18.
Heirman A., Clarysse B. How and why do research-based start-ups differ at founding? A resource-based configurational perspective. *Journal of Technology Transfer* 2004; 29(3-4): 247-268.

Helm R., Mauroner O. Soft starters, research boutiques and product-oriented firms: Different business models for spin-off companies. *International Journal of Entrepreneurship and Small Business* 2011; 12(4): 479-498.
Hindle K., Yencken J. Public research commercialisation, entrepreneurship and new technology based firms: an integrated model. *Technovation* 2004; 24(10): 793-803.
Howells J.R.L. Tacit knowledge, innovation and economic geography. *Urban Studies* 2002; 39(5-6): 871-884.
Hoyningen-Huene P. Context of discovery and context of justification. *Studies in History and Philosophy of Science Part A* 1987; 18(4): 501-515.
Hurmelinna-Laukkanen P., Puumalainen K. Nature and dynamics of appropriability: strategies for appropriating returns on innovation. *R&D Management* 2007; 37(2): 95-112.
Huyghe A., Knockaert M. The influence of organizational culture and climate on entrepreneurial intentions among research scientists. *Journal of Technology Transfer* 2015; 40(1): 138-160.
Jensen R., Thursby M. Proofs and Prototypes for Sale: The Licensing of University Inventions. *The American Economic Review* 2001; 91(1): 240-259.
Jong S. How organizational structures in science shape spin-off firms: the biochemistry departments of Berkeley, Stanford, and UCSF and the birth of the biotech industry. *Industrial and Corporate Change* 2006; 15(2): 251-283.
Karnani F. The university's unknown knowledge: tacit knowledge, technology transfer and university spin-offs findings from an empirical study based on the theory of knowledge. *Journal of Technology Transfer* 2013; 38(3): 235-250.
Kassicieh S. Benefits from using surrogate entrepreneurs in technology commercialization. *International Journal of Innovation and Technology Management* 2011; 8(04): 521-534.
Kirchberger M.A., Pohl L. Technology commercialization: a literature review of success factors and antecedents across different contexts. *The Journal of Technology Transfer* 2016: 1-36.
Kiviluoto N. Growth as evidence of firm success: myth or reality? *Entrepreneurship and Regional Development* 2013; 25(7-8): 569-586.
Knight F.H. Risk, uncertainty and profit. Boston, MA: Hart, Schaffner & Marx; Houghton Mifflin Co.; 1921.
Knockaert M., Bjornali E.S., Erikson T. Joining forces: Top management team and board chair characteristics as antecedents of board service involvement. *Journal of Business Venturing* 2015; 30(3): 420-435.
Knockaert M., Ucbasaran D., Wright M., Clarysse B. The Relationship Between Knowledge Transfer, Top Management Team Composition, and Performance: The Case of Science-Based Entrepreneurial Firms. *Entrepreneurship Theory and Practice* 2011; 35(4): 777-803.
Kochenkova A., Grimaldi R., Munari F. Public policy measures in support of knowledge transfer activities: a review of academic literature. *Journal of Technology Transfer* 2016; 41(3): 407-429.
Kogut B., Zander U. Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. *Organization Science* 1992; 3(3): 383-397.
Kor Y.Y., Mahoney J.T. Penrose's resource-based approach: The process and product of research creativity. *Journal of Management Studies* 2000; 37(1): 109-139.
Kuhn T.S. The Structure of Scientific Revolutions. University of Chicago Press; 1962.
Lakatos I. Falsification and the methodology of scientific research programmes. Can Theories be Refuted? Published: Springer; 1976. p. 205-259.

Laudan L. Progress and its problems: Towards a theory of scientific growth. Univ of California Press; 1978.
Lavie D. Alliance portfolios and firm performance: A study of value creation and appropriation in the US software industry. *Strategic Management Journal* 2007; 28(12): 1187-1212.
Lawton Smith H., Romeoa S., Bagchi-Senb S. Oxfordshire biomedical university spin-offs: An evolving system. *Cambridge Journal of Regions, Economy and Society* 2008; 1(2): 303-319.
Leitch C., Hill F., Neergaard H. Entrepreneurial and Business Growth and the Quest for a "Comprehensive Theory": Tilting at Windmills? *Entrepreneurship Theory and Practice* 2010; 34(2): 249-260.
Leitch C.M., Harrison R.T. Maximising the potential of university spin-outs: the development of second-order commercialisation activities. *R & D Management* 2005; 35(3): 257-272.
Levie J., Lichtenstein B.B. A Terminal Assessment of Stages Theory: Introducing a Dynamic States Approach to Entrepreneurship. *Entrepreneurship Theory and Practice* 2010; 34(2): 317-350.
Lockett A. Edith Penrose's legacy to the resource-based view. *Managerial and Decision Economics* 2005; 26(2): 83-98.
Lockett A., Siegel D., Wright M., Ensley M.D. The creation of spin-off firms at public research institutions: Managerial and policy implications. *Research Policy* 2005; 34(7): 981-993.
Lockett A., Wiklund J., Davidsson P., Girma S. Organic and Acquisitive Growth: Re-examining, Testing and Extending Penrose's Growth Theory. *Journal of Management Studies* 2011; 48(1): 48-74.
Lowe R.A. Who develops a university invention? The impact of tacit knowledge and licensing policies. *Journal of Technology Transfer* 2006; 31(4): 415-429.
Lubik S., Garnsey E. Early Business Model Evolution in Science-based Ventures: The Case of Advanced Materials. *Long Range Planning* 2016; 49(3): 393-408.
Lubik S., Garnsey E., Minshall T., Platts K. Value creation from the innovation environment: partnership strategies in university spin-outs. *R & D Management* 2013; 43(2): 136-150.
Lundqvist M.A. The importance of surrogate entrepreneurship for incubated Swedish technology ventures. *Technovation* 2014; 34(2): 93-100.
Macpherson A., Holt R. Knowledge, learning and small firm growth: A systematic review of the evidence. *Research Policy* 2007; 36(2): 172-192.
Mandelbrot B.B. Fractals and Scaling in Finance: Discontinuity, Concentration, Risk. Selecta Volume E. Springer Science & Business Media; 2013.
Markman G.D., Siegel D.S., Wright M. Research and Technology Commercialization. *Journal of Management Studies* 2008; 45(8): 1401-1423.
Mason C., Brown R. Creating good public policy to support high-growth firms. *Small Business Economics* 2013; 40(2): 211-225.
McKelvie A., Brattström A., Wennberg K. How young firms achieve growth: reconciling the roles of growth motivation and innovative activities. *Small Business Economics* 2017: 1-21.
McKelvie A., Haynie J.M., Gustavsson V. Unpacking the uncertainty construct: Implications for entrepreneurial action. *Journal of Business Venturing* 2011; 26(3): 273-292.
McKelvie A., Wiklund J. Advancing Firm Growth Research: A Focus on Growth Mode Instead of Growth Rate. *Entrepreneurship Theory and Practice* 2010; 34(2): 261-288.
Meoli M., Paleari S., Vismara S. Completing the technology transfer process: M&As of science-based IPOs. *Small Business Economics* 2013; 40(2): 227-248.
Meyer M. Academic entrepreneurs or entrepreneurial academics? Research-based ventures and public support mechanism. *R & D Management* 2003; 33(2): 107-115.

Mian S., Lamine W., Fayolle A. Technology Business Incubation: An overview of the state of knowledge. *Technovation* 2016; 50-51: 1-12.
Miles M.B., Huberman A.M. Qualitative data analysis: An expanded sourcebook. Sage; 1994.
Miller C.C., Cardinal L.B., Glick W.H. Retrospective reports in organizational research: A reexamination of recent evidence. *Academy of Management Journal* 1997; 40(1): 189-204.
Miller C.C., Washburn N.T., Glick W.H. The Myth of Firm Performance. *Organization Science* 2013; 24(3): 948-964.
Miozzo M., DiVito L. Growing fast or slow?: Understanding the variety of paths and the speed of early growth of entrepreneurial science-based firms. *Research Policy* 2016; 45(5): 964-986.
Mohr V., Garnsey E. How do high-growth firms grow? Evidence from Cambridge, UK. *Economics, Management and Financial Markets* 2011; 6(4): 29.
Moray N., Clarysse B. Institutional change and resource endowments to science-based entrepreneurial firms. *Research Policy* 2005; 34(7): 1010-1027.
Mowery D.C. Learning from one another? International policy "emulation" and university-industry technology transfer. *Industrial and Corporate Change* 2011; 20(6): 1827-1853.
Mueller C., Westhead P., Wright M. Formal venture capital acquisition: can entrepreneurs compensate for the spatial proximity benefits of South East England and 'star' golden-triangle universities? *Environment and Planning A* 2012; 44(2): 281-296.
Munari F., Toschi L. Do venture capitalists have a bias against investment in academic spin-offs? Evidence from the micro- and nanotechnology sector in the UK. *Industrial and Corporate Change* 2011; 20(2): 397-432.
Murphy G.B., Trailer J.W., Hill R.C. Measuring performance in entrepreneurship research. *Journal of Business Research* 1996; 36(1): 15-23.
Mustar P., Renault M., Colombo M.G., Piva E., Fontes M., Lockett A. et al. Conceptualising the heterogeneity of research-based spin-offs: A multi-dimensional taxonomy. *Research Policy* 2006; 35(2): 289-308.
Mustar P., Wright M., Clarysse B. University spin-off firms: Lessons from ten years of experience in Europe. *Science and Public Policy* 2008; 35(2): 67-80.
Nason R.S. ON FIRM GROWTH: THE ROLE OF PENROSEAN RESOURCES AND BOUNDARY PERMEABILITY. Syracuse University; 2014.
Nason R.S., Wiklund J. An assessment of resource-based theorizing on firm growth and suggestions for the future. *Journal of Management* 2015: 0149206315610635.
Navarro J.L.B., Casillas J.C., Barringer B. Forms of growth: How SMEs combine forms of growth to achieve high growth. *Journal of Management & Organization* 2012; 18(1): 81-97.
Neergaard H., Ulhøi J.P. Handbook of qualitative research methods in entrepreneurship. Edward Elgar Publishing; 2007.
Nelson R.R., Winter S.G. An evolutionary theory of economic change. Harvard University Press; 1982.
Nicolaou N., Birley S. Academic networks in a trichotomous categorisation of university spinouts. *Journal of Business Venturing* 2003; 18(3): 333-359.
Nightingale P., Coad A. Muppets and gazelles: political and methodological biases in entrepreneurship research. *Industrial and Corporate Change* 2014; 23(1): 113-143.
Nonaka I., Konno N. The concept of "ba": Building a foundation for knowledge creation. *California Management Review* 1998; 40(3): 40-+.
O'Shea R.P., Chugh H., Allen T.J. Determinants and consequences of university spinoff activity: a conceptual framework. *Journal of Technology Transfer* 2008; 33(6): 653-666.

Patzelt H., Shepherd D.A. Strategic Entrepreneurship at Universities: Academic Entrepreneurs' Assessment of Policy Programs. *Entrepreneurship Theory and Practice* 2009; 33(1): 319-340.

Penrose E.T. Biological analogies in the theory of the firm. *The American Economic Review* 1952; 42(5): 804-819.

Penrose E.T. The Theory of the Growth of the Firm. Oxford University Press; 1959.

Perkmann M., Tartari V., McKelvey M., Autio E., Brostrom A., D'Este P. et al. Academic engagement and commercialisation: A review of the literature on university-industry relations. *Research Policy* 2013; 42(2): 423-442.

Phan P.H., Siegel D.S., Wright M. Science parks and incubators: observations, synthesis and future research. *Journal of Business Venturing* 2005; 20(2): 165-182.

Phillips B.D., Kirchhoff B.A. Formation, growth and survival; small firm dynamics in the US economy. *Small Business Economics* 1989; 1(1): 65-74.

Pirnay F., Surlemont B., Nlemvo F. Toward a typology of university spin-offs. *Small Business Economics* 2003; 21(4): 355-369.

Polanyi M. The tacit dimension. Doubleday; 1967.

Powers J.B., McDougall P.P. University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. *Journal of Business Venturing* 2005; 20(3): 291-311.

Pries F., Guild P. Commercial exploitation of new technologies arising from university research: start-ups and markets for technology. *R & D Management* 2007; 37(4): 319-328.

Puranam P., Singh H., Zollo M. A bird in the hand or two in the bush?: Integration trade-offs in technology-grafting acquisitions. *European Management Journal* 2003; 21(2): 179-184.

Puranam P., Singh H., Zollo M. Organizing for innovation: Managing the coordination-autonomy dilemma in technology acquisitions. *Academy of Management Journal* 2006; 49(2): 263-280.

Radosevich R. A test of the surrogate-entrepreneurship model of public-technology commercialization. 2013 46th Hawaii International Conference on System Sciences. IEEE Computer Society; 1995. p. 681-681.

Ranft A.L., Lord M.D. Acquiring new technologies and capabilities: A grounded model of acquisition implementation. *Organization Science* 2002; 13(4): 420-441.

Rasmussen E., Borch O.J. University capabilities in facilitating entrepreneurship: A longitudinal study of spin-off ventures at mid-range universities. *Research Policy* 2010; 39(5): 602-612.

Rasmussen E., Borlaug S.B., Bulanova O., Clausen T., Spilling O.R., Sveen T. Verdiskaping i forskningsbaserte selskaper og lisenser støttet av FORNY-programmet. 2013.

Rasmussen E., Bulanova O., Jensen A., Clausen T. The Impact of Science-Based Entrepreneurial Firms - a Literature Review and Policy Synthesis. Bodø: University of Nordland; 2016.

Rasmussen E., Gulbrandsen M. Government Support Programmes to Promote Academic Entrepreneurship: A Principal-Agent Perspective. *European Planning Studies* 2012; 20(4): 527-546.

Rasmussen E., Mathisen M.T. Science-based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012. In: Fini R., Grimaldi R. Process Approach to Academic Entrepreneurship: Evidence from the Globe. Chapter: 9. Published: World Scientific Reference; 2017.

Rasmussen E., Moen O., Gulbrandsen M. Initiatives to promote commercialization of university knowledge. *Technovation* 2006; 26(4): 518-533.

Rasmussen E., Mosey S., Wright M. The Evolution of Entrepreneurial Competencies: A Longitudinal Study of University Spin-Off Venture Emergence. *Journal of Management Studies* 2011; 48(6): 1314-1345.
Rasmussen E., Mosey S., Wright M. The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures. *Research Policy* 2014; 43(1): 92-106.
Rasmussen E., Mosey S., Wright M. The transformation of network ties to develop entrepreneurial competencies for university spin-offs. *Entrepreneurship and Regional Development* 2015; 27(7-8): 430-457.
Richard P.J., Devinney T.M., Yip G.S., Johnson G. Measuring organizational performance: Towards methodological best practice. *Journal of Management* 2009; 35(3): 718-804.
Roininen S., Ylinenpää H. Schumpeterian versus Kirznerian entrepreneurship: A comparison of academic and non-academic new venturing. *Journal of Small Business and Enterprise Development* 2009; 16(3): 504-520.
Rothaermel F.T., Agung S.D., Jiang L. University entrepreneurship: a taxonomy of the literature. *Industrial and Corporate Change* 2007; 16(4): 691-791.
Rothaermel F.T., Thursby M. Incubator firm failure or graduation? The role of university linkages. *Research Policy* 2005; 34(7): 1076-1090.
Rugman A.M., Verbeke A. Edith Penrose's contribution to the resource-based view of strategic management. *Strategic Management Journal* 2002; 23(8): 769-780.
Salvador E. Are science parks and incubators good "brand names" for spin-offs? The case study of Turin. *Journal of Technology Transfer* 2011; 36(2): 203-232.
Sarasvathy S.D. Causation and effectuation: Toward a theoretical shift from economic inevitability to entrepreneurial contingency. *Academy of Management Review* 2001; 26(2): 243-263.
Sarasvathy S.D., Dew N., Velamuri S.R., Venkataraman S. Three views of entrepreneurial opportunity. Handbook of entrepreneurship research. Published: Springer; 2003. p. 141-160.
Schumpeter J.A. The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle. Transaction Publishers; 1934.
Schweizer L. Organizational integration of acquired biotechnology companies into pharmaceutical companies: The need for a hybrid approach. *Academy of Management Journal* 2005; 48(6): 1051-1074.
Schwienbacher A. An empirical analysis of venture capital exits in Europe and the United States. EFA 2002 Berlin Meetings Discussion Paper. 2005.
Scrucca L., Santucci A., Aversa F. Competing risk analysis using R: an easy guide for clinicians. *Bone Marrow Transplantation* 2007; 40(4): 381-387.
Shane S. Technological opportunities and new firm creation. *Management Science* 2001a; 47(2): 205-220.
Shane S. Technology regimes and new firm formation. *Management Science* 2001b; 47(9): 1173-1190.
Shane S. Academic Entrepreneurship University Spinoffs and Wealth Creation. Cheltenham, UK: Edward Elgar Publishing; 2004.
Shane S., Venkataraman S. The promise of entrepreneurship as a field of research. *Academy of Management Review* 2000; 25(1): 217-226.
Shen J.C., Reuer J.J. Adverse selection in acquisitions of small manufacturing firms: A comparison of private and public targets. *Small Business Economics* 2005; 24(4): 393-407.

