ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Sarja A 47 Series

DIAGNOSING THE GROWING PAINS OF A TECHNOLOGY-BASED INDUSTRY

An Examination of the Finnish Biotechnology Industry in Light of Empirical Economics

Antti-Jussi Tahvanainen

ETLA, The Research Institute of the Finnish Economy
Publisher: Taloustieto Oy

Helsinki 2011

ISBN 978-951-628-528-7
ISBN 978-951-628-529-5 (PDF)
ISSN 0356-7435

Printed in: Unigrafia Oy, Helsinki 2011

Aalto University

ABSTRACT OF DOCTORAL DISSERTATION	AALTO UNIVERSITY SCHOOL OF SCIENCE P.O. BOX 15500, FI-00076 AALTO http://www.aalto.fi

Author Antti-Jussi Tahvanainen

Name of the dissertation

Diagnosing the Growing Pains of a Technology-Based Industry - An Examination of the Finnish Biotechnology Industry in Light of Empirical Economics

Manuscript submitted 12.1.2011	Manuscript revised 26.4.2011

Date of the defence 3.6.2011

☐ Monograph ☒ Article dissertation (summary + original articles)

School School of Science
Department Department of Industrial Engineering and Management
Field of research Venture capital, entrepreneurial growth, renewal of technology-based firms
Opponent(s) Prof. Laurel Smith-Doerr
Supervisor Prof. Markku Maula
Instructor Dr. Raine Hermans

Abstract

Positioned in the context of the technology-based industrial emergence literature, this dissertation identifies and examines organizational, managerial, and institutional challenges that small and medium sized Finnish biotechnology companies have encountered during the emergence of the field as an industry. Based on the results, central Implications for research, management and policy are suggested.

The five separate studies that constitute this dissertation fill specific, clearly demarcated gaps in the underlying literature that have not been explicitly scrutinized in extant works. The contributions are made in three domains that are central to the emergence of technology-based industries:

In the *academic domain* the dissertation brings forth new knowledge on bridging the gaps between academia and industry in university-industry technology transfer (UITT) that has previously been found to be riddled with challenges. The dissertation adds to the understanding on the role and value of organizational practices performed by universities and their respective technology transfer offices (TTO) to overcome the challenges and to bring forth university inventions to industrial and societal use. TTOs are found to lower the threshold of UITT stakeholders to participate in and sustain the process of UITT, to facilitate congruence between the features of scientific discoveries and specific market needs, and to mitigate the detrimental effects that opportunistic incentive structures of diverse stakeholders can have on UITT.

In the *business domain*, the dissertation establishes that academia-based start-ups are at a relative disadvantage regarding their capabilities to attract financing, recruit skilled labor, and design viable business strategies – mostly due to a lack of business-related skills, experience and vision as well as an enchaining bond to academic culture, principles and incentives. Young, high-quality firms are also found to suffer most severely from information asymmetry related problems, because they often have nothing tangible to show for their actual quality and cannot distinguish themselves from so-called lemons. Hence, their capital is under-valued on financial markets.

Finally, contributing in the *public policy domain* the dissertation reveals that strategically weak governmental funding can have two disadvantageous externalities: First, due to information-asymmetry-related difficulties in differentiating between high-quality companies and lemons, risk capital instruments in particular tend to support only the latter type of companies, as high-quality companies refrain from applying for such funding in the first place. And second, governmental funding instruments that do not factor in the compatibility of the business models, contents and embeddedness of funding recipients with their respective regional industry structure tend to artificially ventilate businesses that would not otherwise be viable in these specific regions.

Keywords Industrial emergence, biotechnology, technology transfer, academic entrepreneurship, financing

ISBN (printed) 978-951-628-509-5	ISSN (printed) 0356-7435
ISBN (pdf) 978-952-60-3575-8	ISSN (pdf)
Language English	Number of pages 49 p. + app. 179 p.

Publisher ETLA/Taloustieto Oy

Print distribution Industrial Engineering and Management

☒ The dissertation can be read at http://lib.tkk.fi/Diss/2011/isbn9789526035758

Aalto-yliopisto

VÄITÖSKIRJAN TIIVISTELMÄ	AALTO-YLIOPISTO PERUSTIETEIDEN KORKEAKOULU PL 15500, 00076 AALTO http://www.aalto.fi
Tekijä Antti-Jussi Tahvanainen	
Väitöskirjan nimi Diagnooseja Bioteknologiateollisuuden Kasvukivuista Empiirisen Taloustieteen Valossa	
Käsikirjoituksen päivämäärä 12.1.2011	Korjatun käsikirjoituksen päivämäärä 26.4.2011
Väitöstilaisuuden ajankohta 3.6.2011	
☐ Monografia	☒ Yhdistelmäväitöskirja (yhteenveto + erillisartikkelit)
Korkeakoulu Perustieteiden korkeakoulu Laitos Tuotantotalouden laitos Tutkimusala Pääomasijoitustoiminta, kasvuyrittäjyys, teknologialiiketoimintojen uudistaminen Vastaväittäjä(t) Professori Laurel Smith-Doerr Työn valvoja Professori Markku Maula Työn ohjaaja Dr. Raine Hermans	

Tiivistelmä

Osana teknologialähtöisen teollisuustoiminnan syntyä käsittelevää kirjallisuutta, tämä väitöskirja tunnistaa ja tarkastelee organisaatiollisia, liikkeenjohdollisia, ja institutionaalisia haasteita, joita pienet ja keskisuuret suomalaiset bioteknologiayritykset ovat kohdanneet alan kehittyessä teollisuudeksi. Tarkastelun tuloksien pohjalta väitöskirja esittää keskeisiä johtopäätöksiä koskien tutkimusta, liikkeenjohtamista, ja politiikkatoimenpiteitä.

Väitöskirja koostuu viidestä yksittäisestä tutkimuksesta, joista jokainen täydentää yksityiskohtaisia, tarkoin määriteltyjä puutteita olemassa olevassa kirjallisuudessa. Tarkemmin väitöskirja lisää ymmärrystä kolmessa, teknologialähtöisen teollisuustoiminnan synnyn kannalta keskeisessä ulottuvuudessa:

Synnyn *akateemisessa ulottuvuudessa* väitöskirja luo uuta tietämystä yliopistotutkimuksen ja siitä syntyvän kaupallisen toiminnan välillä olevan kuilun ylittämisestä, mikä on aiemmin todettu olevan erittäin haasteellista. Tässä yhteydessä tarkastellaan erityisesti yliopistollisten teknologiansiirtotoimistojen suorittamien organisaatiollisten käytänteiden roolia ja lisäarvoa haasteiden kohtaamisessa ja voittamisessa. Löydösten mukaan teknologiansiirtotoimistot alentavat eri tahojen kynnystä osallistua ja ylläpitää teknologiansiirtoprosessia yliopistoista teollisuuteen, ne auttavat parantamaan tieteellisten löydösten ominaisuuksien ja markkinatarpeiden vastaavuutta, ja ne ehkäisevät teknologiansiirtoprosessiin osallistuvien tahojen opportunistisista kannustinrakenteista johtuvia haitallisia seurauksia.

Teollisuuden synnyn *liiketoiminnallisessa ulottuvuudessa* väitöskirja todentaa, että yliopistolähtöiset teknologiayritykset ovat suhteessa muun tyyppisiin yrityksiin heikompia hankkimaan rahoitusta, rekrytoimaan osaavaa työvoimaa, ja suunnittelemaan kestäviä liiketoimintamalleja. Tämän arvioidaan johtuvan lähinnä liiketoimintaosaamisen, kokemuksen ja vision puutteesta, ja kahlitsevasta siteestä akateemiseen kulttuuriin, periaatteisiin, ja kannustimiin. Tämän lisäksi nuoret, mutta korkealuokkaiset ja lupaavat yritykset kärsivät eniten informaatioasymmetrian aiheuttamista ongelmista, koska heillä ei usein varhaisesta kehitysvaiheestaan johtuen ole keinoja erottautua heikommista yrityksistä. Seurauksena on tämänkaltaisten yritysten pääoman aliarvioiminen rahoitusmarkkinoilla.

Lopuksi väitöskirja luo ymmärrystä *julkisen politiikan ulottuvuudessa* havainnoimalla, että strategisesti kohdentamattomilla julkisilla rahoitusinstrumenteilla saattaa olla ainakin kaksi haitallista ulkoisvaikutusta: Ensiksi, edellä mainittujen informaatioasymmetriaan liittyvien vaikeuksien vuoksi etenkin riskirahoitusta muistuttavat instrumentit tukevat pääasiallisesti vain heikkoja yrityksiä. Tämä johtuu siitä, että korkealuokkaiset, lupaavat yritykset eivät lähtökohtaisesti halua hakeutua tämän tyyppisen rahoituksen piiriin. Ja toiseksi, rahoitusinstrumentit, jotka eivät huomioi rahoitusta vastaanottavien yritysten liiketoimintamallin, erikoistumisen, ja integroitumisen asteen yhteensopivuutta suhteessa näiden alueella vallitsevaan teollisuusrakenteeseen, saattavat olla ainoastaan tekohengitystä yrityksille, jotka muuten eivät olisi elinkelpoisia kyseisellä alueella.

Asiasanat	Teollisen toiminnan synty, bioteknologia, teknologiansiirto, akateeminen yrittäjyys, rahoitus		
ISBN (painettu)	978-951-628-509-5	ISSN (painettu)	0356-7435
ISBN (pdf)	978-952-60-3575-8	ISSN (pdf)	
Kieli	Englanti	Sivumäärä	49 s. + liitteet 179 s.
Julkaisija	ETLA/Taloustieto Oy		
Painetun väitöskirjan jakelu	Tuotantotalouden laitos		
☒ Luettavissa verkossa osoitteessa http://lib.tkk.fi/Diss/2011/isbn9789526035758			

Foreword

What began as a simple means to an end and a mere requirement for my profession soon turned out to be so much more. This dissertation began as the spontaneous spark of an idea on the subway train one bright summer evening somewhere between Herttoniemi and Sörnäinen, and, over the following years, turned into an epic journey stretching across continents, over time, and through a maze of unforgettable experiences and emotions.

Now, roughly eight years later, looking back at the adventures I experienced while writing this dissertation is like watching a great road movie with all its classic elements: larger-than-life challenges, heart-breaking drama, moments of paralyzing despair, frustration and disappointment, but also constantly changing scenery, thrilling enthusiasm and defiant determination, great victories and, above all else, the support, encouragement and consolation of faith, love and friendship.

Like all great stories, a good road movie is never a mere compilation of events strung together. What fascinates us most in stories is the way that the characters transform through their experiences, hardships and triumphs over the course of the narrative. Through catharsis, the protagonists recognize their failures and weaknesses and outgrow them. They evolve and ultimately surpass themselves. Similarly, the experiences involved in writing this dissertation have had a lasting impact on the way that I perceive my professional, social, economic, and moral environments and on how I will set my goals in the future.

I am humbled by the sheer immensity of knowledge in this world. It has made me appreciate what it takes to stand on the shoulders of giants and to contribute to the creation of knowledge. As a fresh initiate in the society of scholars, I am thankful for the many opportunities that I have been given to learn from the established, honorable pioneers of this profession.

Patience is another attribute that I hope to have gained. Great things do not necessarily happen overnight. As a pragmatist, I found this lesson particularly difficult to learn. Hopefully, I have gained a deeper peace of mind and more tolerance and perseverance to face the minor setbacks of everyday life.

I also hope to have honed my analytical thinking and judgment, which are pivotal prerequisites to any scholar's success. Beyond the professional applications of analytical thinking, however, I have learned that this skill complements experience, spontaneity and emotions, which are the ultimate bases of personal decisions. Critical thinking infuses them with a hint of informed rationality but

does not quench the *joie de vivre* that has become so rare in today's goal-oriented society. Adopting an analytic approach was a great challenge because it required me to abandon the familiar guides of intuition and common sense and admit how seldom they reveal the truth of things. Reality is a more complex and timid creature than I ever dared to imagine. In some contexts, I learned that objective reality never existed in the first place and that we find ourselves constructing it through our thoughts, expectations and actions.

Having said all this, the most important and most precious of my experiences in this process has been the enormous support, both in scale and scope, from the great variety of individuals and institutions I have been lucky enough to have in my life. I would not be writing this foreword today without the unconditional help I received from my fellow students and scholars, sponsors, fantastic colleagues, dear friends, caring family, my loving and encouraging wife, a joyful little furball of a pet, and, of course, our heavenly Father.

In his role as supervisor, Professor Markku Maula has patiently guided me through the ups and downs of the doctoral program at Aalto University, School of Science. I am most grateful to Markku for clearly communicating the scientific standards expected of a doctoral dissertation. These standards have helped me to push myself and make the appropriate trade-offs between my ambition and the feasibility of my objectives. I feel prepared for and look forward to the scholarly work ahead. It is also all to the credit of Markku that I could conduct research at Stanford University's Scandinavian Consortium for Organizational Research (Scancor) in 2007 as a visiting scholar. Beyond the incredible opportunity to experience the dynamics of Silicon Valley in person and to meet numerous new colleagues, the visit was vital to the completion of this dissertation because it provided the necessary evidence for one of the included articles.

Raine Hermans, the instructor of this dissertation, is to me what Mentor is to Telemachus in Homer's *Odyssey* and what, in Lucas' contemporary saga, Obi-Wan Kenobi is to Luke Skywalker: a colleague, a counselor, a mentor and, above all, a true friend in life and faith. It was Raine who, in 2002, did not hesitate to hire a spike-haired undergraduate with a metal chain around his neck for a summer internship at Etlatieto Ltd. Raine mentored me through my Master's thesis in the following year and provided assistance in data management, statistical analyses and the interpretation of results. Thus, he laid the foundations for my capabilities as a researcher. Then, a year later, Raine turned the above-mentioned spark of an idea into action; he was the first to grab the phone to call the university and put my enrollment in a doctoral program in motion. Ever since, Raine has been the most supportive of instructors, both as a colleague and superior at Etlatieto before he took a position at Tekes in 2007 and as as a friend and fellow in the private domain and on our various joint adventures in international research.

An active mentor, Raine has also co-authored many of the studies that I have produced in the past decade, including four of the articles in this dissertation. I continue to admire him for his contagious enthusiasm, relentless drive and ability to see that light at the end of the tunnel when many of the rest of us have long given up. Both my wife and I are deeply grateful to Raine for many of the happiest twists and turns in our life.

Moreover, I am in great debt to Martti Kulvik, with whom I have had the pleasure of working in the past years at Etlatieto. Martti has guided me in many aspects of my professional, private and spiritual life and has grown to be a dear friend. As a medical doctor, he has been my ethical and moral backbone, making sure that I always observe things from multiple angles and consider the human condition. Thanks to Martti, I have come to comprehensively understand the phenomena that we have studied. By calmly and constructively questioning the status quo and dominant assumptions, Martti has often induced me to rethink the given, come to new conclusions and broaden my horizon beyond the obvious. Thus, in many ways, the world as I see it today is a much richer place. Along the way, we have co-authored a number of joint papers, one of which is the fourth study presented in this dissertation. Regarding the study, I want to further thank Professor Morton Kamien for his co-authorship and valuable guidance.

