ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS

Antti-Jussi Tahvanainen

DIAGNOSING THE GROWING PAINS OF A TECHNOLOGY-BASED INDUSTRY

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

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Helsinki 2011

Correction

Deviating from the information provided in Abstract,
the opponent of this dissertation is Prof. Laurel Smith-Doerr.

Oikaisu

Poiketen tiivistelmässä annetuista tiedoista
tämän väitöskirjan vastaväittäjänä toimii Prof. Laurel Smith-Doerr.

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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

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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

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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 suggesting 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 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, April 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.

Under review at the Journal of Engineering and Technology Management.

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

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[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.

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[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 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 university technology transfer offices (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 to alleviate 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 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 our 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 practice 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 a 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 a 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, private equity investments in the industry.

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 supported 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.

Our 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.

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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 that, 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 accompanied 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. The various phenomena are treated separately in the dissertation but are combined in this introduction to construct a coherent picture of the emergence of the Finnish biotechnology industry.

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.

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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 (f*orthcoming*). 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).

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Appendix 1

ETLA
ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 358-9-609 900
Telefax 358-9-601 753 World Wide Web: http://www.etla.fi/

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Antti-Jussi Tahvanainen* – Raine Hermans**

MAKING SENSE OF THE TTO PRODUCTION FUNCTION: UNIVERSITY TECHNOLOGY TRANSFER OFFICES AS PROCESS CATALYSTS, KNOWLEDGE CONVERTERS AND IMPACT AMPLIFIERS

* Aalto University School of Science and Technology, Department of Industrial Engineering and Management, PL 5500, 02015 TKK, Finland / The Research Institute of the Finnish Economy (ETLA), Lönnrotinkatu 4B, 00120 Helsinki, Finland. E-mail: antti.tahvanainen@etla.fi

** Helsinki School of Economics, PL 1210, 00101 Helsinki, Finland.
E-mail: raine.hermans@aalto.fi

Corresponding author: Antti-Jussi Tahvanainen, The Research Institute of the Finnish Economy, Lönnrotinkatu 4B, 00120 Helsinki, Finland. Phone: +358 44 535 1797. Fax: +358 9 601753.
E-mail: antti.tahvanainen@etla.fi.

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ABSTRACT: This inductive case study of 7 US university technology transfer offices (TTOs) examines the value added that TTOs contribute to university-industry technology transfer (UITT). We therefore (i) characterize a set of central organizational TTO practices, (ii) describe how TTOs systemically manage intangible resources to generate these practices, and (iii) describe the conceptual mechanisms through which the practices add value to UITT. The results form an inductive framework that establishes the TTO as (i) a process catalyst that lowers the threshold of UITT stakeholders to engage in technology transfer and to maintain its sustainability, (ii) a knowledge converter that enables congruence between university technology and market needs, and (iii) an impact amplifier that alleviates problems related to the opportunistic incentive structures of UITT stakeholders and maximizes societal impact. The study thus provides new insights into the internal logic of the TTO production function by qualitatively expanding and refining our understanding of the value added generated by TTOs and by helping to comprehend the relationship between inputs and outputs that underlie it.

KEYWORDS: University-industry technology transfer; technology transfer office; organizational practices; Intellectual Capital; knowledge management

JEL: O31, O32, O33

> "A match-making service is what we provide. We are not the stars, we are not making the inventions, and we are not selling the product. We are the ultimate middlemen. I think the world needs middlemen, because people are complicated creatures. Nothing will get done if everybody is myopically focused on their own "what's-right-in-front-of-me" -activities. […] Somebody has to look at the whole, and look at it from the perspective of the public benefit […] I am the person who has my eye on the entire path. The inventors are worrying about their thing. The entrepreneurs are worrying about their thing. The department has its own angle on things. But somebody has to be there to say how this benefits the public, and how the deal will be done. We will help connect the dots […]."

1. Introduction

With the evolution of globalization and the emergence of the "second unbundling" (Baldwin, 2006), i.e., the global competition between any given stage of a firm's production and the offshoring of individual tasks within those stages, even firm functions that add substantial value, such as R&D, have undergone divisions. The appropriate parts of these functions are offshored to countries with lower costs, better market proximity, or superior knowledge.

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. 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 maintain cutting-edge knowledge bases as growth plates for high value-added innovation to retain and attract economic activity.

However, the maintenance of such knowledge bases, which has traditionally been the task of academic institutions such as universities, is not sufficient. These bases must be accessible to firms to be attractive. Accessibility has thus far presented a major obstacle to UITT. As Siegel, Waldman and Link (2003) state, "universities in the US have been criticized in some circles for being more adept at developing new technologies than moving them into private sector applications (p. 27)." Similar conclusions have also been reached in much smaller and more peripheral countries, which are even more dependent on progressive innovation capabilities. Finland, for example, seems to struggle with commercializing its otherwise rather competitive academic research achievements (Ali-Yrkkö et al., 2004).

A well-studied institutional response to this challenge is the university technology transfer office (TTO). Mandated mainly by the Bayh-Dole Act of 1980, US universities have established TTOs and charged them with facilitating the diffusion of university-generated technology toward its industrial or societal use through licensing. Since their emergence, TTOs have been the subject of many studies. Most of these studies have scrutinized their effectiveness in enhancing university-industry technology transfer (UITT) (Siegel and Phan, 2005).

Studies have established that an array of institutional, environmental and organizational factors determine TTO effectiveness (e.g., Siegel, Waldman and Link, 2003; Mustar et al., 2006, and Chapple et al., 2005). The impact of these factors is commonly analyzed using a "TTO production function." Factors of interest are fed into the function as inputs and related to certain output measures using quantitative statistical methods. The question of how the inputs are transformed into outputs, i.e., the logic of the production function itself, has largely remained a black box, however.

The most recent contributions to the TTO literature have examined the impact of organizational factors in general and organizational practices in particular on TTO performance. Because practices are difficult to capture quantitatively, these studies have reverted to more qualitative approaches. They have shown that practices can indeed affect TTO effectiveness as measured by conventional measures such as the number of annual licensing deals or royalty turnover (e.g., Siegel, Waldman and Link, 2003). Also, practices that cannot be captured with conventional metrics have been recently examined in studies investigating the broader societal impacts of TTOs (e.g., Siegel et al., 2004, and Sorensen and Chambers, 2008).

However, both lines of research still largely fail to provide deeper understanding on the conceptual mechanisms of TTO practices and how these facilitate the process. These studies typically fail to provide a "value generation logic" for TTO practices beyond an exploratory intuition and the general statement that they are important to the process. We know even less about how TTOs manage and apply their resources, especially intangible ones, to generate value-adding practices. The production function thus remains opaque.

Given the above shortcomings, this inductive case study of 7 university TTOs contributes to the TTO literature by looking into the black box that has thus far obscured an understanding of the value-adding mechanisms of TTOs. We (i) identify a set of central organizational practices through which TTOs facilitate UITT, (ii) show how TTOs manage their intellectual capital resources, i.e., human, structural, and relational capital, to generate these practices, and (iii) describe the conceptual mechanisms through which the practices add value to UITT and facilitate its process. The results form an inductive framework, which establishes the TTO as (i) a process catalyst that lowers the threshold of UITT stakeholders to engage in technology transfer, (ii) a knowledge converter that enables congruence between university technology and market needs, and (iii) an impact amplifier that alleviates problems related to the opportunistic incentive structures of UITT stakeholders and that maximizes societal impact.

In this manner, the study provides valuable new insights into the internal logic of the TTO production function. A qualitative intuition for the logic expands and refines our understanding of TTO effectiveness and helps us understand the relationship between the inputs and outputs that determine it. The study thus reinforces the foundation for the development and adjustment of measures used in the assessment of TTO effectiveness in future research.

The study is structured as follows. The next section examines the existing literature on TTOs and positions the present study within it. Section 3 presents the data and the applied methodology. Section 4 introduces Edvinsson and Malone's (1997) Value Platform Model, which is a tool used in the initial structuring of the data and which allows the systematic depiction of how intangible resources are managed to generate TTO practices in the analysis proper in Section 5. Section 5 constitutes the analytical core of this paper. It presents the results of the study in the form of an inductive framework that depicts three TTO mechanisms (catalyst, converter, and amplifier) through which TTOs generate value added for UITT. Section 6 concludes the study with a discussion of the findings and their implications. Appendix 8.1 contains a brief descriptive disquisition of the systemic flow of the licensing process as it emerged from the data and the interview protocol.

2. Literature review

The contributions of this study must be framed by extant previous research on TTOs and their effectiveness in mediating the flow of resources and information (Siegel and Phan, 2005) between academia, industry, and other actors that participate in UITT.

The need for TTOs as "boundary spanners" presupposes the existence of gaps, barriers, inhibitors, structural holes (Burt, 1992), or other boundaries between actors that inhibit the efficient flow of technology. Barriers that have been identified 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 the diversity of universities' research missions (Rahm, Bozeman and Crow, 1988). Finally, in a more generic context, Bozeman's (2000) Contingent Effectiveness Model of technology transfer attributes the ineffectiveness of the transfer process to incongruence in the "characteristics" of the "dimensions" that constitute his model: the transfer agent, object, media, and recipient, as well as the demand environment.

Due to the inhibiting effects of inter-actor boundaries in UITT, the effectiveness of TTOs in facilitating the UITT process by "spanning" these boundaries has been an object of intense study. Studies on this topic relate institutional, organizational, and/or individual drivers to select transfer process output proxies (licensing deals, filed patents, number of university start-ups, research funding, invention disclosures, licensing revenues, etc.) to determine the effectiveness of TTOs (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Rogers, Yin and Hoffman, 2000; Thursby and Kemp, 2002. For comprehensive reviews cf. Phan and Siegel, 2006; Mustar et al., 2006; Siegel and Phan, 2005; Bozeman, 2000). For instance, Siegel, Waldman and Link (2003) establish a production function for US TTOs and find that, after controlling for a number of environmental factors, their performance is affected by the number of inventions disclosed to the office, the size of the TTO staff, and the amount of legal expenditures on internal and external legal consultation by the office.

Markman et al. (2005a) analyze which TTO structures and licensing strategies are most favorable to new venture formation and which of these are correlated, and Markman et al. (2005b) study commercialization speeds at US universities. They find that the generation of revenue streams and spin-off ventures is positively correlated with the speed with which TTOs are able to commercialize patent-protected technologies. Central determinants of commercialization speed include TTO resources and competency and the active participation of the original inventors in the process. Lockett and Wright (2005) back up these findings by establishing a positive correlation between the number of spin-off companies created and the expenditure on IPR protection, the business development capabilities of TTOs, and the royalty regime of the university. The positive effects of business competency among other determinants such as previous success in UITT, faculty quality, and federal funding on start-up formation have been further verified by O'Shea et al. (2005) and Di Gregorio and Shane (2003).

Despite this work, the qualitative link between inputs and outputs, i.e., resources, capabilities, and effectiveness, remains at least somewhat obscured by a black box because the above analyses do not directly address the practices that a TTO performs to transform inputs into outputs. Some approaches have begun to dismantle the black box by exploring the roles of organizational practices in TTO performance more directly. Bercovitz et al. (2001) relate organizational structures, i.e., the degree of centralization of UITT-related units at three universities, to a number of performance indicators and find that structure indeed matters. Scrutinizing organizational practices, Colyvas et al. (2002) provide evidence of the significance of TTOs' marketing efforts in cases where links between academia and the industry are weak. Jensen, Thursby, and Thursby (2003) observe TTOs' practices in balancing the tensions that arise from the clashing objectives of universities and their faculty. They find that TTOs adhere to the agendas of both parties and, as agents, try to serve these agendas in a manner that maximizes utility. The authors show that a faculty's propensity to disclose an invention is dependent on its quality, the equilibrium licensing income, whether projects are sponsored research, and the inventor's rate of time preference. Debackere and Veugelers (2005) show how a decentralized management style, in contrast to the style applied by a more traditional university administration, would provide the TTO with more leeway to address the diverse needs of its heterogeneous stakeholders.

Three recent contributions are tightly focused on organizational practices and their impact on TTO performance. Swamidass and Vulasa (2009) examine the effects of scarce staffing resources and inventions-processing capacity in 99 US TTOs. Based on multiple regression analyses, they show that, when short on staff and budget, TTOs reduce their marketing efforts in favor of securing proper IP protection, which is argued to have a negative impact on the UITT process as a whole. A deficiency in the appropriate competencies would lead to problems in identifying markets for inventions and in the translation of the technology into a form that can be appropriated by industry. In the current paper, we will provide an inductive argument that supports Swamidass and Vulasa's (2009) finding.

Sorensen and Chambers (2008) examine TTOs' ability to facilitate access to knowledge protected by faculty and university IP, which the authors propose is the ultimate benchmark of TTO performance. In line with our own findings, the authors claim that such an access metric is based on nonmonetary indicators and takes into account practices that are not captured by conventional measures of performance. According to the authors, practices that "drive value in UITT" but that cannot be directly measured based on monetary indicators could be captured through, for example, citation analyses, indicators related to alliance management, counting research and humanitarian use exceptions, as well as the identification of practices related to open source business modeling, patent pooling and bundling, exclusivity shifting, and regional economic development through capacity building. As we shall corroborate, Sorensen and Chambers (2008) conclude that TTOs "may actually make less money by adopting a nonmonetary benefit strategy, but less money through royalty revenue is not necessarily less societal value (p.535)."

Finally, based on a qualitative exploratory approach, Siegel et al. (2004) establish that the different objectives of and cultural barriers between universities and industry, as well as inadequate compensation, staffing, and reward practices, explain poor TTO performance to a certain extent. These findings are much in line with those of Clarke (1998) and Roberts (1991), who claim that the existence of an entrepreneurial culture and certain social norms such as the unspoken acceptance of entrepreneurial activities can be prerequisites of successful entrepreneurship at universities. Siegel et al. (2004) conclude that certain organizational practices, such as incentive schemes favoring scientists, the integration of technology transfer into promotion and tenure schemes, the inclusion of informal technology transfer into TTO objectives, and increases in overall TTO resources, could potentially enhance UITT effectiveness.

Despite recognizing the central role of practices in TTO performance, however, the above studies provide few in-depth insights into the value generation logic, that is, into the internal logic of the TTO production function. Regarding staffing practices, for instance, Siegel et al. (2004) state that "it appears that the marketing aspect of the TTO is often given short shrift (p. 134)." In an earlier study based on the same data, Siegel, Waldman and Link (2003) argue that "a lack of requisite business skills and expertise could have a significant deleterious effect on TTO productivity (p.43)." However, the authors do not explain explicitly why "deleterious effects" arise, what role "requisite business skills" play in the value generation logic of TTOs, or how such a lack in skills disrupts a given TTO practice or value generation mechanism. As another example, Siegel et al. (2004) also state that "knowledge transfer appears to work in both directions" and that "interacting with firms enables them [scientists] to conduct "better" basic research (p. 131)." However, they do not identify the mechanisms and practices through which TTOs help establish bi-directional interactions, the resources that are necessary to generate such practices, or the value that is added in the broader context of UITT, beyond micro-level benefits such as the refinement of experiments and new perspectives on problems.

Likewise, Sorensen and Chambers (2008) laudably begin a discussion on the societal mission of TTOs and advocate the development of metrics that capture related outcomes. However, they fail to provide (i) arguments about why such objectives should be preferable over (or at least complementary to) more conventional ones and (ii) examples of practices through which TTOs might fulfill societal objectives.

The study presented here will build upon the work of Siegel, Waldman and Link (2003), Siegel et al. (2004) and Sorensen and Chamber (2008) by inductively analyzing the value adding practices of TTOs at the interface of industry and academia to reveal the TTO production function logic. The study thus informs existing theory by answering the aforementioned questions inductively rather than by creating an entirely new theory.

For more readings on the issue of UITT, there are at least two excellent review studies in addition to those of Siegel and Phan (2005) and Phan and Siegel (2006). Von Ledebur (2008) reviews studies that pinpoint the differences in the institutional framework between Europe and USA regarding academic patenting and the organizational design of TTOs, and Rothaermel, Agung, and Jiang (2007) review over 170 studies related to university entrepreneurship in broader terms. One of the fields of study they review focuses specifically on the productivity of TTOs.

3. Data and methodological approach

3.1. Data

The data utilized in the present study were taken from three separate sources between April and October 2007. The most central body of data was acquired by interviewing directors and, when the director was unavailable, high-ranking technology transfer officers at 7 US university technology transfer offices at Stanford University, Massachusetts Institute of Technology, Northwestern University, Harvard University, UC Berkeley, UC San Diego, and University of Massachusetts. All of the included TTOs were among the top 20 in the US as measured by the number of start-ups founded in 2005, which served as the primary criterion for being considered for the study. The final choice of cases was further refined by recommendations from TTO practitioners who were active in AUTM, The Association of University Technology Managers. However, our intention was not to capture the best performing TTOs but those that could provide us with a rich description of practices and underlying resources based on a long track record of experience with both success and failure.

Because this is a case study, TTOs in the sample are not intended to represent the average or the majority of US TTOs. Instead, using a handful of select cases, our intention is to approximate a model of a TTO as constructed from the underlying data. In building a conceptual framework of value-adding TTO practices, we do not attempt to establish a 1:1 model of the entire population of US-based TTOs but to learn from TTOs with profound experience and to organize individual practices into a coherent framework. It is important to emphasize this point because normative claims or arguments for the generalizability of results beyond the sample would strongly undermine the validity of our research design.

Among many alternative measures of technology transfer activity,[1] the number of start-ups was chosen to identify experienced offices because it not only mirrors activity in the TTOs but also reflects the entrepreneurial environment in which the offices are embedded. TTOs do not exist in a vacuum, and we wanted to incorporate their context into our analyses. Table 1 summarizes a number of other indicators that are commonly used to determine the relative position of TTOs.

Table 1 Positioning of sample TTOs in total population, 2004 figures (Source: AUTM STATT, 2007)

Indicator	Sample	Total	Sample share
Number of university technology transfer offices	7	164	4 %
Invention disclosures received	1 727	14 396	12 %
New patent applications filed	1 212	9 248	13 %
Licenses and options executed	404	3 870	10 %
Total number of active licenses and options	3 105	22 465	14 %
Licensing income received (million USD)	151	951	16 %

As Table 1 reveals, our sample comprises 4% of all 164 TTOs active at different US Universities in 2004. The TTOs in our sample were particularly efficient at generating codified knowledge as a foundation for commercial applications such that they generated 12% of all invention disclosures and 13% of all new patent applications filed by US universities. Furthermore, the TTOs in the sample accounted for 151 million USD, or roughly 16%of the total licensing income received by all TTOs in 2004. The ratios serve to further corroborate our assumption that the TTOs in our sample had experience with at least some successful UITT transactions in the past.

The interviews were conducted using a semi-structured interview template that allowed interviewees the freedom to respond in their local contexts, which differed among offices along several dimensions (private vs. public university, self-sustaining vs. university financed, small vs. large office, multi-campus vs. single campus system, etc.). At the same time, the template ensured that all vital aspects of our analytical framework were addressed in sufficient scale and scope. We obtained roughly 20 hours of recorded data from the interviews, which were then transcribed for further analysis.

The second data source comprised a large quantity of official and publicly distributed electronic and printed material on the activities of the TTOs in the sample. The function of this secondary data was to complement the views of interviewees (especially in cases where interviewees explicitly referred to these secondary data) and to verify these views against officially communicated policy, i.e., to triangulate the views provided in the interviews.

Our third and final data source was the AUTM STATT (Statistics Access for Tech Transfer) database that provided time series data on 21 important variables regarding the technology transfer activities of US TTOs covering a period from 1996 through 2005. Table 1 is entirely based on the STATT data. In addition to demarcating our sample, the STATT data were mainly used to verify the numeric information provided in the interviews.

[1] In addition to a rather high number of start-ups, all but one office participating in the interviews estimated reporting around 30 million USD for the current fiscal year in royalty income, which places them in the top echelon of US TTOs in terms of royalties. Due to reasons explained in the analytical part of the paper, we did not utilize royalty income streams as the primary selection criterion for participants.

3.2. Methodology

3.2.1. Approach

Regarding methodology, the present study applies content analytical techniques to probe the underlying data using ATLAS.ti text analysis software. The content analytical approach employed in this study is inductive in nature. The analysis is not concerned with ontological issues regarding the phenomena that emerge from the data. Their truthful existence is presupposed and remains unchallenged. Rather, it arranges these phenomena into a framework that reveals their systemic role in generating value added in the UITT process. This implies that we regard the interview data as rich descriptions of reality.

The inductive nature of the study further implies that we draw our conclusions primarily from the data. With the exception of the literature that underlies the discussion and the construction of the Value Platform Model (Section 4), which serves as a structural frame for reporting our results, pre-existing views from literature play only a minor role in the interpretation of the data, as the following description of the analytical process will show. The process itself is strongly guided by the template presented by Eisenhardt (1989). To show parallels to findings reported in other literature, to position our work among existing literature, and to anchor and verify our own interpretations against the established body of knowledge, however, references to studies that are relevant to our findings are included in the argument in Section 5.

3.2.2. Initial objective

The process originally began with the intermediate objective of mapping components of Intellectual Capital (IC) that are relevant to TTOs for the purpose of building measurable metrics for large-scale quantitative analyses. In later studies, these indicators were to be applied in analyses that would assess the impact of different configurations of IC in TTOs on UITT outcomes. However, the objective shifted and expanded radically shortly after we initiated coding of the data. We will discuss this in more detail shortly.