Shepherd D., Wiklund J. Are We Comparing Apples With Apples or Apples With Oranges? Appropriateness of Knowledge Accumulation Across Growth Studies. *Entrepreneurship Theory and Practice* 2009; 33(1): 105-123.
Siegel D.S., Veugelers R., Wright M. Technology transfer offices and commercialization of university intellectual property: performance and policy implications. *Oxford Review of Economic Policy* 2007; 23(4): 640-660.
Siegel D.S., Wright M. Academic Entrepreneurship: Time for a Rethink? *British Journal of Management* 2015; 26(4): 582-595.
Slaughter S., Rhoades G. Academic capitalism and the new economy: Markets, state, and higher education. JHU Press; 2004.
Spilling O.R., Borlaug S.B., Iversen E.J., Rasmussen E., Solberg E. Virkemiddelapparatet for kommersialisering av forskning–status og utfordringer: Sluttrapport fra evalueringen av virkemiddelapparatet for kommersialisering av offentlig finansiert forskning. 2015.
Stam E. Growth beyond Gibrat: firm growth processes and strategies. *Small Business Economics* 2010; 35(2): 129-135.
Stam E., Garnsey E., Heffernan P. A Penrosean theory of the firm Implications and applications for the study of the growth of young firms. *Economics of the Firm: Analysis, Evolution and History* 2006; 30: 146-168.
Stam E., Wennberg K. The roles of R&D in new firm growth. *Small Business Economics* 2009; 33(1): 77-89.
Steffensen M., Rogers E.M., Speakman K. Spin-offs from research centers at a research university. *Journal of Business Venturing* 2000; 15(1): 93-111.
Stuart T.E., Ding W.W. When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. *American Journal of Sociology* 2006; 112(1): 97-144.
Suddaby R. From the editors: What grounded theory is not. *Academy of Management Journal* 2006; 49(4): 633-642.
Taleb N.N. The black swan: The impact of the highly improbable. Random house; 2007.
Thumm N. Strategic patenting in biotechnology. *Technology Analysis & Strategic Management* 2004; 16(4): 529-538.
Treibich T., Konrad K., Truffer B. A dynamic view on interactions between academic spin-offs and their parent organizations. *Technovation* 2013; 33(12): 450-462.
Van Looy B., Landoni P., Callaert J., van Pottelsberghe B., Sapsalis E., Debackere K. Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research Policy* 2011; 40(4): 553-564.
Vanaelst I., Clarysse B., Wright M., Lockett A., Moray N., S'Jegers R. Entrepreneurial team development in academic spinouts: An examination of team heterogeneity. *Entrepreneurship Theory and Practice* 2006; 30(2): 249-271.
Venkatraman N., Ramanujam V. Measurement of Business Performance in Strategy Research - a Comparison of Approaches. *Academy of Management Review* 1986; 11(4): 801-814.
Vincett P.S. The economic impacts of academic spin-off companies, and their implications for public policy. *Research Policy* 2010; 39(6): 736-747.
Visintin F., Pittino D. Founding team composition and early performance of university Based spin-off companies. *Technovation* 2014; 34(1): 31-43.
Vohora A., Wright M., Lockett A. Critical junctures in the development of university high-tech spinout companies. *Research Policy* 2004; 33(1): 147-175.
Walter A., Auer M., Ritter T. The impact of network capabilities and entrepreneurial orientation on university spin-off performance. *Journal of Business Venturing* 2006; 21(4): 541-567.

Wennberg K., DeTienne D.R. What do we really mean when we talk about 'exit'? A critical review of research on entrepreneurial exit. *International Small Business Journal* 2014; 32(1): 4-16.
Wennberg K., Wiklund J., Wright M. The effectiveness of university knowledge spillovers: Performance differences between university spinoffs and corporate spinoffs. *Research Policy* 2011; 40(8): 1128-1143.
Widding L.Ø. Building entrepreneurial knowledge reservoirs. *Journal of Small Business and Enterprise Development* 2005; 12(4): 595-612.
Widding L.Ø. Entrepreneurial knowledge management and sustainable opportunity creations: a conceptual framework. *International Journal of Learning and Intellectual Capital* 2007; 4(1): 187-202.
Widding L.Ø., Mathisen M.T., Madsen O. University-affiliated venture capital funds: Funding of university spin-off companies. *International Journal of Technology Transfer and Commercialisation* 2009; 8(2): 229-245.
Wiklund J., Patzelt H., Shepherd D.A. Building an integrative model of small business growth. *Small Business Economics* 2009; 32(4): 351-374.
Wiklund J., Shepherd D. Aspiring for, and achieving growth: The moderating role of resources and opportunities. *Journal of Management Studies* 2003; 40(8): 1919-1941.
Wright M., Clarysse B., Mustar P., Lockett A. Academic Entrepreneurship in Europe. Cheltenham, UK: 'Edward Elgar Publishing, Inc.'; 2007.
Wright M., Lockett A., Clarysse B., Binks M. University spin-out companies and venture capital. *Research Policy* 2006; 35(4): 481-501.
Wright M., Stigliani I. Entrepreneurship and growth. *International Small Business Journal* 2013; 31(1): 3-22.
Wright M., Vohora A., Lockett A. The formation of high-tech university spinouts: The role of joint ventures and venture capital investors. *Journal of Technology Transfer* 2004; 29(3-4): 287-310.
Yin R.K. Case study research: Design and methods. Sage publications; 1994.
Zahra S.A., Van de Velde E., Larrañeta B. Knowledge conversion capability and the performance of corporate and university spin-offs. *Industrial and Corporate Change* 2007; 16(4): 569-608.
Zerbinati S., Souitaris V., Moray N. Nurture or nature? The growth paradox of research-based spin-offs. *Technology Analysis & Strategic Management* 2012; 24(1): 21-35.
Zhang J.F. The performance of university spin-offs: an exploratory analysis using venture capital data. *Journal of Technology Transfer* 2009; 34(3): 255-285.
Zimmerman M.A., Zeitz G.J. Beyond survival: Achieving new venture growth by building legitimacy. *Academy of Management Review* 2002; 27(3): 414-431.

8 ENDNOTES

[1] The terms "trade sale" and "acquisition" are reciprocal terms and can be used interchangeably. This dissertation prefers the former because the dissertation primarily takes the perspective of the new venture in such transactions. The latter term is dominantly used when researchers take the perspective of the acquirer.

[2] Penrose's contributions are substantial and have broad relevance and influence on several disciplines, theories, and areas of study. It is (unfortunately) outside the scope of this dissertation to review any more than the key points of particular relevance to this work. However, it is pertinent to mention that Penrose is often mentioned as one of the key intellectual roots of resource-based theory, which is primarily concerned with the concept of competitive advantage. However, above all, Penrose was focused on understanding firm growth, and the canonical contemporary reference to Penrose (1959) often misrepresents her position. In at least two areas does Penrosean thought diverge significantly from cornerstones in resource-based theory: (1) Penrose was concerned with growth and not relative performance differentials between firms. Her disequilibrium approach focused on value creation rather than value appropriation; (2) Penrose rejected the notion of long-run sustained competitive advantage, and assumed that economic rents would be competed or regulated away (for more details, see Lockett, 2005; Nason and Wiklund, 2015).

[3] Zimmerman and Zeitz (2002) argue that gaining legitimacy is crucial to achieve growth. Causality between legitimacy and growth likely goes both ways, as is the case with many factors affecting growth.

[4] Please see Chapter 3 and Paper 3 in Part 2, which demonstrate that RBSOs in fact follow such distributions.

[5] RBSOs can operate in the market for technologies; essentially licensing-out technology to other firms (Conceicao et al., 2012; Gans and Stern, 2003). However, it is quite rare the technologies RBSOs possess can be successfully commercialized using this business model, and some form of knowledge transformation is probably needed in any case.

[6] Relative growth can be measured in many ways: percentage change (like Shepherd and Wiklund, 2009, have done), log-differences, or scaling down by size. However, all measures of relative growth should be monotonic transformations that do not affect the ranking of firms. See Coad (2014) for more detailed information on of both absolute and relative growth measures.

[7] A more precise interpretation of Taleb's Black Swan theory would imply that RBSO outcomes are not Black, but Grey, Swans. The distinction is subtle, yet important, but requires a more thorough discussion considered outside the scope of this dissertation. The distinction relates to RBSO outcomes not being fully unexpected, but still very difficult to predict. In short, while we can expect some RBSOs to become very successful, we still cannot predict which ones or the degree of success (Taleb, 2007: 37). This is unlike fully unexpected events (e.g., financial recessions).

[8] Please see Paper 1 in Part 2 for a more elaborate treatment of this issue.

[9] The weakness with the RBSO term is that it does not explicitly set the boundary of the parent institution to only be academic institutions.

[10] Please see http://www.forskningsradet.no/prognett-forny/Home_page/1226485703319

[11] However, was embedded as an independent program in RCN from year 2000.

[12] Licensing is not within scope of this thesis and, therefore, was excluded in the data collection required for the objectives of this dissertation.

[13] Excluded should be understood as not being part of the comprehensive data collection presented in this chapter. Some data were available and collected for these firms also. For instance, Paper 3 in Part 2 is an analysis of all 471 firms associated with the FORNY portfolio.

[14] For instance, corporate announcements are only available from 1999. Further, annual reports are not electronically available prior to 1999 and, thus, needed to be collected manually and scanned to electronic versions. Finally, news articles, press releases, and other bulletins are generally far less frequent online prior to 1999 due to the significant growth of the internet since then.

[15] Please see: www.brreg.no.

[16] Although structured formats were implemented by BRREG in late 2003, not all types of announcements were included in this change. Other announcement types were gradually phased in to an XML format. From early 2007, all corporate announcements are available in a structured format.

[17] These requirements were enacted in 2005. From 1999-2005, firms were required to disclose the twenty largest owners controlling more than 1% of shares. Because of these requirements, there are some instances where we do not have the full ownership structure either because there are more than ten owners or only owners with very small shares.

[18] Founder, Founder personal holding company, Other private person, Personal holding company, University/TTO (or equivalent), Incubator/science park, Municipality/other governmental, Nonprofit organization, Institutional venture capital, Institutional seed capital, Corporate venture capital, Academic venture capital, Other venture capital, Other private company (small), Other private company (large), Public company (incl. any subsidiaries), Foreign company, Affiliated company (industry), Affiliated company (founders/individuals), Affiliated company (own shares/holding), Affiliated company (other), Mutual funds/investment banks, Other/unknown.

[19] The largest telecommunication company in Norway, largely owned by the Norwegian government and created by deregulation of the telecom sector around 2000. The spin-offs included in the FORNY portfolio relate primarily to the period when the former state telecommunication monopoly operated a public research institute. For a detailed description of this please see https://snl.no/TF_-_utdypning.

[20] This is essentially the sample that was used in Paper 5 in Part 2, where the additional three firms were added later due to certain data not being available for these firms when that study was conducted.

[21] University of Oslo (UiO, established 1811), University of Bergen (UiB, established 1946), University of Tromsø (UiT, established 1968), and the Norwegian University of Science and Technology (NTNU, established 1910). RBSOs with origins at the associated university hospitals are included and considered part of the university.

[22] University of Nordland, UiN (established 2011; Nord University since 2016), The Norwegian University of Life Sciences, UMB (established 2005; Merged with Norwegian School of Veterinary Science in 2014 to form NMBU), University of Stavanger, UiS (established 2004), and the University of Agder, UiA (established 2007).

[23] SINTEF is the largest research organization in Scandinavia, with approximately 2,000 employees and about 3.2 billion NOK in revenue. The organization, and the majority of its employees, are located in Trondheim. Established in 1950 as a spin-off from NTNU, it is organized as a foundation. Please see www.sintef.no for more information.

[24] IRIS is an independent research institution focused on energy and environmental technologies. It is located in Stavanger and is 50% owned by the University of Stavanger. It has approximately 200 employees and revenues of about 300 MNOK. Please see www.iris.no for more information.

[25] IFE is a research foundation with research and development activities with several sectors related to energy technology. The institute has approximately 650 employees and revenues of about 1 billion NOK.

[26] In fact, eleven RBSOs are established more or less in equal partnership between NTNU and SINTEF. These RBSOs have been registered and counted with NTNU as the parent institution and, hence, the total number of RBSOs associated with SINTEF is a conservative estimate.

[27] The apparent minor discrepancy between the two figures in this section is expected. For instance, while RBSOs based on software represent 40% in Figure 4-4, the combined software categories in Figure 4-5 is only 34%. The Life Sciences category is 24% in Figure 4-4 and the combined biomedical categories in Figure 4-5 is 21%. The reason for this is that some RBSOs are partly based on either software or biomedical technology, but *not* regarded as the primary product or service.

[28] A technical domain is understood here as the scientific discipline or area that the technology/scientific knowledge stems from. Technical sub-domains are defined to provide more details into the application areas (i.e., industry) and form (immaterial vs. physical) of the technology.

[29] This is most likely an understatement as the available data relate to Norwegian patent applications in the name of the company only. I expect that some firms rely on patent applications in the inventor's or university's name, or have patented directly outside Norway.

[30] The definition adopted in this analysis goes beyond that of a joint venture (i.e., that an industry incumbent has equity in the new venture). In addition, RBSOs that have developed the technology in close cooperation with or funded by an industry partner is also counted as having an industry partner.

[31] The definition of VC includes corporate VC investors (i.e., institutionalized venture capital arm of a larger industry incumbent), but excludes investment vehicles/holding companies of PROs.

[32] Since all RBSOs in the portfolio are at least four-years-old at the time of the analysis, the curve up to this point will not change.

[33] The distribution is weighted based on the average equity stake (i.e., percentage ownership) each VC investor holds.

[34] There is only one example in the portfolio of a private equity group investment focused on the late/expansion stage of a target company. Please see http://www.nordiccapital.com/news/news-listing/resman,-a-world-leading-provider-of-

wireless-oil-reservoir-surveillance,-welcomes-nordic-capital-as-new-owner.aspx for more information.

[35] These investors could be labelled as business angels. However, the qualitative difference between a business angel and the investors in this category is that the latter operate with a professional investment organization, including websites listing investment criteria and current portfolios (similar to institutional VCs).

[36] Ownership outside the four categories are primarily municipalities/governmental agencies, nonprofit organizations (e.g., foundations), mutual funds (i.e., only relevant for the few public firms in the portfolio), and share repurchases by the firms. Some ownership is unknown due to the requirement of small firms in Norway to only report owners over a certain ownership threshold. Please see Section 3.6.

[37] Founders are defined as private individuals that hold 5% or more in one of the first two operating years (Cooney, 2005). Individuals that do not satisfy these criteria are defined as "Other Individuals." Individual owners are identified regardless of upholding the ownership directly or through wholly-owned financial holding companies.

[38] Three of the largest TTOs in Norway have sold their portfolios (i.e., their shares in several RBSOs) to an external VC. Please see http://www.forskningsradet.no/prognett-FORNY2020/Nyheter/Erfaringene_med_Norsk_Innovasjonskapital/1253996991915.

[39] 67% of the transformed outcomes occur when the RBSO merges with another company, but not falling within the criteria of a trade sale (i.e., the buyer is not an industrial incumbent but another small business, or a holding company of an associated stakeholder of the firm). The other transformed outcomes are related to transfer of the core business activities to another, often associated, company, essentially leaving the original entity unrecognizable and typically without any significant activity. There is no evidence that any of RBSOs labelled as transformed outcomes experienced any significant success at a later stage within the observation period.

[40] Essentially, the sum of the cumulative incidence functions from all causes is equal to 1 minus the Kaplan-Meier estimate of survival (Allison, 2014; Scrucca et al., 2007).

[41] Acquisition values could not be reliably estimated for about one-third of the trade sales. However, by manual investigation of all available data, all of these trade sales appear to have low or even marginal value exchanges.

[42] Downloaded from the websites of the Oslo Stock Exchange, March 28, 2017.

[43] "Setback" corresponds to growth strictly lower than the 33.3333th percentile for all RBSOs at the same age. "Growth" corresponds to growth strictly above the 66.6667th percentile. "Stasis" is the category in between.

[44] It is a coincidence that these two numbers of RBSOs surviving five years, and number of possible growth paths (i.e., 3^5), are almost equal.

[45] Labor cost and number of employees are highly, and statistically significantly, correlated ($r = 0.93$).

[46] The RBSO is *ResMan AS* (www.resman.com), which also has the highest revenues of any firm in the portfolio. The mentioned three years represent over 15% of all the *positive* operating result created from the portfolio (approx. 106 MNOK of a total 686 MNOK in positive operating result). However, the accumulated *total* operating result is approximately −3.7 billion NOK, dominated by losses.

[47] For example, *BerGenBio* AS (www.bergenbio.com) is one RBSO with major losses in recent years. Yet, this company has raised about 470 MNOK (approx. €52M) in equity financing and is aiming for an IPO in 2017 with valuations in the range of 1.6-1.8 billion NOK (approx. €180-200M). Source: http://www.dagbladet.no/nyheter/bergensmilliardaer-sikter-mot-bors-med-kreftselskap/67382495.