I also thank Professor Martin Kenney and Professor Rikard Stankiewicz for providing excellent comments on the strengths and weaknesses of this dissertation in their role as pre-examiners.

There is not the flimsiest shred of doubt that this dissertation would never have seen the light of day if it were not for the unwavering commitment, belief, resources, flexibility, openness and guidance of my employers Etlatieto and Etla over the years. The extraordinary opportunity to work for one of the leading economic research institutes in Finland has had a great impact on the scope and quality of the research in the following pages. Given the institute's esteemed reputation, our team has had almost unrestricted access to corporate and institutional research participants, and thus, we have always been able to compile unique, high-quality data from which this dissertation has greatly benefitted. The institute's open, unreserved and collegial culture and the dedication of expert colleagues to sharing insights and providing comments on my research have also been invaluable resources. At the institute, I have been able to utilize the results of my work directly in the dissertation, which has significantly expedited its completion.

In particular, I would like to express my gratitude to Pekka Ylä-Anttila and Petri Rouvinen, my superiors at Etlatieto, for their belief in and patience with my work from the beginning. I have never once been turned down when sug-

gesting new ideas or alternative avenues for future research endeavors. Pekka and Petri have given me great autonomy in designing my research agenda and experimenting with different approaches to a multitude of diverse phenomena. The multi-disciplinary approaches in this dissertation are tangible proof thereof. Moreover, both have been active sponsors in encouraging and providing resources for my research visits abroad; those visits have been memorable experiences and important foundations for this dissertation. Thank you both for your wisdom, foresight and leadership. I feel privileged to have your trust.

Very special thanks go to my colleague and friend, Tuomo Nikulainen. We have shared a common path, both in our education and careers, since our undergraduate studies. The value of a true friend accompanying me through every up and down on these academic and professional roads cannot be appreciated enough. I hope it is sufficient to say that I acknowledge its rarity. Along the way, I feel that we have developed a shared view on the standards of our profession, which has helped us to collaborate on numerous projects and defend our approaches together. Although our skill profiles are rather different, they are highly complementary and have provided the perfect vantage point for commenting on each other's work. Indeed, some of the articles in this dissertation, and the introductory chapter in particular, have greatly benefitted from Tuomo's critical insights in his customary and much-appreciated role as the devil's advocate. Through his ambitiousness and goal-oriented perseverance, Tuomo has also provided a healthy amount of peer pressure, which has helped me to push through the final stages of completing the dissertation.

Many other colleagues at Etlatieto and Etla have also been of invaluable support in spirit and deed. Jyrki Ali-Yrkkö has been an infallible advisor, expert and source of information on the economics of technology-based industries. Our adventure in the Far East remains a cherished memory that I shall not forget. Mika Pajarinen has been an irreplaceable resource and an unstoppable force of nature in data procurement, data management and statistical analyses. Saying that Mika speaks STATA as his first language is a gross understatement. In his simultaneous role as a university professor, Professor Olli Martikainen has engaged me in many interesting debates on the topic of university technology transfer and has thereby unknowingly contributed to establishing some of the practical implications presented in the first study of this dissertation. I am grateful for Olli's interest in my research and look forward to our future discussions. I am deeply indebted to Matthias Deschryvere for infecting us all with his high spirits and joyous hunger for life, day in and day out. The burdens of research were half as heavy on the days that Matthias enriched our work environment with his presence. I wish you all the happiness in life and great success in your new tasks outside the Etla community. I am sad to lose you as a colleague, but all the more happy to keep you as a friend. Timo Seppälä has been a whirlwind

of energy whose fervor and resolute optimism have rubbed off on my attitude to challenges and risk-taking. Through his extensive experience in industry, Timo has deepened my understanding of the connections between research, its applications and its relevance to business.

At Etla and Etlatieto, I have enjoyed the luxury of drawing on the indispensable help of expert support staff whenever there was a need. I would like to express my appreciation to Petteri Larjos, Jarkko Aitti, Christina Tigerstedt and Heikki Vajanne who have repeatedly bailed me out of IT-related predicaments and helped me to overcome other technical challenges. Honest thanks and humble bows also go to Laila Riekkinen, Kaija Hyvönen-Rajecki and Tuula Ratapalo for helping me with all of those necessary and time-consuming tasks related to publishing. Special thanks go to Kimmo Aaltonen, who has not only been in charge of the graphic design and layout of many of my contributions, including this dissertation, but has also been a magnificent opponent on the badminton court all these years. And thank you further for finally convincing me which hockey team to cheer for; the Finnish winter season is starting to make sense at last. Pirjo Saariokari, Hannele Heikkinen, Arja Räihä and Sinikka Littu have brightened my days with their individual humor, catering to the needs of visiting colleagues, arranging meetings, trying to keep up with monitoring my constantly changing work hours and taking care of other important back office tasks. Kirsti Jalaistus and Markku Lammi have diligently protected my interests in matters related to contracts, budgets, salary, foreign visits and other economic affairs since I joined the Etla community. Finally, I would like to extend my gratitude to a number of colleagues, present and past, who have made research such an exiting profession and have helped me endure the inevitable rough times along the way with their encouragement and expertise. These colleagues include Mika Maliranta, Christopher Palmberg, Ari Hyytinen, Heli Koski, Pasi Sorjonen, Antti Kauhanen, Nuutti Nikula, Ville Kaitila, Terttu Luukkonen, Hannu Hernesniemi and many others.

Outside the workplace, many people have both directly and indirectly supported this dissertation. To begin, I would like to acknowledge the tremendously important role of several foundations in funding large parts of the research presented here, including my time as a graduate student and visiting scholar at the University of Seville and Stanford University. For their financial support, I humbly thank the Academy of Finland, Foundation for Economic Education, Finnish Cultural Foundation, Instrumentarium Science Foundation, Jenny and Antti Wihuri Foundation and Yrjö Uitto Foundation. I further thank Tekes and Technology Industries of Finland Centennial Foundation for funding several of the projects at Etla and Etlatieto that resulted in a number of studies in this dissertation.

The frequent use of knowledge management literature, particularly the Value Platform Model, in the various studies of this dissertation is due to the influence of one man alone: Tomi Hussi. Tomi and his teachings are the single most important reasons why I ever dared to venture beyond the boundaries of pure economics and have a sneak peek into the world of management science. Since then, I have constantly shuttled between these two paradigms, trying to combine insights from both in new ways to capture phenomena more comprehensively. Thank you Tomi; you have no idea how many larger-than-life experiences you have helped to bring about, including the next adventure I am about to embark on at Stanford.

Professor Otto Toivanen is more or less solely responsible for the fact that I became a researcher in the first place. Otto directed and instructed me during my undergraduate studies in Technology Management and Policy at the Helsinki School of Economics in 2000-2003 and, through his intensive and hands-on mentorship in my Master's thesis, taught me the principles of scientific work early on. It was Otto who, through his connections to Etla, encouraged me to apply for that decisive summer internship in 2002. Thus, in many ways, I regard him as the catalyst of my professional career. For that I am forever grateful. I wish you all the success in your current endeavors at K.U.Leuven.

I would also like to thank the 2007 Scancor Spring Seminar participants at Stanford University for their many insightful comments on the research design and implementation of the first study in this dissertation. As it was my first attempt at qualitative research, I found the comments from experts on organizational research invaluable. In particular, I would like to thank Robin Gustafsson and his family for the hospitality and unreserved friendship that they showed us upon our arrival in Silicon Valley. Robin has remained a valued friend since. It has been a pleasure to debate theories over a good cigar and a glass of Cognac every once in a while, and I hope we are able to keep up the tradition far into the undetermined future.

As the American poet and essayist Ralph Waldo Emerson once wrote, "it is one of the blessings of friends that you can afford to be stupid with them". I must admit, I have taken full advantage of that privilege throughout the past years because studies, research and work have often kept me too busy and grumpy to mind other important things in life to the extent they deserve. Having had the opportunity to let go of the stress and be just, well, stupid in the good company of friends every now and then has been a blessing and a welcome escape. Sincere thanks to all of you; I take none of you for granted.

Finally, I would like to thank my family for all their support. Dear Raija and Rauno, you took me in like a son almost 15 years ago and gave me a second home. You have continuously supported my endeavors in word, deed, pride and

prayer and have been that steady, soothing force amidst all the turmoil that your beloved daughter and I have had to overcome together during the work on this dissertation. Your wisdom has often helped me to put matters in perspective and to conquer self-doubt in times of desperation. You have shared all that you have with me and never withheld your help when called upon. Thank you for being there for us; without you, it would have been so much harder.

Dear mother and father, some 17 years ago I told you how you did something right in my upbringing. I still firmly believe in those words. Today I want to thank you again for giving me a great set of values and virtues that have brought me more success and happiness in life than I ever could have imagined. I am also most grateful for your generosity, which has given us the opportunity to escape the hectic carousel of everyday life every now and then, to take time off from other duties to work on the dissertation exclusively, and to take the extended visits abroad that have been so pivotal in completing this dissertation. Thank you.

My greatest gratitude, respect and appreciation belong to you Tiltu, my beloved wife. It is impossible to capture all that you represent and all that you have done for me in mere words. Here are just a few. You are in every fiber of my being, for it is you who has helped me refine those values I took from home and turn them into who I am today. I have grown with you, because of you, and we have grown together. You have taught me the courage to make my own decisions, to choose my own path and to stand up to the expectations of others. You have taught me that I have options. In that sense, you have given me freedom and self-respect. There are no greater gifts. No one is more proud of me than you are, and no one defends me as ferociously as you do. You are the only person I have heard of who, on top of a demanding work schedule, registered for an educational program just so I would not be the only one to sit at home studying and writing articles at dead of night. Your love has been unconditional; even in times when the work on this dissertation has rendered me distant and I have not been able to give you the least bit of the attention that you deserve. Through your steadfast support and belief in me, by standing at my side every day, you have created the safest of spaces, in which working on the dissertation has been motivating and meaningful. I dedicate this work to you. Thank you for being there with me. I cannot wait to grow old with you. I love you to the moon and back.

Antti-Jussi Tahvanainen

Helsinki, May 2011

Table of contents

List of publications

This dissertation consists of a summary article and the following papers:

Study 1: Tahvanainen, Antti-Jussi – Hermans, Raine (2011): Making Sense of the TTO Production Function: University Technology Transfer Offices as Process Catalysts, Knowledge Converters and Impact Amplifiers. Discussion Paper No. 1236, 40 pages. The Research Institute of the Finnish Economy (ETLA), Helsinki.

Contributions: Research design by Tahvanainen. Tahvanainen assumed the main responsibility for implementation, data management, inductive analyses, the construction of the conceptual framework and reporting.

Study 2: Tahvanainen, Antti-Jussi (2004): Growth Inhibitors of Entrepreneurial Academic Spin-offs: The Case of Finnish Biotechnology. International Journal of Innovation and Technology Management, 1(4).

Study 3: Tahvanainen, Antti-Jussi – Hermans, Raine (2005): Funding Intellectual-Capital-Abundant Technology Development: Empirical Evidence from the Finnish Biotechnology Business. Knowledge Management Research & Practice, 1(3), 69–86.

Contributions: Research design by Hermans and Tahvanainen. Tahvanainen assumed the main responsibility for implementation, data management, statistical analyses, construction of the analytical framework and reporting.

Study 4: Hermans, Raine – Kamien, Morton – Kulvik, Martti – Tahvanainen, Antti-Jussi (2009): The effect of technology subsidies on industry strategies and market structure. In Hermans, Raine – Kamien, Morton – Kulvik, Martti – Löffler, Alicia – Shalowitz, Joel (eds.): Medical innovation and government intervention. The Research Institute of the Finnish Economy (ETLA), B series 236, Helsinki.

Contributions: Research design by Hermans. Tahvanainen contributed to the implementation, the initial development of the conceptual framework and reporting.

Study 5: Tahvanainen, Antti-Jussi – Hermans, Raine (2008). Agglomeration and Specialisation Patterns of Finnish Biotechnology – On the Search for an Economic Rationale of a Dispersed Industry Structure. Discussion Paper No. 1133, 43 pages. The Research Institute of the Finnish Economy (ETLA), Helsinki.

Contributions: Research design by Hermans and Tahvanainen. Tahvanainen assumed the main responsibility for implementation, data management, statistical analyses, construction of the analytical framework and reporting.

Introduction to the dissertation

1 Background

1.1 Premises

The motivation for studying challenges in the emergence of an industry sector that is still in its early stages of development and of small economic significance (Luukkonen, Tahvanainen, and Hermans, 2004; Hermans, Kulvik and Tahvanainen, 2006) can be traced back to broader issues at the heart of discussions on Finland's competitiveness in the global economy: comparative advantage and the need to focus on highly value-adding economic activities in global value chains.

According to the principle of comparative advantage (Ricardo, 1817; Heckscher and Ohlin, 1919; Samuelson, 1948; Leamer, 1985), Finland has to focus on technological innovation to protect its competitiveness because it cannot compete on the basis of mass production and economies of scale due to small domestic markets and relatively high cost (Secretariat of the Economic Council (Finland), 2006).

For a peripheral, small and open economy such as Finland's, globalization is the most significant driver of this need for a strategic focus on highly value-adding activities. There has been a clear shift toward free trade, concomitant with the development of new technologies that significantly accelerate the transfer of knowledge and goods across geographic borders. With the emergence of the newest phenomenon of globalization, the "second unbundling" (Baldwin, 2006) (i.e., global competition at single stages of production and individual tasks within those stages), even those firm functions that add substantial value (e.g., R&D) have undergone geographic subdivisions. The appropriate parts of these functions are offshored to countries with lower costs, better market proximity, or superior knowledge (e.g., Ali-Yrkkö and Tahvanainen, 2009).

For highly developed, high-cost countries that rely on superior innovation capabilities for their global competitive advantage, these developments pose a serious challenge because quickly developing, low-cost countries such as China and India are advancing in the race for knowledge and innovation at a considerable pace. They are quickly moving into the competitive domain of "incumbent" countries. Companies from around the world have already offshored parts of their R&D activities to these countries. In light of the challenge to preserve competitive advantage, incumbent countries need to develop and maintain geographically exclusive, cutting-edge knowledge bases as growth plates for highly value-adding innovation to retain existing economic activity and to attract new activity.

The above developments have forced regions and nations to take measures to restore and enhance the competitiveness of their industries. As traditional trade barriers have decreased, other competitiveness-enhancing industrial policies have emerged. For example, countries have created national innovation systems to stimulate and strengthen dynamic interactions among industrial clusters, universities and public institutions (Porter, 1990; Niosi, 1991; Nelson, 1993; Mowery and Nelson, 1999). Such systems aim to support the development and commercialization of new technologies by facilitating industry access to the academic knowledge base and encouraging active collaboration between academia and industry. High-technology sectors, often still in their infancies, are expected to provide new growth opportunities for incumbent countries and bolster their competitive advantage by focusing on developing highly value-adding solutions.