3.2.3. Interview protocol

The original objective necessitated the systematic collection of specific data that describe the IC components that are prevalent in TTOs in detail. This implied the use of a priori defined constructs (Eisenhardt, 1989), i.e., the inclusion of the fixed set of IC components identified in the knowledge management literature (primarily Edvinsson and Malone, 1997), in our interview protocol. The mapped components included human, relational and structural capital, each of which was discussed with interviewees after providing them with generic, noncontext-specific definitions of the constructs. Regarding the validity of our claims related to the inductive nature of the study, it is paramount to point out that the underlying IC framework (Value Platform), which will be introduced in more detail in Section 4, was not presented to or discussed with the interviewees in any form. In fact, the naming of IC components was deliberately reformulated to prevent any accidental recognition of the framework by interviewees. Human capital was the sole exception because it is a widespread and common concept that does not exclusively refer to the Value Platform framework. The applied protocol template is attached in Appendix 8.2. In addition to the three IC components, we further asked the interviewees to provide us with (i) depictions of occurrences when they felt their respective TTO had achieved success, and (ii) a walk-through of the process of technology transfer from the perspective of the TTO.

3.2.4. Case selection

Once the protocol was established, we proceeded with the selection of appropriate cases. This selection was not random, but followed the tenet of Eisenhardt (1989) to choose cases such "in which the process of interest is transparently observable." Given our initial objective to map IC components for later quantitative uses, it was crucial to select cases that yielded as broad a spectrum of IC component descriptions as possible. Hence, following the IC framework, according to which experienced and successful organizations are endowed with a balanced and more complete set of IC components than less experienced and successful ones, we focused on a set of comparatively experienced TTOs. The purpose was to avoid analyzing the IC bases of TTOs that we would a priori expect to be more deficient in some aspects of IC. To cover IC relevant across different TTO types, we included public and private TTOs and economically dependent and independent TTOs in the sample. The recommendations from TTO practitioners active in AUTM were helpful in identifying potential target that matched these criteria. Given the number and choices of participating TTOs, the presence of multiple cases in each category allowed the findings to be replicated within categories in the analysis in Section 5.

There is a central caveat regarding the selection of cases. Given the research question addressed by this study, we recognize that to make any normative claims based on the findings, i.e., to state that the sample TTOs fare better than others because of the practices they perform, we would have to incorporate TTOs that are far less successful into the sample and utilize comparative techniques to pinpoint differences in their respective practices. Thus, we emphasize that we do not provide normative implications but instead examine the role of TTO practices in creating value added for UITT and how the TTOs in our sample manage and apply IC to generate these practices. In this context, "value added" is not to be understood as a comparative concept like the difference in monetary indicators of effectiveness or productivity between "successful" and "less successful" TTOs. Rather, it refers to the concept of enabling and triggering the process of UITT to advance from one phase to another. According to this concept, a TTO provides value added not by performing better than other TTOs but by performing necessary functions that other stakeholders of UITT (e.g., inventors, universities, financiers, industry, entrepreneurs, etc.) are not able or willing to perform to overcome the gap between academia and industry. We do not need to contrast high performers to low performers to understand the role of practices in providing value added as defined above because we are not interested in the factors underlying the differences in TTO performance but in what performance is and how it is generated.

3.2.5. Data collection

All interviews were conducted with both investigators present and making independent notes in addition to full audio recordings. Extensive discussions between investigators after each interview introduced overlap between data collection and preliminary theme-searching data analysis, which led to some minor and subtle adjustments to the interview protocol between interviews. These took the form of follow-up questions in cases where respondents did not touch on newly emerging themes independently (e.g., the role of monetary objectives). Protocol alterations were made to probe and confirm themes that emerged from prior cases. As a result, toward the end of the iterative data collection process of alternating team discussions and interviews, we had a collection of loosely connected themes at our disposal, and we were thus able to preliminarily identify potential inter-case similarities. Central emerging themes included, among others, the need for inter-institutional human capital in bridging knowledge gaps, the importance of customer orientation in dealing with faculty, the role of feedback loops in marketing, and the systematic downplay of purely monetary objectives. Although we had not yet established the interplay of themes or their relative positioning in a coherent framework, we developed an early sense of the potential of the data to answer questions beyond the mere mapping of the IC components that are relevant to TTOs.

3.2.6. Within-case analysis – A shift in objectives

Once the interviews were transcribed and, together with the secondary data material, inputted into the text analysis software tool, we proceeded with the first rounds of coding by flagging references to IC components as established in the original research design. IC components were identified according to the guidelines of the IC measurement literature (see, e.g., Bontis, 2001, for a review on IC measurement models) and the categorization implied by the Value Platform Model introduced in Section 4. The coding was performed for each case separately and gave primary emphasis to the interview-based data. Secondary data were used mainly for triangulation and validation purposes.

It became evident early on that the interviewees were not able to define the IC components without reference to the contexts in which they were applied, i.e., to the practices performed by the TTOs. Because these practices constituted the dominant themes that emerged in every case, we saw the opportunity to shift our research question away from building indicators of IC components and toward understanding how IC is applied to generate practices in TTOs and how these practices add value to the UITT process.

In the following analytic iterations, we coded the practices thematically for each case separately. Each of the resulting categories of practices (e.g., education, feedback looping, and problem assistance) consolidated a number of different practices with common objectives or functions.

Having shifted our level of analysis from IC components to practices, we further recognized that several different IC components were defined by interviewees when describing their role in generating the same practices. Thus, several different components seemed to be simultaneously at play in the generation of any given practice. Therefore, we were able to capture the dynamic interplay of IC components underlying the generation of TTO practices.

This inductively derived finding is particularly interesting from a conceptual perspective because the dynamic interaction of IC components as the prerequisite to value generation is incidentally also the central tenet of the Value Platform Model (VPM). It encouraged us to return to and utilize VPM to structure our report of the results in Section 5.

3.2.7. Inter-case analysis

In the subsequent inter-case analysis, we compared the presence of practice categories, and not necessarily of specific practices, across cases. Specific practices within practice categories might have differed among TTOs, but we required them to serve the same or similar function in facilitating UITT. Along this line of interpretation, specific practices represented different aspects of the same constructs, i.e., practice categories. Identifying practice categories that were common to all sample TTOs was important to facilitate separating these constructs from specific TTOs or types of TTO (private vs. public, and economically dependent vs. independent) to link them to general value-adding mechanisms. Thus, in a final round of analytical iteration, we further abstracted away from practice categories to code them according to their role in furthering UITT. This resulted in the constructs that were labeled “catalyst,” “converter,” and “amplifier” to describe the conceptual mechanisms through which TTOs add value to UITT.

To introduce more plasticity to our own interpretations, we present a fair number of direct quotes from interviewees who, for the purposes of obtaining responses that were uninhibited by political, diplomatic, personal, or other concerns, were promised complete anonymity.

4. Value Platform

4.1. Rationale for utilizing VPM

To present the relevant resources commanded by TTOs and to show how these resources are put into action to generate organizational practices in a cohesive manner, we integrate these aspects into a single comprehensive framework. To this end, when reporting the results in Section 5, we will employ the Value Platform Model (VPM) first presented by Saint-Onge et al. in Edvinsson and Malone (1997). It should be noted that VPM is a pre-existing concept that is not the result of our own interpretation of the data. It originally served as a structural foundation in the data collection phase that was intended to map intellectual capital components that were relevant to TTOs. The model was not used to interpret the data beyond identifying these components. The identification of practices, their value-adding functions, and the interplay of IC components necessary to generate the practices are the result of inductive analysis.

To rationalize the application of an intellectual capital (IC) and knowledge management based approach, one must consider the characteristics of the object of UITT (Bozman, 2000). Thus, it is relevant to ask: what is technology?

University technology is only rarely tangible before being licensed to a third party for further development (Jensen and Thursby, 2001). In UITT, technology goes from an initially very intangible state, existing only in the domain of the inventor's knowledge, to a slightly more tangible or codified form, such as a patent, proof of concept or a prototype. Thus, the fundamental task of a TTO is to understand, protect, and transfer knowledge created by one actor to another. This process necessitates a vast array of specific expertise, relationships, and support structures, as will be shown in our analysis.

It is important to note that there are very few, if any, tangible assets to be managed. UITT leaves virtually no physical trail. The process involves the management of knowledge or intellectual capital inherent in external parties and the TTO. Thus, utilizing the IC framework that deals explicitly with the management of intangible assets is an appropriate approach to analyzing the prerequisites of TTO practices in UITT.

4.2. VPM in a nutshell

Edvinsson and Malone (1997) discuss the significance of IC to an organization. IC consists of three components – human, structural, and relational capital. The component designations used differ from the original designations to capture broader contexts (see e.g., Tahvanainen and Hermans, 2005). IC provides a framework that enables the examination of components in relation to each other. According to the framework's central tenet, even one weak or inadequately managed component of the Value Platform Model (presented in Figure 1) may disrupt an organization's value creation process even when the remaining two components are strong. The model further claims that the dynamic interaction of all three components is the prerequisite for creating value (Saint-Onge et al. in Edvinsson and Malone 1997). In this generic context, knowledge management is the strategic management of the synergetic interaction of the components in a way that maximizes value. The merit of the Value Platform is its comprehensiveness in capturing the systemic interplay of three central dimensions of organizational development in a single framework (Mouritsen et al. 2000).

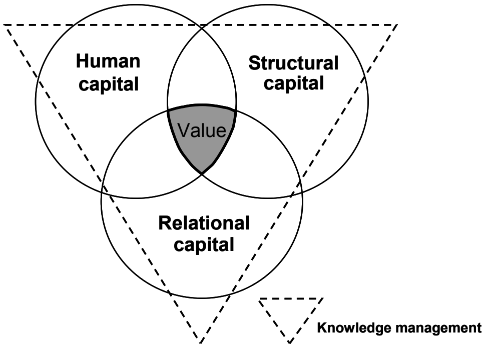

Fig. 1 The value platform model

In the following section, we will briefly describe each of the three components of the concept of IC and introduce their TTO equivalents as identified in our data for their use in the analysis in Section 5. For further discussions on the role of IC in knowledge management, see e.g., MERITUM project (2002) and Bontis (2002).

4.2.1. Human capital

Human capital (HC) is defined as an individual's knowledge, experience, capabilities, skills, creativity, and innovativeness (Edvinsson and Malone, 1997). These are interconnected and collectively contribute to workplace success (Ranki, 1999). Sveiby (1997) adds the concept employee competence to this list, which he defines as the capacity to act in different situations to create both tangible and intangible assets. The ability to perceive changes in the operational environment is also included in HC (Edvinsson and Malone 1997).

The fact that an organization cannot own its HC distinguishes this component of IC from other resources (Edvinsson and Malone, 1997). Despite this fact, competent personnel are fundamental to an organization's ability to realize and develop its ideas (Hansson, 2001). Investments in personnel are as crucial for knowledge-intensive organizations as a mass producer's investment in tangible assets (Sveiby and Lloyd, 1987).

In the TTO context, we identified several key dimensions of HC that are crucial to TTOs' organizational capabilities: For technology transfer officers, a technical background and a PhD facilitate communication with faculty. A technical background is also necessary to understand the disclosed technologies well enough to protect and market them. Furthermore, industrial experience is a prerequisite to understanding industry needs, its incentive structures and its value-creation logics. This understanding is vital to interpreting how an invention complies with value-creation logics and adds value to a potential licensee's business model. Although both types of expertise are necessary and valuable in their own right, it is their fusion in a single individual (the licensing officer) that bridges the gap between the academic and commercial universes. According to our data, the typical licensing officer, who is often responsible for processing a single invention from its initial disclosure to its post-licensing phases (cradle-to-grave principle), had both a solid scientific background, which was usually formalized through an advanced degree in a particular science, and long-term experience in industry or start-ups (usually ten or more years). A failure to employ officers with such an interdisciplinary background would internalize the gap between academia and industry.

Another central aspect of HC is robust negotiation skills because operating at the interface of actors with very different incentive structures and objectives necessitates the re-alignment of interests, the re-definition of objectives, and the negotiation of viable compromises. Strong communication skills are also paramount in this respect. Solid experience in legal issues, particularly in the field of intellectual property, was another prerequisite demanded from a competent licensing officer. These competencies were rarely required for the purposes of drafting patent applications because this task is often outsourced to law firms. Instead, they were necessary to conduct a proper prior art search and to check a given invention against existing IPRs. Finally, robust organizational and management skills were identified as important to run a TTO efficiently. Organizational skills expand the capacity of the office to deal with the increasing volume of work implied by the 340+ invention disclosures received by the bigger TTOs. Because there is no natural upper limit to the total volume of potential technologies to be transferred, organizational skills can represent a bottleneck that limits annual deal flow. Experience and a sufficiently large support staff alleviate the related problems.

4.2.2. Structural capital

Structural capital (SC) includes patents, concepts, models, administrative systems, and organizational culture (Sveiby 1997). Edvinsson and Malone (1997) define SC as the context, empowerment of employees, and structures supporting human capital, organizational capital, innovation capital, and process capital:

Structures that support human capital include recruiting capabilities, organizational culture, development activities, and motivating strategies. Organizational capital consists of systems and tools, the enhancement of knowledge flows, and organizational competence. Innovation capital includes an organization's renewal capability, results from innovativeness protected by intellectual property rights, and results that can be used to create new products and services and develop them quickly into applications. Process capital is practical knowledge including definitions and improvements of work and production processes (Edvinsson and Malone 1997).

An organization's knowledge base accumulates from numerous daily decisions and experiences. Among others, these are stored in work processes, instructions, and forms, and they result in organizational learning. Organizational culture can be understood as a result of organizational learning because it forms a shared framework for defining and solving problems. Schein (1992) associates organizational culture with leadership and defines them as different sides of the same coin.

According to Edvinsson and Malone (1997) SC further includes all of the codified knowledge and organizational structures an organization has created from its HC or otherwise acquired for the organization. Organizational structure, various documents and databases, and all IPR (patents, trademarks, copyrights, etc.) are included in SC. Unlike HC, the company owns its SC and, therefore, it is also able to sell specific parts of it, such as the databases.

According to our findings, SC in the TTO context includes: team-work based problem solving and the allocation of cases according to matching expertise; TTO internal job circulation for reasons of motivation and organizational learning; the empowerment of licensing officers with autonomous decisions rights regarding entire cases, tracking docket databases, industry out-reach events, formal and informal university and TTO policies; an open-door culture that encourages licensing officers to share HC unrestrictedly within the TTO and across TTOs; monitoring routines; and recreation programs to nurture familiar organizational culture; entrepreneurship contests.

Providing licensing officers with autonomy regarding decision-making rights enables the efficient and unrestricted application of their HC. Structural capital in the form of written policy and unwritten rules is therefore required to keep autonomous decisions within acceptable boundaries. Such rules and policies are internalized through learning, which is facilitated through an open-door culture. Often, such a culture did not emerge accidentally, but is strategically enforced and demanded of the personnel. Given officer's liberties and the emphasis on interaction between them, clear boundaries are necessary to uphold efficiency and to avoid "committee meetings."

4.2.3. Relational capital

Relational capital (RC) includes all external relationships with customers, suppliers, and the organization's collaboration networks (Edvinsson and Malone, 1997; Sveiby, 1997; Stewart, 1998). In the context of a TTO, this translates into potential licensees (industry and start-ups), faculty inventors, university administration, corporate liaisons offices, surrogate entrepreneurs, financiers, intermediaries, entrepreneurship associations and centers, governmental agencies, and collaboration with other parties that are important to the process of UITT. In the traditional knowledge management literature, concepts such as customer capital, networking, and virtual organizations have been associated with relational capital. In this respect, we observe a broader stakeholder base than Siegel et al. (2004), who limit their analyses to university scientists, university technology managers and administrators, and firms/entrepreneurs.

Customer capital consists of the strength and loyalty of the customer relationship. In our context, the most important customer is the faculty inventor, but the industry searching for a license and the entrepreneur willing to license a university technology to build a commercial enterprise around it are also customers. An enduring and trusting relationship between the organization and the customer is crucial to the sustainability of UITT. In a more commercial context, relationships are judged based on penetration, coverage, and loyalty, which are measured as a customer's probability of continuing the partnership (Stewart, 1998). However, even in the context of TTOs, maintaining long-term relationships with inventors and existing licensees is valuable.

The following analysis discusses the value creation logic of sample TTOs by showing how the interaction of IC components is managed to perform organizational practices that add value to UITT.

5. Analysis and results

The TTO operates between two universes: the academic universe and the commercial universe. As reviewed earlier, extant literature has verified the existence of a gap between the two obstructing the process of UITT (Rahm, Bozeman and Crow, 1988; Lee, 1996; Link and Siegel, 2003; Siegel, Waldman and Link, 2003; Siegel et al., 2004; Siegel and Phan, 2005; Jensen and Thursby, 2001; Macho-Stadler, Pérez-Castrillo and Veugelers, 2007). The value created by the TTO, then, is inherent in its many practices, which either dissipate the gap or bridge it. In essence, this implies the conversion of the value created by the academic universe in the form of knowledge into relevant input, which is fed into the value creation process of the commercial universe. The ultimate value to commercial entities and to society does not accrue before that input is converted into applicable products or services unless the created knowledge itself is valuable and can be used for normative purposes, for example.

Below, we characterize each of the value-adding, "boundary-spanning" practices of the TTO as they emerged from our data. We show how, in its capacity as a process catalyst, knowledge converter, and impact amplifier, the TTO employs these practices to (i) decrease the barrier to initiate and sustain the transfer of technology on both sides of the value creation continuum, (ii) effect a match between the supply of knowledge created in the academic laboratory and market-based industry demand, and (iii) maximize the overall societal impact of university technologies by favoring breadth of use over short-term financial objectives.

5.1. TTOs as process catalysts

As UITT catalysts, TTOs are not unlike chemical catalysts that decrease the amount of energy needed to initiate and maintain chemical processes and enable reactions between reagents that would otherwise be blocked or slowed by kinetic barriers. TTOs were found to lower inhibitions, counteract fears and correct prejudices of academic scientists and potential industrial partners that had arisen due to a lack of knowledge and experience, uncertainty, misinformation, and cultural legacies in both the academic and commercial realms. TTOs dismantle these barriers by: performing educational and emancipatory practices; providing guidance for commercialization attempts; solving administrative, IPR-related and other problems that inventors are helpless to solve; strengthening the system of the technology transfer community including entrepreneurs, financiers, and support organizations by serving as a nexus of contacts and, in some cases, by being actively involved in designing business plans; attracting funding; and assembling management teams for university start-ups. In the following section, we review a number of identified catalytic practices and show how they are generated.

Molding academic culture - The academic universe, which is epitomized by the individual inventor, involves catalyzing practices that take the form of educational services. Among other goals, these aim to: familiarize researchers with the concepts of protecting intellectual property and its fundamental centrality in commercializing the results of research; to provide guiding information about the support services provided by the TTO; to build confidence in the TTO's capabilities; to offer detailed instructions and guidelines on the concrete steps to take if there is interest in commercialization; to provide initial insights into alternative methods of financing entrepreneurial activity, and to explain the role of investors in start-up companies.

> "[We] educate students and faculty on everything from IP to how you go from just thinking about research questions to how to go from the laboratory to the market."

> "We will do a start-up boot camp every couple of years. We have panels of VCs and attorneys talk about this, again open to the public, anybody can attend, even people outside [the university] can attend, and we hope our faculty are motivated to come to these things."
> "Technology licensing is not often high on their list. The younger people are interested in getting tenure and that involves publications and does not involve licensing. And you also have to make sure that they have confidence in you. Otherwise, if they think you are incompetent, they are not going to give you their technologies, because they are going to think it is a waste of time. […] I think getting them to disclose is not the issue; showing them that you are savvy and able to license the technology [is]. […] You have to get out there and educate them to some degree and try to get them thinking about what you are doing."

According to Markman, Gianiodis and Phan (2006) inventor-related obstructions such as resistance or indifference to commercialization are the main impediments to the UITT process. As a catalyst, the TTO aims to activate researchers and inventors to gain interest in the possibilities of commercialization and to encourage them to disclose their results to the office by lowering inhibitions and fears and by mitigating prejudices that are attributable to a lack of interest in, knowledge of, and familiarity with these issues. By dismantling inhibitions, discomfort, and prejudices, TTOs mold academic culture toward being more conducive to commercialization and the application of research results, which has been identified as a key driver affecting the willingness of academic scientists to engage in commercial activities (Bercovitz and Feldman, 2008). To this end, the TTO utilizes its own interdisciplinary HC, which comprises both scientific and business knowledge. Further, applied RC is in the form of expertise from law firms, financial institutions, and experienced entrepreneurs. The knowledge that is inherent in HC and contracted through RC is channeled through the TTO's SC to the faculty. SC relevant to molding the academic culture finds expression in established educational events and programs on campus, regular laboratory rounds and related liaison activity, and business courses that are arranged jointly with local business schools.

> "They had a course run by the [local] business school […].They would just go over the whole thing about patents, mostly about entrepreneurship, about starting companies. We particularly invited those young, very bright, but sort of naïve and who are not really thinking about these things and are more concerned about papers. […] it was a great success. […] In physical sciences we meet once a week, […] and talk about new inventions that have come in. It is mainly marketing oriented. […] so we are very active in meeting with faculty members."

Thursby and Thursby (2002) attribute the rise in UITT to a greater willingness of university researchers to patent. Based on the above discussion, we argue that the value added of the educational and emancipatory practices provided by TTOs is evident in a given faculty member's increased propensity to commercialize research. Therefore, this value added is at least a partial contributor to the phenomenon evidenced by Thursby and Thursby (2002). Although Thursby and Thursby measure the increase in UITT based on the number of licensing deals and patents, we favor the number of disclosures per dollar of federal research funding as a primary indicator of researchers' willingness to engage in UITT. The number of disclosures is more neutral to technological, environmental, economic and other factors that are external to the researcher's initial willingness to participate in UITT.

Problem assistance and service - Another cornerstone of maintaining a steady stream of disclosures is to provide faculty with high-quality support services concerning all issues, which not only include their ambitions as entrepreneurs but their work in academic research. Building and sustaining a reputation of being able to solve problems quickly and reliably in all aspects regarding commercialization is key to maintaining long-term relationships with faculty, who are the vital origin of emerging technology.