PART 2:

RESEARCH PAPERS

RESEARCH PAPER 1

The Development, Growth, and Performance of University Spin-Offs: A Literature Review with Research Implications

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Is not included due to copyright

RESEARCH PAPER 2

Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study

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Institutional Determinants of University Spin-Off Quantity and Quality: A Longitudinal, Multilevel, Cross-Country Study

ABSTRACT

The creation of spin-off firms from universities is seen as an important mechanism for the commercialization of research, and hence the overall contribution from universities to technological development and economic growth. Governments and universities are seeking to develop framework conditions that are conductive to spin-off creation. The most prevalent of such initiatives are legislative changes at national level and the establishment of technology transfer offices at university level. The effectiveness of such initiatives is debated, but empirical evidence is limited. In this paper, we analyze the full population of universities in Italy, Norway, and the UK; three countries adopting differing approaches to framework conditions, to test whether national- and university-level initiatives have an influence on the number of spin-offs created and the quality of these spin-offs. Building on institutional theory and using multilevel analysis, we find that changes in the institutional framework conditions at both national and university levels are conductive to the creation of more spin-offs, but that the increase in quantity is at the expense of the quality of these firms. Hence, the effect of such top-down changes in framework conditions on the economic impact from universities seems to be more symbolic than substantive.

Keywords: Commercialization of research, institutional framework, technology transfer offices, university spin-offs, venture capital.

INTRODUCTION

Creating favorable framework conditions for entrepreneurship is perceived as an important tool to foster the creation and subsequent development of new ventures, especially among policy makers (Arshed et al., 2014; Nightingale and Coad, 2014). The orientation of such initiatives is debated (Mason and Brown, 2013; Van Praag and van Stel, 2013): while some argue that stimulating more entrepreneurship in general is favorable to the economy, others argue that support should be targeted at high-quality, high-growth firms only (Shane, 2009). The creation of new ventures to commercialize university research is an example of potentially high-growth firms that could have significant economic impact at national and regional levels (Garnsey and Heffernan, 2005; Lawton Smith and Ho, 2006; Vincett, 2010). Governments and universities have introduced many initiatives to promote spin-off creation, such as legislative changes and economic support at national level and the establishment of technology transfer offices (TTOs) at university level. However, the effects of such initiatives on spin-off creation are not yet well understood. In this paper, we consider the effect of university and national-level framework conditions on the creation and performance of university spin-offs (USOs).

Although there has been an increase in the number of USOs created in both the USA and Europe (Shane, 2004; Wright et al., 2007), there are concerns that the majority of these firms have limited growth and impact (Grimaldi et al., 2011; Mowery, 2011). Especially in Europe, several studies have noted that most USOs remain small and appear to be lifestyle firms rather than high-growth ventures (Borlaug et al., 2009; Harrison and Leitch, 2010). Hence, it could be questioned: (1) Whether the framework conditions put in place at national and university level may have different impacts on the quantity and quality of these firms, and (2) whether the observed growth in the number of university spin-offs results in a more symbolic, rather than substantive, increase in the economic impact from university entrepreneurship.

The commercialization of research, and spin-off creation in particular, is a rather new and unfamiliar activity at many academic institutions across Europe. Creating a successful spin-off firm requires different competencies compared to the traditional core academic missions of teaching and research (Ambos et al., 2008; Rasmussen et al., 2011). The effectiveness of top-down policies and legislative changes to promote commercialization have been debated (Goldfarb and Henrekson, 2003; Kenney and Patton, 2011; Muscio et al., 2016). Individual, social, and cultural factors appear to have a much stronger impact on the propensity of academics to be involved in entrepreneurial activities than institutional arrangements such as

TTOs (Clarysse et al., 2011). Clearly, the creation and development of spin-offs in a university context is a highly complex task involving many actors within and outside the university organization (O'Shea et al., 2007; Rasmussen and Borch, 2010). Hence, changes in the institutional framework, at both national and university levels, may only have modest effects unless fully embraced at all levels within the academic organization.

Most research investigating university spin-off creation has measured the number of firms and paid limited attention to the quality of these firms (Powers and McDougall, 2005; Van Looy et al., 2011). USOs are typically resource constrained and need to overcome liabilities or thresholds to survive and grow (Rasmussen et al., 2011; Vohora et al., 2004). Obtaining venture capital (VC) is often necessary to satisfy the capital requirements of spin-offs (i.e., key to bring a technology from the laboratory to the market), and overcoming this threshold improves the chances for success (Rosenbusch et al., 2013; Shane and Stuart, 2002). Moreover, VC investments provide a qualified third-party evaluation of the commercial potential of USOs. Hence, we use the first formal VC investment as a proxy to measure firm quality, and thus university performance in creating quality firms.

Moreover, there is a paucity of research that compares different countries (Clarysse et al., 2007; Fini and Grimaldi, 2016), and the evidence about the effect of changes in the institutional framework on spin-off creation and quality is limited. We therefore pose the following research question: *How do changes in the institutional framework at national and university levels influence the quantity and the quality of spin-offs from a university?*

To explore this question, we build on institutional theory proposing that changes in formal structures may result in symbolic rather than substantial modifications in operation efficiency (Dimaggio and Powell, 1983; Tolbert et al., 2011). We rely on a unique panel dataset comprising the 2,323 USOs created from the full population of universities in Italy, Norway, and the UK, between 2000 and 2012. Our findings reveal that changes in the institutional framework, measured as changes in the intellectual property rights (IPR) legislation at national level and the establishment of a TTO at university level, have a positive effect on the number of spin-off created, while the quality of these ventures decreases.

Our study makes several contributions to the literature on framework conditions for entrepreneurship and USOs. First, while several studies have looked at the link between

institutional determinants and the number of spin-offs created from universities, this study, by using a multilevel approach, isolates the effects of national- and university-level initiatives in predicting both the quantity and quality of the firms created. Second, most datasets of USOs comprise a single university or single country and, in the vast majority of the cases, rely on cross-sectional research designs. As this study compares the full population of universities across three different national contexts over a thirteen-year period, we extend our understanding of the within- and between-country influences on the quantity and quality of USOs. Third, we show that differences in the macro-institutional context regarding university IPR ownership are significantly associated with the extent and nature of USOs. The paper proceeds as follows. In the next section, we develop hypotheses related to how changes in university and national frameworks may influence the number of spin-offs created and the quality of these firms. The method section outlines our panel study of spin-off creation and quality in the full population of universities in Italy, Norway, and the UK. Then, the findings from our multilevel panel study are presented. Finally, conclusions and implications for research and practice are provided.

THEORY AND DEVELOPMENT OF HYPOTHESES

It is increasingly recognized that the institutional context where entrepreneurs operate both constraints and facilitates the opportunities for starting and growing a business (Urbano and Alvarez, 2014; Welter and Smallbone, 2011). The institutional context provides the "rules of the game in a society" (North, 1990), and include the economic, political, and socio-cultural environment in which the new venture is created (Shane, 2003). Emerging evidence shows that favorable institutional conditions at national level increases the probability of entrepreneurship (Levie and Autio, 2011; Urbano and Alvarez, 2014).

Institutional theory is particularly helpful in understanding entrepreneurship in organizational contexts, which are largely determined by culture, tradition, history, legal environment, and economic incentives (Aldrich and Fiol, 1994; Bruton et al., 2010). Entrepreneurs launching USOs are likely to adapt their behavior and strategic model according to the opportunities and limitations of the formal and informal institutional framework they are exposed to (North, 1990). Entrepreneurial activity is indeed influenced by the social context and institutional environment in which the scientists are embedded, and a supporting environment will impact scientists' propensity to engage in spin-off activity (Huyghe and Knockaert, 2015; Kenney and Goe, 2004; Meoli and Vismara, 2016). One example is how scientists conform to the behavior of their heads and peers when deciding to engage in the commercialization of research

(Bercovitz and Feldman, 2008; Tartari et al., 2014).

Moreover, the institutional framework reduces uncertainty by providing human interaction with a stable structure (North, 1990), providing a common basis where actors can evaluate the outcome of their behavior. Institutional pressures operate at many levels, from international systems to organizational subsystems (Scott, 2013). These levels can be viewed as interacting in a nested structure, where each institutional level will have distinct influence on scientists' participation in entrepreneurship (Kenney and Goe, 2004; Rasmussen et al., 2014). Hence, university scientists may consider whether entrepreneurial activity is rewarded, socially and economically, before they choose to engage in spin-off creation. Likewise, universities are likely to consider societal, legislative, and financial pressures when giving priority to entrepreneurial activities. External actors, such as investors or industry partners, make similar judgments about the probability that the new venture is appropriate and will gain acceptance before they are willing to commit resources (Zimmerman and Zeitz, 2002). Hence, to increase the chances for a new spin-off venture to be created and succeed, it should be regarded as a legitimate entity across many levels in its institutional environment (Scott, 2013). An example of a university that has been remarkably productive in generating spin-offs is MIT. At MIT, spin-off creation is institutionalized through an interrelated set of factors both within and outside the university that has developed over several decades (O'Shea et al., 2007).

This paper emphasizes how institutional changes at national level shape spin-off formation. Governments have implemented legislative frameworks aimed at increasing the commercialization of research, including university spin-off formation. A well-known example is the US Bayh-Dole Act from 1980, which gave universities options to manage IPR and provided licensing preference to small businesses (Grimaldi et al., 2011; Stevens, 2004). This legislation has been emulated by most European countries where IPR ownership has been assigned to universities, rather than being held by academics (the so-called professor's privilege) (Damsgaard and Thursby, 2013). The rationale has been to increase the commercial output from university research in terms of both spin-off firm formation and technology transfer to established firms.

While there is limited evidence on how institutional forces at national level influence university spin-off creation, patenting activity is a proxy of university technology transfer that has been extensively studied. The legislative changes appear highly successful because there has been a

dramatic increase in university patenting following the implementation of the US Bayh-Dole Act (Mowery et al., 2001), and also following similar reforms in for instance Italy (Baldini et al., 2006). However, it has been debated whether the increasing number of patents reflects an average lower quality of these patents (Henderson et al., 1998; Sampat et al., 2003) or have other negative effects on the impact of university technology transfer (Czarnitzki et al., 2009).

In parallel with patenting activity, we may expect the number of spin-offs to increase as a result of an augmented attention and institutional pressure upon universities to produce spin-offs. The rationale for this is that scientists, universities, TTOs, and other stakeholders will tend to strategically conform to the presence of such a new framework (Suchman, 1995), and increase the number of entrepreneurial ventures. Conversely, changes in the institutional framework increase the level of environmental uncertainty, thus making successful entrepreneurship more difficult to unfold. It takes time for the new institutionalized practices to settle and generate the anticipated benefits. Hence, uncertainties about how the legal framework, the academic community, universities, and other stakeholders will respond to legislative changes may prevent important resource holders from supporting the new venture in the short term (Zimmerman and Zeitz, 2002). VC investors, for example, will be less willing to invest in spin-off firms, which they already perceive as more difficult than other high-tech ventures (Wright et al., 2006). Further, while institutional pressures may increase the number of spin-offs, the underlying base of viable research-based business opportunities at the university may not increase at the same pace. As such, the increase may comprise lower-quality spin-offs that would not have surfaced in the previous legislative environment. Accordingly, we propose:

> *Hypothesis 1. Universities in a national context with more changes in national IPR legislation will generate (a) more spin-off companies but of (b) lower quality, than universities in a context with less changes.*

Spin-off formation is not only influenced by the institutional framework at the national level but also the organizational environment. This is evident by the uneven and path-dependent numbers of spin-offs created across universities (O'Shea et al., 2005). Moreover, it seems clear that university faculty complies with local group norms when it comes to involvement in spin-off creation (Bercovitz and Feldman, 2008; Louis et al., 1989).

The creation of a TTO may be a symbolic reaction to institutional change, signaling that the

university acknowledges commercialization and spin-off activity as a part of its mission. As such, the number of spin-offs created may be expected to increase, as scientists become encouraged to engage with TTOs and the officers in TTOs seek to meet activity-based targets. A related example is how patenting activity increases as a result of internal changes in IPR regulation at the university level (Baldini et al., 2006). However, the creation of quality USOs is a highly complex process requiring access to entrepreneurial competencies to help the venture overcome the initial critical junctures (Rasmussen et al., 2011; Vohora et al., 2004). The creation of high-performing spin-offs appears to be more dependent on individual and group-level characteristics, rather than on formal structures and policies (Kenney and Goe, 2004; Rasmussen et al., 2014; Shane and Stuart, 2002). TTOs need to have the capabilities to make spin-offs investor ready and the social networks to identify and attract VC investors. Such capabilities take time to develop, and TTOs also need time to engage with the scientific environment at the university to influence the culture toward commercial exploitation of research results. Thus, there may be a mismatch between universities' intention to create quality spin-offs and the resources and capabilities they possess to achieve this goal (Clarysse et al., 2005).

Further, the opportunity recognition capacity and prior entrepreneurial experience of individual academics are the strongest predictors of quality new spin-off creation (Clarysse et al., 2011). To be effective, changes in the framework conditions, such as TTO establishment, need to trigger the development of appropriate competencies and behaviors at lower levels in the organization. For university spin-off creation, this means that scientists and their surrounding environment must be both willing and capable of becoming engaged in pursuing potential high-growth spin-off firms. Without a larger transformation of the university, its capabilities, and the surrounding ecosystem (Rasmussen and Borch, 2010), the establishment of a TTO may only be a symbolic act with limited short-term effect on bringing new research to the market. A TTO may improve output targets such as creating more spin-offs, but the additional new ventures are not as likely to become high-growth firms. Hence, we propose:

> *Hypothesis 2. Universities with a TTO will generate (a) more spin-off companies but of (b) lower quality, than universities without a TTO.*

Finally, government legislations and university-level support mechanisms may also interact in predicting academic entrepreneurship. Given the top-down nature of both the governmental and

the university frameworks, we might expect a self-reinforcing effect. The idea is consistent with the evidence provided by Fini et al. (2011), who show that the introduction of a new national legislative framework to support entrepreneurship and the creation of university TTOs complement each other in predicting academic entrepreneurship. Hence, we propose:

> *Hypothesis 3. Universities with a TTO and in a context with more changes in national IPR legislation will generate (a) more spin-off companies but of (b) lower quality, than universities in a context with less changes.*

RESEARCH DESIGN AND DATA

The Institutional Landscape

To test our hypotheses, we used data from three European countries: Italy, Norway, and the UK, in which institutional changes to support the commercialization of university research, at both national and university levels, have been implemented following different pathways.

At national level, as a result of the catalytic effect of the Bayh-Dole Act in the USA (Mowery et al., 2001) and to boost technology transfer activities from public research institutions, several European countries revoked the so-called professor's privilege, which granted IPR on employees' inventions not to the employer but to the employees themselves (Geuna and Rossi, 2011). The UK was the first to abolish it in 1977, followed by France (1982), Spain (1986), the Netherlands (1995), Denmark (2000), Germany (2002), and Norway (2003). Italy, on the contrary, introduced the "professor's privilege" late in 2001, abandoning it in 2005 (Baldini et al., 2014b).

In a similar fashion, UK universities have been proactive in introducing internal policies to foster technology transfer activities by academics, i.e., by year 2000 more than the 80% of UK universities had a TTO (Lockett et al., 2015; UNICO/NUBS, 2002). The Norwegian universities, instead, established their TTOs later, between 2003 and 2005 (Borlaug et al., 2009), whereas the Italian ones have been the least proactive, with more than 40% of them without a TTO by the end of 2005 (Baldini et al., 2014a).

This evidence suggests that, at both country and university level, the UK has been acting as a leader in establishing formal initiatives to enable technology transfer. Norway, with something of a lag, has put in place similar conditions, while Italy has lagged significantly behind.

The Sample

To account for cross-national differences, we pooled data from different national and EU sources. As to country-level information, data on gross domestic product and unemployment rates have been retrieved using the World Bank Database (2014b). Data on the number of days required to start a business were obtained from Doing Business project of the World Bank (2014a). Data on investment freedom were from the Index of Economic Freedom provided annually by the Heritage Foundation (2014), whereas data on VC financing were downloaded from the Eurostat Statistics Database (2014). Finally, changes in the national IPR regimes have been coded according to the assessment provided by Baldini et al. (2014a).

University-level data have been collected using a two-pronged strategy. First, through the EUMIDA database, we extracted harmonized, EU-level, time-invariant information on universities' localization, legal status, year of establishment, educational fields, the presence of a university hospital, and whether the university emphasizes Science Technology Engineering and Mathematics (STEM). The EUMIDA database stores information on 2500 higher education institutions from 29 EU countries. Data refer to year 2008 (for details, see European Commission, 2010).