In the 1990s and early 2000s, the ICT sector was the primary area of Finnish innovation and exports growth (Ali-Yrkkö, 2010). However, as the sector matures, markets saturate, and the nature of demand changes due to harsh global competition and the evolution of consumer preferences, Finland has to map and develop new sectors that satisfy the discussed criteria for global competitive advantage. Specifically, the sectors need to (a) have access to and exploit globally leading research that is unique to Finland and that is structural and cumulative; (b) form a strong and sustainable platform for broad technological innovation that can create applications for use in different industries and support new ones; and (c) show adequate potential for economic significance on the global scale to provide incentives for investment in the sectors.

Biotechnology[1] is a potential candidate to satisfy all of the above criteria.

Nevertheless, commercial biotechnology is far from established in Finland. Despite its tremendous growth in the past decade, it is still a young and emerging sector that is not expected to generate added value equivalent to that of the Finnish electronics or forest industries for the next 30 to 50 years (Hermans and Kulvik, 2004). Understanding the emergence of the biotechnology business and its challenges and requirements for operations, management and politics is crucial to implementing effective policies to support the sector and promote Finland's long-term global competitiveness. Furthermore, gaining insights into the enablers and challenges of emerging technology-based and, in the case of

[1] The definition of biotechnology in this dissertation complies with that of the Second OECD Ad Hoc Meeting on Biotechnology Statistics (May, 2001): "Biotechnology is defined as the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."
(http://stats.oecd.org/glossary/detail.asp?ID=219; last access on April 5, 2011)

biotechnology, science-based industries is indispensable because Finland is not adequately commercializing its otherwise competitive research compared to other OECD countries (Georghiou et al., 2003, and PMO, 2006). Thus, there is a need for in-depth research because the biotechnology sector seems to differ from others in many ways[2]. This dissertation responds to this need by shedding light on the central challenges in the emergence of this sector.

1.2 Positioning

In the literature to date, the insights related to the emergence of technology-based industries have not been systematically unified into a distinct body of knowledge. As the premise of their review, Ford, Routley and Haal (2010) identify the need to connect the separate debates by claiming that

> "[w]*hile numerous studies have to date focused on aspects of industrial evolution, (e.g., innovation, internationalization, new product introduction, technological lifecycles and emerging technologies),* ***far fewer have focused on technology-based industrial emergence****. It is clear that if assistance is to be provided to firms and industrial policymakers attempting to navigate industrial emergence, then we need an improved understanding of the characteristics and dynamics of this phenomenon*." (p.1222)

Because the field is still relatively fragmented, contributions have been made in various disciplines. Early foundations for the literature can be traced back to seminal works such as Dosi's (1982), which was an early attempt to model technological evolution, both continuous and discontinuous, as an outcome of the interaction of scientific progress, economic factors, institutional variables, and unresolved obstacles on established technological paths. Dosi's (1982) study is especially relevant to the premises of this dissertation because it relates the emergence of new technological paradigms to the industrial structures associated with the respective technologies. He argues that the emergence of a new technological paradigm can frequently be associated with entrepreneurial and new "Schumpeterian" companies and that the establishment of a paradigm as an industrial sector often involves oligopolistic stabilization. As shall be discussed below, this dissertation deals with these Schumpeterian companies and their challenges as actors in an emerging industrial sector.

[2] For comparisons between the Finnish biotechnology and other high technology sectors, refer to Palmberg and Luukkonen (2006), and Nikulainen and Kulvik (2009).

The field has flourished since Dosi's work in terms of methodology and focus. Macdonald (1985), for instance, extends the literature by examining the strategic management choices that small entrepreneurial companies in new industries face. He identifies three strategic options that such companies can implement to remain competitive: (i) enter an industry that is still fragmented and provides niches; (ii) develop the capacity to anticipate shifts in industrial structure to exit disadvantageous industries and pioneer others; and (iii) build barriers to entry for others as a first mover.

In a different approach, Rip (1995) applies insights from sociology and economics to provide 13 normative suggestions for introducing new technologies into society. He builds his arguments on the need to articulate demand, generate acceptability and take into account the innate non-linearity and the situated characteristics of new technologies.

In a more recent study, Srinivasan (2008) identifies the features of new technologies that, he argues, have not been subject to inquiry in the literature on marketing or organizational innovation and might contribute to the relatively high product and firm default rates in new technology-based industrial sectors. The identified features include fast "clock speeds", the convergence of technologies, dominant designs, and network effects arising from the connectivity of products and users. The managerial and organizational effects of these features, Srinivasan (2008) argues, manifest in shifting value chains, the digitization of goods, and the externalization of innovation activities.

Nemet (2009) shifts his focus away from the innate features of technology and their implications for business, the economy, and society and asks why certain governmental demand-pull policies that aimed to support the emergence of new technology-based industrial sectors have failed. He attributes the failure to three main challenges related to these policies: (i) quickly emerging, dominant designs limit the necessary market opportunities to support an entire industrial sector; (ii) uncertainty regarding the longevity of government-induced demand discourages investments by companies; and (iii) a simultaneous decrease in public R&D funding, political disengagement from the agendas associated with the technologies, and other miscellaneous factors counteract the effects of demand-pull policies.

Other studies take more exploratory and empirical approaches to examine facilitating (e.g., Hourd and Williams, 2008) and inhibiting (e.g., Wells, Coady and Inge, 2003) micro-level factors in technology-based industrial emergence. Jacobsson and Bergek (2004) also include macro-level factors in their analyses,

which scrutinize both inducement (e.g., government policy, firm entry/activity, feedback from markets) and blocking (e.g., uncertainty, lack of legitimacy, weak connectivity) mechanisms in the emergence of the renewable energy sector in Germany, Sweden, and the Netherlands.

The fragmented state of the literature on technology-based industrial emergence and the various types and approaches it includes provide ample opportunities for contribution. As discussed in detail below, each of the articles in this dissertation extends the broader framework of technology-based industrial emergence by filling specific gaps that have not been investigated in previous works. These gaps include, for instance, a weak understanding of (i) cultural and organizational challenges in capitalizing on academic research as a resource for emerging technologies; (ii) the role of information asymmetries between highly knowledge-intensive companies and private capital markets, which cause difficulties in attracting financing; (iii) the role of governmental funding in creating viable technology clusters and alleviating problems related to information asymmetries; and (iv) the inhibitors of growth specific to small and medium–sized, university-based, high-technology companies. Of course, in exploring these niches, the articles build on and combine various issues that the reviewed literature has established as important.

1.3 Approach

This dissertation identifies and examines organizational, managerial, and institutional challenges that small and medium-sized Finnish biotechnology companies have encountered during the different stages of this field's emergence as an industry. It comprises five studies (Appendices 1-5), each of which examines a clearly demarcated challenge to the companies' growth as businesses.

To provide a foundation for understanding the challenges that these mostly university research –based companies experience, the first study analyzes the general difficulties of university-industry technology transfer. To this end, the study identifies the role and added value of the organizational practices that university technology transfer offices use to mitigate these difficulties.

The second study builds on the findings of the first by asking whether the entrepreneurial biotechnology companies that originated in university research differ from biotechnology companies from other origins and whether they have been plagued by certain challenges more severely.

Expanding on the findings of the second, the third study is an in-depth analysis of the difficulties of attracting external financing. In particular, it explores to what extent information asymmetries between biotechnology companies and financial markets can explain these difficulties and asks whether potential financers assess companies' intellectual capital endowments to decrease these asymmetries.

The fourth study examines the role of government grants and government risk financing instruments in alleviating the problems related to the market failure of private funding.

The fifth study concludes the dissertation by going beyond a company-level perspective on Finnish biotechnology and analyzing the industry's geographic agglomeration and specialization patterns. The objective of the study is to establish whether the patterns are economically justified in light of geographical economics.

This dissertation's aims and research questions are driven by specific phenomena. Thus, the contributions of the dissertation are largely *empirical* and aim to obtain new and well-structured insights into topical real-world issues. That said, this dissertation also contributes to existing *theory* through its empirical applications.

One strength of the empirical approach is that it produces results that open new, interconnected avenues for subsequent research. This approach facilitates a continuous and logical structure for the diverse research themes in the dissertation. For an adequate analysis of these themes, the approach further demands a study- and theme-specific use of multi-disciplinary literature. The relevant literatures include studies on academic entrepreneurship, knowledge management, corporate finance, economics of geography, organization theory, and technology transfer. Studies 1, 3, and 4 integrate several of these fields to grasp the underlying aspects of their target phenomena.

Along with multi-disciplinarity, a variety of analytical tools were necessary to study the given phenomena and related research questions. This multi-methodological dissertation includes studies using qualitative, inductive methodology (Study 1) and quantitative, statistical methodology, including regression and principal component analyses (Studies 2 through 5).

The multi-thematic, multi-disciplinary, and multi-methodological approach facilitates new empirical insights on the studied phenomena, but it also renders the positioning of the dissertation in any single field challenging.

Fortunately, from a positioning perspective, the technology-based industrial emergence literature is inherently diverse and multi-disciplinary in nature, allowing for inquiries from various specific disciplines. Thus, throughout this introduction, the five studies constituting the dissertation are positioned in the relevant bodies of knowledge for their specific disciplines.

The introduction is structured as follows. The next section reviews the specific research questions of each of the five studies separately, positions them in the existing literature, and establishes the thematic flow of the dissertation by illustrating the links between the individual research questions. Section 3 summarizes the key results and contributions of each study and outlines their implications for research, policy and practice. Section 4 concludes by reviewing the dissertation's more general contributions, discussing its limitations and suggesting avenues for future research.

2 Research questions and the thematic flow of the dissertation

This section introduces the specific research questions of the five studies in the dissertation. In doing so, it establishes the motivations for the questions by positioning them in the existing literature. It also establishes the thematic flow of the dissertation by connecting the questions and their respective levels of analysis in a coherent framework.

2.1 Research questions

Research question 1:

What are the mechanisms and value added of organizational practices that university technology transfer offices use to facilitate university-industry technology transfer?

Biotechnology is a knowledge-intensive business that often originates in academic research. Thus, it can be exposed to challenges that are characteristic of university-industry technology transfer in general. To understand these challenges and their detrimental impact on knowledge-intensive businesses, Study 1 examines the role of organizational practices that the university technology transfer offices (TTO) at seven prominent US universities use to address these challenges.

Many of the challenges are caused by gaps, barriers, inhibitors, structural holes (Burt, 1992), or other boundaries that inhibit the efficient flow of technology. These barriers include differences in incentive structures; objectives and cultures among scientists, TTOs, and companies (Lee, 1996; Link and Siegel, 2003; Siegel, Waldman and Link, 2003; Siegel et al., 2004; Siegel and Phan, 2005); information asymmetries between actors (Jensen and Thursby, 2001); uncertainty regarding the technological and commercial potential of inventions (Macho-Stadler, Pérez-Castrillo and Veugelers, 2007); and variation in universities' research missions (Rahm, Bozeman and Crow, 1988).

Research has suggested, then, that TTOs can mitigate these gaps and barriers. Much of the existing research on the role of TTOs in university-industry technology transfer (UITT) focuses on estimating the so-called TTO production function. These studies estimate identified inputs to UITT against a variety of

performance measures in the TTO context (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Thursby and Kemp, 2002). However, these approaches typically fail to provide direct evidence and an explicit, in-depth understanding of the inner workings of the production function. Previous studies have neglected the questions of why certain practices are important and how they are generated and have instead focused on finding statistical explanatory power between a set of variables and TTO performance.

More recent contributions to the literature have taken up the challenge of examining the role of organizational practices in TTO performance (e.g., Siegel, Waldman, and Link, 2003; Siegel et al., 2004; Sorensen and Chambers, 2008; Swamidass and Vulasa, 2009) and taken the first steps toward generating qualitative explanations of the production function. However, even these attempts have made few conceptual connections between resources and practices and their role in adding value to UITT. The qualitative link between inputs and outputs (i.e., resources, capabilities, and effectiveness) remains relatively unclear because research to date has not directly addressed TTO practices that transform inputs into outputs. It has been claimed that there is evidence that certain resources are vital to performance, but little has been said about the reasoning underlying this claim (i.e., how a particular resource enables a practice and thereby affects a certain aspect of value generation).

Thus, the first study aims to illuminate the TTO production function to (i) identify and characterize key organizational practices and demonstrate their centrality in the role of TTOs in UITT; (ii) show the dynamic interaction of the central resources that underlie those practices; and (iii) show how these practices add value to the UITT process. By providing the reasoning underlying the process, starting with the resources and concluding with the value added, this study explains why the lack or mismanagement of certain key resources can be detrimental to UITT and identifies the processes it might obstruct, and what kind of value might be foregone.

In the context of this dissertation, the findings lay a foundation to understand the general challenges related to the commercialization of academic research. Commercial biotechnology in Finland largely originates in such research; thus, these challenges are expected to have an impact on the commercial development of Finnish biotechnology companies.

Research question 2:

Given that the commercialization of academic research faces various challenges, what are the inhibitors of growth specific to academic entrepreneurship in biotechnology?

The first study demonstrates that UITT faces various challenges and benefits from institutional structures, such as TTOs and their organizational practices, in overcoming them. The second study builds on these findings by asking whether the challenges have an impact on the business start-ups that originate in academic research.

Specifically, the study empirically compares small- and medium-sized Finnish biotechnology companies that were founded by the academic researchers who performed the underlying research with other biotechnology companies. This study contributes to the existing literature by empirically identifying the strengths and weaknesses of academic biotechnology spin-offs and the factors that either promote or inhibit their success from an entrepreneurial perspective. The implicit assumption is that, due to the challenges specific to UITT, academic spin-offs differ in many ways from the spin-offs of large corporations and other firms that did not originate in academia.

In addition to its phenomenon-driven justification (i.e., the majority of biotechnology start-ups in Finland have an academic background), the study aims to fill gaps in the literature at the time of writing. The first comprehensive studies of the Finnish biotech sector are provided by Halme (1994), Halme (1996), Ahola and Kuisma (1998) and Tulkki, Järvensivu and Lyytinen (2001). All three studies use a descriptive, firm-level approach to explore a given stage of the Finnish biotechnology sector. Hermans and Luukkonen (2002) present quantitative, survey-based results on the evolution of the sector in terms of a set of indicators such as revenues and R&D-expenditures. Hermans and Tahvanainen (2002) is a descriptive study of the capital and ownership structure of Finnish biotech SMEs, and Tahvanainen (2003) examines this structure more in-depth through theoretical frameworks. Hermans (2003) focuses on the capital structure and other characteristics of the business operations of biopharmaceuticals in Finland, and Hermans and Kauranen (2003) relate the growth expectations of Finnish biotech companies to their intellectual capital.

Although the above studies provide important insights into Finnish biotechnology, none of them differentiates between entrepreneurial academic start-ups and other types of biotechnology businesses or focuses on identifying their growth challenges. The latter also holds true for the majority of the

relevant international literature of the time (see, e.g., Shan, Walker and Kogut, 1994, Powell, 1998, Zucker, Darby and Brewer, 1998, and Smith and Fleck, 1988). Wells, Coady and Inge (2003) are an exception in that they identify the reasons for Australia's relatively poor performance in commercializing biotechnology. However, even they do not distinguish between academic spin-offs and other types of biotechnology companies.