> "Think of us as having two sets of customers. First set is the faculty. And if they are not happy, we never get to deal with the second set. And the second is the external business community. [There are] probably two, three things that keep your faculty happy. […] The first is responsiveness: Answer the phone, respond to the email, and do not let them move your office from campus. It is very important that faculty can just walk in here between classes. […]
> Second, smart people, bright people. The faculty are naturally trained to figure out in five minutes whether you are smart or not, because that is their job. And it makes a big difference even if they start with the assumption that all university administrators are idiots, if in ten minutes they can get their mind changed. […] And then competence. Let the faculty know that you understand them, get the job done. If there is a delay, it is an intelligent delay. […] We understand that we put the academic priorities first, that we listen to them, that we know what we are doing. And when the point comes they come for your advice, not just to do what they want you to do, then you know that you have earned their respect."

Because their primary focus and career interests are mainly academic, the opportunity costs of not participating in UITT are generally low among faculty. Thus, if the TTO were to suffer a blow to its reputation as a service provider, word would likely spread among faculty with devastating effects on disclosure rates. A damaged reputation is difficult to repair as many of the interviewees emphasized.

The services requested by faculty members are too numerous and situation-specific to be exhaustively catalogued here. To provide a few examples, however, one might list: the acquisition of material transfer agreements from third parties; the negotiation of sponsored research agreements in cooperation with the university's contracts office (if it is not integrated into the TTO); solving faculty's infringement suspicions regarding research conducted by fellow or competing scientists; providing live support for questions concerning commercialization; solving conflicts of interest between financiers, the faculty, and the university, and "getting the job done" quickly and effectively. "Getting the job done" is to be understood as an emphasis on being responsive and closing deals as opposed to risk avoidance and administrative back-office tasks.

> "Solve problems, basically. Solve them and let the researchers get on with their work. We do not know what is going to happen. But we will figure it out. You cannot imagine all the stuff. You cannot tell what the problems are going to be. You cannot invent what happens."
>
> "I think one of the key ways to fail that I have seen too many times, is that you fall into the bureaucratic mindset. […] That I think is the ultimate failure of a tech transfer office, whereas the ultimate success is you are a valued member of your local business community. […] In the end it is your reputation, it is your ability to have repeat positive relations with the people who are going to make things happen."

Solving a wide variety of problems necessitates the context-specific interplay of different aspects of IC. While tackling prior art-related questions, for instance, is dependent on licensing officers' technical and IPR-related expertise (HC), consultations with external law offices, other university administrative departments (RC), database inquiries, internal procedural guidelines, and university IP policies (SC), settling infringement disputes, as another example, draws on an entirely different set of IC. Here, negotiation and communication skills, diplomacy, and other social aspects of HC come to the fore in an attempt to uphold the involved faculty's motivation to participate in UITT despite the obvious inconveniences involved.

By providing responsive help and support concerning questions and tasks that are not in the traditional domain of the responsibilities and capabilities of faculty members, the TTO brands itself as an easy-to-approach interface between academia and the commercial world. It lowers the faculty's inertia to engage in further commercialization and thereby catalyzes the initial phases of the UITT process. Furthermore, solving specific problems for faculty effectively removes tangible obstacles that inhibit the UITT process and thereby facilitates its sustainability.

Start-up support - The Bayh-Dole Act requires universities to give preference to small businesses when licensing technology. This has resulted in the active promotion of university spin-offs that involve the academic inventors to varying degrees. Although the TTO does not interfere with running the start-up as a business, it often provides valuable services to the inventors in the pre-start-up stage. The degree of involvement depends on the TTO and its policies. Some TTOs follow a laissez-faire strategy and leave issues of business formation entirely in the hands of the inventors or surrogate entrepreneurs.

> "We do not incorporate the company for [faculty]. We tell them where to go and what people have to sign up and make the payment, and they do it by themselves. In the past, we have had

some [business school] students select a few projects from here to write business plans, so they have had some interactions with groups of [business school] students and, of course, entrepreneurs, because our faculty member cannot be the CEO."

"We do not formally assist in pulling in the money. We try to make introductions and let things go where they go, because the best people to talk about the start-up are the entrepreneurs themselves. […] Making an introduction or two will help that, but I cannot get too involved, because, in the end, the start-up is not our property."

Offices that represent the other extreme are actively involved in securing financing, building management teams, establishing the organization of the start-up and feeding it a complementary IP.

"[…] The first couple of steps we would do everything until a VC, an owner, would come along and incorporate. Then the responsibilities would go to that person. […] We can […] give them intelligence especially after they form. We know other IP is coming through this office that might be of use to them. […] What we want to do now is to be much more at the front end of the formation of the companies, because we get so much more of the founder's stock. […] We have gone to a faculty member and [seen] what the technology looked like, it was a good start-up situation, and so put together a business plan and then went out and sought entrepreneurs and money."

More subtle approaches that are closer to the average degree of involvement include support in writing business plans or in preparing presentations to investors or entrepreneurs who are interested in taking the commercialization process further. The lack of these services has been identified as constituting one of several nonnegligible bottlenecks in UITT (Swamidass and Vulasa, 2008).

"In two or three cases, the faculty member did everything. In almost all the other cases we played a sub-role. The role starts from helping out with making the presentation. […] We would invite a group of venture guys or angel investors and we would have five or six faculty members lined up. Each one will be making a 20-minute presentation, and those presentations are very focused on what is the significance of the science, what are the applications, where is the market, and the business preference."

Preparing business plans and presentations necessitates a conversion of purely technical features and scientific insights related to an invention into commercially saleable concepts and viable business models. In addition to the catalytic function, it establishes the TTO as a converter of knowledge between academia and industry. Converting knowledge is probably the most significant practice a TTO performs to add value to UITT because it bridges the gap between the fundamentally different human capital of the academia and the industry. This fundamental difference is a major factor behind the incongruence of university technology and market needs. We shall return to the subject later, in Section 5.2.

To effect the conversion, HC in the form of the interdisciplinary expertise of the individual licensing officer, which combines solid scientific understanding and business sense, is a prerequisite. RC is involved in the process such that business plans and presentations are developed in cooperation with contacts in industry and finance or with the help of local centers for entrepreneurship and business schools, for example. The organization of business plan contests refereed by guests from industry is one example of the involvement of SC in the process.

Furthermore, leveraging its network of actors in industry, government, and finance (RC), the TTO actively introduces inventors to potential partners in an attempt to bridge the usually wide gap between the respective networks. Bringing the actors together is essential to the success of UITT because the TTO cannot replace the inventor, who is the ultimate expert in relation to the respective technologies. Because technology largely consists of a tacit component proprietary to and inherent in the inventor, its successful transfer inevitably necessitates the personal interaction of the inventor with the individuals who promote the business, whether as an active member of the staff or management or, in a more passive role, as a member of the scientific advisory board (see Nonaka and Takeuchi, 1995, for the transfer of tacit knowledge in organizations). The active participation of the inventor has been argued to increase the probability of transfer success (Jensen and Thursby, 2001) and speed (Markman et al., 2005b). Therefore, providing the right connections can be argued to add value to UITT. Here, the TTO functions as a catalyst that actively initiates the reaction between two or more reagents that self-sustainably propel the process toward the final commercialization of an invention.

Figure 2 below summarizes the above findings and conceptualizes the catalytic practices according to Edvinsson and Malone's (1997) Value Platform Model, which was discussed earlier. We apply the model here to emphasize the importance of the synergetic interaction of TTO resources in the generation of practices as identified by the interviewees. Again, we must emphasize that the model was not used to interpret the data, i.e., to identify practices, and that it has been used in this paper only because it tightly conforms the manner in which the interviewees depicted resource interaction.

Fig. 2 Practices of the TTO as a process catalyst

5.2. TTOs as knowledge converters

In their role as knowledge converters, TTOs add value to UITT by affecting the congruence between the features of scientific discoveries and specific market needs (i.e., customer preferences, profit requirements and business models). To do so, TTOs open and maintain a bi-directional feedback loop between the academic and commercial universes. TTOs convey invention-specific responses that are gathered from industry through marketing and other related outreach practices (conventions, business plan competitions, etc.) to the academic inventor who is then able to incorporate the insights and specifications into the invention and increase its commercial value. In the following section, we will present a selection of identified conversion practices and the underlying interaction of IC resources.

Technical assessment - One of the central functions performed by the TTO is the technical evaluation of invention disclosures. The evaluation determines a technology's viability to be protected and licensed and whether the office will pursue the respective UITT process further. Licensing officers use their scientific expertise to initiate a rigorous prior art search. During the search, measuring the features of a given invention against the existing technological landscape and the related IPR protection requires the ability to grasp the essence of the prospective technology. One must be able to perceive and understand the essential differences and similarities to existing technologies to be able to make comparisons. In fact, one must be able to identify the boundaries of the relevant technological field against which the prospective technology is measured. Here, an in-depth understanding of the particularities of the given technology is paramount because the decisive differences between existing and protected technologies, as well as between the applications of these, can be minuscule. Again, parts of the IC base of the TTO are activated: A robust technical background (HC) is argued to provide the foundation for understanding technologies, identifying their key features, and determining whether these are relevant to a given case.

> "I would much rather have somebody with a very strong technical background […], because the heavy work, the most time-consuming work, is done at the front-end, where you're understanding what the technology is, you're doing very extensive prior act search to make sure this is a novel idea."

HC in the form of the licensing officers' scientific knowledge and experience in IP legislation is complemented by RC in the form of services from external law offices that specialize in IP protection and support in the prior art search. In addition, the expertise of the inventor, which is brought to bear through intensive cooperation during the search, is crucial to the outcome because the relatively generic technical knowledge of licensing officers can never substitute for the knowledge of the inventor, who is the ultimate expert on the technical dimensions of his invention.

> "And to be honest, it's highly technical work. It's a wide variety of technologies that you deal with. You have to know enough detail to understand the important parts, but you can't become the technical expert, that's the faculty member."

SC that supports and facilitates the evaluation process comprises the comprehensive technology and IP databases that are maintained by most of the offices, as well as regular internal meetings and more informal knowledge sharing that facilitate the identification and diffusion of case-relevant knowledge among licensing officers. The allocation of cases in accordance with their respective fields of expertise makes efficient use of the entire stock of available HC in the office and enhances its effectiveness at the same time. A culture of open interaction and the frequent strategic absence of incentive structures and compensation schemes that are tied to monetary or other performance-related indicators promote the uninhibited and comprehensive application of the office's HC because competition among officers is reduced to a minimum.

> "We get 500 invention disclosures a year. So, that is 10 a week. […] The office manager [ponders:] "Who do you think should take this case, is it what Tom does. Or is it chemistry, it looks like chemistry. Martin does software, it looks like software", so they get distributed to the people. […] And if it is not obvious, it gets fixed at the Wednesday meeting: "No, I really should have that one, because I am working on X" or "I don't really know anything about this, it looks like software but it is really biology". Then you just go round the table with 30 people, if anybody has anything to say they say it […]."

The precise positioning of disclosed inventions within the relevant technological landscape enables the evaluation of the inventions' potential to be protected and, ultimately, to serve as a foundation for profitable business. Limited freedom to operate in the technological dimension entails equally limited freedom to operate in the commercial dimension, which lowers the value of an invention. Thus, by screening out unviable technologies, TTOs add value to the UITT process (i) by reducing the total flow of technology to inventions that have an obvious potential to survive IP protection, (ii) by sparing the university redundant costs that are related to IP prosecution and marketing, and (iii) by sparing the inventor unnecessary strain and disappointment related to unfulfilled hopes of commercial success. Regarding the first two aspects, screening is of utmost importance when considering the efficiency of the UITT process. Regarding the last aspect, the early assessment of technical potential is crucial to the successful management of inventors' expectations and to sustaining their continued motivation toward the commercialization of research, which is a prerequisite of sustainable UITT.

> "The biggest challenge we have is managing expectations that every innovation made should be a very successful proposition, and that every innovation is worth half a million to five million dollars to the industry. That is quite common and I guess it is expected, because if you are the inventor, and you have been doing research in the field for a decade, or five decades, and you bump into this great idea. Emotionally, psychologically, you are very attached to it."

Search practices - From the perspective of any given invention, marketing activities are the first to initiate contact with industry. Efficient marketing requires the identification of the industrial actors that the invention might potentially provide benefits to. While cold-calling potential customers is an indispensable and frequently-used method in the attempt to make new contacts, it is not necessarily the most effective or the most popular method among the TTOs in the sample. As a more focused and strategic way of marketing new technologies, TTOs lean heavily on the existing RC and its contacts. A proper search for suitable industrial partners considerably lowers transaction costs in the subsequent intense marketing phase, which allows a focused allocation of resources. The search process itself can be burdensome, however, because the mere identification of potential licensees requires interaction with each prospect.

> "It starts as a kind of dating service: "Are you interested in blondes, are you interested in brunettes? Well, I got one who is blond but she is 6'3'', do you mind if they are tall?" So I describe a little bit what [the technology] is about and why it is interesting and then send them off to talk with the professor. And if they get further interested, then they come in, and we will send them a term sheet or a draft license agreement, and then we start talking."

Frequently, initial contacts are also provided by the inventors because they have personal experience in the industry and are familiar with contacts through prior industrial-sponsored research projects or conferences, for instance (cf. also Thursby, Jensen and Thursby, 2001).

> "It is the actual inventors that are often a major player in building the network and the contact base. Not always, but they are certainly an important factor. They have their own network. That being said, we encourage them to attend conferences, people read their papers, they get contacts… So, often that is the first place you go to ask: "Do you know anybody or industries, or fellow researcher that have companies that have an interest in the technology that you are doing?", because they know the field best."

To implement an effective search, licensing officers must have the appropriate technical and industrial expertise (HC) to analyze the technology bases of potential licensees for sufficient compatibility with the invention. The officer needs to be able to convert technical specificities into industrial solutions and to identify their potential as parts of larger and systemic existing solutions. Locating companies with the right technological base is insufficient, however, because the success of establishing durable communication links to these organizations and transmitting the intended information depends on locating the appropriate individuals and on the licensing officers' ability to elucidate the key features of an invention. The importance of individual-level contact is also recognized by Siegel et al. (2004). Technical expertise facilitates the identification of these individuals because it enables licensing officers to communicate with industrial partners on a sufficiently deep level.

> "I [prefer] somebody with a strong technical background. [They are able to] identify companies, who are in the field, identify individuals within those companies, who we should be in touch with. […] These are very raw ideas that we are trying to find partners for, these are not ideas or prototype products that really need to be polished and packaged and managed to customers. These are ideas that nobody knows whether there is a market, whether there is anybody to pay anything to buy these things, or what type of products might come out of these ideas, even that is not known."

Established partners who belong to the existing RC of the TTO and the inventor are well known and familiar, which is a valuable asset in finding a compatible customer, because search costs are comparatively lower than in the cold-calling mode. In existing relationships, organizational procedures and norms (SC) are also well known, and personal ties have already been formed, which mitigate the costs of establishing functioning and trustful communication. If a suitable and interested customer is not to be found in the RC of a TTO, existing contacts are exploited as indirect links in the search. The actors who compose a TTO's RC are embedded in networks that can be accessed through recommendations and suggestions. With every new contact, the RC of the office grows and can be leveraged in future.

Because it searches industry for potential licensing partners, the TTO excuses the inventor from this strenuous and time-consuming task. Because it has a comparative advantage over the inventor, the office: experiences greater outreach due to its broad RC base; is better able to identify potential partners through its interdisciplinary HC, which is not limited to a given field of science or business; and has more monetary and structural resources (databases, personnel, etc.) to use in the search. TTO search practices thus add value to UITT by increasing search effectiveness (if not efficiency) and the probability of finding suitable licensing partners.

Feedback looping - After potential licensees are identified in the initial search, rigorous marketing ensues. As discussed earlier, a major objective of TTO marketing practices involves obtaining feedback from industry. The office mediates invention-specific feedback, which is collected from the industry in the early phases of marketing a particular invention to the academic inventor. Based on that feedback, she can make necessary modifications to the invention to raise its commercial applicability and value. The modifications are then presented to the industry for additional comments or to close a licensing deal. Feedback sharing between industry and inventors constitutes a mechanism that facilitates the matching of scientific endeavors with market needs:

> "The marketing process is not only to find an interested party who will take a license, but also to get feedback from the private sector: "This is what we have, tell us what advantage you see in this technology, and if you do not see any interest from your company, do you know others, who may be doing something similar and might have an interest?" It is really to get their feedback as well as to find out if they are interested. Their feedback does not always help us. By that I mean, we always share all the feedback that we gather with the inventors. If the feedback is negative, then many times our inventors do not want to accept it, or do not want to believe it, but in the process, though, inventors may come up with a different way of doing things, or may come up with a different idea that they did not think about before. It helps both parties quite a bit. And because we have this dialogue, we can come back to the same people within the same industries with other ideas, because during this first dialogue they might be

> saying: "But in the event you have something along those lines, contact us". That is how the network expands."

Again, the interdisciplinary HC, which fuses scientific and business savvy into one individual licensing officer, is paramount to converting the mainly technical specifications of a marketed invention as provided by the inventor into marketing jargon that highlights the business solutions the technology is able to support. Further, the interdisciplinary HC is necessary to incorporate feedback provided by the industry into technical specifications that the invention will have to meet before a customer is truly interested in licensing it.

> "I need to be able to not become glassy-eyed when I talk to my inventors and they discuss their invention, because it is all going over my head. I need to be able to grasp the essentials and be able to articulate those to a potential licensee. Otherwise I am not helping my inventor. They are doing much of the work, so I need to be able to save them time that way. I translate the hardcore technical document that the inventor provides. It gives all the details. But it is all the details; it is not a concise, digested presentation of the features and benefits. Can I give an elevator speech, the usual venture capital-style elevator speech, on this technology? I must be able to do that. Technical background helps me do that, especially in a way that does not put additional burden back onto the inventor."

For the purposes of gathering relevant feedback on a given technology, the TTO must be have a large and diverse base of industrial RC because finding actors who are capable of providing relevant feedback with regard to a specific technology is not a trivial task. In the form of docket databases that track case-specific details (contacts, recommendations, dialogues, requests, demanded specifications, agreements etc.) that help codify the evolution of inventions through the iterative feedback loop between the inventor and industry, databases with information on industry contacts who mitigate the search costs related to identifying potential sources of feedback, regular TTO internal meetings, and an organizational culture that nurtures knowledge sharing. Through knowledge sharing, the relevant HC is allocated to cases within the office, which underlies efficient marketing practices. The allocation of the relevant HC to cases is of special importance because the effectiveness of the knowledge conversion depends heavily on the licensing officers' ability to link technological features to business solutions and vice versa.

Regarding value creation, feedback looping actively helps establish the vital bi-directional bridge to the commercial universe through which knowledge is diffused and encourages the active involvement of industry in the transfer process. O'Gorman, Byrne, and Pandya (2008) argue that "the principal benefit of the TTO is in the domain of putting external resource providers in contact with scientists committed to commercialization." In so doing, they can "help individuals or organizations with resources learn of new knowledge developed by scientists." We find that TTOs have an even more pivotal role: As a knowledge converter, the intrinsic value of TTOs lies in their affect on the congruence between features of scientific discoveries and specific market needs by maintaining the bi-directional iterative feedback loop between the academic and commercial universes. This notion extends on Siegel et al's (2004) discourse on the bi-directional interaction between academia and industry by showing how it benefits UITT and society in a much broader sense than a single researcher's ability to conduct "better research."

Figure 3 summarizes the findings and conceptualizes the interaction of the IC resources that are required to generate the respective practices.

Fig. 3 Practices of the TTO as a knowledge converter

5.3. TTOs as impact amplifiers

Unlike previous studies (e.g., Siegel, Waldman and Link, 2003, and Siegel et al., 2004), we found that the maximization of monetary returns and other volume-related indicators such as deal flow were de-prioritized as indicators that were monitored to track TTO performance. Aside from one of the universities we studied, the interviewees clearly distanced themselves from return-driven TTO policies for a number of reasons that are discussed in greater below. Instead, there is a clear emphasis on maximizing the greater societal impact of university technologies and supporting the university in its primary tasks of education and research. Thus, most of the TTOs involved in this study were geared toward maximizing the breadth and speed of application of university technology.

The reasons not to adopt revenue stream-focused strategies alone are manifold. First, pure revenue streams seem to be an unreliable measure of value creation because creating significant revenues is viewed as a numbers game, or a matter of "getting lucky," and not as the main function of TTO activities. "Doing things right", as an interviewee stated, does not guarantee commercial success due to the technological and market uncertainties inherent in early-stage technologies that are independent of TTO actions (see also Macho-Stadler, Pérez-Castrillo and Veugelers, 2007). Further, licensing revenue generation is dependent on the commercialization abilities of the licensee.

> "I think the monetary thing is a canard. First of all, statistically you have to get lucky before you make a lot of money. Secondly, most people think that they can play and get lucky. If you could do that, it would be much easier to buy a lottery ticket than to do the kind of work we do. As you look across the country, there are a few universities that have won the lottery once in a while and made a significant difference in the fortunes of the university for a while; but not very many. So, there are so many false expectations about the money […]. If you set up an organization with unreachable financial goals, and with the thought that you are going to run it primarily with financial benefit when that is not how it works, everyone is doomed to unhappiness."

Second, maximizing profits by focusing only on transfer transactions that are expected to reap the highest payoff might compromise the transfer of technologies that could potentially have great societal or human impacts. Third, when only the few inventors who are accountable for potential blockbuster technologies are served, the majority of the faculty will be dissatisfied with the office's services. The problem is that this dissatisfied majority of inventors constitute a potential source for future blockbuster technologies.

> "You cannot focus too much on revenue for a lot of reasons. A deal that brings in a hundred dollars may be very meaningful to the faculty member who submitted that disclosure and just went through the process. […] If you only focus on the home runs and only serve the people who might give you those home runs, you are only serving a very small percentage of the faculty, and the rest will be pretty unhappy and the popular perception is then that you are not running a good office. […] Everybody gets a basic level of service when they submit the disclosure. Maybe [it generates] low dollars and maybe high dollars, but we are going to do the same basic service for everyone."