Secondly, we relied on national sources, collecting time-variant information on universities' size (i.e., number of faculty members, number of PhD students), operational characteristics (i.e., number and size of research grants awarded from public institutions, number and size of grants and contracts secured from private organizations) and intellectual eminence (i.e., national university quality rankings). For the UK, data on size and operations have been retrieved through the Higher Education Information Database for Institutions (HEIDI) (2014). Data on universities' intellectual eminence have been assessed using the UK University League Tables and Rankings from the Complete University Guide (2014). For Norway, comparable data on size and operations were obtained from the Database for Statistics on Higher Education (2014), Science and Technology Indicators for Norway (The Research Council of Norway, 2013) and on national ranking from the CWTS Leiden Ranking (2014), respectively. For Italy, we used the MIUR Web sites (2013), as well as the overall academic rating score of Italian universities published in the "Grande Guida dell'Università" (Repubblica, 2013).

Finally, firm-level data have been retrieved through both the universities' TTO and the national Companies' Houses. For the UK, data on firms were mainly retrieved from the Spinouts UK

Survey (2014) which includes all spin-off companies from UK universities and institutions since 2000. These data were further complemented and corroborated by data from FAME (2014) and Zephyr (2014). For Norway, firm-level data originate from a database maintained by the Research Council of Norway's FORNY-program, which is designed to support universities in commercializing research results (Borlaug et al., 2009). These data have been complemented with information from the companies' annual reports accessed through the Norwegian Register of Company Accounts (www.brreg.no/english) as well as TTOs' databases, media archives, web pages, and other secondary information. For Italy, the list of firms has been compiled by contacting the universities' TTOs every two years since 2003, the last time being 2013. Each firm has been looked up on Infocamere Telemaco, the database of the Italian Companies House (2013), retrieving information on the operational characteristics as well as on the capital structure (for more information please refer to the TASTE project; Bolzani et al., 2014a; Bolzani et al., 2014b).

The final dataset comprises 185 universities (68 from Italy (IT), 4 from Norway (NO) and 113 from the UK) and their 2,323 spin-offs (878 from IT, 120 from NO[1], and 1,325 from UK). The observation period is from 2000 to 2012.

Dependent Variables

The two dependent variables are *University spin-off quantity* and *quality*. We index quantity as a count of the number of USOs from a given university in a given year. Firm quality denotes the future impact or growth potential of the venture. Following previous work (e.g., Lockett and Wright, 2005), we operationalize quality as a count of the number of USOs from a given university in a given year, which have received the first round of VC financing in that year. Firm performance has been measured in many ways, with distinct benefits and concerns (Murphy et al., 1996). USOs typically have long development paths before entering a growth phase (Lawton Smith and Ho, 2006), making traditional financial performance measures less relevant in the short term. Obtaining external financing is a desired goal for the majority of USOs, partly due to poor access to debt financing for this type of ventures (Carpenter and Petersen, 2002). Being able to attract VC financing provides an objective measure of external validation of venture quality in terms of expected returns. Although many venture-backed firms ultimately fail, research has shown that the ability to raise VC is significantly related to later

[1] The significantly larger number of spin-offs per university in Norway is primarily driven by the country's centralized university structure, comprising four relatively large research universities at the start of our observation period.

success (e.g., Shane and Stuart, 2002).

Predictor Variables

IPR institutional changes: To account for the effect of institutional changes in IPR-related-matters, we divided the number of changes in a country's IPR legislation by the number of years included in the observation period (i.e., 13). This variable ranges from 0 (UK) to 0.15 (Italy). We also used alternative measures of the changes/turbulence in the institutional environment in a country, as discussed in the robustness checks section.

Establishment of the university TTO: To measure the effect of TTO presence on university spin-offs quantity and quality, we specified a dummy variable that switches from 0 to 1 the year in which the TTO is established. If the TTO was established before 2000, the variable takes the value of 1 throughout the whole observation period.

Control Variables

Country-level. *Investment freedom:* Because we expect that spin-off quality would be positively influenced by fewer constraints on the flow of investment capital, we include the Economic Freedom Index by the Heritage Foundation (2014), as a measure of the level of freedom for individuals and firms to move their resources into/out of specific activities in a given country in a given year. This index may range from 0 to 100, and in our sample, countries are bounded between 50 and 90.

Ease of doing business: Higher levels of bureaucracy may hinder entrepreneurial behaviors, especially the intention and likelihood of entry. To account for this aspect in the spin-off quantity model, we used data from the World Bank (2014a), examining the number of days required to start a business in a given country in a given year. In the sample, this variable ranges from 6 to 23.

Gross domestic product per capita (GDP): The environmental conditions also influence the structure of opportunities to be exploited by individuals. The higher the GDP, the more resources flowing into innovation and research, the higher the likelihood that entrepreneurship would occur. To account for this, we included in our models the GDP of a given country in a given year, discounted by the yearly consumer price index. The variable was logarithm transformed and its value in the sample ranges from 10.4 to 11.1.

Unemployment rate: Similarly, countries with higher unemployment rates may generate less high-tech entrepreneurship compared to those with lower rates. To properly account for this, we examined the unemployment rate of a given country in a given year. The rate in our sample is bounded between 2.5 and 10.8.

VC availability: Finally, the number of spin-offs financed by VCs can be influenced by the availably of VC financing. Hence, we control for the amount of early-stage VC investments in a given country in a given year. The variable has been retrieved via the Eurostat Statistics Database (2014), is expressed in million €, and ranges between 22 and 4240.

Regional-level. Some regional-level factors may also impact on spin-off foundation and growth. To account for this, via the Eurostat Statistics Database (2014), we have retrieved data at NUTS 2 regional level, between 2000 and 2012, on the *Total intramural R&D expenditure* (GERD), the *Population on 1 January* as well as the *Unemployment rates*.

University-level. *Foundation year:* Under the assumption that the older the university, the higher the prestige of the institution, the higher its impact, we control for the university's year of establishment.

Size: University size may also be a predictor of university spin-off activity. The higher the number of faculty members and support staff, the higher the likelihood that some research may be effectively transferred to the market. To account for this, we control for the number of employees of a given university in a given year.

Sponsored research expenditure: Because the knowledge exploited by spin-offs is generated by university research, we may expect that that the amount of research funding secured from for-profit institutions by a given university in a given year will likely be related to spin-off quantity and quality. The variable is operationalized in monetary terms and is discounted for the yearly consumer price index.

Prior knowledge in technology transfer activities: University TTO expertise in supporting spin-offs may take some time to develop. Some universities have been involved in technology transfer activities before 2000. To account for the accumulated knowledge and experience, we control for the cumulative number of USOs established before 2000 by a given university.

Cumulative spin-off entry: The number of firms from a given university receiving VC funding in a given year can be positively correlated with the total number of spin-offs emerging from that university until the year of observation. We therefore control for the cumulative number of spin-off from a university up to the focal year in the quality model.

Average age of spin-offs: Firm age can predict the likelihood of receiving VC financing. To account for this, we have calculated the average age of the spin-off portfolio, for any given university in any given year. The variable ranges between 0 and 12.

Intellectual eminence: We also assume that the universities' intellectual eminence may be related to their ability to foster entrepreneurial behavior by academics. We relied on national rankings to categorize each university in either the top 25%, 25-50%, 50-75%, or lower 25%. The variable is country-specific and time-variant.

Educational fields. We account for the comprehensiveness of the educational offering by the universities under scrutiny. Relying on the information stored in EUMIDA, we assessed whether each university had education programs in each of the following fields: general programs; education; humanities and arts; social sciences, business and law; sciences; engineering, manufacturing and construction; agriculture; health and welfare; services. The nine variables are time-invariant, non-mutually exclusive, and can take the value of either 1 or 2.

Industrial variance: In the quality model, we also controlled for the variance in the industrial sectors of the spin-offs established by each university in a given year. This is because firm quality in terms of access to VC could be influenced by the number of firms that are similar to them emerging from the same university in the same year. This variable is measured by the Herfindahl index. It is measured by the sum of the squares of the shares of spin-offs of a university in a given year within an industrial sector: $\sum_{i=1}^{N} s_i^2$, where s_i is the proportion of total spin-offs of a university in a given year within sector i, and N is the number of industrial sectors. The higher the industrial variance, the lower the critical mass of similar others, the less the competition and more resources a firm would get, which would result in better performance.

High-tech firm rate: We finally account for the entry rate of firms established in high-tech sectors (i.e., Biopharma and ICT) that spun out from each university every year.

ECONOMETRIC MODELS

As our data feature a hierarchical structure at multiple levels, we applied a multilevel modeling approach to model and test our hypotheses (Bliese et al., 2007). Specifically, our dataset comprises time series cross-sectional data at university level, which is clustered within three countries, over 13 years. Therefore, university-level data are likely to be correlated over time; moreover, universities from the same country may be more similar than those selected randomly. Hence, ignoring the multilevel structure can result in violating the assumption of data independence in traditional multiple regressions, which gives rise to unreliable estimates. Indeed, multilevel modeling enables us to account for interdependence by capturing residuals at different levels, and to specify country-year fixed effects.

Moreover, we are not only interested in the effect of university-level predictors, but we also aim to assess to what extent country-level institutional dimensions impact the quantity and quality of university spinoffs. Multilevel modeling provides ways to evaluate the impact of factors from different levels simultaneously, and makes the test of cross-level interaction effects possible.

Finally, as both dependent variables in the analyses are measured by count data with over-dispersion, we chose multilevel negative binomial regressions over multilevel Poisson modeling, nesting university-level data (level 1) into country-level ones (level 2).

RESULTS

Main Models

Table 1 shows descriptive statistics, and Table 2 shows the correlation matrix for all variables in our models. With respect to the main effects, TTO establishment is positively correlated with both quantity and quality, whereas IPR institutional changes are weakly correlated with quantity and negatively correlated with quality. No multicollinearity issues emerge from the data.

Variable	Mean	SD	Min	Max
Dependent variables and main predictors				
U: Spinout quantity	0.97	2.11	0	31
U: Spinout quality	0.15	0.59	0	8
U: TTO establishment	0.72	0.45	0	1
C: IPR institutional changes	0.06	0.07	0	0.15
University-level controls				
U: Cumulative entry	6.79	14.44	0	197
U: Prior knowledge in tech transfer activities	5.29	16.47	0	115
U: Average age of spinouts	2.33	2.62	0	12
U: Foundation year	1838	207	1088	2004
U: Sponsored research expenditure	6.60	2.26	0	10.48
U: University size	7.26	1.13	1.39	9.28
U: Intellectual eminence: rank top 25%	0.25	0.43	0	1
U: Intellectual eminence: rank 50-75%	0.26	0.44	0	1
U: Intellectual eminence: rank 25-50%	0.24	0.43	0	1
U: Education field; general	1.01	0.07	1	2
U: Education field; education	1.72	0.45	1	2
U: Education field; humanities and arts	1.90	0.30	1	2
U: Education field; social sciences, business and law	1.97	0.16	1	2
U: Education field; sciences	1.91	0.29	1	2
U: Education field; engineering, manufacturing, and construction	1.85	0.36	1	2
U: Education field; agriculture	1.48	0.50	1	2
U: Education field; health and welfare	1.89	0.31	1	2
U: Education field; services	1.64	0.48	1	2
U: Industrial variance	2.03	3.14	0	24.5
U: High-tech firm rate	0.09	0.25	0	1
Regional-level controls				
R: R&D expenditure	5.89	0.79	3.46	7.87
R: Population	14.65	0.69	12.65	16.09
R: Unemployment rate	7.18	4.05	1.8	27.3
Country-level controls				
C: GDP per capita	10.52	0.10	10.39	11.10
C: Easiness of doing business	13.14	4.10	6	23
C: Unemployment rate	6.80	1.82	2.5	10.8
C: Investment freedom	77.62	10.01	50	90
C: VC availability	617.49	893.6	22	4,240.39

Table 1: Descriptive Statistics. U: university-level variable; R: regional-level variable; C: country-level variable. N=2,405 observations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 U: Spinout quantity	1.00															
2 U: Spinout quality	0.46	1.00														
3 U: TTO establishment	0.14	0.08	1.00													
4 C: IPR institutional changes	0.02	-0.13	-0.36	1.00												
5 U: Cumulative entry	0.65	0.53	0.17	-0.03	1.00											
6 U: Prior knowledge in tech transfer activities	0.17	0.19	0.17	-0.06	0.46	1.00										
7 U: Average age of spinouts	0.64	0.57	0.12	-0.18	0.73	0.23	1.00									
8 U: Foundation year	-0.31	-0.17	-0.05	-0.19	-0.32	-0.14	-0.34	1.00								
9 U: Sponsored research	0.40	0.27	0.03	0.21	0.44	0.43	0.35	-0.30	1.00							
10 U: University size	0.31	0.29	0.32	-0.53	0.37	0.33	0.36	-0.25	0.41	1.00						
11 U: Intellectual eminence: rank top 25%	0.30	0.24	-0.07	-0.02	0.34	0.17	0.31	-0.11	0.28	0.15	1.00					
12 U: Intellectual eminence: rank 50-75%	0.03	0.01	-0.02	0.00	0.03	0.15	0.02	-0.07	0.18	0.13	-0.34	1.00				
13 U: Intellectual eminence: rank 25-50%	-0.15	-0.13	0.09	0.01	-0.17	-0.14	-0.16	0.05	-0.18	-0.08	-0.33	-0.33	1.00			
14 U: Education field; general	0.00	0.05	-0.02	0.02	0.01	0.05	-0.02	0.05	0.04	0.02	-0.04	-0.04	-0.04	1.00		
15 U: Educ. field; education	-0.02	0.00	0.13	-0.26	-0.03	-0.07	-0.03	-0.06	-0.11	0.27	-0.23	0.06	0.08	0.05	1.00	
16 U: Educ. field; humanities and arts	-0.04	-0.05	0.11	-0.31	-0.05	0.01	-0.01	-0.19	0.02	0.43	-0.08	0.05	0.06	0.02	0.34	1.00
17 U: Educ. field; social sciences, business and law	-0.05	0.03	0.06	-0.22	-0.07	0.00	0.04	-0.08	-0.01	0.16	-0.16	0.05	0.05	0.01	0.27	0.38
18 U: Educ. field; sciences	0.09	0.08	0.24	-0.33	0.10	0.18	0.10	-0.13	0.18	0.52	-0.10	0.09	0.02	0.02	0.18	0.32
19 U: Educ. field; engineering, manuf. and construction	0.15	0.09	0.27	-0.09	0.16	0.14	0.12	-0.13	0.25	0.37	-0.07	0.04	0.06	-0.17	0.14	0.01
20 U: Educ. field; agriculture	0.10	0.07	0.13	-0.09	0.11	0.05	0.15	-0.17	0.08	0.23	-0.16	0.04	-0.03	0.08	0.17	0.15
21 U: Educ. field; health and welfare	0.06	0.07	0.14	-0.12	0.06	0.12	0.08	-0.15	0.12	0.31	-0.12	0.03	0.04	0.03	0.29	0.28
22 U: Educ. field; services	-0.16	-0.20	-0.01	0.25	-0.21	-0.16	-0.22	-0.07	-0.13	-0.13	-0.39	-0.01	0.19	0.06	0.20	0.15
23 U: Industrial variance	0.33	0.12	0.15	0.22	0.31	0.42	0.15	-0.25	0.43	0.16	0.13	0.12	-0.08	0.00	-0.10	-0.01
24 U: Hi-tech firm rate	0.29	0.14	0.06	0.05	0.20	0.15	0.13	-0.06	0.26	0.17	0.12	0.03	-0.05	0.18	0.01	-0.05

(continuing)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
25 R: R&D expenditure	0.10	0.20	0.09	-0.40	0.15	0.05	0.17	0.00	-0.02	0.29	0.19	0.07	-0.12	0.03	0.07	0.13
26 R: Population	-0.01	-0.08	-0.19	0.41	-0.02	-0.08	-0.02	-0.05	0.12	-0.21	0.05	0.00	-0.06	-0.17	-0.18	-0.17
27 R: Unemployment rate	-0.09	-0.09	-0.20	0.33	-0.06	0.06	-0.08	0.06	-0.01	-0.22	-0.16	-0.17	0.11	-0.06	-0.12	-0.15
28 C: GDP per capita	0.06	0.24	0.28	-0.51	0.14	0.14	0.07	0.13	0.00	0.37	0.01	0.00	-0.01	0.28	0.19	0.12
29 C: Easiness of doing business	-0.08	-0.05	-0.36	0.15	-0.20	-0.33	-0.02	-0.03	-0.12	-0.16	0.00	0.00	0.01	-0.03	-0.05	-0.04
30 C: Unemployment rate	-0.08	-0.16	-0.32	0.63	0.01	0.12	-0.10	-0.14	0.06	-0.38	-0.01	0.00	0.01	-0.13	-0.19	-0.18
31 C: Investment freedom	-0.08	0.04	0.23	-0.55	0.13	0.32	0.11	0.09	-0.15	0.28	0.01	0.00	0.00	-0.17	0.11	0.19
32 C: VC availability	-0.01	0.05	0.14	-0.46	-0.04	-0.10	0.08	0.08	-0.11	0.22	0.01	0.00	-0.01	-0.04	0.11	0.15

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17 U: Educ. field; social sciences, business and law	1.00															
18 U: Educ. field; sciences	0.41	1.00														
19 U: Educ. field; engineering, manuf. and construction	0.02	0.28	1.00													
20 U: Educ. field; agriculture	0.16	0.23	0.17	1.00												
21 U: Educ. field; health and welfare	0.37	0.49	0.19	0.20	1.00											
22 U: Educ. field; services	0.15	0.11	0.09	0.21	0.28	1.00										
23 U: Industrial variance	-0.04	0.07	0.13	0.04	0.04	-0.01	1.00									
24 U: Hi-tech firm rate	-0.03	0.08	0.08	0.00	0.06	-0.10	0.21	1.00								
25 R: R&D expenditure	0.05	0.14	-0.07	-0.10	0.00	-0.19	-0.08	0.07	1.00							
26 R: Population	-0.20	-0.31	-0.12	-0.19	-0.23	0.12	0.04	-0.10	0.02	1.00						
27 R: Unemployment rate	-0.01	-0.19	-0.03	-0.07	-0.04	0.09	0.00	-0.08	-0.45	0.26	1.00					
28 C: GDP per capita	0.13	0.21	0.02	0.01	0.10	-0.21	-0.03	0.21	0.37	-0.38	-0.34	1.00				
29 C: Easiness of doing business	-0.03	-0.05	-0.01	-0.01	-0.02	0.05	-0.26	-0.07	-0.19	0.07	0.11	-0.27	1.00			
30 C: Unemployment rate	-0.14	-0.23	-0.05	-0.04	-0.09	0.20	0.10	-0.11	-0.36	0.35	0.48	-0.68	0.22	1.00		
31 C: Investment freedom	0.11	0.16	0.06	0.07	0.05	-0.10	-0.06	-0.14	0.16	-0.11	-0.03	0.26	-0.19	0.01	1.00	
32 C: VC availability	0.10	0.15	0.04	0.05	0.05	-0.11	-0.14	-0.04	0.19	-0.17	-0.19	0.37	0.02	-0.38	0.29	1.00

Table 2: Correlation matrix. Number of observations: 2,405. Correlations above +/- 0.04 is significant at 5%.