Since Study 2 was published in 2004, other relevant international studies have emerged. For example, Colyvas and Powell (2007) use an in-depth case study method to study the institutionalization of academic entrepreneurship in the life sciences and identify the factors that lead to its cultural acceptance in academia. Toole and Czarnitzki (2007) show how governmental entrepreneurship programs help biotechnology start-ups to improve their performance. Both examples build on the existing literature by assuming a set of identified challenges in the life-cycles of academic and entrepreneurial biotechnology companies.

This study's research question is exploratory in nature. Given the topic of this dissertation (i.e., the identification and analysis of industry growth problems in Finnish biotechnology), this exploratory approach is justified by the need to obtain a first detailed depiction of the empirical phenomenon under study and to map potential growth problems for further investigation in the subsequent studies.

Research question 3:

Having established that financing is of special concern to a university-based biotechnology company in Finland, can the Intellectual Capital structure of such a company explain its financing behavior and serve to alleviate the funding problems related to information asymmetries?

Study 2 finds that, among other problems, academic biotechnology SMEs suffer from difficulties attracting financing. Following up on these results, Study 3 asks whether the technology- and company value-related information asymmetries between biotechnology companies and potential financiers can partially explain these difficulties.

Specifically, Study 3 uses biotechnology companies' intellectual capital endowments to approximate company value and their financial structures to approximate their financing behavior. It then asks whether these two aspects are related. The study employs the conventional pecking order theory as a theoretical backdrop and recent results from empirical research to scrutinize the obtained

results and argues that information asymmetries play a role in explaining the identified relationships.

Study 3 draws on the questions that emerged from the findings of Study 2 and is further motivated by the failure of the financing literature (Myers and Majluf, 1984; Myers, 1984; Harris and Raviv, 1991) to apply the existing insights of knowledge management research. Specifically, financing research does not use the literature on intellectual capital (see, e.g., Sveiby, 1997, Edvinsson and Malone, 1997, and Bontis, 2001) to explore funding behavior when the traditional indicators of firm value are difficult to apply.

Companies in young and knowledge-intensive industries (e.g., biotechnology) with long R&D-cycles are often unable to provide reliable indicators and show certain distinguishing characteristics that make it difficult to assess their value (e.g., lack of revenues, early-stage product development, and non-existent market shares). In these industries, a firm's balance sheet value conveys only limited information about its true value. Even more importantly, intellectual capital, the critical driver of value creation according to the knowledge management literature, is not captured in the balance sheet (Edvinsson & Malone, 1997; Sveiby, 1997; Lev, 2001). Moreover, high R&D intensities lead to a pronounced business risk, which further complicates the reliable assessment of company value because the probability of success in the early stage of operations is relatively uncertain. Nevertheless, when a company succeeds, the returns can more than offset the risks. In global markets, the revenues created by pharmaceutical products, for example, are massive.

The challenge is to evaluate knowledge-intensive businesses without conventional indicators. The knowledge management literature has proposed a solution in which a company's intellectual capital base is its primary source of value and the generator of future sales (Edvinsson & Malone, 1997; Sveiby, 1997). Thus, this indicator might serve as a basis for value assessment. This hypothesis is suitable for knowledge-intensive industries because it measures intangible assets that are in place even in young and small companies that might not have necessarily entered the markets yet. If a company's intellectual capital base is a good proxy measure for its ability to generate value and provide investors with the necessary information to make reasonable investment decisions, it should have an effect on the company's ability to obtain financing.

In one of the few examples of this method, Catasús & Gröjer (2003) have examined this effect on the availability of debt financing. Study 3 expands this type of investigation to take into account a company's capital structure, including retained earnings, capital loans and external equity.

Research question 4:

Can governmental grants and risk financing alleviate funding challenges, and how do these rank in the financial pecking order of biotechnology companies?

Study 3 shows that information asymmetries do aggravate the difficulties that young and knowledge-intensive biotechnology companies face in attracting external funding and that financial markets fail to assess these companies on the basis of their intellectual capital endowments to decrease information asymmetry.

Given that public sector support for high-technology industries is prominent in Finland, Study 4 asks whether the governmental grants and risk financing that Finnish biotechnology companies receive under the Infant Industry Argument (IIA) can alleviate the failure of private financial markets and lessen information asymmetry-related problems. Specifically, the study examines whether these funding instruments also affect the companies that suffer most from information-asymmetry problems (i.e., companies with well-balanced intellectual capital endowments and high expected company values). In parallel with the methodology of Study 3, Study 4 uses financial pecking order theory to identify different types of companies' preference ranking for governmental funding instruments.

This research question is primarily motivated by the need to complement the findings of Study 3 and is thus phenomenon-driven. To reach a satisfactory conclusion on funding hardship in Finnish biotechnology companies, it is necessary to examine the government's role and effectiveness in responding to the failures of the private financial markets, identified in the previous study. In the broader literature, others have also identified the need for this type of analysis. Hall (2002), for instance, empirically identifies under-investment, or a "funding gap" related to R&D-intensive business activities, and therefore calls for "further study of government seed capital and subsidy programs using quasi-experimental methods". Incorporating the role of governmental funding in corporate financing also extends the conventional literature on corporate capital structures (Myers and Majluf, 1984; Myers, 1984; Harris and Raviv, 1991).

Research question 5:

Given the identified challenges, how has Finnish biotechnology developed as an industry, and, more specifically, can the agglomeration and specialization structure of this industry be justified in light of GE theory?

Having established the various challenges that biotechnology companies in Finland face on the company level, the dissertation concludes with Study 5, which asks how these challenges have affected the regional development of Finnish biotechnology as an industry. Specifically, the study empirically investigates whether the existing theory in Geographical Economics (GE) can provide a rationale for the industry's controversial structure (i.e., its spatial agglomeration and regional specialization patterns).

In the context of the dissertation, this study aims to deepen the understanding of the industry's growth challenges by broadening the analytical focus and examining Finnish biotechnology on the industry level. All of the previously reviewed studies deal with challenges on the company level.

In addition to this phenomenon-driven motivation, this study attempts to fill a gap in the literature that it uses as a theoretical background. Despite the GE literature's extensive theoretical contributions (e.g., Krugman, 1991, Venables, 1995, Brezis and Krugman, 1997, Duranton and Puga, 2001, Martin and Rogers, 1995, and Monfort and Nicolini, 2000), it suffers from a lack of empirical research. In addition to providing evidence of GE in action, Study 5 builds on the findings of Study 4 and introduces the potential effects of active public technology policy on geographic structures of industries into its analysis. The active public innovation policies that are characteristic of Finland make it possible to analyze their interaction with the studied GE framework.

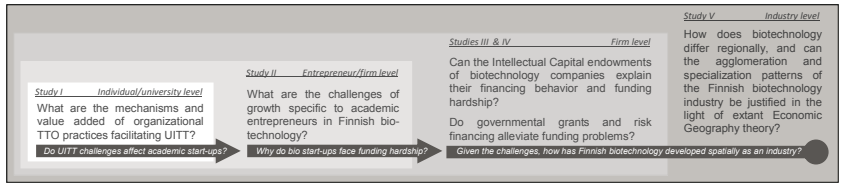
2.2 Thematic flow

As discussed above, this dissertation identifies and examines the challenges that Finnish biotechnology companies encounter at different stages in their life-cycles. Thus, the themes of the studies can be arranged into a quasi-linear flow that loosely conforms to the stages of a given company's life-cycle. The first study begins the analysis by examining the challenges in the transfer of technologies from universities to industry and society, even before the establishment of a company. The second scrutinizes university start-ups and their initial growth inhibitors, and the subsequent two studies analyze well-established companies.

The final study observes the current state of Finnish biotechnology as an established industrial sector.

In addition, this structure is reflected in the ascending levels of analysis used to examine the different stages. Beginning with a study on the university level, the subsequent analyses ascend through the levels of the entrepreneur and the company to conclude the dissertation on the level of the industry. Figure 1 summarizes the above discussion and establishes the thematic flow of the dissertation.

Figure 1 Integrating the levels of analysis and the research questions of the dissertation



3 Study-specific results, contributions, and implications

3.1 Overview

This section summarizes the studies' key results, discusses how they contribute to the literature, and identifies their implications for research, management and policy. As in the previous section, the findings, contributions and implications are discussed separately in their respective contexts because each study contributes to a specific body of literature and addresses a distinct phenomenon within the larger context of this dissertation. As the interconnectedness of the studies has been established above, the connections between the results and contributions will not be covered here.

Figure 2 provides an overview of the results of each of the five studies and summarizes key information for their respective research questions, levels of analysis, study designs, underlying datasets, and contributions to the literature.

3.2 Individual studies

Study 1

Making Sense of the TTO[3] Production Function: University Technology Transfer Offices as Process Catalysts, Knowledge Converters and Impact Amplifiers

Key results

Study 1 is an inductive case study of seven US university technology transfer offices (TTOs) and aims to identify the added value of the organizational practices that TTOs perform to bridge the infamous gap between academia and industry in university technology transfer (UITT). To this end, the study inductively characterizes the various core practices and the respective resources underlying them. The study establishes three central concepts to address the added value that TTOs provide and considers the TTO as (i) a process catalyst, (ii) a knowledge converter, and (iii) an impact amplifier.

[3] Technology transfer office (TTO)

As process catalysts, TTOs lower the threshold of UITT stakeholders to participate in and sustain the process of UITT on both sides of the transfer continuum (i.e., academia and industry).

Figure 2 Overview of the dissertation: Summary of research questions, design, results, and contributions

	Study I	Study II	Study III	Study IV	Study V
Title	Making Sense of the TTO Production Function: University Technology Transfer Offices as Process Catalysts, Knowledge Converters and Impact Amplifiers	Growth Inhibitors of Entrepreneurial Academic Spin-offs: The Case of Finnish Biotechnology	Funding Intellectual- Capital-Abundant Technology Development: Empirical Evidence from the Finnish Biotechnology Business	The Effect of Technology Subsidies on Industry Strategies and Market Structure	Agglomeration and Specialisation Patterns of Finnish Biotechnology - On the Search for an Economic Rationale of a Dispersed Industry Structure
Key question about commercialization of knowledge-based industries	How do universities facilitate in the commercial exploitation of academic research results?	Do university spin-offs differ from other types of biotechnology companies?	How does the information asymmetry regarding the true value of biotechnology companies affect their ability to attract financing?	Can governmental funding instruments alleviate challenges related to financing in biotechnology?	Given the identified challenges, how has Finnish biotechnology developed as an industry?
Specific research question	What are the mechanisms and value added of organizational TTO practices in facilitating UITT?	What are the challenges of growth specific to academic entrepreneurs?	Can the Intellectual Capital structure of a biotechnology company explain its financing behavior?	How do governmental grants and risk financing rank in the financial pecking order of biotechnology companies?	Can the agglomeration and specialization structure of the Finnish biotechnology industry be justified in the light of EG theory?
Level of analysis	Researcher / University (TTO)	Entrepreneur / Firm	Firm	Firm	Industry (region)
Research design	Qualitative, inductive, theory-informing	Quantitative, empirical, exploratory, cross-sectional, regressions	Quantitative, empirical, cross-sectional, PCA and regressions	Quantitative, empirical, cross-sectional, PCA and regressions	Quantitative, empirical, cross-sectional, PCA
Data source	In-depth interviews (hand-collected), AUTM STATT database, university web-sites (hand-collected)	Survey (hand-collected), National Board of Patents and Registration of Finland databases	Survey (hand-collected), National Board of Patents and Registration of Finland databases	Survey (hand-collected), National Board of Patents and Registration of Finland databases	Survey (hand-collected), National Board of Patents and Registration of Finland databases
Key results and insights	TTOs function as (i) process catalysts lowering the thresholds of UITT stakeholders to engage in the transfer of technology and maintaining its sustainability, (ii) knowledge converters enabling congruence between university technology and market needs, and (iii) impact amplifiers alleviating problems related to opportunistic incentive structures of UITT stakeholders and maximizing societal impact. Certain resources and practices are vital to these functions.	Academic spin-offs lack market-orientation and commercial skills, the traditional perception of the academia's detached role within society hinders the recruitment of skilled labour, and Finland's equity markets are underdeveloped with new seed capital being next to unavailable to young spin-offs, as private and foreign venture capitalists invest primarily in companies being already very close to the markets.	Biotechnology firms with a well-balanced IC base finance their operations to a larger extent with retained earnings and debt while companies with less well-balanced IC bases revert to other sources of financing such as external equity. Thus, financial markets seem to ignore the possibility to assess intangibles to overcome information asymmetries. The findings are in line with the conventional pecking order theory of financing.	Government funding affects the financial pecking order and corporate strategy: (i) government subsidies and loans without stringent payback conditions are the most preferred instrument. (ii) Government risk financing is the least preferred instument and considered only by companies with non-market oriented, research-based strategies due to principal-agent problems and risks related to changing political climates.	Results provide evidence of a theory-based rationale that gives only weak justification for the industry's structure. 72 % of the variance in the sample can be explained. The rationale reveals several challenges different regions have to overcome to keep on the track of sustainable economic development in the future. Peripheries need more regional collaboration, and centers are not innovative enough to offset agglomeration costs.
Contributions *Existing research*	TTO production function (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Thursby and Kemp, 2002; Siegel, Waldman and Link, 2003) TTO practices (Siegel et al., 2004; Sorensen and Chambers, 2008)	State of the Finnish biotechnology industry (Halme, 1996; Ahola and Kuisma, 1998; Hermans and Kauranen, 2003; Hermans, Kulvik and Tahvanainen, 2006) Academic entrepreneurship in biotechnology (Powell, 1998; Zucker, Darby and Brewer, 1998; Wells, Coady and Inge, 2003)	Knowledge management and Intellectual Capital (Edvinsson & Malone, 1997; Sveiby, 1997; Lev, 2001; Bontis, 2001) Financial pecking order (Myers, 1984; Myers and Majluf, 1984) Relating Intellectual capital and financial structures (Catasús & Gröjer, 2003)	Infant Industry Argument (List, 1841/1844; List, 1856; Marshall, 1920) Financial pecking order (Myers, 1984; Myers and Majluf, 1984) Relating Intellectual capital and financial structures (Catasús & Gröjer, 2003; Tahvanainen and Hermans, 2005 (study 3)).	Geographical economics (Krugman, 1991, Venables, 1995, Brezis and Krugman, 1997, Duranton and Puga, 2001, Martin and Rogers, 1995, and Monfort and Nicolini, 2000)
Contribution of study	Establishment of an inductive framework relating TTO resources to TTO practices, and practices to the value-added of TTOs. The framework thereby provides a qualitative intuition for the so far rather opaque TTO production function.	Exploratory description of Finnish academic spin-offs helps in identifying new aspects that require further analysis and are theoretically underdeveloped. The study's contribution is valuable in the context of this dissertation, as the remaining studies comprising it explore the avenues pointed at by the results of study 2.	Expansion of the examination of IC and financial structures to comprise the whole capital structure including retained earnings, capital loans and external equity. Application of the capital structure theory to explain found relationships, and integration of two separate strands of literature to provide new understanding on the phenomenon at hand.	Extension of the conventional financial pecking order model to explicitly encompass governmental funding sources. The extension enables the model's application in empirical environments characterized by active innovation policies.	Application of Geographical Economics as a tool for evaluating industry in terms of its geographical distribution and its justification. The literature provides a framework suggesting a set of criteria for the successful development of different types of regions that empirical settings can be tested against.