Fourth, publicly financed universities, which have an implicit societal mission to strengthen local economies, are constrained in measuring their success in terms of revenue. The goal of maximizing the university's profits stands in strong contrast to (i) the taxpayers' perceived right to benefit from technologies that are largely generated based on taxes they paid and (ii) the expectations of paying licensees that their royalties will be injected into the local economy in one form or another. Obviously, private university TTOs do not have these same constraints.

> "We are [a] public university. So if we focused on gross revenue, it will be too easy for those 38% of [local] licensees to say "Hey wait a minute, we are working. All that money is coming out of our pocket [through royalties and taxes]. You're not helping the [local] economy; you're just a cash register for the university."

Finally, some technologies require the bundling of single inventions to comprise an economically viable and protectable whole. Bundling is an arbitrary decision, however, and should be made with the goal of optimal transfer in mind, not to increase deal flow. TTOs with internal incentive structures based on deal flow have the motivation to license technology in sub-optimally small pieces in an attempt to increase deal flow.

> "The other thing is [how] we count our deals. Each licensed deal is counted as one even though each one may have anywhere from half a dozen inventions to as many as 48 inventions. But we will count that as one deal and not six or 48. And, we do not count as deals where a company has sponsored a research project, and in that agreement we have entered license terms. When an invention is disclosed [from such a project], there will be no separate license deal, however, because most of the terms are already part of the research agreement […]. So, I know that different universities have very, very different criteria for doing this counting and even though we are regarded as a low number of deal flow in terms of licenses, I do not want to change it."

How, then, do TTOs maximize the breadth of application that some interviewees seemed to prefer over others? We found this process to be less about concrete action than about a philosophy of picking the option among a set of alternatives, which most likely results in the application of a technology. This does not necessarily have to coincide with the most lucrative option in terms of possible economic returns.

> "I look at the resources put on the table, and by resources I don't mean just the financial capital, but the human capital, the understanding of that human capital in the technology, and whose proposal really indicates the fastest [track from] the development phase through to the product […]. Even if a large corporation offers me a huge amount of upfront fee that a start-up company cannot, I still would not go to that one million, if it's a huge amount as much as one million, if it looks like the start-up company would really aggressively develop it and take it to market. So, [the question is] really, what makes sense for that particular technology, for that particular market, and who are offering the most resources to develop it."

Applying such a philosophy is a balancing act between the diverging objectives of intrinsically opportunistic UITT actors and upholding incentives structures for all involved parties. As an impact amplifier, the TTO mitigates the detrimental effects that the opportunistic incentive structures of the diverse stakeholders might have on UITT. Left to determine an equilibrium outcome for UITT on its own, the system of opportunistic actors might converge toward suboptimal solutions at the cost of the diffusion of technology and the benefit to society. We provide support for this argument in the following section.

Maximizing diffusion – Regardless of whether the university in question is public or private, interviewees insisted that putting a technology to use in society is regarded as more important than its licensing terms or the monetary benefit that accrues to the office or the respective university. Maximizing technology diffusion and public benefit more broadly involves various concrete measures.

A fair number of these measures were outlined in the form of stipulations in a public initiative publication (December 2009) signed by 51 US university TTO,s including all but one that participated in this study: In the Public Interest: Nine Points to Consider in Licensing University Technology (available at http://www.autm.net/White_Papers/2188.htm, last accessed on September 28th, 2009).

Among other things, the stipulations prompt TTOs to design license agreements in a manner that allows the office to "reserve the right to practice licensed inventions and to allow other nonprofit and governmental organizations to do so" so that performing and publishing research related to the field of the invention is not constricted unnecessarily.

Moreover, license agreements that provide the licensee with exclusive rights to an invention are encouraged to include clauses that demand the development and use of the underlying invention by setting milestones or including the obligation to give sublicenses to third parties that aim to fulfill unmet market or public health needs. In general, exclusive rights should be reserved for cases in which a "significant investment of time and resources in a technology" is required to develop and widely implement it. Inventions in the area of research tools, in particular, should be kept widely accessible. Again, exclusive licensing is discouraged due to its potential negative impacts on unanticipated uses, further research, future commercialization efforts and markets.

Further, the unnecessary licensing of "future improvements" of existing licensed inventions should be considered carefully to avoid tying the inventor's research program to the licensee. This could strongly restrict the inventor's ability to obtain industrial and other research funding and to collaborate with colleagues working for other companies.

According to the stipulations, special attention is to be paid to licensing to "patent aggregators." Aggregators, who operate according to the "value added" model, gather coherent and comprehensive IPR portfolios from multiple sources around single technologies. Thus, they are in a position to provide themselves or secondary licensees with great freedom to operate. Because universities are not able to assemble such portfolios, the stipulations of the initiative publication argue that "value adding" aggregators "serve an important translational function in the successful development of new technologies and so exert a positive force toward commercialization," In contrast, aggregators that operate under the "patent troll" model represent pitfalls to be avoided. Trolls strive to obtain broad rights that apply across technological fields. Their intention is not to develop the technologies but to strongly limit other actors' freedom to operate.

Finally, agreements should include provisions that attend to special societal needs such as the therapeutic, diagnostic, and agricultural needs of the developing world or of patient populations that are too small to be of interest to commercial ventures. These provisions would be designed to ensure that orphan markets have access to relevant technologies at little to no cost. To provide an illustrative example, in addition to donating the rights to a therapeutic technology that addressed an orphan population to the central association corresponding to the underlying disease, one of the sampled TTOs offered its own proprietary funds to develop a prototype of the therapeutic instrument that was later used to treat the disease.

The principles outlined above, which guide licensing officers in their decisions and negotiations, form an integral component of a TTO's SC. In conjunction with other written and unwritten guidelines, they serve two primary purposes. First, the principles set tangible boundaries for the autonomy of licensing officers, which ensures that the correct decisions are made regarding which organizations to partner with and what outcomes to favor to achieve intended goals. Setting well-defined boundaries provides officers with greater autonomy in applying their expertise in an environment that is too dynamic for rigid hierarchies in decision-making.

> "You need clear policies, no exceptions, so everything doesn't deteriorate into a committee meeting. [Establish] clear boundaries and then give people autonomy within the boundaries. It is the ideal way of doing things anyway. The place can be called controlled chaos. The new president who is not from [this university's] culture is trying to bring the chaos under control. We are not sure if that is a good idea. It is a long, long history of letting smart people do the right thing, and they figure it out."

Second, the principles integrate the generic TTO mission to benefit mankind while preserving the university's primary mission of education and research into licensing officers' daily decision-making. The systematic absence of performance-related compensation schemes for licensing officers is a structural solution that further precludes opportunistic decision-making by officers that could lead to suboptimal deal structures, for instance, piece-meal licensing, that counteract the impact-amplifying effects of the principles discussed above.

To apply the above policies in choosing licensees and structuring deals, the licensing officer must have diplomatic negotiation and communication abilities (HC) because many of the stipulations impose restrictions on the preferred solutions of other actors such as industrial for-profit licensees.

> "You also have to have negotiating skills. You really have to be able to see the other side. It is more diplomatic negotiation than negotiating the price of a car, because you are going to be living together for a long time. There are a lot of things you need, they need, and it is two different cultures that you have to explain to each other. This is why the industrial experience benefits us so much, because we are hiring people who are bilingual in the languages of academia and industry. They have an academic background and they understand how industry thinks. […] They have to feel that even though you are on the university's side and are negotiating for the university's benefit you are fair, that you can creatively solve problems for both sides […]. You do not have to win in a negotiation. But instead see the victory in getting a fair deal done."

The licensing officers are entirely responsible for generating incentives for involved parties that guarantee the sustainability of the UITT process. Thus, their ability to argue the benefits of proposed solutions to the industrial partners net of the imposed restrictions is critical. In turn, this ability requires considerable understanding of the licensees' business models, technological portfolios and markets. Again, technological expertise and business acumen prove to be central aspects of the prerequisite HC. Establishing the "rules of the game" and thereby gaining credibility with industry is achieved though the common commitment of the larger TTO community (RC) to the rules. Active relationships with other TTOs are a vital part of the RC of the sampled TTOs. The relationships to other TTOs were systematically characterized as cooperative and noncompetitive. The emergence of such an initiative as the Nine Points to Consider in Licensing University Technology is a tangible artifact that attests to a shared view of which objectives TTOs should emphasize. Finally, society's perception of the university's role and the expectations implied by that role represent another important stakeholder in the determination of the principles a TTO must take into account when developing its decision-making protocols.

Monitoring infringement and noncompliance of deals - The last value adding practice that will be discussed in this study is the monitoring of closed licensing agreements. This practice is essential to the longevity of UITT because the strength of IP protection is equal to the credibility of its prosecution. Even though clauses included in license agreements to ensure the rapid and broad application of a technology only take effect if they are enforced, the determination of the true advantages of infringement and noncompliance prosecution is not straightforward. Prosecution is not recommended if no direct benefit to the transfer process can be expected because involvement in lawsuits seldom reflects well on any of the involved parties. Prosecution might do more harm than good in the long run, especially in cases where an infringer is a great contributor of industrial sponsorships to the university's research endeavors.

> "[…] he had this idea, he said: "[With] the semi-conductor [industry] we are having great difficulties licensing, and companies are very persistent and don't want to have licenses. So why don't we pool our inventions in that area, and then hire a law firm to enforce these patents […] and threaten to sue if they don' t [license]." And I said: "That's the worst idea I have ever heard in my entire life, because these are companies that are bringing in tens of millions of dollars into the interdisciplinary research center […]." It is a good example. You need to look at it in the context of the university rather than just the office itself and what is going to get the most money to the office."

Monitoring practices add value to the UITT process in two ways. First, they add credibility to the enforcement of IP protection regarding university technology. An academic inventor not only lacks the means and expertise to search for possible cases of infringement but also lacks the appropriate resources to follow up on any infringements that are detected. The TTO, which is supported by the university's infrastructure and resources, is a much more credible opponent. Therefore, one aspect of the value added by monitoring practices is the difference in the volume of infringements and cases of noncompliance from a scenario in which the inventor is responsible for the enforcement of IP.

The second aspect of value added is inherent in the TTO's ability to respect the university's societal mission when enforcing IP. Because licensing officers seldom directly benefit from an increase in licensing income or other comparable metrics due to the absence of performance-related compensation schemes (only one office included in this study employed deal volume-related compensation to licensing officers), the stipulations and principles discussed earlier weigh heavily in decisions regarding whether and how enforcement action should be taken. Maximizing the breadth of use and speed of diffusion, considering a deal's impact on the university's ability to conduct further research on the technology in question, and protecting the university's dual reputation as an academic institution and as a partner in industrial cooperation are just some of the priorities considered when choosing an IP enforcement action. The incentive structures of all parties involved in UITT, including the inventors, the licensees, the universities and the greater public, must be respected to ensure the longevity of the process. As on interviewee stated, although single actors tend to be "myopically focused on their own what's-right-in-front-of-me," TTOs are able "to look at the whole, and look at it from the perspective of the public benefit meaning that a discovery will get out of the lab and be more than just a journal article gathering dust on the shelf."

Effective monitoring and follow-up action engages a TTO's entire IC base. While the code of conduct that emphasizes the long-run sustainability of UITT and maximizes diffusion is an artifact of SC, HC is required in the form of technical and legal expertise to detect infringements and assess their severity. Negotiation skills are also necessary to solve conflicts diplomatically without breaking the UITT continuum. Further, external law firms, which provide expert legal support, are a central example of the involvement of RC.

Figure 4 summarizes the findings and conceptualizes the interaction of IC resources required for the generation of the respective practices.

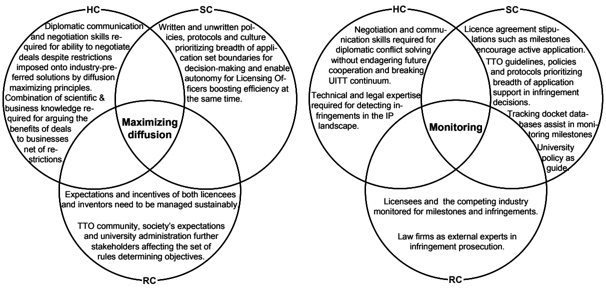

Fig. 4 Practices of the TTO as an impact amplifier

6. Discussion and conclusions

In this inductive study of 7 US university technology transfer offices (TTOs), we set out to identify the added value of the practices that TTOs perform to bridge the infamous gap between academia and industry in university technology transfer (UITT). To this end, we inductively characterized various core practices and some of the respective resources underlying these practices. We were able to establish three central concepts for the value added that the offices provide by considering the TTO as: (i) a process catalyst, (ii) a knowledge converter, and (iii) an impact amplifier.

As process catalysts, TTOs lower the threshold to participate in and sustain the process of UITT on both sides of the transfer continuum, that of academia and of industry. These thresholds are caused by various factors, including lack of experience with commercialization, cultural barriers, IPR issues, economic, professional and other uncertainty, misinformation, and prejudices. TTOs lower thresholds by educating and emancipating researchers, giving them personal 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 iterative feedback loop between the academic and commercial universes by bringing technology-specific responses gathered from industry through searches, marketing and other related outreach practices (conventions, business plan competitions, etc.) to the academic inventor who can incorporate these insights and specifications into the 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 office facilitates congruence between the features of scientific discoveries and specific 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 industry and the academic inventor, respectively.

As an impact amplifier, the TTO mitigates the detrimental effects that the opportunistic incentive structures of diverse UITT stakeholders might have on the scale, scope and speed of the technology transfer. It thereby amplifies the impact a given technology will have on society and the environment. Left to determine an equilibrium outcome on its own, the system of opportunistic actors with divergent objectives regarding UITT might converge toward suboptimal solutions on the cost of the diffusion of technology and the societal impact. For instance, licenses to inefficiently small parts of technology could be granted; IPR could be licensed to patent trolls that only use patents to strategically block competition; infringements could be prosecuted without considering long-term detrimental effects to the university; licenses could be structured in ways that impede further academic research related to the underlying technology; the breadth of use might be endangered by exclusive licenses; and improvements to existing technologies might be obstructed if ex post additions to licensed technologies are included in licensing contracts. To prevent value-destroying opportunistic behavior, the TTOs in our sample apply a set of principles and stipulations that favor breadth of use over purely monetary objectives when managing stakeholder expectations, considering potential licensees, structuring licensing deals, and monitoring infringements.

The TTOs' motives as an impact amplifier necessitate further discussion. In a cynical world where the "educational industry" is increasingly competitive and incentive-driven, one must inquire as to the origin of universities' motivation to diffuse technology at all costs and to favor technological impact over income. If resources for universities' primary functions of research and education are limited, why should universities allocate them to a function that does not necessarily provide any additional resources and might even incur losses? How do a university's research and education missions benefit from the distribution of technology? Despite the empirical evidence gathered by this study, these questions cannot be conclusively answered. However, we argue that profits and other monetary indices are comparatively of little importance to a university's reputation, its impact in the academic world, and its capability to attract high caliber faculty and students. They do not necessarily convey signals of academic merit or a high standard of research and education. In contrast, the number and impact of technologies that have emerged from a given university are important markers of that university's academic achievements.

We provide the case of Yahoo! as an illustrative example. Although it was conceived by two Stanford University students in their spare time, the company has been one of the most popular Internet services for many years. Because the students used their own resources, Stanford University has no rights to the algorithms used to run the Internet portal. Nevertheless, Yahoo! has benefited Stanford greatly because the credit for developing the students' abilities and entrepreneurial drive are credited to the university and its progressive education.

We argue that the societal impact and application of breakthrough technologies, rather than their revenues, are important signals of a university's standards and quality of education and research. This signal provides universities with an important edge in the competition for key faculty, ambitious students, and a rank among top universities.

> "When I was at school [X], there was a number of potential faculty that were looking at positions at the medical school that actually came in and interviewed the licensing office as part of their own due diligence for accepting a position."

Thus, we argue that universities have strong internal and strategic incentives to maintain TTO operations with the ultimate objective to diffuse technology as broadly as possible.

In addition to establishing the TTO as a process catalyst, a knowledge converter, and an impact amplifier, the study showed how the scrutinized TTOs manage key resources and, more specifically, their Intellectual Capital (human, structural, and relational capital), to generate organizational practices that underlie the three constructs of value added. Perhaps the most crucial of the identified resources was the amalgamation of solid technical expertise and extensive industrial experience in the individual licensing officer. The fusion of capabilities from both the academic and the industrial universes was a prerequisite to most of the value adding practices analyzed in the study. However, such boundary-spanning human capital is effectively applied only if it is supported by practice-specific structural and relational capital.

The study's inductive approach to linking resources to practices and practices to value creation enabled us to contribute to the existing literature on TTOs. Much of the existing body of knowledge focuses on estimating the so-called TTO production function. Identified inputs to UITT are estimated against a variety of performance measures in the TTO context (Friedman and Silberman, 2003; Lach and Schankerman, 2004; Thursby and Kemp, 2002). While the mechanisms through which inputs are transformed into performance are based on intuitions, logics and arguments derived from previous (mostly quantitative) literature in these studies, the extant approaches typically fail to provide first-hand evidence and an explicit, in-depth understanding of the inner workings of the production function. The questions of "why" and especially "how" have received little attention because previous studies have focused on finding statistical explanatory power between a set of variables. More recent contributions to the literature have taken up the challenge to examine the role of organizational practices in the generation of TTO performance (e.g., Siegel, Waldman, and Link, 2003, Siegel et al., 2004, and Sorensen and Chambers, 2008) and made initial 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 generating value to UITT. It is claimed that data indicate that certain resources are vital to performance, but little is said about the intuition behind this connection, i.e., about how a particular resource enables a specific practice and thereby affects a certain aspect of value generation.

Therein lies the contribution of the present study. We illuminate one corner of the black box that has thus far obscured the TTO production function to (i) show the dynamic interaction of the central resources that underly the generation of key organizational practices, (ii) identify and characterize those practices and demonstrate their centrality to the role of TTOs in UITT, and (iii) argue how these practices add value to the UITT process. Providing the internal intuition for the process starting with resources and concluding with the value added enables one to explain why the lack or mismanagement of certain key resources can be considered detrimental to UITT, which processes it might obstruct, and what kind of value might be forgone.

We further contribute to the empirically weak literature on Intellectual Capital by qualitatively analyzing the interaction of IC components in empirical cases. The categorization of resources implied by the Value Platform Model of IC was shown to be a well-suited approach to capture resources that are quantitatively difficult to measure and link to organizational practices. Having previously been the subject of theoretical debate, the framework was shown to be highly applicable in empirical research. However, it is emphasized that such application is only feasible under considerable context specificity. This aspect is one of the framework's central strengths.

Regarding managerial implications, in showing how the three components of intellectual capital are managed to generate value-adding practices, the study implicitly presented a model of TTO management, the basic principles of which are applicable to TTOs worldwide. While specific practices and functions may strongly depend on local, regional, or national contexts, the governing principles implied by the case study are universal. Among others, these include employing interdisciplinary licensing officers endowed with both technical expertise and personal industry experience, abandoning purely profit-maximizing objectives, and focusing on serving the faculty as a cherished customer and valuable resource.

A few caveats must be issued regarding the study setting. First, the results are not generalizable. They are not intended to represent the average university technology transfer office because providing a general description of TTOs not the aim of the study. Instead, using a handful of select experienced cases, the intention is to understand the TTO's role in the technology transfer process and how the office adds value to this process as constructed from the underlying cases. Thus, deductions should be made with care and awareness of the underlying generalizations.

Second, given the focus on 7 relatively successful TTOs, we cannot derive normative implications based on the results, i.e., we cannot claim that by strictly following the example of the TTOs in our sample, other TTOs will achieve comparable success. To make such claims we would have had to (i) include a number of less successful offices in the sample and (ii) apply comparative techniques to discern practices that have a decisive impact on TTO performance. Our focus is on making sense and providing an understanding of the TTO production function and the value added by the underlying organizational practices. We do not claim to measure the production function or to compare value added among the sample TTOs.

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

Fourth, it is fully recognized that UITT is a complex process in which TTOs play only one of many roles. A TTO is not an isolated entity that is capable of providing value to the process detached from its systemic environment comprising the 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 the present study is an in-depth analysis of one of the central parts of the process and not of the process as a whole. We emphasize this throughout the study by concentrating on the value added of TTO practices.

Fifth, despite the prevalence of the term "process" in the terminology of this study, we primarily investigate constructs (intellectual capital, practices, and TTOs as catalysts, converters, and amplifiers). We do not claim to construct a process flow, but use the framework of UITT to position individual practices and to illustrate their value. The existence of the process as such is assumed a priori based on its established treatment in the existing body of knowledge. Phan and Siegel (2006), for example, discuss the flow of certain resources such as money, intellectual property and information in the technology tranfer process.

Finally, the practices reported in this study are not exhaustive. Many others arising from the data could be argued to add value to the process of UITT as well. Due to space and scope restrictions, and for the sake of coherence, only the practices that were most prevalent in each of the interviews are reported.

To conclude the study, some valuable avenues for future research should be discussed. Because the focus of this study was to establish a conceptual framework that identifies the value-adding TTO practices of a small set of experienced offices and to place them into a coherent context, more rigorous empirical testing could not be incorporated into the limited space available. There is a clear need to follow up our efforts with a survey of a larger sample of TTOs to verify our conclusions and interpretations regarding their role in UITTand the variety of practices they perform 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 potentially fruitful approach to the phenomenon would be to apply comparison and contrasting techniques to highlight the variation in practices to provide greater insight into the challenges facing the UITT process and to discuss the range of behaviors and practices employed by TTOs.