We present the estimation results on the *quantity* of USOs in Table 3. Model 1 shows the baseline model that includes university-level and country-level control variables only. The main effects of institutional changes and TTO establishment were estimated in Model 2. The cross-level interaction effect was tested in Model 3 with the introduction of the cross-level interaction term.

Model 2 shows that the level of institutional changes in the IPR regime at country level has a significant positive influence on the number of USOs established (0.521, $p < 0.05$). The establishment of a university TTO has the same significant positive effect (0.178, $p < 0.05$). The interaction effect of university TTO and country-level institutional changes shown in Model 3 is positive and significant (0.336, $p < 0.05$). Therefore, Hypotheses 1a, 2a, and 3a are supported.

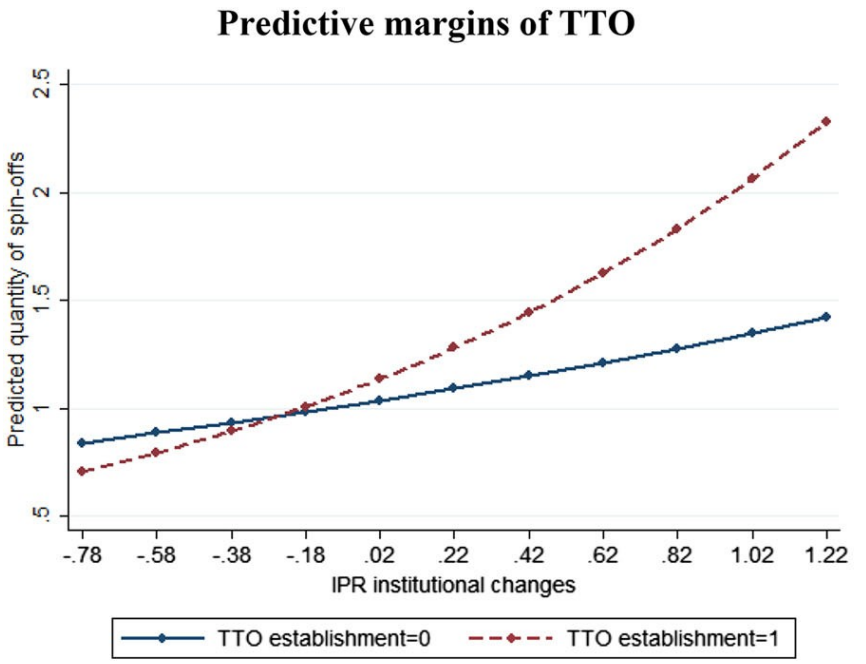
To better elaborate the cross-level interaction effect of establishment of university TTO and institutional changes in IPR at country level on the quantity of USOs, we compared the marginal effect of universities with and without TTO across different levels of institutional changes (see Figure 1). Figure 1 (left part) shows the predictive margins of TTO (at value 0 and 1, respectively) across different values of institutional changes. We can see that more changes in the IPR regime are associated with a higher number of USOs. Universities with a TTO in place almost always produce more spin-offs than those without a TTO. The difference (i.e., the gap between the two lines) is increasing, in a statistically significant way, with the increasing level of changes in IPR regime at country level. This is represented graphically with the conditional marginal effects of TTO shown in Figure 1 (right part). We also showed the predictive margins and the conditional marginal effects of TTO with a 95% confidence interval in the Appendix A (see Figure 3).

	Model 1	Model 2	Model 3
U: TTO establishment		0.178*	0.085
		(0.085)	*(0.087)*
C: IPR institutional changes		0.521***	0.262**
		(0.067)	*(0.094)*
U x C: TTO X IPR institutional changes			0.336***
			(0.084)
U: Prior knowledge in technology transfer activities	0.260***	0.283***	0.307***
	(0.024)	*(0.024)*	*(0.024)*
U: Foundation year	-0.000	-0.000	0.000
	(0.000)	*(0.000)*	*(0.000)*
U: Sponsored research expenditure	0.833***	0.657***	0.596***
	(0.082)	*(0.077)*	*(0.078)*
U: Size	0.199*	0.342***	0.343***
	(0.085)	*(0.081)*	*(0.081)*
U: Intellectual eminence: rank top 25%	0.842***	0.910***	0.933***
	(0.129)	*(0.129)*	*(0.130)*
U: Intellectual eminence: rank 25-50%	0.682***	0.746***	0.786***
	(0.121)	*(0.121)*	*(0.122)*
U: Intellectual eminence: rank 50-75%	0.180	0.179	0.202+
	(0.120)	*(0.119)*	*(0.120)*
U: Education field; general	0.473	0.389	0.433
	(0.421)	*(0.412)*	*(0.409)*
U: Education field; education	-0.039	-0.051	-0.116
	(0.073)	*(0.072)*	*(0.074)*
U: Education field; humanities and arts	-0.096	0.011	0.029
	(0.131)	*(0.129)*	*(0.130)*
U: Education field; social sciences, business and law	-1.224***	-0.982***	-0.980***
	(0.280)	*(0.276)*	*(0.274)*
U: Education field; sciences	0.708**	0.634**	0.525*
	(0.219)	*(0.214)*	*(0.215)*
U: Education field; engineering, manufacturing, and construction	0.486**	0.470**	0.539***
	(0.162)	*(0.162)*	*(0.162)*
U: Education field; agriculture	0.012	0.026	0.022
	(0.067)	*(0.067)*	*(0.066)*
U: Education field; health and welfare	0.045	-0.042	0.098
	(0.178)	*(0.178)*	*(0.182)*
U: Education field; services	0.164+	0.055	0.081
	(0.091)	*(0.090)*	*(0.090)*

(continuing)

	Model 1	Model 2	Model 3
U: High-tech firm rate	0.270***	0.250***	0.246***
	(0.027)	*(0.026)*	*(0.026)*
R: R&D expenditure	-0.139**	-0.113*	-0.131**
	(0.044)	*(0.044)*	*(0.044)*
R: Population	-0.142***	-0.162***	-0.158***
	(0.041)	*(0.039)*	*(0.039)*
R: Unemployment rate	0.066	0.082+	0.0909+
	(0.048)	*(0.048)*	*(0.048)*
C: GDP per capita	-0.083	-0.131**	-0.105*
	(0.067)	*(0.049)*	*(0.050)*
C: Easiness of doing business	-0.130*	-0.123**	-0.096*
	(0.061)	*(0.040)*	*(0.042)*
C: Unemployment rate	-0.083	-0.289***	-0.274***
	(0.092)	*(0.059)*	*(0.061)*
Constant	-1.391+	-2.093*	-2.241**
	(0.830)	*(0.832)*	*(0.826)*
Variance of intercept	0.097*	0.013	0.015
	(0.041)	*(0.011)*	*(0.011)*
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-2,353*	*-2,329*	*-2,321*
Degrees of freedom	*23*	*25*	*26*
Chi2	*1,415****	*1,485****	*1,513****

*Table 3: Results of multilevel negative binominal regression: spin-off quantity. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included.*



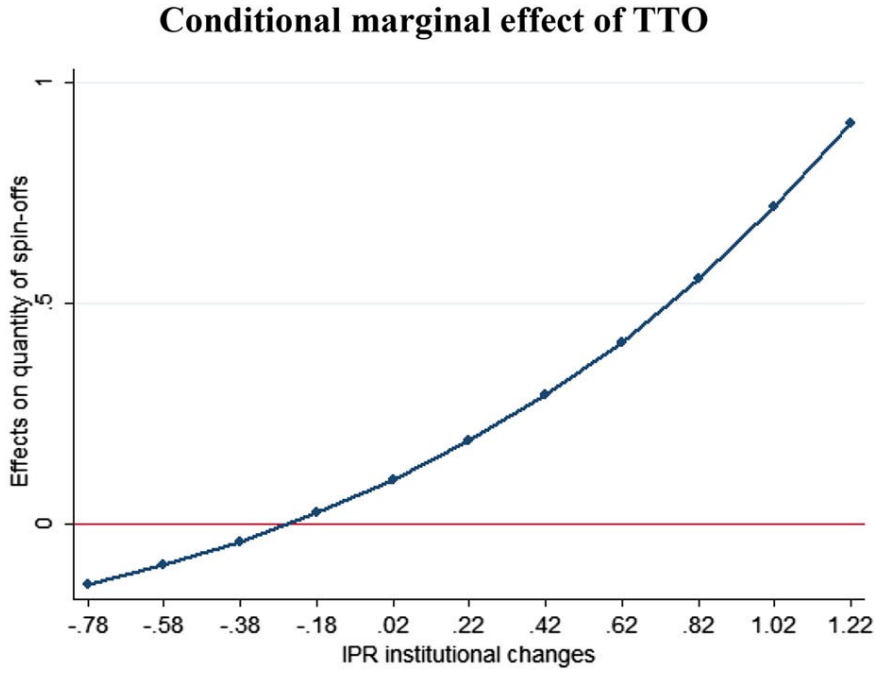


Figure 1: Interaction effects of TTO and IPR institutional changes on the quantity of USOs.

The estimation results on the *quality* of USOs are shown in Table 4. As before, Model 4 shows the baseline model with control variables only. Model 5 shows the main effects of IPR institutional changes and TTO establishment. The cross-level interaction effect is displayed in Model 6. Regression results for Model 5 show that country-level institutional changes in IPR regime have a significant negative influence on the quality of USOs (-0.590, $p < 0.01$). The establishment of a university TTO has a negative effect on the quality USOs, although the coefficient is only marginally significant (-0.341, $p < 0.1$). The interaction effect of the two variables is also negative and statistically significant (-0.685, $p < 0.01$) as shown in Model 6. The above results provide support for Hypotheses 1b, 2b, and 3b.

We plotted the interaction effect of the two main explanatory variables on the quality of USOs in Figure 2. As predicted, Figure 2 shows that the more changes in IPR regime in a country, the lower the quality of USOs measured by the number of spin-offs receiving VC financing. Universities with a TTO in place produce less spin-offs receiving VC financing than those without a TTO. The negative effect is intensified by the increasing level of changes in IPR regime at country level.

	Model 4	Model 5	Model 6
U: TTO establishment		-0.342+	-0.527*
		(0.208)	*(0.207)*
C: IPR institutional changes		-0.590**	-0.099
		(0.189)	(0.246)
U x C: TTO X IPR institutional changes			-0.685**
			(0.239)
U: Cumulative entry	0.173***	0.177***	0.153***
	(0.045)	*(0.042)*	*(0.040)*
U: Average age of spin-offs	-0.017	0.066	0.110
	(0.130)	*(0.123)*	*(0.120)*
U: Foundation year	0.000	-0.000	-0.000
	(0.000)	*(0.000)*	*(0.000)*
U: Size	1.566***	1.165***	1.110***
	(0.228)	*(0.269)*	*(0.260)*
U: Sponsored research expenditure	0.339	0.485*	0.608**
	(0.211)	*(0.233)*	*(0.232)*
U: Education field; general	3.703***	3.687***	3.423***
	(1.061)	*(1.051)*	*(1.039)*
U: Education field; education	-0.037	-0.097	0.020
	(0.161)	*(0.168)*	*(0.169)*
U: Education field; humanities and arts	-0.669*	-0.818**	-0.749**
	(0.291)	(0.291)	(0.284)
U: Education field; social sciences, business and law	1.488	0.805	0.606
	(1.047)	*(1.081)*	*(1.082)*
U: Education field; sciences	1.016	1.082	1.177
	(1.254)	(1.284)	(1.281)
U: Education field; engineering, manufacturing, and construction	1.608*	1.801*	1.605*
	(0.776)	*(0.773)*	*(0.768)*
U: Education field; agriculture	-0.051	-0.093	-0.083
	(0.159)	*(0.158)*	*(0.156)*
U: Education field; health and welfare	-0.897+	-0.538	-0.706
	(0.480)	*(0.484)*	*(0.485)*
U: Education field; services	-0.171	0.051	0.037
	(0.200)	*(0.206)*	*(0.203)*
U: Intellectual eminence: rank top 25%	0.852*	0.833+	0.788+
	(0.432)	*(0.434)*	*(0.430)*

(continuing)

	Model 4	Model 5	Model 6
U: Intellectual eminence: rank 25-50%	0.791+	0.814+	0.738+
	(0.418)	*(0.418)*	*(0.415)*
U: Intellectual eminence: rank 50-75%	-0.062	0.007	-0.066
	(0.462)	*(0.462)*	*(0.463)*
U: Industrial variance	0.382***	0.406***	0.429***
	(0.103)	*(0.098)*	*(0.093)*
U: Hi-tech firm rate	-0.033	-0.013	-0.019
	(0.055)	*(0.054)*	*(0.053)*
R: R&D expenditure	0.014	-0.055	-0.014
	(0.102)	*(0.105)*	*(0.103)*
R: Population	0.021	0.179	0.204+
	(0.110)	*(0.121)*	*(0.120)*
R: Unemployment rate	-0.327*	-0.329*	-0.385*
	(0.163)	*(0.162)*	*(0.161)*
C: GDP per capita	0.190*	0.287***	0.291***
	(0.079)	*(0.081)*	*(0.078)*
C: Investment freedom	-0.005	-0.138	-0.135
	(0.097)	*(0.101)*	*(0.098)*
C: VC availability	0.041	0.007	0.004
	(0.078)	*(0.064)*	*(0.063)*
Constant	-13.074***	-11.467***	-10.741**
	(3.347)	(3.330)	(3.324)
Variance of intercept	0.023	0.004	0.004
	(0.044)	(0.031)	(0.028)
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-663.1*	*-657.6*	*-653.8*
Degrees of freedom	*25*	*27*	*28*
Chi2	*499.5****	*537.1****	*562.8****

*Table 4: Results of multilevel negative binominal regressions: spin-off quality. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included.*

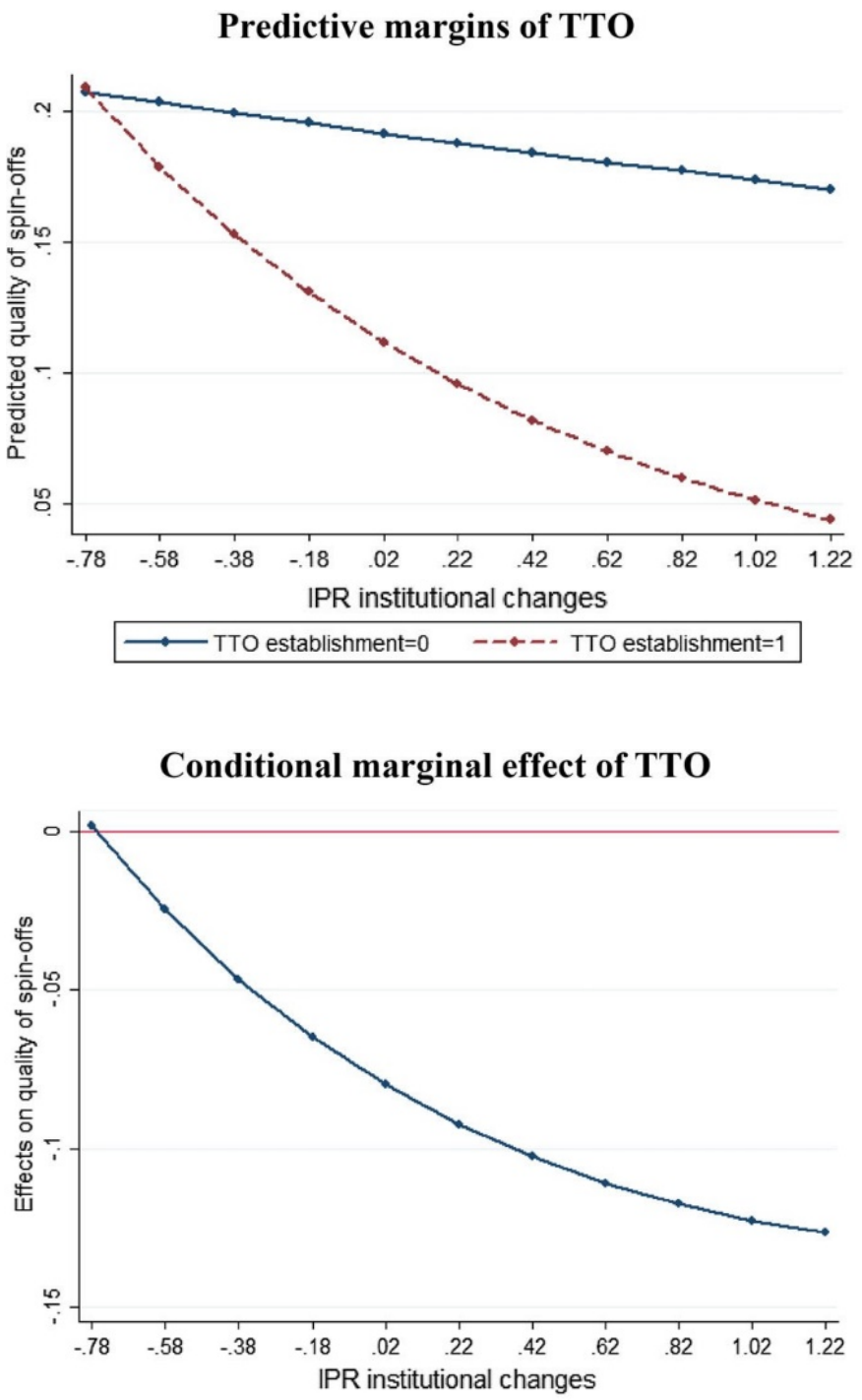


Figure 2: Interaction effects of TTO and IPR institutional changes on the quality USOs.