Various factors cause these thresholds, including lack of experience with commercialization, cultural barriers, IPR issues, misinformation, prejudices and economic, professional and other kinds of uncertainty.

TTOs lower thresholds by educating researchers, giving them guidance in commercialization, settling disputes, solving problems that inventors cannot solve, serving as a nexus of contacts, and, depending on university policy, designing business plans, attracting funding, and assembling management teams for university start-ups.

As knowledge converters, TTOs open and maintain a bi-directional and iterative feedback loop between the academic and commercial universes. They gather technology-specific responses from industry through searches, marketing and other related outreach practices (e.g., conventions, business plan competitions) and bring them to the academic inventor, who can incorporate these insights into an invention to increase its commercial value. Changes to the invention are then presented to the industry for iteration. Through search practices and feedback looping, the TTO facilitates congruence between the features of scientific discoveries and market needs (i.e., customer preferences, profit requirements and business models). The tangible value that these practices add is related to the TTO's ability to convert the essence of an invention's technical features and the respective industry feedback into concepts and propositions that can be appropriated by both industry and the academic inventor.

As an impact amplifier, the TTO mitigates the detrimental effects of diverse UITT stakeholders' opportunistic incentive structures on the scale, scope and speed of technology transfer. It thus amplifies the impact of a given technology on society and the environment. If a system of opportunistic actors determines an equilibrium outcome alone, their different objectives for UITT might converge on suboptimal solutions and limit the diffusion of technology and its societal impact. For instance, licenses might be granted to inefficiently small parts of technology; immaterial property rights could be licensed to patent trolls, which use patents only to strategically block competition; infringements might be prosecuted without consideration for the long-term detrimental effects to the university; licenses might be structured in ways that impede further academic research on the underlying technology; exclusive licenses might limit the scope of technology use; and improvements to existing technologies might be obstructed if licensing contracts include *ex post* additions to licensed technologies.

To prevent opportunistic behavior, the TTOs in the sample apply a set of principles that favor breadth of use over purely monetary objectives when they

manage stakeholder expectations, consider potential licensees, structure licensing deals, and monitor infringements.

In addition to establishing the TTO as a process catalyst, a knowledge converter, and an impact amplifier, this study shows how the scrutinized TTOs manage key resources, particularly Intellectual Capital (i.e., human, structural, and relational capital), to generate organizational practices that target the three constructs of value added. Perhaps the most crucial of the identified resources is the individual licensing officer's combination of technical expertise and industrial experience. This combination of abilities from both academia and industry is a prerequisite for most of the value adding practices analyzed in the study. However, the study finds that this human capital must be supported by identified, practice-specific structural and relational capital.

Research implications

In the literature, the existing approaches to TTO practices and the role of various resources in them typically fail to provide an in-depth portrayal of the TTO production function (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Thursby and Kemp, 2002; Siegel, Waldman, and Link, 2003; Siegel et al., 2004; Sorensen and Chambers, 2008; Swamidass and Vulasa, 2009). Studies often claim that certain resources are vital to TTO performance, but they do not provide a qualitative intuition to support the relationships (i.e., how a resource facilitates the generation of a practice and thereby affects value generation).

To provide such an intuition, Study 1 (i) inductively identifies central TTO resources and explains how their dynamic interaction facilitates the generation of key organizational practices; (ii) identifies and characterizes those practices; and (iii) shows how these practices add value to the UITT process. The intuition explains why the lack or mismanagement of certain key resources can be detrimental to UITT and identifies the processes it might obstruct and what kind of value might be foregone.

The study further contributes to the empirical gaps in the literature on Intellectual Capital (IC) (e.g., Sveiby, 1997, Edvinsson and Malone, 1997, and Bontis, 2001) by qualitatively analyzing the interaction of IC components in empirical cases. The study shows that the categorization of resources in the Value Platform Model of IC captures resources that are difficult to measure and link to organizational practices. This framework, which has been the subject of previous theoretical debates, is shown to be a suitable approach for empirical

research. However, the study emphasizes that this application is only feasible under considerable context specificity.

Because this study aimed to establish a conceptual framework to identify and contextualize the value adding TTO practices of a small set of experienced offices, it could not incorporate more rigorous empirical testing. Thus, there is a clear need to follow up Study 1 with a survey of a larger sample of TTOs to verify its conclusions regarding the role of TTOs and their practices in UITT and, most importantly, to explore how widespread such practices are among TTOs. In a large-scale setting, one could also test whether these practices have a statistically significant impact on UITT outcomes. Another fruitful approach would be to compare and contrast the variation in practices to provide greater insight into the challenges of the UITT process and the range of TTO practices. These endeavors would benefit from participant observer designs, such as Owen-Smith's (2005), which shed light on the deeper organizational and institutional antecedents of the concepts and resources identified in Study 1. However, this study does not analyze these antecedents due to its survey-based, self-report approach to data collection.

Managerial implications

The study shows how the three components of intellectual capital are managed to generate value-adding practices and thus implicitly presents a model of TTO management. The basic principles of this model are also applicable to TTOs in other contexts. Although specific practices and functions may depend on local, regional, or national contexts, the governing principles implied by this case study are universal. These principles include employing interdisciplinary licensing officers who have both technical expertise and industry experience, abandoning purely profit-maximizing objectives, and focusing on serving the faculty as a valuable customer and resource.

Policy implications

Regarding university policies, the study establishes that the transfer of technologies from university laboratories to industrial or societal uses faces a variety of obstacles, such as the opportunistic incentive structures of UITT participants, cultural differences between academia and industry, and a lack of business-related skills and perspective on the part of academic inventors. The study argues that overcoming these obstacles and designing an environment conducive to UITT

is of special importance because universities might benefit from the societal impact of their technologies (not necessarily the profits thereof) as an indication of high-quality research and education.

Therefore, universities that aim to compete globally for top faculty and students and to establish an international reputation should design policies to enhance their technology transfer activities. TTOs might be an appropriate and necessary mechanism to facilitate the transfer and should therefore be integrated into university policy. In turn, the role of TTOs should be defined in a network of other public and private actors who are active in university technology transfer. UITT strategies should be designed that account for universities' strengths and empower TTOs with the autonomy to interact flexibly with external UITT stakeholders. Most importantly, these strategies should provide TTOs with the resources to recruit the necessary skillsets for effective operation.

Finland's revised Universities Act (2009) and University Inventions Act (2007) made societal impact a mission for Finnish universities. Thus, the responsibility regarding the provision of appropriate resources for the transfer of university technologies to societal use do not rest with the universities alone but is a matter that could be directly addressed by national innovation policies.

Study 2

Growth Inhibitors of Entrepreneurial Academic Spin-offs: The Case of Finnish Biotechnology

Key results

This study compares Finnish biotechnology SMEs that were founded by the academic researchers who performed the original research for the companies with biotechnology companies of other origins.

The results show that Finnish entrepreneurial academic spin-offs are at a relative disadvantage compared to other types of biotechnology SMEs and face major impediments to growth:

(i) They face more initial financial difficulties. On one hand, Finland's equity markets are underdeveloped, and new seed capital is rarely available because private and foreign venture capitalists invest primarily in the companies that are close to the markets.

(ii) However, the primary reason is that they lack the strategic business sense and skills necessary to transform research into a thriving business through collaboration and a market-oriented approach.

(iii) They are also handicapped in attracting skilled people, not least due the traditional perception of academia's detachment from society and the cultural and economic risks individuals take when they leave promising academic careers for business ventures.

Probably the most critical challenge is to shift companies' focus from a technology-oriented approach to a more open and market-oriented one, in which technologies are evaluated less in terms of technological prowess and primarily in terms of their market potential.

Research implications

The contributions of Study 2 are more practical than theoretical. This exploratory study describes, in detail, the challenges that academic entrepreneurs in the field of biotechnology encounter in different phases of business development. The literature often focuses on specific aspects of academic entrepreneurship for more in-depth theoretical formulations (e.g., networking: Powell, 1998; or the role of star scientists in evoking local economic activity: Zucker, Darby, and Brewer, 1998). However, an exploratory and comprehensive empirical description of reality, which this study aims to provide, helps to identify new issues for in-depth theoretical analysis. This study's contribution is especially valuable in the specific context of this dissertation because the following studies explore the avenues for further research opened by the results of Study 2.

This study opens diverse avenues for future research. Firstly, research on other emerging biotechnology clusters is necessary to clarify the influence of national innovation systems, cultural environments and other external country-specific factors on academic entrepreneurship in biotechnology. Such studies might draw comparisons between countries and between different industrial sectors. Secondly, research on the viability of alternative, revenue-creating business models for biotechnology ventures would be of great value to the discussion on commercializing research because, at present, financial markets seem reluctant to invest in research-intensive businesses. Furthermore, research might explore how biotechnology start-ups could use partnerships to access the resources needed in particular growth phases. Thirdly, as biotechnology is a knowledge-intensive business, future studies might apply the knowledge management literature to the economics of biotechnology as an innovative approach that accounts for the nature of biotechnology. Finally, this study identified constraints on company growth due to flaws in the economic environment and in the entrepreneurs and companies. Future efforts could be directed at revealing the dynamic links between these

two areas. For instance, would the availability of financing improve if companies took a more market-oriented approach to business development? In turn, if more financing were available, would the companies face fewer problems in attracting skilled labor? From the perspective of industrial emergence, it is necessary to clarify the processes that impact the speed and direction of industrial evolution. Structural equation modeling could be a fruitful approach to discern the simultaneous, multi-directional relationships between the phenomena under study.

Managerial implications

The transition from a technology-driven organization to a business-oriented one implies managerial challenges that need to be addressed on the firm level. Perhaps the most urgent issue is the apparent deficit in business skills. This problem could be addressed with the recruitment of people who have experience in leading and managing R&D-intensive ventures. However, as Finland has a relatively small pool of people with a background in the fields relevant to biotechnology (e.g., pharmaceuticals, diagnostics), it could recruit from established sectors that are comparably R&D- and technology-intensive. In the Finnish case, the strongest candidate is the ICT sector that, led by Nokia, has become one of the three pillars of the economy in the last 20 years. Sitra, a Finnish public organization that provides venture capital, has already reported success stories, according to which former ICT managers have been integrated into biotechnology companies with positive results.

Another critical challenge is the development of parallel business models that help a company survive the financial draught in the early stages of business. A company's founder usually has a clear long-term vision, but achieving this vision, especially in the biotechnology business, takes a long time and significant resources. It might also require exploring alternative business models that utilize a company's existing assets to provide constant revenues to keep the company afloat in its early stages. These approaches require unconventional thinking and patience, but they are necessary in times of insufficient financing. Companies might offer contract research or other generic research services or act as a distributor; these possibilities are just a few of many options for parallel business models.

Finally, the poor inter-organizational collaboration of academic spin-offs is a threat to their competitiveness. A well-organized and managed network of partners might result in synergy effects and more efficient cost structures. It might also improve a company's ability to seize emerging opportunities because

reaction times are faster and joint resources can be leveraged efficiently. Furthermore, R&D efforts benefit from collaboration because combining knowledge from multiple sources can lead to innovative ideas to problems that could not be solved in isolation.

Policy implications

The identified impediments to business growth do not arise exclusively from academic spin-offs' inabilities and lack of skills. The traditional perception of academia's role in society, high income taxes, and an underdeveloped equity market in Finland contribute unfavorably to the conditions in which academic spin-offs operate. Companies cannot address these factors, which should be discussed on a national level. Currently, the Finnish biotech sector is under pressure to show evidence of its success to justify past and future public investments into the sector. Instead of being impatient, it may be more beneficial to find solutions that address the structural and cultural issues discussed above. These are issues that only the public as a whole can change.

Since the publication of this study in 2004, major changes have been implemented to address some of these weaknesses in the Finnish innovation system. The Universities Act (2009) was revised to give universities more flexibility to support their faculties' commercial pursuits, and the University Inventions Act (2007) aimed to clarify the regulation of immaterial property right regimes in university research. Furthermore, the Strategic Centres for Science, Technology and Innovation (SHOKs) were created to bring academia and industry into closer collaboration. As Tahvanainen (2009) shows, however, these changes have also created a number of new challenges.

Study 3

Funding Intellectual-Capital-Abundant Technology Development: Empirical Evidence from the Finnish Biotechnology Business

Key results

Study 3 takes an interdisciplinary approach to investigate whether and how a company's intellectual capital (IC) is related to its financial structure. The results provide evidence for the existence of such a relationship.

While companies with well-balanced IC bases have relatively high retained earnings and debt ratios, companies with only structural capital have relatively

high capital loan ratios. Companies with IC bases that consist of human and relational capital only show relatively high external equity ratios.

The findings are analyzed to clarify the role of information asymmetries in the identified relationships. The study offers an interpretation of the findings that favors the financial pecking order framework of Myers (1984) and Myers and Majluf (1984).

It could be argued that the results support the pecking order framework in so far as the firms of high value with a well-balanced IC base reject external equity financing and display higher retained earnings and debt ratios than the other types of firms. According to the pecking order hypothesis, this behavior aims to avoid the undervaluation of market-based equity. Furthermore, firms of allegedly lower value (i.e., with a less well-balanced IC structure) use relatively more external equity financing because their equity is not as severely undervalued. Firms with a single IC component (in this case, structural capital related to research intensity and innovation) prefer capital loans as a source of financing more than other firms do.

If the pecking order hypothesis is the driving force behind the findings, then they imply the existence of strong information asymmetries between the sample firms and financial markets. Therefore, even a strong IC base would not positively affect the availability of financing. If the IC base of companies were observable and revealed a company's true value by nullifying information asymmetries, the researcher would be unable to find evidence of a pecking order-like behavior because the companies' equity would always be priced fairly on the markets. Thus, firms would be indifferent to the choice between financing sources.

Research implications

This study was able to show, for the first time, that companies with different intellectual capital bases also exhibit different capital structures. Prior to this study, only Catasús and Gröjer (2003) examined this effect on the availability of debt financing. Study 3 expands the examination to include the whole corporate capital structure, including retained earnings, capital loans and external equity. This study further contributes to the literature by applying conventional capital structure theory to explain the relationships it found. Thus, it integrates two separate strands of literature to shed new light on the studied phenomenon.

Due to a lack of time series data, the study was unable to control for the possible reverse causality of the results. The dynamic development of a company's

IC base and capital structure could be induced by either or both, and the direction of effect might shift over a company's life-cycle. The dynamic interaction between intellectual capital and capital structures is an area for further research that has the potential to shed light on corporate financial behavior from the perspective of knowledge management. The introduction of new interdisciplinary ideas into this field is welcome because the related discussion has followed rigid trajectories for two decades and made only incremental additions to the existing frameworks (for a comprehensive review of capital structure theories and their development over time see, e.g., Harris and Raviv, 1991). The need to use time series data has to be addressed if such research is conducted.