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9. Appendix

9.1. Transfer process

For the purpose of providing a descriptive reference of the UITT process for the analysis proper, Figure A.1 presents a systemic flow of the licensing process as it emerged from the data. It should be pointed out that the model is generic and, thus, is not an attempt to capture differences in practices across the 190+ TTOs currently active in the US. Nor does it go into the details of micro-level practices performed by the office to drive on the process. These are the subject of Section 5 where we construct the conceptual framework of TTO practices adding value to UITT.
The process of UITT begins prior to the emergence of an invention. The office often activates researchers and faculty in issues of commercialization through educational events, personal laboratory visits, expert guest speakers, regular department meetings, etc. raising the propensity of inventors to submit an invention disclosure to the TTO. The first disclosure might be informal and it is pre-reviewed by technology transfer officers. Should the first impression seem promising, a formal disclosure is submitted to the office.

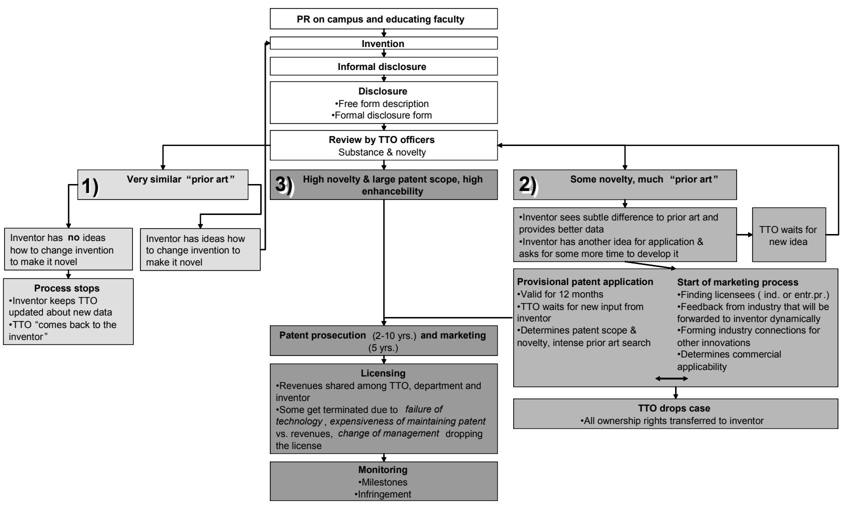

Fig. A.1 Transfer process blueprint

The disclosure initiates a rigorous prior art search and a technical evaluation process. With help from external patent offices, technology transfer officers search the existing IPR landscape for potential hurdles in an attempt to determine whether the disclosed invention can be protected through IP protection. At the same time they evaluate the technical feasibility and the potential impact factor of the invention. Further action depends on the outcome of the prior art search. Outcomes can be roughly divided into three different scenarios:

First, there might be considerable existing prior art in the field that the invention is supposed to be positioned in. In such an event the inventor is given the opportunity to change major aspects of the invention in an attempt to infuse a twist of novelty into it. The "re-invented" invention is then fed back into the process via a completely new disclosure. Should the inventor not know how to modify the invention, it is not pursued further. The inventor is free to report back once novel ideas emerge, and usually keeps the office up-to-date about the latest data and developments.

Second, in the event of moderate existing prior art and, hence, some novelty inherent in the invention, the inventor is required to show how the invention distinguishes itself sufficiently from existing technology. The inventor can provide proof in the form of better and more detailed data, for example, but might also have ideas as to how to apply the invention in a way different than previously intended. The TTO stands by until the inventor has modified the invention, if necessary, and then initiates the next phase. This includes filing a provisional patent that is valid for 12 months. During that time the inventor can make further modifications to the invention and improve it. Simultaneously, the TTO determines the novelty of the technology by intensifying the prior art search and designing the final scope of the impending patent. Moreover, the TTO initiates an extensive marketing process that serves several vital functions: (i) finding a potential licensee for the up-coming IPR; (ii) gathering feedback on the commercial potential and applicability of the invention directly from the relevant industry. The feedback is forwarded to the inventor who, then, is able to make the appropriate modifications to the invention in an attempt to adapt it to industry requirements; and finally, (iii) expanding the network of industry connections of the TTO that can be tapped into when marketing future inventions. Depending on the outcome of the final prior art search and the industry feedback, the promotion of the invention is either terminated (often, then, the rights to the invention are transferred to the inventor) or its proper patent prosecution is instigated. The prosecution process can take anywhere from two to ten years. Simultaneously, the marketing efforts continue for several years or until the invention is licensed. Once licensing occurs, the ensuing royalties are shared between the inventor, the university department, and the TTO. An active license is monitored by the TTO for agreed milestones (e.g., the invention has to be commercialized within a period of X years beginning from the date of licensing) and possible patent/license infringements. Occasionally, some licenses might also be terminated by the licensee, because, say, the technology simply fails in the marketplace, the patent maintenance is too expensive relative to generated revenues or for strategic reasons.

Third and lastly, the initial prior art search and technical evaluation might indicate that the invention is highly novel, offers a large scope for patenting and is highly upgradable through follow-up inventions. These are the most sought after inventions. In such an event, the TTO immediately initiates full-scale patent prosecution, marketing, and licensing efforts omitting the provisional patenting phase.

9.2. Interview template

Q1: From the perspective of the Technology Transfer Office (TTO), and from its perspective alone, what is the mission of the office, both officially and unofficially? In other words, which different instances would you say the office does achieve success?" (Alternatives for the term mission: strategic objectives, value proposition)

> !!! The interviewer should emphasize that the question is *purposefully ambiguous* with regard to third parties, for example, that the terms *success* or *value* might relate to or be defined by, because their type and nature, too, are of interest to the study and, thus, shouldn't be predetermined by the researcher !!!

Allocated time: 10min.

Cumulative time: 10min.

Q2: "Could you elaborate in detail, even on individual level, on the human capital employed by the TTO that is instrumental in achieving the objectives you just defined in the prior question?"

"Human capital encompasses specific skills, experiences, education, knowledge and other intangible assets inherent in an individual employed by the TTO. It does not include these aspects inherent in individuals outside the office that still might be associated with the office in some respect. This type of human capital will be dealt with later on during the interview."

Allocated time: 15min.

Cumulative time: 25min.

Q3: "Could you elaborate on and characterize in detail, even on individual level, those relationships of the TTO personnel to external instances that are instrumental in achieving the objectives or fulfill the TTO's mission as you defined in the beginning of the interview? We are just as interested in informal ties to, e.g., acquaintances of any kind, friends, ex-colleagues, family, etc., as we are interested in formal relationships corroborated through, e.g., contracts or long-term relationships given that they contribute to achieving the TTO's mission. "

> !!! The interviewer should emphasize that the question is *purposefully ambiguous* with regard to the function and type of external relationships as those are of interest to the study and, thus, shouldn't be predetermined by the researcher!!!

AAllocated time: 15min.

Cumulative time: 40min.

Q4: "What can you tell us about the internal infrastructure of the TTO that a) codifies b) creates, c) supports/enhances, d) renews, e) protects and f) maintains, the knowledge inherent in human capital and external relationships discussed earlier? Such infrastructure can consist of, e.g., established organizational routines, organizational culture, official or unofficial guidelines, rules, information systems that personnel can share information through, explicitly communicated strategies, brands, IPRs and so forth."

Allocated time: 15min.

Cumulative time: 55min.

Q5: "Referring constantly to the elements you have described in the previous questions so far – human capital, external relationships and internal infrastructures – please, elaborate as vividly as possible on the process that technologies are transferred by starting from the lab toward its ultimate application in the field from the perspective of the TTO."

Allocated time: 45min.

Cumulative time: 100min.

END OF INTERVIEW

Some notes for the researcher:

- It is always valuable to emphasize that **characterizing** concrete elements of intellectual capital in detail is key. The true value of the study relies to a great degree on in-depth depiction and characterization of the elements. *E.g.* simple statements on external contacts in the form "a couple of IT-focused VCs regularly work together with us." should be followed by clarifying questions like "how would you depict your relationship to them?" and "how was the relationship established?" *etc*.
- Anecdotes are of great value. They anchor theory to reality.
- Interviewers **must avoid** leading questions in the form "isn't it true that…" or questions that ask the interviewee to explicitly depict phenomena that should arise from the complexities of the interview as a coherent whole: e.g. "what is knowledge management from the perspective of a TTO" or "**how** does a TTO create value".

Appendix 2

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GROWTH INHIBITORS OF ENTREPRENEURIAL ACADEMIC SPIN-OFFS: THE CASE OF FINNISH BIOTECHNOLOGY

ANTTI-JUSSI TAHVANAINEN
ETLA The Research Institute of the Finnish Economy
Lönnrotinkatu 4 B, FIN-00120 Helsinki, Finland
antti.tahvanainen@etla.fi
http://www.etla.fi

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This study compares Finnish biotechnology SMEs founded by the academic originators of the underlying basic research projects with biotechnology companies of other origins. The comparison facilitates the identification of factors affecting the prosperity of these "academic spin-offs" as a business. Results indicate several inhibitors of growth: Academic spin-offs lack market-orientation and commercial skills, the traditional perception of the academia's detached role within society aggravates the recruitment of skilled labour, and Finland's equity markets are underdeveloped with new seed capital being next to unavailable, as private and foreign venture capitalists invest primarily in companies being already very close to the markets.

Keywords: Academic entrepreneurship; biotechnology; small and medium sized enterprises.

1. Introduction

This paper portrays characteristics of Finnish biotechnology SMEs[a] having their origin in academic research conducted in universities or other comparable research institutions. In order to emphasize their entrepreneurial aspects and background, academic spin-offs are defined to be firms founded or at least co-founded by the originator of the academic research a particular firm is commercializing. The focus on these entrepreneurial academic spin-offs is factually justified, as the majority of biotechnology start-ups in Finland exhibit such a background. The aim is to explore whether and how these firms differ from biotechnology firms spun off by

[a]SMEs in this paper are defined according to official definitions of the EU including firms that match 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.

large corporations and other firms that do not build on academic research.[b] To this end, I set the null-hypothesis stating that there is no difference between the two types of firms.

The portrayal contributes to existing literature by providing a detailed first-time look at Finnish academic biotechnology spin-offs. It facilitates the positioning of these firms within the sector as a whole and, even more importantly, enables the identification of strengths and weaknesses of academic biotechnology spin-offs as well as factors that either promote or inhibit their prosperity from an entrepreneurial perspective. Furthermore, findings have implications on future studies aiming at generating (a) knowledge on entrepreneurship that is rooted in academic research, on one hand, and (b) advise for policy making concerning the promotion of industrial biotechnology on the other.

1.1. *Background*

The motivation for studying academic entrepreneurship in a sector that is still regarded to be in its early days of development and of small economic significance at the present, at least from the Finnish perspective, can be traced back to a framework that is in the core of discussions about Finland's competitiveness in the global economy.

According to the principle of comparative advantage, Finland has to focus on generating technological innovations in order to protect its competitiveness, as competition based on mass production and economies of scale are ruled out due to small domestic markets and a high cost level. In the 1990s, the ICT sector bore the function of being the locomotive of innovation and exports growth. As the sector matures and markets saturate due to harsh global competition, Finland has to map and develop new sectors that (a) form a strong platform for technological innovation activities and (b) are of significance on the global scale. Biotechnology is one candidate satisfying both criteria. Understanding the nature of the biotechnology business and its requirements posed to the operational, political and social environments become crucial, if one aims at an efficient and effective policy for the support of the sector. This in turn necessitates profound research, as the sector seems to differ in many ways from more traditional ones.[c]

At the heart of sector growth are start-ups and, in more general terms, entrepreneurship. Growth can certainly be achieved through expansion of existing organizations, but the critical mass forming a self-nurturing network that generates sustainable growth through complementary diversity can only be provided by an expansion of the company base, increasing the sector not only in size but also

[b]Large biotech corporations are excluded from the analysis due to inconsistencies in the data and because one could assume that larger and more mature companies resemble those in other sectors in terms of firm characteristics relatively more than small and medium sized companies due to the more consolidated state of business. Thus, the inclusion of large sized firms might have diluted findings stemming from characteristics distinctive for biotechnology businesses. The question whether this assumption holds true stands open for further research and is not answered to in this paper.

[c]For a comparison of the Finnish biotechnology and ICT sectors refer to Palmberg and Luukkonen [2004].

in scope. Thus, critical attention should be paid to the analysis of start-ups. This paper takes a first step in that direction by shedding light on the characteristics of entrepreneurial academic biotechnology spin-offs.

1.2. *Prior literature*

This study positions itself amongst a fairly young and lean but steadily growing literature on the Finnish biotechnology sector. The first comprehensive disquisitions of the Finnish biotech sector in general are provided by Halme [1994], Halme [1996], Ahola and Kuisma [1998] as well as Tulkki, Järvensivu and Lyytinen [2001]. All three studies are descriptive of nature and incorporate a firm level description of the state of the Finnish biotechnology sector at given times. Hermans and Luukkonen [2002] present quantitative results on the evolution of the sector in terms of the number of established firms, their location and difficulties at the start-up phase, funding, customers and markets, R&D-intensity and collaboration, personnel and skills, sources of funding and intellectual property rights (IPRs).

Hermans and Tahvanainen [2002] is a descriptive study on the capital and ownership structure of Finnish biotech SMEs, whereas Tahvanainen [2003] examines this structure more in-depth in the light of central theoretical frameworks. Hermans [2003] focuses on the capital structure and other characteristics of business operations of biopharmaceuticals in Finland, while Hermans and Kauranen [2003] relate growth expectations of Finnish biotech companies to intellectual capital residing in them.

The literature referred to so far serve the purpose of indicating that there is close to none existing literature focusing explicitly on entrepreneurial academic biotechnology spin-offs in Finland. More relevant to the matter of this study is a sub-branch of the generic entrepreneurship discussion focusing on *academic entrepreneurship.* In the following, I deliberately provide more extensive reviews of these studies as they provide a backdrop for the discussion of results towards the end of the study. As the present study is explorative in nature and examines a variety of isolated aspects related to academic spin-offs, the review does not follow one thematic path but introduces a selection of very heterogeneous studies that all contribute to a deeper understanding of results presented in the present study.

One of the most intensively studied aspects concerns cooperation patterns, networking and cluster formation of firms. Shan, Walker and Kogut [1994] examine the association between inter-firm cooperation and the innovation output of start-ups in the biotechnology industry. Their key finding suggests that commercial ties to other companies are a pre-condition to higher innovation output.

Nilsson [2001] analyzes the role of interaction between researchers, managers, and venture capitalists in the process of recognizing and pursuing emerging opportunities in biotechnology. Whether an actor takes an entrepreneurial role or not in capturing emerging commercial opportunities depends on particular characteristics, like the ability to recognize opportunities in the first place and the relative position "in networks through which financial and human capital can be gathered" [Nilsson (2001), p. 64]. Particular emphasis is laid on interaction, which according to Nilsson is a prerequisite of acquiring and preserving social capital. Social capital, in turn, is needed to locate complementary human and financial capital that facilitates the pursuit of opportunities in biotechnology. Thus, interaction is regarded to be central to successful commercialization in biotechnology.

Similarly, Powell [1998] sees relationships as a critical pre-condition for knowledge diffusion, learning, and technology development that in turn are vital for keeping up with the competition in the "learning race". Shan [1990] investigates the determinants of entrepreneurial biotechnology firms to establish cooperative agreements. He shows that a late entrant or a follower is more likely to pursue such arrangements than an industry leader. Shan additionally finds that firm size is negatively correlated to the propensity to cooperate. New high-tech firms that try to commercialize a product on foreign markets also seek after cooperation.

Another heavily covered aspect of academic entrepreneurship relates to locational, cultural, and policy issues of different regions and countries. According to Zucker, Darby and Brewer [1998], for example, the geographic location and the point of time where and when firms initially start to utilize biotechnology is positively correlated to where and when star bioscientists are actively producing publications and contributing to the basic science underlying the commercialized technology.

Smith and Fleck [1988] draw a picture on the development phases of business models that biotech firms apply in different stages of their life cycle, especially in order to cope with binding financial constraints in the early phases. They find that firms start with a business logic that requires relatively little capital, e.g. contract research and production as well as different services. These modes generate incoming cash flows much earlier than heavily R&D-intensive modes. As a next step, biotech firms move towards diagnostic products that require substantially more R&D efforts, but reward firms with higher returns on success. The ultimate goal, according to Smith and Fleck [1988], is the development, production and sale of pharmaceuticals, which requires large amounts of capital. Another paper concerning integration and cooperation strategies of commercialization in biotechnology is presented by Pisano [1991].

Deeds [2001] analyzes whether entrepreneurial wealth — as measured by MVA (Market Value Added) — can be related to the R&D-intensity, technological capabilities and the absorptive capacity. Deeds finds that all three aspects are positively related to entrepreneurial wealth. This means that markets appreciate firms with high R&D-intensities, in late product/service development stages and firms that are involved and embedded in scientific communities.

Wells, Coady and Inge [2003] deal with issues that concern bioentrepreneurship in Australia. They identify reasons for Australia's relatively poor performance in commercializing biotechnology. Major impediments are an inadequate level of commercialization skills, on one hand, and insufficient financial support by the government and the private industry on the other. The traditional "ivory tower" conception of the role that public research institutions take in society is also pointed out as a factor that slows the diffusion of technology towards the industry.

Literature dealing with entrepreneurship is reviewed comprehensively at least by the following two papers. Blanchflower [2004] summarizes works on entrepreneurship that deal with the entrepreneur as a person, mainly in the field of labor economics.

Davidsson, Low and Wright [2001] picture the development of entrepreneurship research within the past decade including works that study entrepreneurship from diverse angles.

The paper proceeds as follows. Section 2 provides a description of the research data as well as the analysis of firm characteristics that are specific to academic spin-offs as compared to other types of biotech SMEs in the Finnish biotechnology industry. Section 3 discusses the findings and Sec. 4 closes the paper with conclusions.

2. Firm Characteristics of Academic Spin-Offs in Biotechnology

2.1. *Data*

The empirical evidence in this paper is based on data originating primarily from the ETLA 2002 survey of biotechnology firms, and the National Board of Patents and Registration of Finland (PRH). The survey data serves as a primary basis for the analysis and consists of information disclosed by the firms surveyed. No data from PRH is used that originates from periods prior to the year 2000. The survey covers the majority of companies operating in the Finnish biotechnology sector. Out of an estimated 120 active biotech companies at the end of 2001, the sample includes 84 companies of which 68 are small or medium-sized.[d]

The companies in the sample are independent businesses, partnerships or subsidiaries of bigger corporations. In the latter two cases the businesses had to be independently responsible business units in order to be included in the sample. If the criteria were not fulfilled, the data were collected from the parent company. No companies being 25 years of age or older met the criteria for inclusion. It has to be pointed out that the majority of firms excluded already for their large size belonged to this age category and the remaining SMEs over 25 years of age could not be included due to the lack of coherent data. Therefore the final sample consists of SMEs that are younger than 25 years of age.

2.2. *Model*

For the purposes of estimating characteristics of entrepreneurial academic spin-offs in the sample, I use a standard probit regression analysis, the results of which are presented in Table 2 in Sec. 2.3. The formal expression of the model takes the following form:

$$D_i = c + \alpha I_i + \beta C_i + \varepsilon_i. \tag{1}$$

[d] The sample is smaller than the population for the following reasons. The existence of a number of companies was unknown prior to the execution of the survey so that 116 companies were initially contacted. The contacts were based on the member list of the Finnish Bioindustries Association that serves as a central organization for the Finnish biotechnology sector. One of the companies was tracked from the Internet. Out of these 116 companies, one was untraceable, 13 refused to respond, 12 were operating in an irrelevant sector, three were not in operation, two had merged with another company and five could not be included due to other reasons. Altogether nine companies were further excluded since they were too large to fit the definition of SMEs. Three companies were excluded because no sensible data was available on them. Another three firms were excluded due to incoherent data. The final sample used in the analysis is thus 65.

D represents the dependent variable, which is a dummy indicating whether a firm is an entrepreneurial academic spin-off as defined in more detail in the next subsection. The constant is represented by the lowercase c in the formula. The independent variables are incorporated into the model by the vector I. The content of the vector is examined more closely later. α is the coefficient of the vector I. C is the control vector representing control dummies and other control variables. β is the coefficient of the vector C. ε is the error term and the subscript index i serves as the firm index.

Dependent variable

The dependent variable of this analysis is a dummy that splits the sample into entrepreneurial academic spin-offs and other biotechnology SMEs. Thus, statistically significant coefficients of independent variables indicate that entrepreneurial academic biotechnology spin-offs differ from other types of biotech SMEs in the sample in respect to the particular independent variable. The dummy is denoted "academic spin-off". It obtains the value "1" only if both of the following criteria are fulfilled: (a) the firm's establishment is based on the results of academic research carried out in universities or other comparable academic research institutions, and (b) the scientist being the originator of the pre-foundation academic research is also the founder or one of the founders of the company. While criterion (a) is the common definition of an academic spin-off, I wanted to narrow down the research target further to encompass only those companies that are based on academic entrepreneurial spirit expressed by the will of an individual scientist to cross the border between the worlds of academia and the industry. This narrow definition excludes firms that, for example, have started operations by acquiring academic research related IPRs from a scientist or organizations like Licentia — A Finnish company specialized in technology transfer between companies, research institutes and universities. It also excludes cases in which the original scientist did not want to abandon her academic career and preferred to pass on the idea of commercializing research results to somebody more willing and eager. By definition, corporate spin-offs and firms that are not spin-offs in the first place are not regarded academic spin-offs.

75% of observations within the sample met criterion (a). After the application of both criteria 67.6% of the sample could be identified as entrepreneurial academic spin-offs.

Independent variables

As this study is explorative in nature and aiming at revealing as many distinctive characteristics of academic biotechnology spin-offs as possible, the choice of independent variables is not restricted by leaning on existing literature alone. In fact, explorative literature focusing on characteristics of academic spin-offs is quite lean and usually has a narrower focus than the underlying study. Instead, all available variables present in the data were included into the initial versions of the model. The final model encompasses only those that show explanatory power. A relatively large number of variables with no statistical significance were excluded from the final model. Excluded variables include, e.g., turnover indices, growth expectation indicators and locational controls.