Robustness Checks

To check for the stability and replicability of our results, we ran the selected econometric specifications using two alternative operationalizations of the *IPR Institutional Changes* construct. We obtained the first measure by dividing the number of years in which the "professor's privilege" was in place during the observation period, by the total years included in the observation period (13). This index ranges from 0 (UK) to 0.38 (Italy). The second measure was the count of absolute number of changes in the IPR legislation, which is the number of switches between enforcement of "professor's privilege" and "university's privilege" in a country over the 13 years of observation time. The value of this variable changes from 0 (UK) to 2 (Italy). We adopted the same model specifications for both spin-off quantity and quality in the robustness checks as the ones used in the previous test, respectively. The results remain unchanged. We present the results of the robustness checks in Appendices A and B.

Furthermore, by using a seemingly unrelated regression approach, we modeled simultaneously quantity and quality, assuming that the two equations are partially related through their error terms. This approach gave us the same set of results as we had in our original models (results are available upon request).

As a further robustness check, we also tested for the impact of alternative policies and structural changes introduced in the three countries over the period under scrutiny. Specifically, we focused on the *introduction of a R&D tax-credit scheme*. USOs are R&D-intensive firms that frequently use such instruments. Consistent with the IPR-related measures, the variable was operationalized as the total number of changes in the tax-credit scheme during the observation period, as well as total number of changes over the total number of years included in the observation period. Results are very similar to the ones obtained with the IPR scheme (available upon request).

We also adopted an alternative measure for the quality of USOs. Rather than using count data, we measured it as the share of firms receiving VC funding in each university each year. Results are qualitatively the same. Moreover, we included additional control variables, such as the share of firms receiving VC funding in past (e.g., discrete and cumulative rate in the previous 2 years or since the beginning of the observation period). Similar results were obtained. Finally, we split the sample according to university rankings. Results based on the top 50 percentile

confirmed our results.

Economic Significance

We also evaluated the economic significance of our findings. For spin-offs quantity, the natural log of the expected number of spin-offs in a given year is .178 units higher for universities with a TTO. In other words, keeping other factors constant, the incidence rate of spin-off creation in a given year is about 20% higher (i.e., $e^{.178} - 1 = .195$) for a university with a TTO than if the university did not have a TTO. One additional IPR institutional change increases the natural log of the expected number of USOs in a given year by .521 units. Hence, everything else being equal, a change in the IPR legislation at national level increases the expected number of USOs in a given year by nearly 70% (i.e., $e^{.521} - 1 = .683$).

The spin-offs quality models show that the natural log of the expected number of spin-offs that receive first-round VC funding in a given year is .342 units lower for universities with a TTO. In other words, everything being equal, universities with a TTO have about 30% fewer spin-offs that receive first-round VC funding in a given year (i.e., $e^{-.342} - 1 = -.29$). Moreover, one IPR institutional change reduces the incidence rate of USOs that receive first-round VC funding by a factor of .55 (i.e., $e^{-.59} - 1 = -.55$). This means that one IPR institutional change decreases the number of USOs that receive first-round VC funding by 45% in a given year (i.e., $e^{-.59} - 1 = -.45$)

DISCUSSION

Findings and Contribution

Our study, using a unique panel dataset and multilevel analysis comprising the populations of USOs in three European countries, shows that changes in the institutional framework have a positive effect on the number of spin-offs created, but a negative effect on the quality of these ventures, as measured by their ability to attract VC financing. These findings indicate that the implementation of new institutional frameworks to increase spin-off creation has an effect, but this effect appears to be more symbolic than substantive. The response within the university organization is a significant increase in the number of firms created, while the potential economic impact of these firms seems to be more modest.

Universities and TTOs appear to be complying with the new institutional norms of creating more spin-offs. Institutional pressures and expectations provide strong incentives for TTOs to

generate visible results, and TTO officers consider the number of new commercial ventures created as an important objective (Thursby et al., 2001). There are also examples of explicit incentives embedded in the institutional framework, such as bonus schemes providing additional TTO funding for each new firm established (Gulbrandsen and Rasmussen, 2012). However, any substantive impact on spin-off firm quality needs a much longer time to manifest because founding new firms is easier than the long-term involvement contributing to firm success.

We argue that increasing the number of spin-offs may come at the expense of the quality of these firms, because the underlying commercial potential of the scientific research at the university remains relatively unchanged in the short-run. However, the negative effects on the quality of these firms were stronger than anticipated. Changes in the institutional framework seem to have a detrimental effect on spin-off quality beyond a decrease in average quality resulting from lower quality of the additional spin-offs created. Our findings indicate an absolute decrease in the number of firms able to raise VC funding, suggesting that the presence of a TTO and legislative changes do more harm than good. Such a conclusion would be speculative because there may be several reasons explaining why USOs attract less VC funding following a TTO establishment or legislative change. Possible explanations may be related to a lower demand for VC financing among USOs, a lower supply of VC financing, or unrelated methodological issues. We will discuss these in turn.

First, changes in the profile or composition of the universities' spin-off portfolio may reduce the demand for VC funding. In contrast to individual scientists, TTOs have more flexibility in selecting commercialization instruments. Many scientific discoveries, in particular within the life sciences, can be successfully licensed directly to industry (Thursby and Kemp, 2002). As shown in a comparative study between Sweden and the USA, the incentive scheme under the "professor's privilege" favors the creation of spin-offs, while TTOs tend to prefer licensing to an established firm, which generates a higher commercialization success (Damsgaard and Thursby, 2013). Hence, the lower observed quality of spin-offs may be because a larger share of high-potential inventions is licensed when a TTO infrastructure is in place. While the effect of institutional changes appears negative for spin-off quality, it would be premature to conclude that the total effect on university technology transfer is negative. Moreover, the establishment of TTOs creates an infrastructure at universities where different resources may be added such as access to facilities and funding arrangements such as proof-of-concept and pre-seed funds

(Kochenkova et al., 2016; Munari et al., 2015). Better access to early-stage funding internally may reduce the demand for VC funding among USOs. This is especially true in technological domains with lower capital intensity.

Second, the supply of VC may be reduced as a consequence of institutional changes because USOs become less attractive among potential investors. The establishment of TTOs, and to some degree legislative changes at national level, is part of an increasing formalization of university technology transfer (Geuna and Muscio, 2009). The more formal processes employed by TTOs could have consequences that reduce the attractiveness of USOs as investment targets by VCs. The involvement of TTOs may lead to overvaluation of the spin-off from the offset, which is detrimental to raising VC later due to unrealistic price expectations (Clarysse et al., 2007). Further, it is increasingly common for TTOs to take equity positions in lieu of licensing agreements as compensation for supplying the spin-off's initial intellectual property (IP) (Savva and Taneri, 2015). VC investors may be more reluctant to invest in firms with a more complicated ownership structure and where the university, rather than the founders, holds a significant ownership stake leaving less equity available to incentivize the entrepreneurs.

Finally, methodological issues may have impacted our results (Perkmann et al., 2015). The introduction of a more formalized technology transfer process may change the universities' reporting practice for spin-offs. Universities with "professor's privilege", without a TTO infrastructure in place, may not record all start-ups by their faculty at an early stage. Hence, some of the early failures may go unnoticed, while the more successful cases are picked up and reported as spin-offs from the institution. Another issue currently debated is the tendency of professors to "bypass" the formal technology transfer infrastructure. Academic entrepreneurs may in some cases avoid disclosure to the TTO in order to circumvent the formal process that follows (Fini et al., 2010; Meoli and Vismara, 2016; Siegel et al., 2004). Aldridge and Audretsch (2010) find that "back door" commercialization is more likely in cases with more experienced entrepreneurs and with increased perceived value of the IP. Hence, deliberate avoidance of TTO disclosure and involvement might be a source of underreporting in our data, which potentially could reduce the number of high-potential spin-off formally reported.

Although we control for the supply of VC financing in our analysis, our results could also be impacted by changes in the structure of early-stage VC financing. Research indicates a

migration to larger deal sizes due to persistently lower returns in early-stage investing (Mason, 2012). It is possible that increased investment concentration has impacted the firm's ability to raise VC, independent of volume of VC funds or underlying firm quality. We encourage future research to explore this possibility.

Implications

Our findings have a number of implications for practice and policy. It has been debated whether the most efficient policies for commercialization of research are bottom-up or top-down (Goldfarb and Henrekson, 2003; Rasmussen, 2008). Top-down policies face the risk of being met by strategic responses at the lower levels (Oliver, 1991), thus enacting mimetic behaviors (Baldini et al., 2014b; Salvador, 2009). Top-down initiatives may lead to symbolic conformance in terms of an increase in the number of spin-offs. However, the creation of quality spin-offs is a complex and resource-demanding process that requires more substantial changes at all levels within the universities. Hence, legislative changes and university-level initiatives, such as the establishment of TTOs, need to be complemented with bottom-up initiatives.

Our results therefore provide a general indication across countries that the effects of policy changes and TTO establishment may not lead to the intended increase in the creation of high-performing spin-offs. Rather, it seems important that universities develop capabilities within their entire organization and surrounding ecosystem that can provide the necessary support to make spin-offs investor ready for VC and other external investment. Earlier qualitative evidence from across European universities (Clarysse et al., 2005) has identified capability deficiencies in TTOs in this respect, and our evidence would seem to suggest that these within- and between-country differences persist. It also seems important that universities and TTOs in different countries develop the social capital to be able to attract VC and other external investment (Rasmussen et al., 2015), especially as VC investors typically view spin-offs as being more challenging propositions than regular high-tech start-ups (Wright et al., 2006). Our analysis also suggests a need for policy toward the commercialization of university research to be connected closely to the development of policies toward entrepreneurship and the funding of entrepreneurial ventures.

Limitations

Our paper has limitations that open up avenues for further research. First, while we selected countries with differences in their institutional approaches to academic entrepreneurship,

further research is needed to explore whether our results hold for other countries or whether there are additional differences.

Second, we measured quality by the ability of spin-offs to attract VC funding. Data limitations restricted our ability to measure access to other external funding notably business angel funding which may be especially important for early-stage spin-off ventures. Further research is needed to explore the role of access to different forms of external investment funds. Additionally, we acknowledge that the performance of the spin-off is a dynamic variable and that TTO actions may impact beyond spin-off birth. However, a large number of spin-offs do not generate revenues for many years, if at all, and accounting data are incomplete for a sizable proportion of our sample not least because small firms have exemptions from reporting financial information. As a result, we do not analyze subsequent accounting, financial and economic performance of spin-offs following VC investment. Further research is needed to explore this aspect, although cross-country data limitations may constrain this approach.

Third, as we have indicated, policies toward the commercialization of university IP have varied over time within and across countries, which have implications for university strategies toward the extent and types of spin-offs (Lockett et al., 2015). While our panel data analysis helps to pick up the quantitative effects of these variations, complementary fine-grained qualitative analysis is required concerning the adaptation of the spin-off processes adopted by universities in different countries. For example, TTOs may have different capabilities and routines (Lockett and Wright, 2005). Further, TTOs may be centralized or decentralized which may have implications for the locus of capabilities to support spin-offs and the social capital of technology transfer officers to access external funding (Huyghe et al., 2014). Similarly, different TTOs may have different remits regarding the promotion of different dimensions of academic entrepreneurship which may be reflected in the extent to which they focus on spin-off activity. Further research might attempt to analyze TTO remits, for example by exploring their mission statements. Such mission statements may be time variant as TTOs evolve their approaches to academic entrepreneurship.

Fourth, and related, we have focused on within- and across-country differences in USOs, but TTOs are also involved to a greater or lesser extend or degree of success in other dimensions of commercialization activity. Given the limited qualitative (Wright et al., 2008) and quantitative analyses (e.g., Chapple et al., 2005) of these multiple outputs, additional cross-

country examination is warranted.

Fifth, our results indicate the importance of bottom-up initiatives and TTOs programs improving the motivation and ability of scientists to launch successful USOs. However, due to data limitations, we were not able to measure the implementation of such initiatives and how this explains variance in the quality of spin-offs. Although challenging to study in large-scale cross-country research, further qualitative studies are required to understand in greater detail how TTOs can successfully influence the quality of their spin-off ventures.

Sixth, although we measured differences in investment freedom across countries, data limitations restricted our ability to account for cross-country and within- country differences in access to external finance. Countries differ in the extent of development of VC markets as well as business angel markets, but the proliferation of new sources of venture funding such as crowdfunding and accelerators (Pauwels et al., 2016) potentially introduces additional within- and between-country variations. Subsequent efforts to encompass these differences will be become more important over time.

Seventh, while our focus was on country-level differences, policy variations that impact university spin-off activity may also differ at regional level (Munari et al., 2015). Additional analysis focused on regional aspects may help extend the insights presented here.

Finally, the private or public legal status of a university may be important. Private universities may be less constrained in investing resources into technology transfer activities compared to public ones. However, we were unable to explore this aspect of the influence on spin-off activity, as in our three countries the number of private universities is too small. Future studies might examine this issue in contexts with a higher incidence of private universities, such as the USA.

CONCLUSION

In sum, the creation of spin-off firms from universities is increasingly seen internationally as an important mechanism for the commercialization of research, and hence forms a central element in the overall contribution of universities to technology development and economic growth. Governments and universities are developing framework conditions that are conductive to spin-offs but as yet there is limited systematic cross-country comparative analysis of the

influences on the extent and quality of spin-offs created. Our study adds to the so far limited cross-country analyses of these influences and points the way to further cross-country analyses and policy developments.

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APPENDIX A

See Tables 5 and 6, and Figure 3.