Managerial implications

The findings disprove the study's initial assumption about investors' active use of knowledge management metrics. Either (a) intangible assets are unobservable or (b) investors do not apply information beyond the areas of leadership, management, and tangible assets when they evaluate companies, as Hussi (2004) suggests. The former is not defendable because comprehensive knowledge management metrics are retrievable from target companies in conjunction with the customary Due Diligence analysis prior to investment. Thus, the latter is the more credible explanation and constitutes a challenge for those aiming to promote knowledge management beyond the boundaries of scientific discussion and to encourage its field applications.

Thus, the study suggests that IC metrics should be applied in investment decisions as a comparative measure between an individual firm and the industry. It seems that IC metrics could be a basis on which to evaluate promising investment decisions and, from an investor's perspective, companies' strategic development.

Policy implications

The results provide empirical evidence of a market failure induced by information asymmetries in the Finnish financial market for high-technology businesses. The study argues that these asymmetries exist because investors neglect to assess the value of companies based on their IC endowments. To address this problem and to introduce more transparency into the markets, the government could adopt more rigorous and standardized regulations for companies' reports of their intellectual capital endowments in their financial statements. Currently, IC

reporting is voluntary (e.g., R&D costs do not have to be disclosed but may be activated as assets), and there are no coherent standards. Standardized reporting could have a positive impact on society by reducing information asymmetries and enhancing market efficiency.

A vast array of existing IC metrics could be employed to monitor and assess companies' IC in any given industry sector. The high-technology sectors would benefit from such regulations the most because they frequently lack tangible assets but are rich in IC.

Study 4

The Effect of Technology Subsidies on Industry Strategies and Market Structure

Key results

Study 4 aims to examine whether the governmental grants and risk funding that Finnish biotechnology companies have received under the Infant Industry Argument (IIA) can address the funding difficulties identified in the previous studies. Specifically, the study analyzes whether these funding instruments have affected the companies that suffer most from the information asymmetry-induced failure of the financial market: companies with a strong market orientation and, thus, the most commercial potential.

Like Study 3, Study 4 uses the financial pecking order framework to establish the order of preference for different funding sources and different types of companies separately. The findings indicate that only certain governmental funding instruments offset the low incentives for high-potential companies to utilize external funding. These instruments include free government subsidies, grants and loans without stringent repayment conditions. All firm types, including those with a strong market orientation, seem to prefer these financial instruments, even over internal funding sources, which the pecking order hypothesis ranks highest.

The study suggests an intuition to explain this finding. If the government offers more flexible financing terms than those applied by the financial market, a company's management might prefer government financing to minimize the effort and risks of obtaining and repaying market-based sources. This intuition is particularly true when loans and subsidies do not require repayment should the projects default. In these cases, governmental grants, subsidies and loans are virtually risk-free sources of funding. While the government absorbs the risk for

the companies, they can strive for higher profits by developing their products into later stages than initially planned or taking on more ambitious projects with higher default risks. Subsidies, grant, or loan-based government funding thus go beyond the conventional pecking order framework to become the preferred choice for all company types.

In light of this study's results, governmental risk equity fares much worse. Accepting governmental risk funding and, thus, surrendering a share of company ownership to a government venture capital organization seems to be the last resort for most companies. It only seems to be a relevant option for companies with non-market oriented, research-centered strategies that, it is argued, have less commercial potential than their market-oriented competitors. However, even for these companies, governmental risk financing is the least preferred option in the financial pecking order.

It might be argued that non-market oriented companies cannot attract private equity investments due to bleak commercial prospects and therefore revert to governmental equity sources. Market-oriented companies, in turn, reject such instruments because they have access to the private equity market.

Again, the study proposes a rationale to explain its result. Government financing organizations that specialize in venture capital financing might face an inherent principal-agent problem. Governmental venture capitalists are, by definition, not proper venture capital entrepreneurs because they invest taxpayers' resources and do not face the threat of operational default in the case of investment failure. Thus, they are virtually free of downside risks. Moreover, the upside gains from successful investments are not reflected in the investment managers' personal wealth because civil servants in Finland do not receive performance-based compensation. Consequently, government venture capitalists do not have explicit incentives to pursue results that are in the best interests of the owner of an investee company.

A second problem is related to the political principles of a government venture capital organization. Even if a government venture capitalist faced the same funding conditions as his private counterparts, there might be an additional risk of arbitrary decision-making due to the frequently changing political climates that determine the venture capitalist's agenda.

Both the principal-agent problem and political risk might contribute to this study's finding that government equity financing is less preferable and more expensive than equity financing from private venture capitalists. For the same reasons, a large injection of governmental venture capital might have a negative

signaling effect on subsequent rounds of financing and further increase the difficulties of accessing private equity markets.

Research implications

Gompers and Lerner (2010) state that, despite an increasing amount of academic interest in the role of equity financing in the growth of entrepreneurial companies, there are several gaps in the research that are particularly relevant for policymakers. Study 4 contributes to the literature on corporate capital structures and the effects of information asymmetries on them (Myers and Majluf, 1984; Myers, 1984; Harris and Raviv, 1991) by extending the financial pecking order model to include governmental funding sources. In the Finnish context, this extension is needed to incorporate the strong role of public innovation policy instruments. For example, with the inclusion of governmental funding sources, the model can be applied to empirical environments characterized by the active innovation policies that are typical of Scandinavian countries. Furthermore, it is particularly suitable for investigating industrial sectors that are largely dependent on government subsidies and other forms of public funding.

Management implications

The extended financial pecking order framework has important implications for corporate management.

Companies in knowledge- and technology-intensive sectors, which are subject to strong information asymmetry problems, are well advised to adopt a market-oriented business approach from the beginning of business development and clearly signal this approach to third parties.

As the results of Study 4 show, only market-oriented companies have been able to benefit from private equity markets, and more technology-oriented companies have not. Although private equity remains subject to the challenges related to the information asymmetry-induced undervaluation of equity, market-oriented companies are less likely to be forced to apply for governmental equity funding.

Policy implications

This study's findings indicate that governmental equity investments seem to be predominantly exploited by non-market-oriented companies and, therefore, to promote economically unpromising activities. This finding casts doubt on the efficiency, purposes and justification of such investments.

In some cases, a company's lack of market orientation might be a mere reflection of its early stage of development. Once provided with the support that governmental equity offers, such companies might adopt a more market-oriented approach.

However, attention should be paid to the stringent application and monitoring of funding that requires a transition to a market approach.

Considering the alternatives to governmental risk financing instruments, one might ask whether temporary tax relief could encourage more market-oriented approaches and facilitate access to private equity investments.

Grants, subsidies, and governmental loans without stringent repayment clauses require strong monitoring practices to avoid moral-hazard dilemmas because these instruments are the preferred funding sources in both market- and non-market-oriented companies. These instruments require *ex ante* assessments of proposed funding projects and are thus subject to information asymmetry problems. The IC framework and its related metrics to assess funding projects could help to alleviate these problems, however.

Study 5

Agglomeration and Specialisation Patterns of Finnish Biotechnology. On the Search for an Economic Rationale of a Dispersed Industry Structure

Key results

Study 5 aims to empirically investigate whether the existing theory in Geographical Economics (GE) can provide a rationale for the much-debated structure of Finland's knowledge- and research-intensive biotechnology industry. In addition to providing evidence of GE in action, this study innovatively integrates the potential effects of active public technology policy on the geographic structures of industries.

These findings provide evidence of a theory-based rationale that gives only a weak justification for the industry's structure. This rationale reveals several challenges that different regions have to overcome to maintain sustainable economic development.

Large returns to scale provide a strong incentive for firms to locate in agglomerated centers of economic activity. Companies in agglomerated centers can take advantage of established public infrastructures by cooperating with local universities and increasing their absorptive capacity. However, these young and research-intensive companies fail to connect to the regional network of intra-industry trade, which could provide valuable access to complementary assets in the form of interdisciplinary knowledge provided by partners in the network. Such knowledge, in turn, is the seed for breakthrough innovations, and the lack of innovation is evident in the data. In the long run, a lack of innovation leads agglomerated regions to decline as hotspots of economic activity. Moreover, if companies seek partners mainly outside their regions, the demand links that are necessary for strong local clusters do not emerge, which inhibits the growth of regional economies. Thus, failing to seek regional collaboration can initiate a vicious circle.

Peripheral companies must meet two critical success factors to achieve the necessary efficiencies through economies of scope. These economies, in turn, compensate for the lack of agglomeration-related benefits. Firstly, peripheral companies must specialize in an industry sector. Krugman and Venables (1996) predict that a periphery's economic growth is self-energizing when there is a sufficiently large base of companies that specialize in the same sector in a region. Secondly, for this virtuous circle to emerge, peripheral companies must establish strong intra-industry linkages in the region, which allow companies to benefit from specialized complementary resources. These links also spur demand that attracts new, sector-specific economic activity and accelerates the growth of the specialized region. Although different types of peripheral companies met other success and justification criteria, such as a well-structured public infrastructure in the region, easy access to foreign markets, high innovative capacity and low personnel costs, many of them failed to meet at least one of the two critical success factors mentioned above. They were either not located in a region specialized in their sector, or their links to local industry were insignificant. In the long run, this situation might impact the development of the peripheries negatively because a self-sustaining critical mass of specialized economic activity is difficult to achieve. Peripheries that are too diversified relative to their size do not provide sufficiently large local markets to justify a company's decision to establish a business in that region rather than an agglomerated region with larger markets.

Finally, one of this study's central findings indicates that an emphasis on international ties in R&D collaboration and sales renders the choice of domestic location irrelevant for success. Companies that perform R&D in cooperation

with foreign partners and export a significant share of their products and services generate considerable revenues, employ a large staff and pay high salaries, regardless of their domestic locations. It seems that local demand and intermediate input linkages are not relevant to these companies because they use international infrastructure to access demand and intermediate inputs abroad. Thus, when infrastructure facilitates sufficiently low trade costs, the choice of domestic location becomes irrelevant.

Research implications

As a contribution to existing research, this study shows that the Geographical Economics literature provides an effective tool to evaluate the challenges that industries face in terms of their geographical location. The literature provides a set of criteria to develop different types of regions, against which empirical settings can be tested. So far, there have been few empirical applications in the literature. The study shows that the operationalization of the GE literature is feasible and that it can serve as the basis to draw conclusions about the development of distinct regions.

This study serves as a useful basis for future empirical analyses investigating the questions arising from its results. One promising avenue for research is the question of how public funding and other types of public innovation policy affect companies' location decisions. To improve the efficiency of public policies, we need to understand how geography affects the evolution of industries and what role public sector funding and other mechanisms of policy play in determining it. The results of Study 5 only point to the relevance of these questions, which require a rigorous study using more extensive time-series data. These would preferably include several countries to benchmark results and control for country effects.

Another potential study might relate regional agglomeration and specialization patterns to firm performance indicators. Such a study could test the validity of the implications of Geographical Economics research by asking whether location matters. This type of study has considerable data requirements. The choice of performance measures has to be made carefully because many of the younger research-intensive industries, such as biotechnology, still struggle to be profitable not because of poor performance, but because of their early stage in the long development cycle of products. Moreover, the effects of location on firm performance can be observed more effectively through the changes in an industry's geographic patterns over time, and research on this topic would therefore benefit from using time-series data.

Moreover, future research might investigate the effects of companies' integration into global networks on their location and performance. The initial results of this study suggest a liberating effect because strong international connections do not seem to correlate with location characteristics. However, the result begs the critical question of an alternative explanation: does a firm need to take part in regional, national *and* international networks to access the respective knowledge and capability pools in order to succeed? And, if so, how do these different networks function in unison from a company's perspective?

Finally, future studies might investigate the role of intra-industry links, which are pivotal to many of the claims in the GE literature, by using micro-level proxies for knowledge sharing mechanisms between firms. Reverting to co-patenting data is one promising avenue to link specific companies to each other.

Management implications

It could be argued that the prosperity of companies goes hand-in-hand with the prosperity of their economic region. However, according to the GE literature, companies play a crucial role in establishing the region through intra-industry trade, specialization and knowledge sharing. Thus, companies should pay attention to the above principles and choose their locations according to their resource bases and business development needs.

Choosing a peripheral location helps companies to avoid agglomeration-related costs but requires them (i) to economically interlink; (ii) to choose a location with companies that are active in the relevant sectors for their business development; and thereby (iii) to share their complementary knowledge.

Companies in agglomerated centers will suffer more from agglomeration costs, but they can potentially offset these costs by collaborating with companies across their sector boundaries to access complementary assets and generate innovative and inter-disciplinary products, services and business solutions.

Companies' location choices and contributions to the regional economy facilitate the region's competitive evolution and, in turn, provide benefits to the companies that make up the region's economic structure.

Policy implications

This study establishes that public funding, the primary mechanism of innovation policy in Finland, does not seem to have been coordinated with a regional

strategy that recognizes the unique standards that different *regions* need to meet to achieve sustainable development. Instead, there are weak indications that public funding has focused on supporting certain *industrial sectors*, such as drug development. In the worst case, unfocused public sector funding has provided artificial support to companies that are at odds with their regional environment in terms of specialization and co-operation. This lack of strategy, in turn, might inhibit regional evolution, which depends on a critical mass of companies with complementary and synergetic assets.

The findings call for a revision of current public sector funding practices in the field of biotechnology in Finland. Funding should be channeled through a set of criteria that encourages specialization and close regional co-operation, especially among companies located in peripheries.

A question that remains for future research is whether unfocused public funding has been the major factor in the distortion of incentives for peripheral companies to specialize and co-operate.

In terms of regional innovation policy, this study's finding that location is irrelevant in the presence of strong international collaboration implies that companies' efforts to network internationally are an effective strategy to boost macro-economic development and regional vitality, regardless of company location.

4 General contributions, limitations, and future research

4.1 Contributions to the literature on technology-based industrial emergence

Having established each study's contribution to its respective discipline, this introduction concludes with a brief examination of the dissertation's central contributions to the broader literature on technology-based industrial emergence. In the terms of Dosi's (1985) study, this dissertation mainly focuses on the economic factors affecting the emergence of a technology-based industry, but it also touches on some institutional variables, such as the practices of TTOs.

The contributions are in three domains that are central to the emergence of technology-based and science-based industries, particularly biotechnology: the academia/university domain, the business/company domain, and the government/public policy domain. These domains (and, thereby, the dissertation) broadly cover the early phases of an industry's life-cycle. The industry starts as academic research that transforms into economic activity outside the university through entrepreneurship and other technology transfer mechanisms. Finally, it establishes itself as a nascent industrial sector that is shaped and supported by governmental innovation policy. This partition of domains is grounded in Etzkowitz and Leydesdorff's (1995 and 2000) Triple Helix Model.