Table 1 displays the descriptive statistics of all variables included in the final model. The statistical significance of deviation of means is checked with a two-sample t-test with unequal variances.

Size is expressed via a natural logarithm of the number of personnel employed in the firm. An additional and common approach to capture size effects by using turnover figures has to be neglected since many of the firms do not display positive cash flows yet. Turnover figures do not express the size of operations as much as merely the phase in the life cycle of R&D-intensive firms.

Age is expressed via the natural logarithm of the age of a firm in years. Age was also tested for an exponential distribution with insignificant results.

The biotechnology sector encompasses a variety of sub-sectors ranging from services over food and forestry to pharmaceuticals. The business models applied within those sectors are assumed to vary accordingly, which in turn affects firm characteristics directly. For the purpose of controlling for these effects, I have divided the sector into four sub-sectors. The "*Life sciences*" sub-sector includes firms developing pharmaceuticals, diagnostics and biomaterials. The "*Process industry*" sub-sector incorporates companies active in developing applications in food and feeds, enzymes, agriculture and forestry. "*Services*" comprehends contract R&D and other service activities. Firms not belonging to any of the three sub-sectors are excluded from the analysis as a control group.

Profitability is a measure of economic efficiency and, thus, a performance measure. In this study, profits before interests and taxes (EBIT) serve as the basis for calculating the profitability ratio defined as the share of profits of total turnover. EBIT is used in order to filter out artificial effects that interests, taxes, and especially extraordinary items may have on profits. As many companies display negative profits, the variable is negative in many cases.

Including a variable measuring R&D costs per employee controls for effects of *R&D-intensity*. The usage of more conventional measures like R&D costs per turnover or R&D costs per total costs were not an option due to inconsistencies in the data and because many firms do not display any turnover yet.

Patents serve as a proxy for the innovativeness of companies in the sample and are used for such purposes in a vast amount of literature. The variable is expressed by the *number of patents per employee* a firm has obtained already or applied for. A patent is not double counted if the same patent is obtained in different countries simultaneously.

An *R&D-collaboration* dummy variable is further included into the final model to express whether firms in the sample cooperate with other firms in the same corporation. Other cooperation variables indicating R&D-collaboration relationships with universities, customers, suppliers, competitors and other firms were disregarded due to insignificance.

A dummy variable indicating whether *a firm is a subsidiary* of a corporation is included mainly to control for implicit effects that could interfere with the cooperation variable.

Table 1. Descriptive statistics for included variables.

Variable	Academic spin-off	Obs	Mean	Min/ Max	Std. Err.	t	$P > \|t\|$
Size	0	22	2.589	0.693/4.905	0.2366	1.6155	0.1125
	1	43	2.086	0/4.407	0.2024		
Age	0	22	1.831	0/3.135	0.1697	0.3155	0.7540
	1	43	1.767	0/2.833	0.1127		
Life sciences	0	22	0.455	0/1	0.1087	−0.6034	0.5495
	1	43	0.535	0/1	0.0770		
Process industry	0	22	0.046	0/1	0.0455	−1.8668	0.0666
	1	43	0.186	0/1	0.0600		
Services	0	22	0.273	0/1	0.0972	0.9759	0.3357
	1	43	0.163	0/1	0.0570		
Profitability	0	22	−0.071	−0.600/0.019	0.0311	−1.6374	0.1147
	1	43	−0.019	−0.192/0.050	0.0080		
R&D-intensity	0	22	0.081	0/1.4	0.0341	0.2707	0.7876
	1	43	0.068	0/0.65	0.0324		
Patents/employee	0	22	0.659	0/5.5	0.2633	−1.0210	0.3114
	1	43	1.221	0/20	0.4832		
Is a subsidiary	0	22	0.318	0/1	0.1016	2.5459	0.0173
	1	43	0.047	0/1	0.0325		
Collab. own corp.	0	22	0.409	0/1	0.1073	2.7183	0.0110
	1	43	0.093	0/1	0.0448		
Lead-time protect.	0	22	0.727	0/1	0.0972	−0.5482	0.5867
	1	43	0.791	0/1	0.0628		
Human capital	0	22	0.228	0/1	0.0598	−1.3251	0.1919
	1	43	0.327	0/1	0.0448		
Founder is PO	0	22	0.091	0/1	0.0627	−3.1028	0.0029
	1	43	0.395	0/1	0.0754		
Foreign owners	0	22	0.318	0/1	0.1016	−0.4276	0.6710
	1	43	0.372	0/1	0.0746		
Has licenses	0	22	0.273	0/1	0.0972	1.4347	0.1610
	1	43	0.116	0/1	0.0495		
Export ratio	0	22	39.955	0/100	9.3796	0.2857	0.7766
	1	43	36.721	0/100	6.3367		
Dif. labour	0	22	0.182	0/1	0.0842	−1.2956	0.2011
	1	43	0.326	0/1	0.0723		
Dif. financing	0	22	0.227	0/1	0.0914	−0.2513	0.8027
	1	43	0.256	0/1	0.0673		
Dif. w. bus. idea	0	22	0.091	0/1	0.0627	−1.0956	0.2781
	1	43	0.186	0/1	0.0600		
Dif. experience	0	22	0.091	0/1	0.0627	−1.0956	0.2781
	1	43	0.186	0/1	0.0600		
CEO is PhD	0	22	0.500	0/1	0.1019	0.0870	0.9311
	1	43	0.488	0/1	0.0771		

Another dummy variable is included in the analysis and captures whether firms intentionally and strategically *protect their innovations through lead-time*, the time that the closest competitor lags behind in the development of a competing product/service. Firms that do so, prioritize the speed of R&D processes in order to reap first-mover advantages (e.g. a dominant position on the markets) and thereby discourage competitors from imitating. Other types of protection like patenting and secrecy were also tested for, but were discarded due to statistical insignificance.

The amount of scientific *human capital* residing within a firm is proxied by the share of PhDs in the company's total personnel.

A dummy variable is included to express whether the *original founder or group of founders of the company is still the principal owner* holding a share of equity that provides him with significant power over decisions in the company.

A dummy variable indicating whether *the firm has been able to attract foreign investors* can be a measure of a multitude of aspects, the discussion of which I will defer towards the discussing part of the paper.

Another dummy is used to indicate whether a sample *firm has acquired any licenses* or other kinds of immaterial property rights from other companies that permit the firm to produce products or services as specified by the license/IPR.

The share of sales that is generated through exports is rather high in the biotech sector. An *exports-to-total sales variable* is included in the analysis to test whether academic spin-offs are more globally oriented in terms of markets than other types of biotech SMEs. The ratio is calculated as follows: (Exports/Total sales)*100.

Difficulties to obtain skilled labor represent a clear inhibitor to the growth development of a company. Biotechnology being a highly knowledge intensive business, it is dependent on being able to tap on sources of knowledge and expertise in order to win in the innovation race. Whether the firm experiences difficulties in finding adequately skilled personnel is measured by a dummy in the analysis.

Difficulties in the start-up phase of a company can be argued to constitute stumbling blocks as well. Additionally to the menace of inhibited growth, start-up difficulties might, if known prior to the establishment, deter the entrepreneur from entering in the first place. They are also more critical in the sense that companies are usually more vulnerable to disturbances at the early stage of their life cycles due to limited resources available to respond to such setbacks. In the final model three different types of start-up difficulties are tested, all of which are indicated by a dummy variable: Difficulties obtaining adequate financing, difficulties conceptualizing a clear business idea and difficulties due to the lack of business related experience.

The level of education of the CEO in charge represents a measure of the type of leadership applied in the firm. A dummy splitting CEOs into two categories, PhDs and non-PhDs, acts as a proxy. Generalizing strongly, one could argue that PhDs are more science-oriented than MScs, for example, who in turn are closer to the market in their way of thinking.

2.3. *Results*

The results indicate several characteristics, in which academic spin-offs differ statistically from other types of biotechnology SMEs rejecting the null-hypothesis at the same time. Table 2 summarizes results for all variables included in the final model.

In terms of age, academic spin-offs do differ from other biotechnology SMEs in being slightly younger. The average age of entrepreneurial academic spin-offs is 5.8 years as opposed to an average age of 6.2 years in the case of the rest of biotech SMEs.

Looking at the sector controls, it seems like entrepreneurial academic spin-offs are over represented in life sciences and the process industry as compared to other types of biotech SMEs. In the service sector, on the other hand, they do not distinguish themselves. 53% of academic spin-offs are active in life sciences. Close to 20% are active in the process industry. 15% operate in services. The equivalent figures for the comparison group are 45% for life sciences, 5% for the process industry and 27% for services.

Table 2. Probit regression results with the academic spin-off dummy as dependent variable.

Variables	Coef.	Std. Err.	$P > \|z\|$
Size	−0.920	0.670	0.169
Age	*−1.759	1.023	0.085
Life science	**3.680	1.566	0.019
Process industry	*5.877	3.174	0.064
Services	2.970	2.011	0.140
Profitability ratio	**40.676	19.366	0.036
R&D-intensity	5.371	13.152	0.683
Patents/employee	−0.312	0.416	0.453
Is a subsidiary	−1.371	2.557	0.592
Collabor. w. own corporation	*−3.989	2.317	0.085
Uses lead-time for protection	**3.603	1.782	0.043
Human capital	−1.225	1.535	0.425
Founder is PO	1.874	1.246	0.133
Has foreign owners	**3.624	1.847	0.050
Has acquired licenses	**−2.932	1.435	0.041
Export ratio	−0.017	0.019	0.357
Diffic. obtaining skilled labour	**5.343	2.500	0.033
Diffic. obtaining financing	**4.847	2.393	0.043
Diffic. w. business idea	**11.712	5.706	0.040
Diffic. due lack of experience	−2.881	2.499	0.249
CEO is Ph.D.	**−3.556	1.577	0.024
Constant	1.560	2.487	0.531

N = 65
Log likelihood = −13.6746
LR chi2(21) = 55.8500
Prob > chi2 = 0.0001
Pseudo R2 = 0.6713
Asterisk labels (*) stand for level of statistical risk of rejecting the null hypothesis erroneously. (*) 10% , (**) 5% , (***) 1% risk level.

It appears that academic spin-offs perform better in terms of profitability. They make relatively smaller losses than other types of biotechnology SMEs. Academic spin-offs show losses in the scale of 19% of sales. In the control group losses count for 71% of sales.

Academic spin-offs cooperate with firms within the same corporation significantly less than firms in the control group. Only 9% of academic spin-offs have cooperation relationships in R&D within the same corporation, while 41% of firms in the control group cooperate in such a way. This finding is robust even after introducing a dummy indicating whether a firm is a subsidiary, which excludes the explanation that academic spin-offs do cooperate less within the corporation simply because a majority of them are independent businesses and are, thus, no part of a corporation in the first place. Cooperative relationships with academia, customers, suppliers, competitors and other firms were encountered in both groups to an extent that no significant differences can be pointed out by the means of the regression analysis, although looking at plain figures might tell a different story. Table 3 sums up the figures.

Academic spin-offs resort to lead-time as means to protect innovations more often than other types of biotech SMEs. 79% of academic spin-offs answered to use this kind of strategy whereas 73% of the control group gave the same answer. As already stated above, other instruments of protection like secrecy and patenting could not be identified to be used more by either of the groups in any model run.

Academic spin-offs are more often owned primarily by the original founder than firms of the control group. Such a principal owner is defined as being the single largest stock owner measured by the total number of votes. In 40% of all academic spin-offs in the sample, the founder was the principal owner. Just 9% of the control group was primarily owned by the founder.

Academic spin-offs have more often foreign owners than firms in the control group. 37% of academic spin-off companies in the sample have foreign owners, whereas the percentage for control group firms is 32. The coefficient is positive and significant at the 5% level.

Buying rights to produce products or services developed by other organizations is less preferred among academic spin-offs than in the control group. 12% of academic spin-offs have acquired such rights whereas among firms in the control group 27% have done so. The coefficient is negative and significant at the 5% level.

Academic spin-offs are more often plagued by difficulties to obtain skilled labor needed for operations. A third of firms reported to experience such difficulties. In the control group only 18% struggled with the same problem. The coefficient is significant at the 5% level.

Table 3. R&D cooperation agreements in percentages of firms.

Cooperation with:	Own corporation	Competitors	Customers	Suppliers	Other firms	Academia
Academic spin-offs (%)	9	17	52	31	43	87
Other (%)	41	45	77	50	55	77

Academic spin-offs experience also more often difficulties in the start-up phase than do firms of the control group. 26% revealed that there were problems related to inadequate financing. 19% fought problems related to the lack of a clear business idea. Relevant figures for the control group are 23% and 9% respectively.

According to the regression results, a CEO having a PhD degree less often directs academic spin-offs than firms in the control group. The coefficient of the dummy is statistically significant at the 5% level. Although the finding is counter-intuitive, the dummy serves as a control.

3. Discussion

3.1. *On the findings*

When looking at the results concerning R&D-intensities and R&D-productivity measures, one cannot tell a difference between entrepreneurial academic spin-offs and other types of biotechnology SMEs. In my opinion the finding is rather intuitive. Firms competing in biotechnology must keep up with each other in terms of R&D efforts as future revenues depend greatly on the outcome of patent races that are highly competitive and are played globally. Loosing a race could render invested capital worthless and mean the end of the company, especially in the case of young enterprises that have only a limited project portfolio over which to spread the risk of failure. This applies to all biotechnology firms regardless of their origin, academic or not. With all biotech SMEs being highly R&D-intensive, the relative differences in R&D activity measures between the two groups might be too small to be observed in a small sample.

Recalling the above reviewed paper by Deeds [2001], this would imply that academic spin-offs cannot be expected to create higher entrepreneurial value (Market Value Added) than other types of biotech SMEs, since they do not display higher R&D-intensities or technological capabilities.

However, a word of caution should be uttered concerning the findings on R&D-productivity. A problem causing potential distortions is the measure used for R&D-productivity, patents per employee. Patents do not come automatically with innovation and do not necessarily reflect the number of innovations produced within a company. To obtain a patent, the firm or individual has to have knowledge on what criteria the innovation has to meet before it stands a chance of being patented, how to initiate the patent application process, to what extent a patent protects the innovation, and, most importantly, what to apply for and how to formulate the application in order to obtain maximum protection or to succeed in the application in the first place. Additionally and not least significantly, patenting requires considerable amounts of money to be obtained and maintained. These requirements multiply when going global, as is the case in biotechnology. This kind of expert knowledge is often not existent in young and small companies that have a more scientific background and are run by people with an academic origin. On the other hand, such knowledge can be expected to be resident in corporate spin-offs, for example, that come from a commercial background right from the beginning. Also access to expert advice and financing for patenting through readily established networks can be expected to exist more often in this kind of organizations. This being said, it might be that the R&D-productivity of academic spin-offs is not captured properly and it may seem to be lower than it actually is.

The above intuition might also provide an answer to the question why entrepreneurial academic spin-offs revert more often to lead-time as a means of protecting innovation than firms in the control group do. It is cheaper and does not require the hassle of the patent application process. This being said, it would be interesting to find an answer to the implicit question, whether academic spin-offs are in fact more productive in terms of R&D than other types of firms in the Finnish biotech sector. If the above discussion holds true, then it actually is the case, since academic spin-offs in the sample perform just as well as the control group measured by the number of patents per employee even with constraints in access to resources and knowledge on patenting.

The finding that academic spin-offs operate more often in life sciences and the process industry is fairly intuitive in the sense that these sub-sectors are far more science-based than services, and current technologies represent usually the forefront of technological research and development. Nevertheless, thinking of resources necessary for developing avant-garde products or services and taking them to the market (that a large part of academic spin-offs clearly lack) it would be more plausible to see older and larger firms to be over represented in the life science and process industry sub-sectors as compared to academic spin-offs. As Smith and Fleck [1988] state, in the US it is a common entry strategy of young, resourceless biotech firms to provide different kinds of research services in the initial post-foundation phases to create turnover that can then be directed towards own R&D that aims at breakthroughs. It is a natural way of utilizing valuable and expensive human capital existing in the company right from the start to enhance independence from outside financing and avoid complications related to that. So, why do we not find young and small Finnish academic spin-offs to be relatively more active in the service sub-sector instead of life sciences and the process industry as indicated by the results?

The answer, in my opinion, is rather straightforward. The prominent way of thinking in Finnish academic biotechnology SMEs is extremely technology driven, not business driven. Many academic entrepreneurs apparently establish the firm for the love of the technology, business coming second. In their view it is more important to enhance and work on the technology, their "child", than to think about viable business solutions and ways of establishing a vital revenue stream that would bring a higher degree of independence with it. The firm is seen as a means to apply for further funding (for example Tekes, the National Technology Agency, does not fund individuals but companies) that enables the advanced development of the particular technology. According to expert interviews,[e] some founder-scientists sometimes even hamper the growth and development of their company as a business and do not want to hand over the lead to more business-skilled individuals, because

[e] Personnel in leading position at a Finnish public organization providing funding to Finnish companies with the biotechnology sector being a major target of investments.

they prioritize the development of the technology and their personal involvement in it over the well-being of the company. It is a central concern at conferences and seminars dealing with economic aspects of Finnish biotechnology, that there is a lack of business-related skills employed in the sector that impedes not only the growth of but makes Finnish biotechnology vulnerable to global competition, where the business logic and the requirements set by that are far better understood than in Finland. The finding that academic spin-offs suffer from difficulties related to an unclear business plan at the start-up phase underlines the above discussion empirically.

Just realizing the problem is by far not enough. In fact, many firms are aware of the problem and some even want to improve the situation. Venture capitalists even demand the employment of highly business-skilled people that are experts in business administration and have substantial experience in the field before injecting risk capital into a biotech company. So what stands in the way of improvement? The problem is a structural one. A large pool of skilled individuals with relevant background which to recruit from is simply non-existent in Finland. Finland does not look back at a strong and traditional history of industrial evolution in pharmaceuticals or any other relevant field that could spawn experienced leaders like, e.g. Sweden or the UK. In fact, at present venture capitalists have to look abroad for occupying leading positions with the right individuals in their portfolio firms. But even this is extremely difficult not least due to an uncompetitive income tax regime prevalent in Finland.

Problems of finding adequately skilled personnel do not concern business expertise only. Entrepreneurial academic spin-offs are hard pressed with finding personnel for research activities as well. This is somewhat surprising, since it is a common consensus that the level and quantity of biotech research relevant know-how as well as the amount of educated people with the appropriate skills in Finland is fairly high. There should be no supply shortage of qualified potential recruits. I believe the dilemma has its roots in the perceivably traditional role of universities and the world of academia as a whole that is prevalent throughout Europe.

The academia's perception of itself still, and unfortunately, resembles that of the famous "ivory tower". Interviews with experts[f] actively involved in the world of academic research revealed that commercialization of research and the business world as such are often perceived by academics as "filthy", "greedy" and "dishonorable". The exposure of scientific research to commerciality is perceived to distort the one and only ultimate purpose of science, namely the quest for truth. Scientists leaving the academia are quickly marked as mavericks and traitors of the cause and are put in negative light. In fear of being branded and not being able to return to academia in case of failure in the business world, talented and potential academic scientists with promising academic careers are reluctant to become entrepreneurs or be recruited to work in a commercial company. Apparent risks are too high. This is a real obstacle that cannot be overcome easily. An improvement would require a major change in attitudes and institutional roles throughout the society as a whole

[f] Medical Doctor actively conducting research in the field of neurology.

questioning the positions and power of individuals, which most assuredly will cause inertia and friction in the process of change. This line of argumentation is very similar to that of Wells, Coady and Inge [2003].

Another explanation for problems with the availability of skilled labor is likewise related to the customs of traditional Finnish academia. The entrepreneurial scientist who has freshly started up a firm (a) does probably not understand why they should pay an employee more than this scientist earned at the university or another research institute for the same work he would be conducting at the company and (b) does not necessarily have the capital that it takes to lure personnel from the academia to work for him and compensate them for all the risks explained above.

There are still more impediments that academic spin-offs have to struggle with. According to the results they had problems with acquiring sufficient funding at the start-up stage of their life cycle. Funding shortages or delays stall the momentum of the commercialization process and add to the business risk. According to expert interviews at a governmental finance institution, the present times and the near future look even worse for academic entrepreneurs dreaming of starting-up their own biotech business.

When the ICT-bubble burst at its peak in 2001, the capital financing for new start-ups became difficult. Before that time biotechnology firms were heading towards public capital markets at very early development stages already accelerated by great expectations as high technology related businesses experienced a boom. Exit channels seemed open from the perspective of investors and investment periods were expected to be between two and four years long. After 2001 a quick exit is not viable anymore. With deteriorated expectations market values of early stage companies became extremely low. Investors invest only in firms that are in a late development stage, close to the markets, and are preferably making profits already. The funds of these investors cannot bear to wait as long as it would take to bring an early stage biotech company close enough to the market to reap high enough returns on invested capital. The timeframe from establishment to exit is three times longer than prior to 2001. The only institution that has a policy to provide capital to early stage companies in Finland nowadays is Sitra. But even Sitra is unable to invest in new start-ups as it cannot free capital bound to the existing portfolio. A glimpse of hope is to be expected from a new instrument announced by Tekes, which is aimed at financing firms at the seed stage already. No exact specifications of that instrument are published yet. Tekes also continues to provide capital loans to companies, which has been a rather successful financing tool from the late nineties onwards.

The lack of outside financing is further underlined by the finding that the original founder of the company still holds the sole principal owner position in entrepreneurial academic spin-offs. In over 40% of cases it is the founding scientist that owns the majority of voting rights. The equivalent figure for other types of biotech SMEs is 9%. When the flow of outside equity financing is constraint the implicit consequence on the balance sheet is a high share of equity owned by insiders, here the original founder. It has to be pointed out at this point that the capital and regular loans as well as subsidies provided by Tekes do not constitute an equity item on the balance sheet although capital loans have many traits in common with equity otherwise. A complementary reasoning is the above mentioned reluctance on part of original founders to hand over the control of the company to outsiders as it could jeopardize the founder's right to work on the technology and divert the purpose of the company towards less important priorities from the founder's point of view. Additionally, some founders are just happy with the income they obtain through direct research support schemes and do not even plan to go to financial markets with plans of expansion on their minds.