	Model 1a	Model 2a	Model 3a
U: TTO establishment		0.181*	-0.179
		(0.085)	*(0.122)*
C: IPR institutional changes		2.742***	1.358**
		(0.358)	*(0.500)*
U x C: TTO X institutional changes[a]			1.809***
			(0.454)
U: Prior knowledge in technology transfer activities	0.016***	0.017***	0.019***
	(0.001)	*(0.001)*	*(0.001)*
U: Foundation year	-0.000	-0.000	0.000
	(0.000)	*(0.000)*	*(0.000)*
U: Sponsored research expenditure	0.369***	0.292***	0.265***
	(0.036)	*(0.034)*	*(0.035)*
U: Size	0.176*	0.296***	0.298***
	(0.075)	*(0.071)*	*(0.071)*
U: Intellectual eminence: rank top 25%	0.842***	0.912***	0.933***
	(0.129)	*(0.129)*	*(0.130)*
U: Intellectual eminence: rank 25-50%	0.682***	0.747***	0.785***
	(0.121)	*(0.121)*	*(0.122)*
U: Intellectual eminence: rank 50-75%	0.180	0.178	0.200+
	(0.120)	*(0.119)*	*(0.120)*
U: Education field; general	0.473	0.360	0.418
	(0.421)	*(0.412)*	*(0.410)*
U: Education field; education	-0.039	-0.053	-0.117
	(0.073)	*(0.072)*	*(0.074)*
U: Education field; humanities and arts	-0.096	0.018	0.036
	(0.131)	*(0.130)*	*(0.130)*
U: Education field; social sciences, business and law	-1.224***	-0.992***	-0.989***
	(0.280)	*(0.275)*	*(0.274)*
U: Education field; sciences	0.708**	0.639**	0.530*
	(0.219)	*(0.214)*	*(0.215)*
U: Education field; engineering, manufacturing, and construction	0.486**	0.473**	0.541***
	(0.162)	*(0.162)*	*(0.162)*
U: Education field; agriculture	0.012	0.028	0.024
	(0.067)	*(0.067)*	*(0.066)*
U: Education field; health and welfare	0.045	-0.041	0.099
	(0.178)	(0.178)	(0.182)

	Model 1a	Model 2a	Model 3a
U: Education field; services	0.164+	0.058	0.084
	(0.091)	(0.090)	(0.090)
U: High-tech firm rate	1.083***	1.000***	0.987***
	(0.107)	(0.104)	(0.104)
R: R&D expenditure	-0.176**	-0.147**	-0.169**
	(0.056)	(0.056)	(0.056)
R: Population	-0.206***	-0.227***	-0.224***
	(0.059)	(0.057)	(0.057)
R: Unemployment rate	0.016	0.020+	0.022+
	(0.012)	(0.012)	(0.012)
C: GDP per capita	-0.820	-1.439**	-1.214*
	(0.666)	(0.493)	(0.500)
C: Easiness of doing business	-0.032*	-0.031**	-0.024*
	(0.015)	(0.010)	(0.010)
C: Unemployment rate	-0.045	-0.158***	-0.151***
	(0.050)	(0.033)	(0.034)
Constant	8.002	13.933*	11.690*
	(7.435)	(5.472)	(5.539)
Variance of intercept	0.097*	0.013	0.016
	(0.041)	(0.011)	(0.011)
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-2,353*	*-2,329*	*-2,321*
Degrees of freedom	*23*	*25*	*26*
Chi2	*1,415****	*1,485****	*1,513****

*Table 5: Results of multilevel negative binominal regressions: spin-off quantity. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included. [a] Measured as the number of years in which professor has IPR privilege divided by years of observation time (13 years).*

	Model 1b	Model 2b	Model 3b
U: TTO establishment		0.178*	-0.181
		(0.085)	*(0.121)*
C: IPR institutional changes		0.543***	0.273**
		(0.070)	*(0.098)*
U x C: TTO X institutional changes[a]			0.351***
			(0.088)
U: Prior knowledge in technology transfer activities	0.016***	0.017***	0.019***
	(0.001)	*(0.001)*	*(0.001)*
U: Foundation year	-0.000	-0.000	0.000
	(0.000)	*(0.000)*	*(0.000)*
U: Sponsored research expenditure	0.369***	0.291***	0.264***
	(0.036)	*(0.034)*	*(0.035)*
U: Size	0.176*	0.302***	0.303***
	(0.075)	*(0.071)*	*(0.071)*
U: Intellectual eminence: rank top 25%	0.842***	0.910***	0.933***
	(0.129)	*(0.129)*	*(0.130)*
U: Intellectual eminence: rank 25-50%	0.682***	0.746***	0.786***
	(0.121)	*(0.121)*	*(0.122)*
U: Intellectual eminence: rank 50-75%	0.180	0.179	0.202+
	(0.120)	*(0.119)*	*(0.120)*
U: Education field; general	0.473	0.389	0.433
	(0.421)	*(0.412)*	*(0.409)*
U: Education field; education	-0.039	-0.051	-0.116
	(0.073)	*(0.072)*	*(0.074)*
U: Education field; humanities and arts	-0.096	0.011	0.029
	(0.131)	*(0.129)*	*(0.130)*
U: Education field; social sciences, business and law	-1.224***	-0.982***	-0.980***
	(0.280)	*(0.276)*	*(0.274)*
U: Education field; sciences	0.708**	0.634**	0.525*
	(0.219)	*(0.214)*	*(0.215)*
U: Education field; engineering, manufacturing and construction	0.486**	0.470**	0.539***
	(0.162)	*(0.162)*	*(0.162)*
U: Education field; agriculture	0.012	0.026	0.022
	(0.067)	*(0.067)*	*(0.066)*
U: Education field; health and welfare	0.045	-0.042	0.098
	(0.178)	*(0.178)*	*(0.182)*
U: Education field; services	0.164+	0.055	0.081
	(0.091)	*(0.090)*	*(0.090)*

	Model 1b	Model 2b	Model 3b
U: High-tech firm rate	1.083***	1.005***	0.989***
	(0.107)	*(0.104)*	*(0.103)*
R: R&D expenditure	-0.176**	-0.143*	-0.166**
	(0.056)	*(0.056)*	*(0.056)*
R: Population	-0.206***	-0.234***	-0.229***
	(0.059)	*(0.057)*	*(0.057)*
R: Unemployment rate	0.016	0.020+	0.022+
	(0.012)	*(0.012)*	*(0.012)*
C: GDP per capita	-0.820	-1.304**	-1.044*
	(0.666)	*(0.486)*	*(0.494)*
C: Easiness of doing business	-0.032*	-0.030**	-0.023*
	(0.015)	*(0.010)*	*(0.010)*
C: Unemployment rate	-0.045	-0.158***	-0.150***
	(0.050)	*(0.032)*	*(0.033)*
Constant	8.002	12.516*	9.905+
	(7.435)	*(5.401)*	*(5.482)*
Variance of intercept	0.097*	0.013	0.015
	(0.041)	*(0.011)*	*(0.011)*
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-2,353*	*-2,329*	*-2,321*
Degrees of freedom	*23*	*25*	*26*
Chi2	*1,415****	*1,485****	*1,513****

*Table 6: Results of multilevel negative binominal regressions: spin-off quantity. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included. [a] Measured by absolute number of changes in IPR institution in a country.*

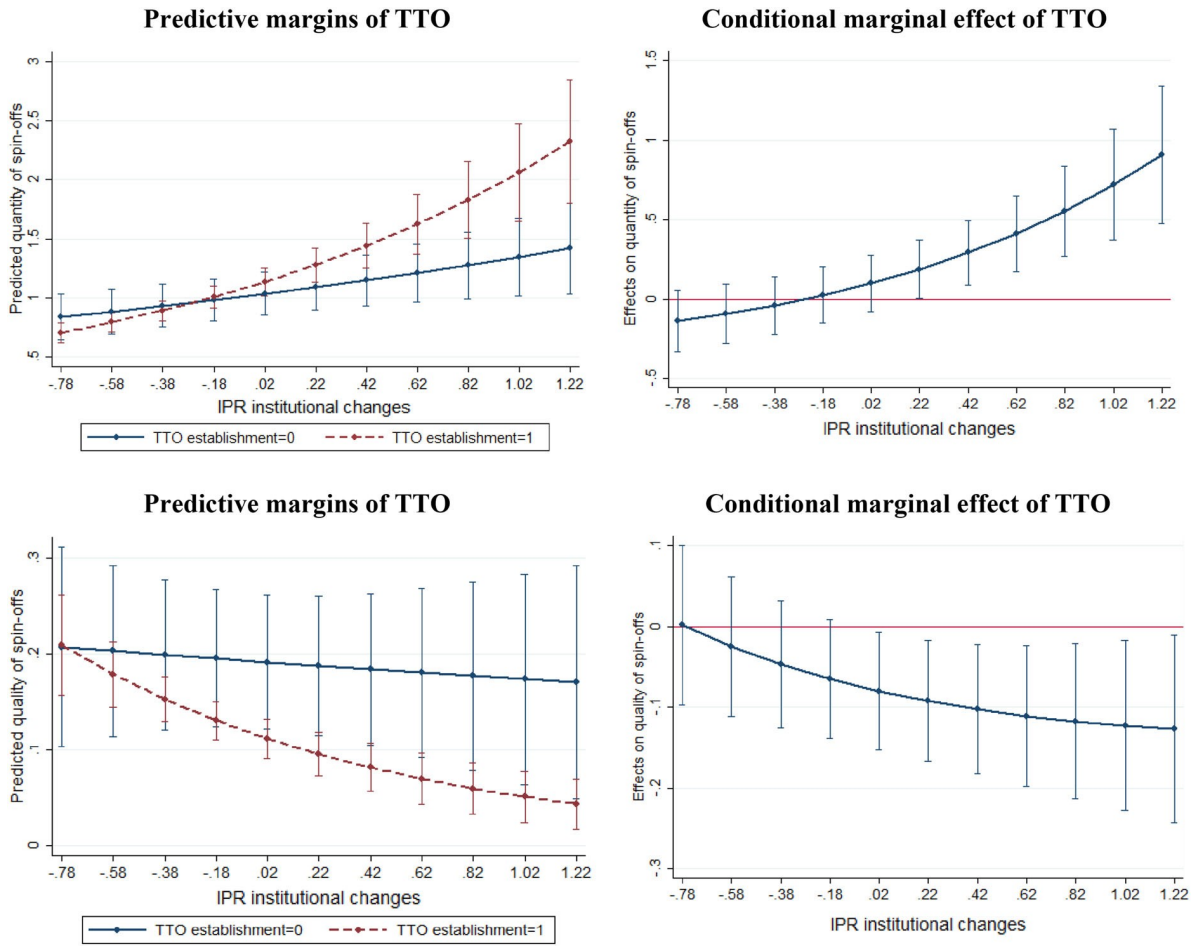

Figure 3: Interaction effects with confidence intervals (95%).

APPENDIX B

See Tables 7 and 8.

	Model 4a	Model 5a	Model 6a
U: TTO establishment		-0.345+	0.038
		(0.208)	(0.245)
C: IPR institutional changes		-3.078**	-0.402
		(0.997)	(1.295)
U x C: TTO X IPR institutional changes[a]			-3.778**
			(1.263)
U: Cumulative entry	0.012***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)
U: Average age of spin-offs	-0.006	0.027	0.045
	(0.050)	(0.047)	(0.046)
U: Foundation year	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
U: Size	1.382***	1.043***	0.986***
	(0.201)	(0.236)	(0.228)
U: Sponsored research expenditure	0.150	0.210*	0.267**
	(0.093)	(0.103)	(0.102)
U: Education field; general	3.703***	3.707***	3.411**
	(1.061)	(1.052)	(1.039)
U: Education field; education	-0.037	-0.097	0.028
	(0.161)	(0.168)	(0.169)
U: Education field; humanities and arts	-0.669*	-0.823**	-0.748**
	(0.291)	(0.292)	(0.284)
U: Education field; social sciences, business and law	1.488	0.834	0.635
	(1.047)	(1.078)	(1.078)
U: Education field; sciences	1.016	1.068	1.168
	(1.254)	(1.282)	(1.279)
U: Education field; engineering, manufacturing, and construction	1.608*	1.802*	1.594*
	(0.776)	(0.773)	(0.768)
U: Education field; agriculture	-0.051	-0.096	-0.083
	(0.159)	(0.158)	(0.156)
U: Education field; health and welfare	-0.897+	-0.547	-0.723
	(0.480)	(0.484)	(0.484)
U: Education field; services	-0.171	0.046	0.033
	(0.200)	(0.206)	(0.203)
U: Intellectual eminence: rank top 25%	0.852*	0.831+	0.785+
	(0.432)	(0.434)	(0.429)

	Model 4a	Model 5a	Model 6a
U: Intellectual eminence: rank 25-50%	0.791+	0.813+	0.735+
	(0.418)	(0.418)	(0.415)
U: Intellectual eminence: rank 50-75%	-0.062	0.010	-0.068
	(0.462)	(0.462)	(0.463)
U: Industrial variance	0.122***	0.129***	0.137***
	(0.033)	(0.031)	(0.030)
U: Hi-tech firm rate	-0.131	-0.048	-0.076
	(0.221)	(0.215)	(0.211)
R: R&D expenditure	0.018	-0.066	-0.009
	(0.129)	(0.132)	(0.130)
R: Population	0.031	0.244	0.289+
	(0.159)	(0.174)	(0.171)
R: Unemployment rate	-0.081*	-0.080*	-0.094*
	(0.040)	(0.040)	(0.040)
C: GDP per capita	1.890*	2.958***	3.074***
	(0.786)	(0.810)	(0.781)
C: Investment freedom	-0.001	-0.015	-0.014
	(0.010)	(0.010)	(0.010)
C: VC availability	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	-44.258***	-53.031***	-54.789***
	(9.595)	(9.578)	(9.269)
Variance of intercept	0.023	0.003	0.003
	(0.044)	(0.031)	(0.027)
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-663.1*	*-657.7*	*-653.5*
Degrees of freedom	*25*	*27*	*28*
Chi2	*499.5****	*536.7****	*565.2****

*Table 7: Results of multilevel negative binominal regressions: spin-off quality. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included. [a] Measured as the number of years in which professor has IPR privilege divided by years of observation time (13 years).*

	Model 4b	Model 5b	Model 6b
U: TTO establishment		-0.342+	0.014
		(0.208)	(0.243)
C: IPR institutional changes		-0.615**	-0.103
		(0.197)	(0.257)
U x C: TTO X IPR institutional changes[a]			-0.714**
			(0.249)
U: Cumulative entry	0.012***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)
U: Average age of spin-offs	-0.006	0.025	0.042
	(0.050)	(0.047)	(0.046)
U: Foundation year	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
U: Size	1.382***	1.029***	0.980***
	(0.201)	(0.238)	(0.230)
U: Sponsored research expenditure	0.150	0.215*	0.269**
	(0.093)	(0.103)	(0.103)
U: Education field; general	3.703***	3.687***	3.423***
	(1.061)	(1.051)	(1.039)
U: Education field; education	-0.037	-0.097	0.020
	(0.161)	(0.168)	(0.169)
U: Education field; humanities and arts	-0.669*	-0.818**	-0.749**
	(0.291)	(0.291)	(0.284)
U: Education field; social sciences; business and law	1.488	0.805	0.606
	(1.047)	(1.081)	(1.082)
U: Education field; sciences	1.016	1.082	1.177
	(1.254)	(1.284)	(1.281)
U: Education field; engineering, manufacturing, and construction	1.608*	1.801*	1.605*
	(0.776)	(0.773)	(0.768)
U: Education field; agriculture	-0.051	-0.093	-0.083
	(0.159)	(0.158)	(0.156)
U: Education field; health and welfare	-0.897+	-0.538	-0.706
	(0.480)	(0.484)	(0.485)
U: Education field; services	-0.171	0.051	0.037
	(0.200)	(0.206)	(0.203)
U: Intellectual eminence: rank top 25%	0.852*	0.833+	0.788+
	(0.432)	(0.434)	(0.430)
U: Intellectual eminence: rank 25-50%	0.791+	0.814+	0.738+
	(0.418)	(0.418)	(0.415)

	Model 4b	Model 5b	Model 6b
U: Intellectual eminence: rank 50-75%	-0.062	0.007	-0.066
	(0.462)	(0.462)	(0.463)
U: Industrial variance	0.122***	0.129***	0.137***
	(0.033)	(0.031)	(0.030)
U: Hi-tech firm rate	-0.131	-0.052	-0.078
	(0.221)	(0.215)	(0.211)
R: R&D expenditure	0.018	-0.070	-0.018
	(0.129)	(0.132)	(0.130)
R: Population	0.031	0.259	0.295+
	(0.159)	(0.175)	(0.173)
R: Unemployment rate	-0.081*	-0.081*	-0.095*
	(0.040)	(0.040)	(0.040)
C: GDP per capita	1.890*	2.852***	2.894***
	(0.786)	(0.803)	(0.776)
C: Investment freedom	-0.001	-0.014	-0.013
	(0.010)	(0.010)	(0.010)
C: VC availability	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Constant	-44.258***	-52.030***	-52.928***
	(9.595)	(9.561)	(9.266)
Variance of intercept	0.023	0.004	0.004
	(0.044)	(0.031)	(0.028)
Observations	*2,405*	*2,405*	*2,405*
Number of groups	*39*	*39*	*39*
Log likelihood	*-663.1*	*-657.6*	*-653.8*
Degrees of freedom	*25*	*27*	*28*
Chi2	*499.5****	*537.1****	*562.8****

*Table 8: Results of multilevel negative binominal regressions: spin-off quality. Standard errors (clustered by country-year) are in parentheses. *** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.01. Observations are grouped per country-year. Continuous variables are standardized. Country-year fixed effects included. [a] Measured by absolute number of changes in IPR institution in a country.*

REFERENCES

Aldrich H.E., Fiol C.M. Fools Rush in - the Institutional Context of Industry Creation. *Academy of Management Review* 1994; 19(4): 645-670.

Aldridge T., Audretsch D.B. Does policy influence the commercialization route? Evidence from National Institutes of Health funded scientists. *Research Policy* 2010; 39(5): 583-588.