In the *university domain*, the dissertation provides new knowledge on bridging the gaps between academia and industry in UITT, which previous studies have found to be riddled with challenges (e.g., Lee, 1996; Jensen and Thursby, 2001; Siegel, Waldman and Link, 2003; Siegel et al., 2004; Siegel and Phan, 2005; Macho-Stadler, Pérez-Castrillo and Veugelers, 2007). The dissertation first establishes that academics are often poor entrepreneurs – mostly due to a lack of business-related skills, experience and vision and a restrictive bond to academic culture, principles and incentives (results of Studies 1 and 2). Thus, the dissertation contributes to understanding the role and benefits of the organizational practices that universities and their TTOs use to overcome such challenges and to put academic inventions to industrial and societal uses. So far, organizational practices in UITT have been understudied and weakly understood (e.g., Siegel et al., 2004; Sorensen and Chambers, 2008; Swamidass and Vulasa, 2009). This dissertation's results highlight that, in technology- and

science-based industries, the successful emergence of economic activity can be affected by mediating activities that universities perform outside and anterior to the business domain. Since public policy often focuses on supporting and developing the business domain, important prerequisites to the emergence of new technology-based industries might easily be neglected. At least in the Finnish context, universities have been left to struggle with the challenges of UITT on their own (Tahvanainen, 2009).

In the *business domain*, the dissertation contributes in a number of ways to knowledge about the challenges that small and medium-sized technology-based companies face in an emerging industry. The dissertation establishes that the companies that originate in academia are at a particular disadvantage, for example, in terms of their abilities to attract financing, recruit skilled labor, and design viable business strategies (Study 2). The existing literature includes many studies on academic entrepreneurship, but most of them focus on the factors contributing to the emergence of academic start-ups (e.g., Zucker, Darby and Brewer, 1998; Klofsten and Jones-Evans, 2000; Powers and McDougall, 2005). Few studies have examined the micro-level challenges of these start-ups once they have been established. Furthermore, some studies have examined the growth challenges of technology-based companies (e.g., Wells, Coady and Inge, 2003) but have neglected to distinguish between academic start-ups and other types of companies.

This dissertation further contributes to the business domain of industrial emergence by shedding light on the possible causes for the growth challenges of technology-based start-ups. In particular, this dissertation examines the role that information asymmetries between companies and financial markets play in preventing firms from attracting financing (Study 3). The main contribution of the dissertation is in the findings that young, high-quality firms suffer the most from information asymmetry-related problems and that the companies have little power to change this issue because investors do not use the appropriate metrics to infer company quality. Technology- and science-based companies that are in the development phase of their proprietary technologies are particularly prone to information asymmetry problems because they often have no tangible evidence of their value. Such evidence (e.g., company revenues and other indicators of economic viability) materializes only after a company's technologies are introduced to the market. In a further contribution to the literature (e.g., Catasús and Gröjer, 2003), this dissertation shows how Intellectual Capital –based indicators could be used to circumvent such difficulties and to infer the quality of emerging companies that have valuable intangible assets that conventional metrics do not capture.

Finally, the dissertation contributes to the *public policy domain* by revealing a number of detrimental effects that policy instruments can have on the emergence of a technology-based industry. Specifically, governmental funding that is strategically weak regarding its geography- and business strategy-related allocation criteria is found to have two disadvantageous externalities. Firstly, due to information-asymmetry-related difficulties in differentiating between high- and low-quality companies, risk capital funding instruments tend to support only the latter companies because high-quality companies do not apply for such funding in the first place (Study 4). Secondly, governmental funding instruments that do not account for the compatibility of their funding recipients' business models, content and networks with regional industry structure tend to artificially support businesses that would otherwise not be viable (Study 5). As a contribution to the general literature, the dissertation reveals a clear need for governmental programs to adopt a strategic focus in the assessment of funding applications and a strategic allocation of funds to companies in specific regions. Regarding contributions to the technology-based industrial emergence literature, the dissertation's findings extend the insights of works such as Himmelberg and Petersen (1994) and Carpenter and Petersen (2002), who examined the role of internal funding in R&D-intensive companies and the financing behavior of companies that suffer from capital market imperfections due to information asymmetry problems.

In summary, this dissertation contributes to the technology-based industry emergence literature by identifying and explaining a set of growth inhibitors that science-based small and medium-sized companies face in the various stages of their sector's emergence and by outlining possible counter-measures in the managerial, policy and research domains.

Although the context of the dissertation is the Finnish biotechnology industry, many of the implications arising from its results could be applied to other contexts and countries. For instance, it could be argued that information asymmetry-related difficulties apply to any emerging high-technology sector where the financial markets are not equipped to assess the market potential of technologies under development. The severity of funding difficulties might depend on the development of the related financial markets and, thus, on the investors' professionalism and methods.

Furthermore, the problems and solutions related to the transfer of technologies from universities to the commercial domain and the establishment of entrepreneurial start-ups are generalizable because academic culture, academics' commercial abilities, and the knowledge-intensive, implicit nature of emerging

technologies can be assumed to share similarities across countries and technologies, even when we account for the existence of contextual differences.

4.2 General limitations

The implications that are discussed above are subject to a number of limitations. For the sake of clarity, all of the limitations will be dealt with here in relation to the specific studies.

Firstly, the data used in Studies 2 through 5 only cover small and medium-sized[4] biotechnology companies. Large biotechnology corporations are excluded from the analyses partly due to inconsistencies in the data. However, the main reason for this omission is that larger and more mature companies resemble those in other sectors in terms of firm characteristics because their businesses are well-established. Thus, the inclusion of large firms might have diluted the findings on the distinctive characteristics of biotechnology businesses. Furthermore, including the few large companies that are active in Finnish biotechnology would have introduced outliers[5] into the analyses and distorted the effects of the largest group of biotechnology companies (i.e., SMEs). The distortion could have rendered the interpretation of the results difficult, at best, and, at worst, largely invalid.

Second, Studies 2 through 5 rely on cross-sectional data, which create the risk of reverse causality in the interpretation of the results. Therefore, the studies make only weak claims about the causality of the studied phenomena, and the discussions and implications of the results are limited to the identified "statistical relationships" between the observed variables. The lack of longitudinal data also made it impossible to examine the temporal dynamics between companies' intangible assets, technological evolution and market success in the presence of the high uncertainty that characterizes the biotechnology business. On the other hand, it should be noted that such designs would have demanded a more dynamic theoretical framework. The knowledge management framework used in this dissertation is an appropriate tool to model the valuation and use of *existing* and *static* intangible assets and their role in value creation.

---

[4] SMEs in this paper are defined according to the EU's official definitions and include firms that meet the following criteria: (i) Number of employees < 250 AND at least one of the following two: (ii) annual turnover < 40 mill. EUR, (iii) balance sheet total < 27 mill. EUR.

[5] A number of large companies in the field of Finnish biotechnology employ more personnel than the entire biotechnology SME sector combined. This imbalance also holds largely true for revenues and other indices of business volume (Hermans, Kulvik and Tahvanainen, 2006).

It should be emphasized that the author recognized the issues related to the cross-sectional nature of the datasets before the research began and took great care to adhere to the resulting limitations. Furthermore, the datasets in this dissertation remain almost unique in the Finnish context and even today, there are no readily available time series data for the Finnish biotechnology industry. Nevertheless, many studies recognize that future research on the topics presented in this dissertation would greatly benefit from approaches based on time series data.

In addition to these general limitations, this dissertation is subject to a number of study-specific limitations. First, the results of Study 1 were obtained using an inductive case-study methodology. Thus, the results are not necessarily applicable to more general contexts, and they are not intended to represent the average university TTO. Rather, this study aimed, using several experienced cases, to understand the TTO's role in the technology transfer process and to clarify how it adds value to this process. Thus, any deductions should be made with an awareness of these limitations.

Additionally, given the focus on seven relatively successful TTOs, this study's results cannot be used to derive normative claims. To make such claims possible, this study would have had to (i) include a number of less successful offices in the sample and (ii) apply comparative techniques to identify the practices that have a decisive impact on TTO performance. The study's focus is on making sense and providing an understanding of the TTO production function and the value added by the underlying organizational practices. However, it does not claim to measure the TTO production function or to compare value added among the sample TTOs.

Additionally, in line with the above caveats, it should be noted that TTOs operate in local environments. Some offices in the sample are embedded in unique environments that are especially conducive to the transfer of technology. Thus, the implications of the results must be applied with care in contexts that are less favorable to UITT.

In addition, it is recognized that UITT is a complex process in which TTOs play only one of many roles. A TTO is not an isolated entity; on the contrary, it adds value to UITT in a systemic environment that includes regional entrepreneurial culture, government interventions, the structure and dynamics of national innovation systems, the availability of risk financing, and other contextual factors. Thus, it is paramount to recognize that Study 1 is an in-depth analysis of one of the central parts of the process and not of the process as a whole.

Furthermore, despite the prevalence of the term "process" in Study 1, it primarily investigates constructs (i.e., intellectual capital, practices, and TTOs as catalysts, converters, and amplifiers). The study does not claim to construct a process flow but uses the framework of UITT to position individual practices and to illustrate their value. The study assumes the existence of the process based on its established treatment in the literature (e.g., Phan and Siegel, 2006).

Finally, the practices reported in Study 1 are not exhaustive, and it could be argued that many other practices arising from the data add value to the process of UITT. Due to space and scope restrictions, and for the sake of coherence, the study only reports the practices that were most prevalent in each of the interviews.

The limitations of Study 2 are mainly related to the technical implementation of the statistical analysis. In contrast to the conventional use of regression analysis as an analytical tool, the present study does not apply it to identify the factors that led to or influenced the establishment of academic spin-offs. Instead, the primary aim is to explore the present, static state of academic biotechnology spin-offs by exploring the firm characteristics represented by the independent variables. Thus, the dependent variable is interpreted as a classification of the firm, which distinguishes it from other types of companies, rather than as an event. In this setting, the study uses regression analysis to reveal affiliations with other firm characteristics and is therefore more explorative than explanatory in nature. The reason for choosing a regression over t-tests, for example, lies in its power to control for the simultaneous effects that independent variables might have on the dependent one.

Another limitation relates to the ratio of the number of cases to the independent variables. Statistical results derived from a small number of cases are usually more unstable than those derived from many cases. In the present study, this rule is true to the extent that the final model is slightly sensitive to the exclusion of some single variables. However, sensitivity analyses showed that the sensitivity is quite small. The exclusion or inclusion of some variables might result in a slight increase of the p-value of the variables in the model but only affect their statistical significance marginally. Throughout the iteration of alternative models, the variables of the final model showed consistent and robust behavior, which justifies their inclusion.

The limitations of Studies 3 and 4 are covered by the above discussion on the cross-sectional nature of the data. In both studies, this limitation made it difficult to show whether a company's capital structure is determined by its IC base (Study 3) and market orientation (Study 4) or whether financing is ac-

companied by constraints that force a company to adapt its IC base and market orientation. Thus, the validity of the former argument relies on the validity of the pecking order hypothesis. The latter argument's position, in turn, can be defended by the intuitive assumption that biotechnology firms, in their infant stage, cannot choose freely between different sources of financing to the extent that knowledge intensive operations require, and that they are usually happy to receive any financing, regardless of its terms. Given that investors, especially venture capitalists, apply strict and direct regulations for investee companies, the receipt of financing from external sources is likely to affect a company's structure and strategy and, thereby, its IC base and market orientation. Both avenues of interpretation are discussed in both studies.

Finally, Study 5 is similarly affected by the limitations of cross-sectional data. The results allow us to observe a detailed temporal snapshot of the industry's regional evolution but do not allow us to pinpoint the precise stage of evolution in each of the various regions separately. Thus, the identified differences between regions could have emerged due to the fact that the study observes regions in different stages of their life-cycles. With sufficient time, the regions might overcome the identified challenges and establish structures that justify their existence from an economic standpoint.

4.3 Avenues for future research

As the study-specific suggestions show, there are many opportunities to extend the findings of this dissertation.

On a more general note, research designs that integrate the various phenomena that have been shown to affect the emergence of technology-based industries would be a valuable contribution to the field. These approaches would allow researchers to discern the relative strength of the effects of factors, which have been treated separately (e.g., public funding schemes, regional industry structure, skill sets of entrepreneurs, and the effectiveness of UITT), on the growth and development of science-based companies. Revealing the systemic interaction and contribution of separate factors in the emergence of technology-based industrial sectors would unite the separate strands of the technology-based industrial emergence literature and help to establish this field as a coherent body of knowledge.

The possible methodological approaches to such endeavors are numerous and include long-term case studies – even inductive approaches if researchers expect new phenomena to emerge from the analyses – and quantitative approaches, which can incorporate diverse factors into single analyses. The key to the success of these approaches is the use of longitudinal data that, unfortunately, were not available for this dissertation. The greatest advantage of time series data is that they allow researchers to make better inferences about the directions of causality between company growth and its underlying factors. Methodologically, such data also allow researchers to use advanced designs (e.g., event studies) that can provide a more in-depth understanding of a factor's impact on company growth. Such approaches would have been of great value to some of the studies in this dissertation (e.g., Studies 2, 3 and 4).

Due to the youth of emerging technology-based industries, it is relatively easy to obtain data covering their entire industrial life-spans. Some industries are especially favorable for study because their establishment can be witnessed in almost real-time. One much-studied example is nanotechnology (Nikulainen, 2010; Robinson, Rip and Mangematin, 2007; Mogoutov and Kahane, 2007), and another is the renewable energy industry.

For further research avenues that are independent of this dissertation, see, for example, Srinavasan (2008), who identifies a set of unexplored research questions in the emergence of technology-based industries.

References

Ahola, E. – Kuisma, M. (1998): Biotekniikkasektori Suomessa – Laboratoriosta lupausten lunastajaksi. (In Finnish). Teknologiakatsaus 61/98, Teknologian Kehittämiskeskus, Helsinki.

Ali-Yrkkö, J. (2010): Nokia and Finland in a Sea of Change. ETLA Publications, Series B, No 244, The Research Institute of the Finnish Economy, Helsinki.

Ali-Yrkkö, J. – Tahvanainen, A.-J. (2009): Kiina T&K-toiminnan sijaintimaana – Suomalaisten yritysten näkemyksiä ja kokemuksia T&K-toiminnasta Kiinassa (China as location for R&D activities – Views and experiences of Finnish companies regarding R&D activities in China). In Ali-Yrkkö, Jyrki (ed.): Yritysten tutkimustoiminta kansainvälistyy – Mitä jää Suomeen? (Corporate R&D activities become globalized – What will remain in Finland?). The Research Institute of the Finnish Economy (ETLA), B series 235, Helsinki.

Baldwin, R. (2006): Globalization – The great unbundlings. Prime Minister's Office. Economic Council of Finland, Helsinki, 50 pp.

Bontis, N. (2001): Assessing knowledge assets: a review of the models used to measure intellectual capital. International Journal of Management Reviews, 3(1), 41-60.

Brezis, E.S. – Krugman, P. (1997): Technology and the Life Cycle of Cities. Journal of Economic Growth, 2(4), 369–383.

Burt, R.S. (1992): Structural holes. Harvard University Press, Cambridge, Mass.