The relatively small size and struggles with financing are reflected in the profitability ratio of entrepreneurial academic spin-offs; they run a smaller deficit in average than firms in the control group. An average profitability ratio of ca. −20% as opposed to ca. −70% of other types of firms indicates not only scale effects stemming from a relatively smaller size of operations in terms of staff employed but also cautious and risk-adverse behavior under resource constraints and a present threat of running out of funds. I assume that as the firm grows and is able to access better financing sources the degree of risk-adverse behavior decreases, as the fear of bankruptcy is not as immediate anymore. In such a case a relatively higher portion of funds is directed towards R&D causing higher losses, assuming that revenues do not increase proportionally to the increase in size simultaneously. This assumption is justified as long as the firm is still in the development phase of an initial product/service and has not entered markets yet.

Small-scale operations and budget constraints also negatively affect the ability to purchase licenses from third parties that would endow the company with rights to market products or services developed by a third party in order to generate initial cash flows. Faint resources are focused on the particular research, which the company has initially been established for. Only 11% of academic spin-offs have acquired licenses from a third party as opposed to 27% of firms in the control group.

The reason for the lack of collaboration between academic-spin-offs and companies in the same corporation seems apparent on the first sight. The vast majority of academic spin-offs (44 out of 46 firms in the sample) are independent in the sense that they are no subsidiaries to another company as already indicated by a high ownership share of the original founder. Nevertheless, even after controlling for this by inserting a dummy identifying whether firms are subsidiaries, the result remains significant. Not being a subsidiary does not exclude the possibility that academic spin-offs are parent companies themselves and have spun out corporate spin-offs during the course of their existence nor that they have merged with other companies out of strategic reasons. The fact that five of 46 entrepreneurial academic spin-offs in the sample, three more than there are academic subsidiaries, do collaborate within the same corporation speaks in favor of this theory. Reasons for the relatively inactive cooperation could include the difficulty to transfer relevant tacit knowledge across firm boundaries in an efficient way as well as the lack of business-oriented thinking that emphasizes the importance of cooperation for successful commercialization.

As already pointed out in Sec. 2.3, cooperation patterns with other stakeholders like customers, competitors and suppliers do not differ significantly in the regression analysis. Nevertheless, simple means of cooperation measures (Table 3) show that a relatively smaller share of entrepreneurial academic spin-offs does cooperate with other interested parties except the academia. According to Shan, Walter and Kogut [1994], Nilsson [2001] and Powell [1998] this is a threatening finding, since interaction is identified as a prerequisite to commercial success that Finnish biotechnology SMEs obviously seem to lack. This seems to be another indication of the void in business related expertise in academic biotechnology spin-offs in Finland. Strategic partnering and networking is one of the major elements in the struggle for competitiveness allowing partners to focus on their particular core competencies cutting inefficiencies to the minimum at the same time. Academic spin-offs seem to be unaware of this fact. Isolation and a too technology-focused attitude compromise the ability of firms to identify and capture emerging opportunities, be they technological or commercial, in the absence of a supportive and complementary network.

The insignificance of the difference in export ratios is explained by the fact that the markets for biotechnology are global. Domestic markets are just too small to build a viable business on. Thus, all Finnish biotech companies have the imperative to aim at foreign markets right from the beginning if they want to secure growth and survival in the long run.

3.2. *On the limitations of the study*

The limitations of the study are mainly related to the technical implementation of the statistical analysis.

In contrast to the conventional purpose of the regression analysis as an analytical tool, the present study is not applying it with the intention to explain what factors led to or influenced the foundation of academic spin-offs. Instead, the primary aim is to explore the present, static state of academic biotechnology spin-offs by exploring firm characteristics represented by the independent variables. In this sense the dependent variable is interpreted as a classification of the firm that distinguishes it from other types of companies rather than an event. In this setting the regression analysis is used as a tool to reveal affiliations with other firm characteristics making the study more explorative than explanatory in nature. The reason for choosing a regression over, e.g. t-tests, as the analytical method lies in its power to control for simultaneous effects that independent variables might have on the dependent one. Possible reverse causalities between the dependent and independent variables pose a potential area for future research that would greatly benefit from time-series data.

Another limitation relates to the ratio of the number of cases and independent variables. Statistical results in a setting with a small number of cases are usually more unstable than in a setting with abundant cases. In the present study this is true to the extent that the final model is slightly sensitive to the exclusion of some single variables. However, sensitivity analyses show that the sensitivity is rather small. Exclusion or inclusion of some variables might result in a slight increase of the p-value of variables already in the model but affect their statistical significance only marginally. The exclusion never resulted in a change of fore signs of coefficients that could have been an indication of multicollinearity among the independent variables. Throughout the iteration of alternative models the variables of the final model showed consistent and robust behavior justifying their inclusion.

4. Conclusions

In conclusion one can say that Finnish entrepreneurial academic spin-offs are at a relative disadvantage as compared to other types of biotechnology SMEs. Hit more often by financial difficulties at start-up, being unable to attract skilled people, and, most unfortunately, lacking the vital strategic sense and skills for transforming research into a thriving business through cooperation and a market oriented approach, academic spin-offs are facing major impediments to successful growth. Probably the most critical challenge is to shift the focus of companies away from a strongly technology-oriented path towards a more extrovert and market-oriented one, where the particular technologies should be evaluated less in terms of technological prowess but more in terms of market potential. Only tapping into the suction of market demand will constitute a viable strategy that brings growth and long-term success with it. A purely technology driven company having the creation of avant-garde technology as the Raison D'être alone, is obsolete and without purpose on markets. It will not last. This implies a major change in modes of thinking in the minds of today's scientists and an active expansion of support and educational services that aim at bringing that message into the hermetically sealed laboratories. The establishment of biotech centers in Finland has been a welcomed first step, since firms are able to establish cooperative inter-firm links with less effort and utilize spillovers. Now, one should make sure that services at these centers encompass more than just facilities. Education in the processes of commercialization, strategic thinking, project and technology management as well as immaterial property rights is anxiously needed.

The impediments do not rise exclusively from inabilities and lack of skills on part of academic spin-offs. A very traditional and detached perception and definition of the academia's role within society, high income tax regimes, and a still underdeveloped market for equity in Finland contribute unfavorably to the conditions academic spin-offs operate in. These are factors that the companies themselves cannot address properly and should be discussed on the national level. Currently the Finnish biotech sector is under pressure to show hard evidence of success in order to justify past and future public investments to the sector. Instead of being just impatient one should sit down and come up with solutions that address the structural and cultural issues discussed above, first. These are issues that only the public as a whole can have an influence on. Only then will public investments into the sector be productive.

The change from a technology driven organization towards a business oriented one implies managerial challenges that need to be addressed on the firm level. Probably the most urgent issue to tackle is the apparent deficit in business skills. The fastest way to cope with the problem, assumed first that there is a will to do so, is probably the recruitment of people that are already experienced in leading and managing R&D intensive ventures. As Finland faces a relatively small pool of such people with a background in fields relevant to biotechnology (pharmaceuticals, diagnostics etc.), one might look beyond biotechnology itself into sectors that are comparably R&D- and technology intensive and already flourishing. In the Finnish case the strongest candidate is the ICT sector that, led by Nokia, has risen to be one of the three main pillars supporting the economy in the last 15 years. Sitra, a Finnish public organization providing venture capital, has already reported success stories, according to which former ICT managers have been successfully integrated into biotechnology companies with positive results.

Another critical challenge is the development of parallel business models that help the company survive the financial gaps in the early stages of business. Surely, a company's founder usually has a clear vision of where he wants to get in the long-run but getting there, especially in the biotechnology business, takes a long time, a deep pocket and might require stepping off the beaten path by exploring alternative business models that utilize existing assets of the company to provide revenues necessary to keep the venture alive on its way to the ultimate goal. Certainly, this requires out-of-the-box thinking and patience, but it is necessary in the times of insufficient financing provided by financial markets.

Finally, 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 leaner cost structures as well as an enhanced capability to capture emerging opportunities as reaction times are faster and joint resources can be leveraged efficiently. Also R&D efforts benefit from collaboration as joining knowledge from multiple sources might spawn innovative ideas to problems that could not be solved in isolation. Certainly, the danger of unwanted knowledge spillovers is existent in every collaborative arrangement, but if handled with care, the benefits outweigh the threat by far.

The study opens diverse avenues for future research. Firstly, for a deeper understanding of the influence of national innovation systems, cultural environments and other external country-specific factors on academic entrepreneurship in biotechnology, studies on other emerging biotechnology clusters are needed. Comparisons could not be drawn only between countries but also between different industrial sectors. Secondly, research on the viability of alternative, revenue creating business models for biotechnology ventures is of great value to the discussion dealing with issues of commercializing such research, as financial markets at present seem to be reluctant to invest into research-intensive businesses after the burst of the IT-bubble. More precisely, it would be interesting to see *how* biotechnology start-ups could utilise partnerships to access resources needed at particular growth phases. Finally, with biotechnology being a knowledge-intensive business, the interdisciplinary application of the knowledge management literature on aspects of economics of biotechnology might enhance the quality of studies and be an innovative approach taking the nature of biotechnology into consideration.

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Biography

Antti-Jussi Tahvanainen is a research economist at ETLA, the Research Institute of the Finnish Economy. With a background in technology management and politics, his current research focuses on economics and managerial perspectives of biotechnology. His prior work deals mainly with financial structures, knowledge management issues and aspects of academic entrepreneurship in the biotechnology industry.

APPENDIX 3

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Funding intellectual-capital-abundant technology development: empirical evidence from the Finnish biotechnology business

Antti-Jussi Tahvanainen[1]
Raine Hermans[1]

[1] *The Research Institute of the Finnish Economy (ETLA) and Etlatieto Ltd, Lönnrotinkatu 4 B, 00120 Helsinki, Finland*

Correspondence: Antti-Jussi Tahvanainen, ETLA, Lönnrotinkatu 4 B, Finland 00120, Helsinki, Finland.
Tel: +358 44 535 1797
Fax: +358 9 601 753
E-mail: antti.tahvanainen@etla.fi

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Abstract

This study takes an interdisciplinary approach to answering the questions of whether and how the intellectual capital (IC) of a company is related to its financial structure. To this end, we consecutively apply factor and regression analyses on a sample of 65 small and medium-sized Finnish biotechnology companies. Based on the results, we find that 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, for example, external equity. Utilizing the conventional pecking order theory as a theoretical backdrop on one hand and recent results from its empirical research on the other, we present two alternative rationales behind deviating capital structure choices made by companies with dissimilar IC bases.
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Introduction

Background

Conforming to the laws of the market mechanism, a company's ability to raise financing is directly linked to its value as perceived by investors. For the assessment of companies' market values, in turn, investors usually consider key indicators like, for example, present market shares, product portfolios, business expertise, turnover figures, and profitability indices, as well as future forecasts thereof. Based on the indicators, it is possible to compute net present values (NPV), pay-off periods, and other indicators that describe the productivity of investments. These indicators serve as the basis for investment decisions.

However, the valuation of companies in knowledge-intensive industries, like biotechnology, can be executed only with high risks based upon such indicators. Companies in knowledge-intensive industries are frequently unable to provide reliable indicators and show certain distinguishing characteristics that make it difficult to assess their value. In Finland, they cannot even be assessed relying on their historical development due to the infant nature of the entire industry. In these industries, the book value on the balance sheet conveys only limited information on the true value of companies as the capitalization of R&D expenditures on the balance sheet is optional and thus, two otherwise identical firms may appear different if just the balance sheet information is consulted. Even more importantly, intellectual capital (IC), the most critical engine of value creation according to the knowledge management literature, is not captured in the balance sheet at all (Edvinsson & Malone, 1997; Sveiby, 1997; Lev, 2001).

In 2002, many Finnish biotechnology companies were still in an infant stage of commercialization. Over 40% of companies founded after 1991 showed negative profits and approximately 60% showed a personnel count of 10 or less. Only 49% employed a full-time marketing expert (Hermans & Luukkonen, 2002). On the other hand, the share of employees with a scientific education was high. 60% of firms employed personnel that also held a university position. Moreover, with high R&D intensities the business risk is pronounced, making a reliable assessment of company value even more difficult as the probability of success in this early stage of operations is still relatively uncertain. This translates into difficulties obtain to financing as observed by Hermans & Luukkonen (2002), especially concerning companies with a history rooted in academia (Tahvanainen, 2004).

Nevertheless, returns in case of success can more than offset the risks. In global markets, revenues created by pharmaceutical products, for example, are massive. The question is how to evaluate these knowledge-intensive businesses without conventional indicators. One answer has been proposed by the knowledge management literature, whereby the intellectual capital base of a company is the primary source of value and the generator of future sales (Edvinsson & Malone, 1997; Sveiby, 1997), and thus might serve as a base for value assessment. The hypothesis is suitable for knowledge-intensive industries since it measures intangible assets that should already be in place even in young and small companies that have not necessarily entered the markets yet. Supportive of the theory, Hermans & Kauranen (2005) are able to estimate 70% of the anticipated future sales of Finnish biotechnology SMEs based on their respective intellectual capital bases.

Assuming that the intellectual capital base is a good proxy for the ability to generate value and provide investors with information necessary to make reasonable investment decisions, it should implicitly have an effect on the ability of a company to obtain financing. Prior to this study, Catasús & Gröjer (2003) have examined this effect on the availability of debt financing. We expand the examination to comprise the whole capital structure including retained earnings, capital loans (capital loans are loans that satisfy the regulations enacted in the Finnish Companies Act. The act states that capital loans must be included in the shareholders' equity in the financial statement) and external equity.

We also contribute to the discussion by applying conventional capital structure theory to justify capital structure choices made actively by sample firms.

Aims and methods

This study analyzes the questions whether and how the IC of a company is related to its financial capital structure and its use of distinctive sources of financing in a cross-section of 65 small- and medium-sized Finnish biotechnology companies. As a theoretical backdrop, we utilize both the recent knowledge management literature and the capital structure literature in the construction of our empirical model.

In terms of methodology, we apply a two-staged approach. In the first stage, the intellectual capital of companies is measured leaning on the value platform model introduced by Edvinsson & Malone (1997). The presence of different configurations of the three IC components (human capital, structural capital, and relational capital) in companies is captured by feeding IC indicators into a factor analysis. The analysis uses the indicators to form factors and factor scores representative of the IC configurations in the sample companies. In the second stage of the analysis, the IC factor scores obtained in stage one serve as independent variables in a linear regression analysis that estimates the capital structure ratios of sample companies that are constructed based on the capital structure literature, especially Myers' (1984) financial pecking order hypothesis.

The paper proceeds as follows. In the subsequent section, we elaborate on the theoretical background, namely the theories on financial capital structure and intellectual capital. Following that, we present the underlying data. Thereafter, the two-staged analysis is elaborated on in detail, followed by the presentation of results. In the discussion of findings, we contrast our results to other recent empirical literature and discuss alternative modeling approaches. The final section closes the paper with conclusions.

Theoretical background

Capital structure literature

The capital structure literature is rather broad, encompassing numerous theories on the rationale behind capital structure choices. In this study, we utilize only Myers & Majluf (1984) and Myers (1984). Comprehensive reviews on the literature as a whole are presented by Harris & Raviv (1991), as well as Klein *et al.*, (2002).

Myers & Majluf (1984) argue that the information asymmetry between insiders of a company and potential investors results in some cases in a decrease of equity value when equity is issued and a rejection of positive NPV investments in others. The chain of argumentation leading to these hypotheses goes as follows.

For simplicity, firms are divided into high value (H) and low value (L) companies. In our case, type H firms are endued with a well-balanced IC base, whereas type L firms display an IC base lacking at least one of the three IC components. Reality is not as simple, of course, but if the terms 'high' and 'low' describe the relative values of companies under comparison, not absolute values, this simplified setting can be transferred to describe any two firms. For investors, it is not possible to determine whether the firm they are about to invest in is type H or L since asset value and revenue streams, and in our case also intangible assets, are assumed to be unobservable before the equity issue. Thus, we have the case of information asymmetry addressed above. For the argumentation to hold, Myers & Majluf (1984) assume that the management maximizes the value of existing shareholders and that investors are rational.

Consider a project that needs outside financing. The outside financing comes in the form of an equity issue and finances 100% of the project. In the moment of the issue, investors cannot observe whether the issuing firm is type H or L due to the information asymmetry. All they know is that if they valued the equity of the issuing company according to the true value of an H type firm and the firm turned out to be type L after the issue, current stakeholders of the L type would gain supernormal pay-offs and new investors would pay too much for their claims due to the overpricing. It is not in the interest of the managers of an L type firm to identify themselves as such, because they maximize the wealth of their current shareholders. Pretending to be type H just might work out, and the equity is overpriced, earning the current shareholders supernormal wealth gains in the amount of the overpriced margin. Anticipating this behavior and being unable to verify the true value of the firm, investors accordingly adjust the price offer for the equity downwards. The result for the L type firm is that its equity is priced fairly. Current shareholders let go of a fraction of their claims equal to the fraction of the investment of total firm value including the added NPV of the project, and gain the net present value of the project.

For an H type firm the situation looks worse. Since the firm cannot credibly verify its true type, the equity to be issued is underpriced by the investors. If the resulting wealth loss incurred to the current shareholders of the firm does not exceed the value created by the investment (i.e. the NPV of the project), the project will still be accepted if and only if the project cannot be financed by any other means. But if undercutting the real equity price is severe enough, that is, the difference of the true value of the H type firm and the value predicted by the investors is sufficiently large, the loss incurred is greater than the value created by the project, and current shareholders experience a net wealth decrease. In this case, the project will be rejected although it has a positive net present value and no equity is issued.

The argumentation implies that, in equilibrium, type H firms never issue equity, and if they do, only as a last resort. L type firms, on the other hand, are always eager to issue equity since they have nothing to lose. Thus, the issue of equity is a signal that the firm is type L. In case of an equity issue announcement, investors therefore tend to lower their assumption of the firm value, no matter what type the firm is, leading to a fall in the value of existing shares.

Myers (1984) names the implications of the argumentation the 'pecking order theory'. He argues that investments of a firm are financed according to the following pecking order. First, a firm in need of financing draws on internal sources. Since the information asymmetry does not appear among insiders, there is no wealth destroying aspect to it. Company shares will not be downgraded. Also, internal financing does not involve any issue costs and is therefore preferred to any kind of outside financing, even if terms would otherwise resemble those of internal funding. Second, only if internally generated cash flows are insufficient to fund all positive NPV projects do managers consider issuing securities of any kind. This can happen, for example, if in times of fluctuating cash flows a sticky dividend policy inhibits the flexible use of cash (i.e. canceling dividend payments and redirecting funds to investments) or cash is simply not generated, as in the case of many biotechnology companies. In such cases, firms always issue debt before equity, because its value is independent of asymmetric information. The single debt security is a fixed claim worth the same no matter whether the firm is of type L or H, assuming that the target of investment and the related risk is known to investors. Thus, debt is priced fairly and is cheaper than equity. Outside equity is at the bottom of the pecking order since its issue incurs the depreciation of firm value on top of the usual issue costs, which are already more expensive for equity than debt.

Myers' (1984) theory has implications on the study at hand. If Hussi (2004) is right and intangible assets are indeed not taken into account by investors, as argued below, the information asymmetry concerning firm value between the companies and financial markets persists, and we should obtain empirical evidence from the data that is in line with the pecking order theory.

Knowledge management literature

We base the measurement of intellectual capital in the sample companies on the value platform model initially introduced in Edvinsson & Malone (1997). The model is presented graphically in Figure 1. The names for the three components of IC, namely human, structural, and relational capital, have been modified to match the definitions proposed by the MERITUM project (2002) (see also Edvinsson & Malone, 1997; Sveiby, 1997). Sveiby (1997) labels the components 'individual competence', 'internal structures', and 'external structures' respectively. Edvinsson & Malone (1997), in turn, talk about 'customer capital' instead of external structures disregarding thereby relationships to all other stakeholders like suppliers, competitors, academia, and so forth that are critical for advancing research towards the market place, as successful R&D activities are often conducted within networks of cooperation (see, e.g., Nilsson, 2001; Hermans & Luukkonen, 2002).

According to the value platform model, value is created in a company when all three components of IC, the generative intangible assets (Hussi, 2004), are managed in a way that they support each other. This is the very purpose of knowledge management. While human capital encompasses the knowledge, experiences, skills, and competencies of the personnel, structural capital comprises physical and conceptual structures present in the company that facilitate the support, enhancement, protection, intra-firm distribution, and documentation of human capital residing in the company. Relational capital can be understood as a network of virtual and physical relationships and connections among the critical stakeholders of a company. Through this network, the company is able to leverage intra-organizational achievements, be it products, intellectual property rights, services, results of research, communication, or people to the periphery of the company. According to the model, all three components are critical success factors in the sense that in the absence of any single component only modest value can be created. The aim of the above-mentioned factor analysis will be to identify and separate companies enduing all three components of IC from companies with incomplete IC bases.

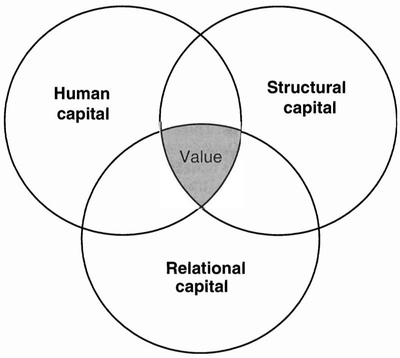

Figure 1 Value platform model.