Ambos T.C., Mäkelä K., Birkinshaw J., D'Este P. When Does University Research Get Commercialized? Creating Ambidexterity in Research Institutions. *Journal of Management Studies* 2008; 45(8): 1424-1447.

Arshed N., Carter S., Mason C. The ineffectiveness of entrepreneurship policy: is policy formulation to blame? *Small Business Economics* 2014; 43(3): 639-659.

Baldini N., Fini R., Grimaldi R. The transition towards entrepreneurial universities: An assessment of academic entrepreneurship in Italy. In: Link A., Siegel D., Wright M. Handbook of University Technology Transfer. Chapter: 8. Published: University of Chicago Press; 2014a.

Baldini N., Fini R., Grimaldi R., Sobrero M. Organisational change and the institutionalisation of university patenting activity in Italy. *Minerva* 2014b; 52(1): 27-53.

Baldini N., Grimaldi R., Sobrero M. Institutional changes and the commercialization of academic knowledge: A study of Italian universities' patenting activities between 1965 and 2002. *Research Policy* 2006; 35(4): 518-532.

Bercovitz J., Feldman M. Academic entrepreneurs: Organizational change at the individual level. *Organization Science* 2008; 19(1): 69-89.

Bliese P.D., Chan D., Ployhart R.E. Multilevel methods: Future directions in measurement, longitudinal analyses, and nonnormal outcomes. *Organizational Research Methods* 2007.

Bolzani D., Fini R., Grimaldi R., Santoni S., Sobrero M. Fifteen years of academic entrepreneurship in Italy: Evidence from the TASTE Project. 2014a.

Bolzani D., Fini R., Grimaldi R., Sobrero M. University spin-offs and their impact: Longitudinal evidence from Italy. *Journal of Industrial and Business Economics* 2014b; 41: 181-205.

Borlaug S.B., Grunfeld L., Gulbrandsen M., Rasmussen E., Rønning L., Spilling O.R. et al. Between entrepreneurship and technology transfer: Evaluation of the FORNY programme. NIFU STEP; 2009.

Bruton G.D., Ahlstrom D., Li H.L. Institutional Theory and Entrepreneurship: Where Are We Now and Where Do We Need to Move in the Future? *Entrepreneurship Theory and Practice* 2010; 34(3): 421-440.

Carpenter R.E., Petersen B.C. Capital market imperfections, high-tech investment, and new equity financing. *The Economic Journal* 2002; 112(477): F54-F72.

Chapple W., Lockett A., Siegel D., Wright M. Assessing the relative performance of UK university technology transfer offices: parametric and non-parametric evidence. *Research Policy* 2005; 34(3): 369-384.

Clarysse B., Tartari V., Salter A. The impact of entrepreneurial capacity, experience and organizational support on academic entrepreneurship. *Research Policy* 2011; 40(8): 1084-1093.

Clarysse B., Wright M., Lockett A., Mustar P., Knockaert M. Academic spin-offs, formal technology transfer and capital raising. *Industrial and Corporate Change* 2007; 16(4): 609-640.

Clarysse B., Wright M., Lockett A., Van de Velde E., Vohora A. Spinning out new ventures: a typology of incubation strategies from European research institutions. *Journal of*

Business Venturing 2005; 20(2): 183-216.
Complete University Guide; http://www.thecompleteuniversityguide.co.uk/league-tables/rankings; Accessed on: 20/8, 2014.
CWTS; Leiden Ranking; http://www.leidenranking.com/; Accessed on: 8/7, 2014.
Czarnitzki D., Glanzel W., Hussinger K. Heterogeneity of patenting activity and its implications for scientific research. *Research Policy* 2009; 38(1): 26-34.
Damsgaard E.F., Thursby M.C. University entrepreneurship and professor privilege. *Industrial and Corporate Change* 2013; 22(1): 183-218.
Database for Statistics on Higher Education; dbh.nsd.uib.no; Accessed on: 8/7, 2014.
Dimaggio P.J., Powell W.W. The Iron Cage Revisited - Institutional Isomorphism and Collective Rationality in Organizational Fields. *American Sociological Review* 1983; 48(2): 147-160.
European Commission; Feasibility study for creating a European University Data Collection; http://ec.europa.eu/research/era/docs/en/eumida-final-report.pdf; Accessed on: 15/5, 2014.
Eurostat; Eurostat Statistics Database; http://epp.eurostat.ec.europa.eu/; Accessed on: 20/08/2014 and 24/01/2016.
FAME; https://fame.bvdinfo.com/; Accessed on: 20/8, 2014.
Fini R., Grimaldi R. Process Approach to Academic Entrepreneurship: Evidence from the Globe. World Scientific Publishing; 2016.
Fini R., Grimaldi R., Santoni S., Sobrero M. Complements or substitutes? The role of universities and local context in supporting the creation of academic spin-offs. *Research Policy* 2011; 40(8): 1113-1127.
Fini R., Lacetera N., Shane S. Inside or outside the IP system? Business creation in academia. *Research Policy* 2010; 39(8): 1060-1069.
Garnsey E., Heffernan P. High-technology clustering through spin-out and attraction: The Cambridge case. *Regional Studies* 2005; 39(8): 1127-1144.
Geuna A., Muscio A. The Governance of University Knowledge Transfer: A Critical Review of the Literature. *Minerva* 2009; 47(1): 93-114.
Geuna A., Rossi F. Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy* 2011; 40(8): 1068-1076.
Goldfarb B., Henrekson M. Bottom-up versus top-down policies towards the commercialization of university intellectual property. *Research Policy* 2003; 32(4): 639-658.
Grimaldi R., Kenney M., Siegel D.S., Wright M. 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy* 2011; 40(8): 1045-1057.
Gulbrandsen M., Rasmussen E. The use and development of indicators for the commercialisation of university research in a national support programme. *Technology Analysis & Strategic Management* 2012; 24(5): 481-495.
Harrison R.T., Leitch C. Voodoo Institution or Entrepreneurial University? Spin-off Companies, the Entrepreneurial System and Regional Development in the UK. *Regional Studies* 2010; 44(9): 1241-1262.
Henderson R., Jaffe A.B., Trajtenberg M. Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988. *Review of Economics and Statistics* 1998; 80(1): 119-127.
Heritage Foundation; Index of Economic Freedom; http://www.heritage.org/index/download Accessed on: 20/8, 2014.
Higher Education Information Database for Institutions (HEIDI); https://heidi.hesa.ac.uk/Home.aspx; Accessed on: 20/8, 2014.
Huyghe A., Knockaert M. The influence of organizational culture and climate on

entrepreneurial intentions among research scientists. *Journal of Technology Transfer* 2015; 40(1): 138-160.
Huyghe A., Knockaert M., Wright M., Piva E. Technology transfer offices as boundary spanners in the pre-spin-off process: the case of a hybrid model. *Small Business Economics* 2014; 43(2): 289-307.
Italian Companies House Database; Infocamere Telemaco; https://telemaco.infocamere.it/; Accessed on: 17/11, 2013.
Kenney M., Goe W.R. The role of social embeddedness in professorial entrepreneurship: a comparison of electrical engineering and computer science at UC Berkeley and Stanford. *Research Policy* 2004; 33(5): 691-707.
Kenney M., Patton D. Does inventor ownership encourage university research-derived entrepreneurship? A six university comparison. *Research Policy* 2011; 40(8): 1100-1112.
Kochenkova A., Grimaldi R., Munari F. Public policy measures in support of knowledge transfer activities: a review of academic literature. *Journal of Technology Transfer* 2016; 41(3): 407-429.
Lawton Smith H., Ho K. Measuring the performance of Oxford University, Oxford Brookes University and the government laboratories' spin-off companies. *Research Policy* 2006; 35(10): 1554-1568.
Levie J., Autio E. Regulatory Burden, Rule of Law, and Entry of Strategic Entrepreneurs: An International Panel Study. *Journal of Management Studies* 2011; 48(6): 1392-1419.
Lockett A., Wright M. Resources, capabilities, risk capital and the creation of university spin-out companies. *Research Policy* 2005; 34(7): 1043-1057.
Lockett A., Wright M., Wild A. The Institutionalization of Third Stream Activities in UK Higher Education: The Role of Discourse and Metrics. *British Journal of Management* 2015; 26(1): 78-92.
Louis K.S., Blumenthal D., Gluck M.E., Stoto M.A. Entrepreneurs in Academe - an Exploration of Behaviors among Life Scientists. *Administrative Science Quarterly* 1989; 34(1): 110-131.
Mason C. Handbook of Research on Venture Capital. Edward Elgar Publishing; 2012.
Mason C., Brown R. Creating good public policy to support high-growth firms. *Small Business Economics* 2013; 40(2): 211-225.
Meoli M., Vismara S. University support and the creation of technology and non-technology academic spin-offs. *Small Business Economics* 2016; 47(2): 345-362.
MIUR; Italian Ministry of Instruction, University and Research; http://nuclei.miur.it/sommario/ Accessed on: 17/11, 2013.
Mowery D.C. Learning from one another? International policy "emulation" and university-industry technology transfer. *Industrial and Corporate Change* 2011; 20(6): 1827-1853.
Mowery D.C., Nelson R.R., Sampat B.N., Ziedonis A.A. The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980. *Research Policy* 2001; 30(1): 99-119.
Munari F., Rasmussen E., Toschi L., Villani E. Determinants of the university technology transfer policy-mix: a cross-national analysis of gap-funding instruments. *The Journal of Technology Transfer* 2015; 41(6): 1377-1405.
Murphy G.B., Trailer J.W., Hill R.C. Measuring performance in entrepreneurship research. *Journal of Business Research* 1996; 36(1): 15-23.
Muscio A., Quaglione D., Ramaciotti L. The effects of university rules on spinoff creation: The case of academia in Italy. *Research Policy* 2016; 45(7): 1386-1396.
Nightingale P., Coad A. Muppets and gazelles: political and methodological biases in

entrepreneurship research. *Industrial and Corporate Change* 2014; 23(1): 113-143.
North D.C. Institutions, institutional change and economic performance. Cambridge: Cambridge University Press; 1990.
O'Shea R.P., Allen T.J., Chevalier A., Roche F. Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy* 2005; 34(7): 994-1009.
O'Shea R.P., Allen T.J., Morse K.P., O'Gorman C., Roche F. Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience. *R & D Management* 2007; 37(1): 1-16.
Oliver C. Strategic Responses to Institutional Processes. *Academy of Management Review* 1991; 16(1): 145-179.
Pauwels C., Clarysse B., Wright M., Van Hove J. Understanding a new generation incubation model: The accelerator. *Technovation* 2016; 50-51: 13-24.
Perkmann M., Fini R., Ross J.M., Salter A., Silvestri C., Tartari V. Accounting for universities' impact: using augmented data to measure academic engagement and commercialization by academic scientists. *Research Evaluation* 2015; 24(4): 380-391.
Powers J.B., McDougall P.P. University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. *Journal of Business Venturing* 2005; 20(3): 291-311.
Rasmussen E. Government instruments to support the commercialization of university research: Lessons from Canada. *Technovation* 2008; 28(8): 506-517.
Rasmussen E., Borch O.J. University capabilities in facilitating entrepreneurship: A longitudinal study of spin-off ventures at mid-range universities. *Research Policy* 2010; 39(5): 602-612.
Rasmussen E., Mosey S., Wright M. The Evolution of Entrepreneurial Competencies: A Longitudinal Study of University Spin-Off Venture Emergence. *Journal of Management Studies* 2011; 48(6): 1314-1345.
Rasmussen E., Mosey S., Wright M. The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures. *Research Policy* 2014; 43(1): 92-106.
Rasmussen E., Mosey S., Wright M. The transformation of network ties to develop entrepreneurial competencies for university spin-offs. *Entrepreneurship and Regional Development* 2015; 27(7-8): 430-457.
Repubblica; Grande Guida dell'Università; http://temi.repubblica.it/guide-universita-2013-2014/; Accessed on: 17/11, 2013.
Rosenbusch N., Brinckmann J., Muller V. Does acquiring venture capital pay off for the funded firms? A meta-analysis on the relationship between venture capital investment and funded firm financial performance. *Journal of Business Venturing* 2013; 28(3): 335-353.
Salvador E. Evolution of Italian Universities' Rules for Spin-offs: The Usefulness of Formal Regulations. *Industry and Higher Education* 2009; 23(6): 445-462.
Sampat B.N., Mowery D.C., Ziedonis A.A. Changes in university patent quality after the Bayh-Dole act: a re-examination. *International Journal of Industrial Organization* 2003; 21(9): 1371-1390.
Savva N., Taneri N. The Role of Equity, Royalty, and Fixed Fees in Technology Licensing to University Spin-Offs. *Management Science* 2015; 61(6): 1323-1343.
Scott W.R. Institutions and organizations: Ideas, interests, and identities. London: Sage Publications; 2013.
Shane S. Academic Entrepreneurship University Spinoffs and Wealth Creation. Cheltenham, UK: Edward Elgar Publishing; 2004.

Shane S. Why encouraging more people to become entrepreneurs is bad public policy. *Small Business Economics* 2009; 33(2): 141-149.
Shane S., Stuart T. Organizational endowments and the performance of university start-ups. *Management Science* 2002; 48(1): 154-170.
Shane S.A. A general theory of entrepreneurship: The individual-opportunity nexus. Cheltenham: Edward Elgar Publishing; 2003.
Siegel D.S., Waldman D.A., Atwater L.E., Link A.N. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management* 2004; 21(1-2): 115-142.
Spinouts UK Survey; http://www.spinoutsuk.co.uk/; Accessed on: 20/8, 2014.
Stevens A.J. The enactment of Bayh–Dole. *The Journal of Technology Transfer* 2004; 29(1): 93-99.
Suchman M.C. Managing Legitimacy - Strategic and Institutional Approaches. *Academy of Management Review* 1995; 20(3): 571-610.
Tartari V., Perkmann M., Salter A. In good company: The influence of peers on industry engagement by academic scientists. *Research Policy* 2014; 43(7): 1189-1203.
The Research Council of Norway. Det Norske Forsknings- og Innovasjonssystemet - Statistikk og Indikatorer. Oslo: Norges Forskningsråd; 2013.
Thursby J.G., Jensen R., Thursby M.C. Objectives, characteristics and outcomes of University Licensing: A survey of major U.S. Universities. *Journal of Technology Transfer* 2001; 26(1-2): 59-72.
Thursby J.G., Kemp S. Growth and productive efficiency of university intellectual property licensing. *Research Policy* 2002; 31(1): 109-124.
Tolbert P.S., David R.J., Sine W.D. Studying Choice and Change: The Intersection of Institutional Theory and Entrepreneurship Research. *Organization Science* 2011; 22(5): 1332-1344.
UNICO/NUBS. Annual UNICO-NUBS-AURIL Survey on University Commercialization Activities. Nottingham: Nottingham University Business School; 2002.
Urbano D., Alvarez C. Institutional dimensions and entrepreneurial activity: an international study. *Small Business Economics* 2014; 42(4): 703-716.
Van Looy B., Landoni P., Callaert J., van Pottelsberghe B., Sapsalis E., Debackere K. Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research Policy* 2011; 40(4): 553-564.
Van Praag M., van Stel A. The more business owners, the merrier? The role of tertiary education. *Small Business Economics* 2013; 41(2): 335-357.
Vincett P.S. The economic impacts of academic spin-off companies, and their implications for public policy. *Research Policy* 2010; 39(6): 736-747.
Vohora A., Wright M., Lockett A. Critical junctures in the development of university high-tech spinout companies. *Research Policy* 2004; 33(1): 147-175.
Welter F., Smallbone D. Institutional Perspectives on Entrepreneurial Behavior in Challenging Environments. *Journal of Small Business Management* 2011; 49(1): 107-125.
World Bank; Doing Business Project of the World Bank; http://www.doingbusiness.org/; Accessed on: 20/8, 2014.
World Bank; World Bank Database; http://data.worldbank.org/; Accessed on: 20/8, 2014.
Wright M., Clarysse B., Lockett A., Knockaert M. Mid-range universities' linkages with industry: Knowledge types and the role of intermediaries. *Research Policy* 2008; 37(8): 1205-1223.
Wright M., Clarysse B., Mustar P., Lockett A. Academic Entrepreneurship in Europe.

Cheltenham, UK: 'Edward Elgar Publishing, Inc.'; 2007.
Wright M., Lockett A., Clarysse B., Binks M. University spin-out companies and venture capital. *Research Policy* 2006; 35(4): 481-501.
Zephyr; https://zephyr.bvdinfo.com/; Accessed on: 20/8, 2014.
Zimmerman M.A., Zeitz G.J. Beyond survival: Achieving new venture growth by building legitimacy. *Academy of Management Review* 2002; 27(3): 414-431.

RESEARCH PAPER 3

Science-Based Entrepreneurial Firms as Real Options: Assessing the Outcomes of the Norwegian Firm Population from 1995 to 2012

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Growing Firm Value:
New Venture Growth and Trade Sales of Research-Based Spin-Offs

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RESEARCH PAPER 5

Signaling through Insider Ownership: An Analysis of Time and Moderation Effects in Academic Spin-Off Acquisitions

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