Carpenter, R.E. – Petersen, B.C. (2002): Capital Market Imperfections, High-Tech Investment, and New Equity Financing. The Economic Journal, 112(477), F54–F72.

Catasús, B. – Gröjer, J.-E. (2003): Intangibles and Credit Decisions: Results from an Experiment. European Accounting Review 12(2), 327–355.

Colyvas, J.A. – Powell, W.W. (2007): From Vulnerable to Venerated: The Institutionalization of Academic Entrepreneurship in the Life Sciences. In: Lounsbury, M. (ed.): The Sociology of Entrepreneurship (Research in the Sociology of Organizations, Vol 25), Emerald Group Publishing Limited, 219–259.

Dosi, G. (1982): Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. Research Policy, 11(3), 147–162.

Duranton, G. – Puga, D. (2000): Diversity and Specialization in Cities: Why, Where and When Does it Matter? Urban Studies, 37(3), 533–555.

Edvinsson, L. – Malone, M.S. (1997): Intellectual Capital – The Proven Way to Establish Your Company's Real Value by Measuring Its Hidden Brainpower. London: Judy Piatkus.

Etzkowitz, H. – Leydesdorff, L. (1995): The triple helix–university–industry–government relations: a laboratory for knowledge-based economic development. EASST Review, 14(1). pp. 14–19.

Etzkowitz, H. – Leydesdorff, L. (2000): The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy, 29(2), pp. 109–123.

Ford, S. – Routley, M. – Phaal, R. (2010): The dynamics of industrial emergence. *PICMET '10 - Portland International Center for Management of Engineering and Technology, Proceedings – Technology Management for Global Economic Growth*, art. no. 5603321, pp. 1222–1229.

Friedman, J. – Silberman, J. (2003): University technology transfer: Do incentives, management, and location matter? Journal of Technology Transfer, 28(1), 81–85.

Georghiou, L. – Smith, K. – Toivanen, O. – Ylä-Anttila, P. (2003): "Evaluation of the Finnish Innovation Support System," Kauppa- ja Teollisuus Ministeriön julkaisut, 5/2003, Edita, Helsinki.

Hall, B. (2002): The Financing of Research and Development. Oxford Review of Economic Policy, 18(1), 35–51.

Halme, K. (1994): Uudet yritykset biotekniikkasektorilla 1994. (In Finnish). Working Studys, No 11/94, VTT, Espoo.

Halme, K. (1996): Biotekniikka uusien yritysten toimialana. (In Finnish). Working studys, No 24/96, VTT, Espoo.

Hall, B. (2002): The Financing of Research and Development. Oxford Review of Economic Policy, vol. 18(1), 35–51.

Harris, M. – Raviv, A. (1991): The Theory of Capital Structure. Journal of Finance 46(1), 297–355.

Heckscher, E.F. – Ohlin, B. (1919): Heckscher-Ohlin Trade Theory. MIT Press, Cambridge, MA.

Hermans, R. (2003): Lääkealan biotekniikkayritysten rahoitusrakenteet ja liiketoiminnan ominaispiirteet. DOSIS. Farmaseuttinen aikakauskirja, No 3, 133–145.

Hermans, R. – Kauranen, I. (2003): Intellectual Capital and Anticipated Future Sales in Small and Medium-sized Biotechnology Companies. Discussion Studys, No 856, ETLA, Helsinki.

Hermans, R. – Kulvik, M. (2004): Biotechnology and Finland's Industrial Future. In Finnish. In Luukkonen, T. (ed.): Biotechnology in Finland: The Promotion of Knowledge-Based Business. ETLA Publications, Series B, No 207, The Research Institute of the Finnish Economy, Helsinki.

Hermans, R. – Kulvik, M. – Tahvanainen, A.-J. (2006): The Biotechnology Industry in Finland. In Hermans, Raine and Kulvik, Martti (eds.): Sustainable Biotechnology Development – New Insights into Finland. The Research Institute of the Finnish Economy (ETLA), B series 217, Helsinki.

Hermans, R. – Luukkonen, T. (2002): Findings of the ETLA Survey on Finnish Biotechnology Firms. Discussion Studys, No 819, ETLA, Helsinki.

Hermans, R. – Tahvanainen, A.-J. (2002): Ownership and Financial Structure of Biotechnology SMEs: Evidence from Finland. Discussion Studys, No 835, ETLA, Helsinki.

Himmelberg, C.P. – Petersen, B.C. (1994): R & D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries. The Review of Economics and Statistics, 76(1), 38–51.

Hussi, T. (2004): Reconfiguring Knowledge Management. Combining Intellectual Capital, Intangible Assets and Knowledge Creation. Journal of Knowledge Management 8(2), 36–52.

Jensen, R. – Thursby, M. (2001): Proofs and Prototypes for Sale: The Licensing of University Inventions. American Economic Review, 91(1), 240–259.

Klofsten, M. – Jones-Evans, D. (2000): Comparing Academic Entrepreneurship in Europe – The Case of Sweden and Ireland. Small Business Economics, 14(4), 299–309.

Krugman, P. (1991): Increasing Returns and Economic Geography. The Journal of Political Economy, 99(3), 483–499.

Krugman, P. – Venables, A.J. (1996): Integration, Specialization, and Adjustment. European Economic Review, 40(3-5), 959-967.

Lach, S. – Schankerman, M. (2004): Royalty sharing and technology licensing in universities. Journal of the European Economic Association, 2(2–3), 252–264.

Leamer, E.E. (1985): Sources of International Comparative Advantage: Theory and Evidence. The MIT Press, Cambridge, MA, 384 pp.

Lee, Y.S. (1996): "Technology transfer" and the research university: a search for boundaries of university-industry collaboration. Resesarch Policy, 25(6), 843–863.

Lev, B. (2001): Intangibles: Management, Measurement, and Reporting. The Brookings Institution, Washington, D.C.

Link, A.N. – Siegel, D.S. (2003): Generating Science-Based Growth: An Econometric Analysis of the Impact of Organizational Incentives on University–industry Technology Transfer. European Journal of Finance, 11(3), 169–181.

List, F. (1841/1844): Das nationale System der politischen Oekonomie. Erster Band: Der internationale Handel, die Handelspolitik und der deutsche Zollverein. Neue unveränderte auflage. Stuttgart/Tübingen: Cotta.

Luukkonen, T. – Tahvanainen, A.-J. – Hermans, R. (2004): Suomen biotekninen teollisuus – yleiskatsaus (The Finnish Biotechnology Industry – An Overview). In Luukkonen, Terttu (ed.): Biotechnology – Knowledge Based Business. The Research Institute of the Finnish Economy (ETLA), B series 207, Helsinki.

Macdonald, R.J. (1985): Strategic alternatives in emerging industries. Journal of Innovation Production Management, 3, 158–169.

Macho-Stadler, I. – Pérez-Castrillo, D. – Veugelers, R. (2007): Licensing of University Inventions: The Role of a Technology Transfer Office. International Journal of Industrial Organization, 25(3), 483–510.

Marshall, A. (1920): Principles of Economics, London: Macmillan.

Martin, P. – Rogers, C.A. (1995): Journal of International Economics, 39, 335–351.

Mogoutov, A. – Kahane, B. (2007): Data search strategy for science and technology emergence: A scalable and evolutionary query for nanotechnology tracking. Research Policy, 36(6), 893–903.

Monfort, P. – Nicolini, R. (2000): Regional Convergence and International Integration. Journal of Urban Economics, 48, 286–306.

Mowery, D. – Nelson, R.R. (ed.) (1999): Sources of Industrial Leadership: Studies of Seven Industries. Cambridge University Press, Cambridge, MA.

Myers, S.C. (1984): The Capital Structure Puzzle. Journal of Finance, 39(3), 575–592.

Myers, S.C. – Majluf, N.S. (1984): Corporate Financing and Investment Decisions When Firms Have Information That Investors Do Not Have. Journal of Financial Economics, 13(2), 187–221.

Nelson, R.R. (ed.) (1993): National Innovation Systems – A Comparative Analysis. Oxford University Press.

Nemet, G.F. (2009): Demand-pull, technology-push, and government-led incentives for non-incremental technical change. Research Policy, 38, 700–709.

Nikulainen, T. (2010): Studies on the Diffusion of New Science-Based Technologies. The Research Institute of the Finnish Economy (ETLA), A Series, No. 45, Helsinki, pp. 115.

Niosi, J. (ed.) (1991): Technology and National Competitiveness: Oligopoly, Technological Innovation, and International Competition. Mc-Gill-Queen's University Press, Montreal.

Nikulainen, T. – Kulvik, M. (2009): How General Are General Purpose Technologies? Evidence from Nano-, Bio-, and ICT-Technologies in Finland. ETLA Discussion Studys, No 1208, The Research Institute of the Finnish Economy, Helsinki.

Owen-Smith, J. (2005): Dockets, Deals, and Sagas: Commensuration and the Rationalization of Experience in University Licensing. Social Studies of Science, 35(1), 69–97.

Palmberg, C. – Luukkonen, T. (2006): The different Dynamics of the Biotechnology and ICT Sectors in Finland. In: Carayannis E. – Campbell D. (Eds.): Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters. Greenwood Publishing Group, Santa Barbara, CA, pp. 347.

PMO (2006): Finland's response to the challenge of globalisation. Report by the Secretariat of the Economic Council - Part 2. Prime Minister's Office Publications, 19/2006, The Prime Minister's Office, Helsinki.

Porter, M. (1990): The Competitive Advantage of Nations. The Free Press, New York.

Powell, W.W. (1998): Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries. California Management Review, 40(3), 228–240.

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

Rahm, D. – Bozeman, B. – Crow, M. (1988): Domestic technology transfer and competitiveness: an empirical assessment of roles of university and government laboratories. Public administration review, 48(6), 969–978.

Rip, A. (1995): Introduction of new technology making use of recent insights from sociology and economics of technology. Technology Analysis and Strategic Management, 17(4), 417–431.

Robinson, D.K.R. – Rip, A. – Mangematin, V. (2007): Technological agglomeration and the emergence of clusters and networks in nanotechnology. Research Policy, 36(6), 871–879.

Samuelson, P. A. (1948): International Trade and the Equalization of Factor Prices. The Collected Scientific Studys of Paul A Samuelson. MIT Press, Cambridge, MA.

Shan, W. – Walker, G. – Kogut, B. (1994): Interfirm cooperation and start-up innovation in the biotechnology industry. Strategic Management Journal, 15, 387–394.

Secretariat of the Economic Council (2006): Finland's response to the challenge of globalisation. Publications, 19/2006, Prime Minister's Office, Helsinki.

Siegel, D. S. – Phan, P.H. (2005): Analyzing the Effectiveness of University Technology Transfer: Implications for Entrepreneurship Education. In: Libecap, G.D. (Ed.): University Entrepreneurship and Technology Transfer: Process, Design, and Intellectual Property. Advances in the Study of Entrepreneurship, Innovation and Economic Growth, 16, 1–38.

Siegel, D.S. – Waldman, D. – Link, A. (2003): Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. Research Policy, 32(1), 27–48.

Siegel, D.S. – Waldman, D. – Atwater, L.E. – Link, A. (2004): 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, 21 (1–2), 115–142.

Smith, J.G. – Fleck, V. (1988): Strategies of new biotechnology firms. Long Range Planning, 21(3), 51–58.

Sorensen, J.A.T. – Chambers, D.A. (2008): Evaluating academic technology transfer performance by how well access to knowledge is facilitated - Defining an access metric. The Journal of Technology Transfer, 23(5), 534–547.

Srinivasan, R. (2008): Sources, characteristics and effects of emerging technologies: Research opportunities in innovation. Industrial Marketing Management, 37(6), 633–640.

Sveiby, K.E. (1997): The new organizational wealth: Managing and measuring knowledge based assets. Berrett-Koehler Publishers, Inc., San Francisco.

Swamidass, P.M. – Vulasa, V. (2009): Why university inventions rarely produce income? Bottlenecks in university technology transfer. The Journal of Technology Transfer, 34(4), 343–363.

Tahvanainen, A.-J. (2009): Finnish University Technology Transfer in a Whirl of Changes – A Brief Summary. Discussion Paper No. 1188, 17 pp. The Research Institute of the Finnish Economy (ETLA), Helsinki.

Tahvanainen, A.-J. – Hermans, R. (2005): Funding Intellectual-Capital-Abundant Technology Development: Empirical Evidence from the Finnish Biotechnology Business. Knowledge Management Research & Practice, 3(2), 69–86.

Thursby, J.G – Kemp, S. (2002): Growth and productive efficiency of university intellectual property licensing. Research Policy, 31(1), 109–124.

Toole, A.A. – Czarnitzki, D. (2007): Biomedical academic entrepreneurship through the SBIR program. Journal of Economic Behavior & Organization, 63(4), 716–738.

Tulkki, P. – Järvensivu, A. – Lyytinen, A. (2001): The emergence of Finnish Life Sciences industries. Sitra Reports series 12, pp. 10–79.

Venables, A. (1995): International Location of Economic Activity – Economic Integration and the Location of Firms. The American economic review, 85(2), 296–300.

Wells, N. – Coady, B. – Inge, J. (2003): Spinning off, cashing up and branching out: Commercialisation considerations for bioentrepreneurs in Australasia. Journal of Commercial Biotechnology, 9(3), 209–218.

Zucker, L.G. – Darby, M.R. – Brewer, M. (1998): Intellectual human capital and the birth of U.S. biotechnology enterprises. The American Economic Review, 88(1), 290–360.

Appendices

Study 1: Tahvanainen, Antti-Jussi – Hermans, Raine (2011): Making Sense of the TTO Production Function: University Technology Transfer Offices as Process Catalysts, Knowledge Converters and Impact Amplifiers. Discussion Paper (*forthcoming*). The Research Institute of the Finnish Economy (ETLA), Helsinki.

Study 2: Tahvanainen, Antti-Jussi (2004): Growth Inhibitors of Entrepreneurial Academic Spin-offs: The Case of Finnish Biotechnology. International Journal of Innovation and Technology Management, 1(4).

Study 3: Tahvanainen, Antti-Jussi – Hermans, Raine (2005): Funding Intellectual-Capital-Abundant Technology Development: Empirical Evidence from the Finnish Biotechnology Business. Knowledge Management Research & Practice, 1(3), 69–86.

Study 4: Hermans, Raine – Kamien, Morton – Kulvik, Martti – Tahvanainen, Antti-Jussi (2009): The effect of technology subsidies on industry strategies and market structure. In Hermans, Raine – Kamien, Morton – Kulvik, Martti – Löffler, Alicia – Shalowitz, Joel (eds.): Medical innovation and government intervention. The Research Institute of the Finnish Economy (ETLA), B series 236, Helsinki.

Study 5: Tahvanainen, Antti-Jussi – Hermans, Raine (2008). Agglomeration and Specialisation Patterns of Finnish Biotechnology. On the Search for an Economic Rationale of a Dispersed Industry Structure. Discussion Paper No. 1133, 43 pages. The Research Institute of the Finnish Economy (ETLA), Helsinki.