According to Hussi (2004), the interaction of the generative intangible assets creates value by turning knowledge into commercially exploitable intangible assets. Such assets can be, for example, cost efficient production processes, intellectual property rights, functioning customer relations, expanding markets, and so forth. These are assets that a company can immediately benefit from financially. Figure 2 shows the comprehensive framework that clarifies the role of intangible assets, comprising both generative and commercially exploitable intangible assets, in the generation of long-run productivity of capital. Since we are not primarily interested in the whole picture but rather in the factors, based on which the financial markets evaluate potential target companies, we have modified Hussi's (2004) model to include a pointer depicting this aspect (black arrow). Otherwise Figure 2 matches the original in Hussi (2004).

Revisiting Hussi's (2004) framework shortly, there are three factors that affect the long-run productivity of capital employed in a company. These are intangible assets, tangible assets, and the expectations of the market. All three factors are influenced and coordinated by appropriate leadership on the part of the company.

What the framework fails to address is the direct interaction between intangible assets and market expectations, more specifically the financial markets. It assumes that investors do not take intangible assets into

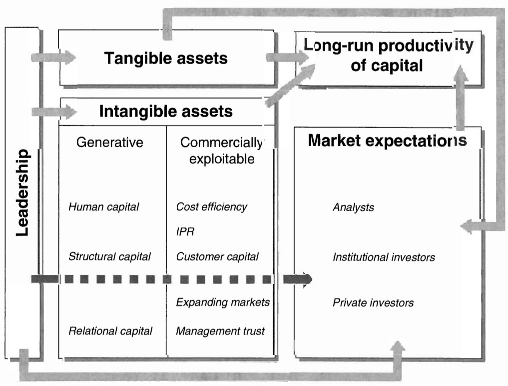

Figure 2 Factors of long-run productivity of capital – modified from Hussi (2004).

account when evaluating a company. As Hussi (2004) states, 'in reality, the financial markets turn out to base their estimates on relatively limited information, as they tend to use mainly information on leadership, management, and tangible assets and even in the best cases scant information on intangible assets.' Thus, Hussi (2004) does not interconnect intangible assets with market expectations.

In the present study, we challenge this view. We claim that intangible assets are measurable using existing 'knowledge management metrics' as reviewed by, for example, Liebowitz & Suen (2000). Exemplary empirical application of such metrics has been performed by Hermans & Kauranen (2005), Hermans & Kulvik (2004), and Hermans (2004). Another claim is that investors use these metrics in the evaluation process of a company. Additionally we propose that, instead of directly evaluating the leadership of a company, investors also use the metrics to assess the quality of leadership indirectly as it expresses itself endogenously in the degree of balance of the IC base. This is intuitive, since good leadership within the value platform framework aims at a well-balanced IC base as a focal engine for value creation. In the case of knowledge-intensive industries, the intangible asset-based valuation of companies would be especially well-founded, since in these industries intangible assets are of far greater value than any other type of asset. Thus, disregarding intangible assets would render the valuation of a knowledge-intensive company futile.

In order to be able to test our claims, we need a pecking order framework that deals explicitly with the kind of information asymmetry that arises between the firm and the financial markets due to the alleged unwillingness of investors to regard intangible assets. Companies with a well-balanced IC base should shun external financing, especially external equity, and utilize internally generated cash flows more heavily than other types of firms. It should be pointed out that the pecking order theory claims that the capital structure of a particular firm is determined by the firm itself choosing the most inexpensive source of financing at a given point in time. It does not address situations in which financing is rationed by the financial market and certain financing sources are simply not available. Leaning on in-depth experience from the Finnish biotechnology sector, we take this matter into consideration when discussing the results in the concluding part of the study.

Sample and data

The analysis at hand is based on cross-sectional private survey data comprising 64 small and medium-sized Finnish biotechnology companies (biotechnology SMEs) at the end of 2001. The data were collected via phone interviews at the beginning of the year 2002. SMEs in this paper are defined according to official definitions of the EU excluding firms that employ more than 250 people and match additionally at least one of the following criteria: (i) Annual turnover >40 million euro, (ii) balance sheet total >27 million euro. Data concerning balance sheet items has been supplemented and checked with data from the National Board of Patents and Registration of Finland (PRH). The original survey encompasses 84 biotechnology companies, the majority of the 120 companies that were operational in 2001 in the Finnish biotechnology sector. Out of these 84 companies, 72 were small and medium sized. The final sample of 64 companies used here is somewhat smaller due to missing values in some individual cases.

The companies in the sample are independent businesses, partnerships, or subsidiaries of bigger corporations. In the two latter cases, the businesses must be independently responsible business units in order to be included in the sample. If the criteria are not fulfilled, the data is collected from the parent company. No companies 25 years or older met the criteria for inclusion. It should be pointed out that the majority of firms excluded for their large size belonged to this age category and the remaining 'old' firms could not be included due to the lack of coherent data. Therefore, the final sample consists of SMEs that are younger than 25 years. There are no severe outliers in terms of data on equity, capital loans, or debt.

The data contains information on company backgrounds, the start-up phase of companies, products, markets, and customers, as well as R&D activities and financing. The information on financial aspects includes the affirmed financial statements of 2001.

Methods and selection of variables

The empirical part of this study consists of a two-stage analysis that aims at relating intellectual capital residing within a firm to its capital structure.

In the first stage, we apply a factor analysis that serves three purposes. Firstly, it identifies different configurations of interaction between the variables representing the three components of IC by breaking down the data into non-correlated factors, with each of them representing a certain configuration. We are especially interested in configurations that display interaction between all three components of intellectual capital, but also need configurations of only two or just a single component in the second stage of the analysis as benchmarks. Secondly, by using the factor analysis technique in the first stage, we avoid potential problems in the second stage of the analysis that might be evoked by correlation among the variables used, since the factors are not correlated. Finally, we need the factors, and the factor scores thereof, as input for the second stage of the analysis.

In the second stage, we use a linear regression model to estimate whether and how the capital structures of companies with differing IC configurations deviate from one another. According to their respective IC configuration, companies receive factor scores in the first stage of the analysis that are then used to estimate their capital structure in the second stage. Based on the results of the second stage, we can draw implications on the relationship between IC and the pecking order hypotheses of Myers (1984).

Factor analysis and independent variables

As already stated above, the purpose of the factor analysis is to form factors that represent different configurations of IC components. Loosely speaking, the generalized least-squares (GLS) factor analysis identifies correlating variables from the set of IC indicators that are input and groups them together as factors that are not correlated with each other. In the present study, we use the VARIMAX rotation method to ensure that the resulting factors are clearly distinguished from one another for higher informational quality. As a result we obtained five factors, each representing a certain configuration of IC. They are presented in Table A2 in Appendix A.

Concerning the construction and choice of variables that measure the quality and quantity of individual IC categories, we lean on the concept of intangible assets displayed in Figure 2 above. Therein intangible assets are subdivided into generative intangible assets and commercially exploitable intangible assets. The separate examination of generative intangible assets and commercially exploitable intangible assets allows us to determine the individual effects that the two categories have on the capital structure of a company.

Commercially exploitable intangible assets

We use three variables for the approximation of commercially exploitable intangible assets (CEIA). Instead of measuring exploitable intangible assets directly, we measure the outcomes of successfully commercialized intangible assets. The first variable is a straightforward turnover indicator measuring the turnover of sample companies in euros per year. It can be argued that turnover quantifies the level to which intangible assets are actually exploited. The second variable measuring commercially exploitable intangible assets is a dummy indicating whether companies have brought an innovation to market in the past three periods. The third indicator is a ratio indicating turnover per employee that measures the companies' efficiency in creating returns as related to labor input. Descriptive statistics for all three variables are presented in Table 1.

Generative intangible assets

For the identification of variables that approximate generative intangible assets appropriately, we rely mainly on the discourses of Sveiby (1997). According to Sveiby, the variables can be broken down into three separate variable classes with each representing a different aspect of generative intangible assets and business as a whole. These classes can be named according to the aspects they are representing, namely, (i) growth and renewal, (ii) efficiency, and (iii) stability.

It can be argued that variables from all three classes are included in the analysis. Nevertheless, it should be pointed out that the class measuring aspects of stability, in particular, is underrepresented. This is because many companies in the sample are still rather young and in the pre-market phase of operations, where stability aspects are not of a central concern. The utmost priority of these companies is to invest heavily in R&D that, in time, will result in a commercially exploitable product or service that will recoup prior investments. R&D investments are very risky in nature and incompatible with the notion of stability by definition. On the other hand, and for the very same reason, the variable class representing aspects of growth and renewal is strongly represented.

In the following, we present all variables that are included in the factor analysis. In accordance with the value platform model of intellectual capital, we have divided the generative intangible assets and the variables approximating them into the three components, namely, human, structural, and relational capital. Each component is treated separately. In conjunction with the presentation of variables in each category, we also briefly discuss which of the variable classes (growth and renewal, efficiency, stability) the particular variables belong to.

Human capital

Four distinct variables are chosen to approximate human capital (HC). These variables comprise (i) the total number of personnel, (ii) the share of personnel holding a doctoral degree, (iii) the experience of the chief executive officer measured in years, and (iv) a dummy indicating whether the companies are endued with full-time in-house marketing expertise. Hermans & Kulvik (2004) use similar variables for the purposes of measuring human capital.

As knowledge in its natural, uncodified, and tacit form resides within individuals, we utilize the total number of personnel to capture and quantify the total mass of knowledge inherent in the companies. As the biotechnology industry is knowledge-intensive in character and depends on human capital as the engine of innovation, we assume that a critical mass of complementary and cohesive human capital is essential for super-normal

Table 1 Descriptive statistics for variables measuring CEIA

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
Turnover (ln)	69	0.00	18.90	11.04	4.596
Innovation on markets	72	0.00	1.00	0.65	0.479
Turnover per employee (million euro)	69	0.00	5.38	0.13	0.650

performance, or taken to the extremes, for survival. In order to avoid problems that result from a skewed distribution of the variable, we transform the variable into the logarithmic form with the natural base.

The share of personnel holding a doctoral degree is obtained by simply dividing the number of personnel with a doctor's degree by the total number of personnel. As opposed to the latter variable that measured the quantity of human capital, this indicator expresses its quality. We assume that through the educational training and the related practical experience, doctors possess the ability to apply knowledge in a more structured and efficient way. Additionally, we assume that doctors have, thereby, assimilated more knowledge than personnel without a doctoral degree.

In contrast to the two latter indicators, which measure human capital related to scientific knowledge, the two remaining indicators quantify knowledge that is related to organizing and managing a company as a business. The CEO's business experience is measured in logarithmically transformed years. The variable indicating the existence of marketing expertise in-house is a dummy variable and quantifies roughly the knowledge required for the promotion of products and services on markets.

While the number of employees over time directly expresses the growth of a company and can therefore be argued to belong to the variable class of 'growth and renewal', at least the latter two variables can be classified to indicate stability.

Structural capital

The structural capital (SC) of a company includes activities, schemes, policies, and programs, as well as systems, regulations, guides, rights, and facilities that support, enhance, protect, distribute, and document the human capital residing in that company. In more concrete terms, this includes the organization of activities like R&D, the protection of R&D investments with immaterial property rights, company policies on diverse aspects like secrecy and competing activities, information systems and guidelines concerning the standards of conduct in the laboratory, as well as bonus and educational programs.

In the IC literature, one encounters numerous alternatives for measuring structural capital. According to the ICM Group study (1998) SC can be proxied by, for example, administrative expenses, computers per employee, corporate quality performance, and investments in IT. Roos *et al.*, (1998) suggest measures like training expenses per employee, renewal expenses, and new patents filed. Sveiby (1997) lays emphasis on information technology inputs. In this study we utilize four different indicators to proxy structural capital that are more in line with Deeds' (2001) notion, stressing the importance of research and development-related activities for the maximization of a company's innovation potential and, thus, its value creation ability.

The indicators used here are (i) R&D costs per employee, (ii) number of patents per employee, (iii) the share of patent applications of the sum of applications and existing patents, as well as (iv) the age of the company. As opposed to Sveiby's (1997) more static IT-oriented variables that can be argued to belong to the class 'stability', the included variables clearly represent the variable class 'growth and renewal' and express the companies' ways of organizing their research and development activities that aim at maximizing their respective innovation potential.

The variable indicating R&D costs per employee is obtained by dividing the number of personnel by total research and development costs. It expresses the intensity with which a company aspires to transform the human capital residing in its personnel into commercially exploitable assets by providing incentives, facilities, equipment, and other resources that translate into R&D costs. This variable belongs to the class 'growth and renewal'.

In this study, the number of patents per employee is a measure of structural capital. It is not conceived to be a measure of commercially exploitable intangible assets as in, for example, Ahonen (2000). Surely, Ahonen's argumentation, that patents *per se* can be sold or licensed and generate revenues thereby, holds and speaks in favor of his categorization of the variable. Nevertheless, it should be pointed out that the number of patents conveys no information on the quality of these and, thereby, on the extent to which they actually are commercially exploitable. In other words, the sheer presence of patents does not imply their importance to the companies' value creation. In this study, we interpret patents as a structural device for the codification of tacit knowledge, that is human capital, and the investments therein. From this perspective, it is justifiable to see patents as structural capital. Another argument in favor of this interpretation relates to the fact that patents are the tangible output of human capital that is owned by the company as opposed to human capital itself that is the property of each individual employee. By patenting, the company secures its proprietary rights to the products of human capital that could otherwise spillover outside the company with any employee leaving the organization.

The variable indicating the share of patent applications of the sum of applications and existing patents describes the state and nature of the company. A company that displays very few new applications in comparison to its existing patent portfolio is more established and static in nature and exploits already existing assets. It has its roots in the past. A company with a high share of patent applications, on the other hand, is more dynamic, strives to renew itself and expects to create value in future. This variable belongs to the class 'growth and renewal'.

The age of a company expresses the stability of operations and the ability to create value steadily. It also proxies the amount of learning that has taken place within the company and become a part of the company structure. Usually, such learning is eminent in, for example, established unwritten codes of conduct that have proven to be efficient. Since such codes and ways of doing things are not codified in the data, we revert to age as an approximation.

Relational capital

Relational capital (RC), in contemporary literature also often referred to as customer capital (Edvinsson & Malone, 1997; Stewart, 1997), can be measured in many ways. Indicators of relational capital include, according to the ICM Group study (1998), market share and customer satisfaction indicators, customer specific sales figures, and numbers of new customers, as well as markets. These indicators express a company's relationship to its customers, the most focal interest group in terms of revenue creation. Sveiby (1997) extends this customer-oriented approach on relational capital to also encompass the relationship of the company to its suppliers. In this study, we further extend variables to also capture relations to academia. For the process of value creation, bilateral access to synergetic and complementary research on a cooperative basis is a critical success factor for biotechnology companies as product development can be accelerated and modified in line with advancements in basic research. Close contact with academia also secures direct access to human capital within academia that can be directly utilized through cooperative arrangements, out-sourcing, or recruitment.

Since many of the biotechnology companies do not yet have customers, indicators like those suggested by the ICM Group (1998) above are not sensible from the perspective of validity. Nevertheless, we use a variable that depicts the companies' relationship to markets abroad, as the real potential for value creation resides not within domestic boundaries but on global markets. The variables used to proxy the relational capital of companies include (i) the share of exports of total turnover, (ii) the share of public R&D support used for university research, and (iii) a dummy variable indicating whether the companies' cooperate with a foreign university.

An additional dummy variable is inserted into the factor analysis in order to control for effects related to the unique characteristics of the pharmaceutical industry. Features of the pharmaceutical industry include very long product development phases and resource consuming drug approval processes. Thirty-five percent of the sample consists of companies active in the pharmaceutical industry.

In the descriptive statistics, the number of observations varies depending on the variable throughout Tables 1–5. Our intent is to provide maximum information at this stage. In the process of the factor analysis itself observations with missing values are automatically excluded and

Table 2 Descriptive statistics for variables measuring human capital (HC)

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
Number of personnel (ln)	72	0.00	4.91	2.31	1.159
Share of doctors of total personnel	72	0.00	1.00	0.30	0.308
CEO's business experience (in years)	71	0.00	3.71	2.23	0.729
In-house marketing expertise	72	0.00	1.00	0.43	0.499

Table 3 Descriptive statistics for variables measuring structural capital (SC)

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
R&D Costs per employee	72	0.00	1.40	0.07	0.186
Number of patents per Employee	72	0.00	21.43	0.81	2.665
Patent applications/(applications+patents)	71	0.0	0.92	0.31	0.297
Age (ln)	72	0.00	3.18	1.92	0.650

Table 4 Descriptive statistics for variables measuring relational capital (RC)

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
Exports per turnover	71	0.00	1.00	0.37	0.411
Share of public support used for university research	69	0.00	1.00	0.23	0.305
Firm collaborates with a foreign university	69	0.00	1.00	0.13	0.650

Table 5 Descriptive statistics for control variable 'Pharma'

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
Pharma (= 1)	72	0.00	1.00	0.35	0.479

N settles at 65 after the exclusion of seven observations. The results of the factor analysis are reported in more detail, together with the results of the regression analysis.

Table A1 (see Appendix A) displays the correlation matrix of all variables included in the factor analysis. The matrix facilitates a more elaborate and structured depiction of the underlying data. It also shows that the data is coherent in the sense that it displays patterns that are in line with common sense expectations.

For example, firms that employ experienced CEOs can be positively related to relatively large and old companies. They also correlate positively with relatively large revenue streams and cooperative links to academia in R&D. Furthermore, they have in-house marketing expertise. Firms that employ a relatively high share of doctors, on the other hand, are negatively related to firm size and in-house marketing expertise. These firms also less often have an existing product or service on the markets. Also, pharmaceutical companies can be associated with features that are rather plausible, namely, with relatively high R&D and labor intensities, high patent creativity, and collaborative arrangements with universities. They also have less often succeeded in bringing products or services to the market place.

Regression analysis and dependent variables

The purpose of the regression analysis is to test whether different IC configurations of companies affect their respective capital structure. Four different financial ratios are estimated using factor scores obtained in stage one of the analysis as independent variables: for each of the five factors obtained in the first stage of the analysis every observation receives a factor score, the value of which depends on how well the particular factor represents the particular observation.

Instead of estimating a simple debt-to-equity ratio, we scrutinize partial ratios for two reasons. First, testing Myers' (1984) pecking order hypotheses requires a more detailed analysis of the debt-to-equity ratio, including the separate identification of the share of internal equity, external equity, and debt of a firm's total financing. Second, as already concluded in Tahvanainen (2003) and Hermans (2004), the controversial features and a central role of capital loan financing in Finnish biotechnology necessitate its explicit and separate treatment. The estimated ratios include (i) the earnings, (ii) the external equity, (iii) the capital loan, and (iv) the debt ratio, (see Table 6).

The ratios are calculated as follows. The earnings ratio measures the degree to which operations are

Table 6 Descriptive statistics for dependent variables

Variable	N	*Min*	*Max*	*Mean*	*Std. deviation*
Earnings ratio	67	−11.38	0.98	−0.82	1.917
External equity ratio	69	0.00	1.00	0.56	0.383
Capital loan ratio	69	−2.46	5.04	0.51	0.986
Debt ratio	69	0.00	1.09	0.37	0.339
Tangible assets ratio	69	0.00	0.75	0.14	0.164

financed internally:

$$\text{Earnings ratio} = \frac{\text{retained earnings}}{\text{total equity} + \text{total liabilities}}, \quad (1)$$

where total equity includes capital loans in accordance with Finnish accounting legislation, and total liabilities are corrected for accounts payable, as well as accrued charges and deferred credits. The correction of liabilities is performed because the above-mentioned balance sheet items do not express financing decisions that have been made explicitly and strategically, but are the sheer result of the size, volume, and life cycle effects of the business.

External equity is the share of adjusted total equity owned by individuals or organizations not being actively involved in the daily business of the company of which they are shareholders.

$$\text{External equity ratio} = \frac{\text{external equity}}{\text{Adjusted total equity}}, \quad (2)$$

where adjusted total equity is computed from total equity by subtracting capital loans and retained earnings from it. Additionally to retained earnings, we exclude capital loans from total equity prior to any ratio computations to avoid potential distortions caused by the controversial features of capital loans that, although legally treated as equity, show many characteristics of debt financing. Retained earnings are an internal source of equity. Thereby, the definition of adjusted total equity in this study matches that of equity in the pecking order literature as closely as possible.

Capital loan ratio is calculated as follows:

$$\text{Capital loan ratio} = \frac{\text{capital loans}}{\text{adjusted total equity} + \text{total liabilities} + \text{capital loans}}, \quad (3)$$

where the definitions of elements comply with those already treated above. It should be pointed out that retained earnings are left out of the equation intentionally, because a number of companies display negative earnings so large that their unadjusted total equity (without capital loans) is negative. Computing a ratio thereof does not provide results with interpretative value. As stated by Tahvanainen (2003), capital loans as a source of financing deserve and require a separate examination due to their hybrid nature, combining features of equity and debt. The treatment of capital loans as an integral part of equity might result in distortions that render the results of the analysis worthless. Debt ratio is denoted as:

$$\text{Debt ratio} = \frac{\text{total liabilities}}{\text{adjusted total equity} + \text{total liabilities} + \text{capital loans}}, \quad (4)$$

where definitions of elements comply with those already treated above. Again, the problematic effects of retained earnings are corrected for by excluding them from the computation.

As already discussed, the factors of the analysis in stage one represent generative intangible assets. According to the framework presented in Figure 2, investors infer the value of a company by taking its tangible assets into account. Therefore, we include a separate variable indicating the share of tangible assets of the balance sheet total into the regression.

In order to estimate the effects of different IC configurations and tangible assets on the above ratios, the independent variables are inserted into a linear regression model using the OLS method. The model is run separately for all four ratios. The formal expression of the model takes the following form:

$$D_i = \alpha + \beta I_i + \delta C_i + \varepsilon_i, \quad (5)$$

where D represents the dependent variable, here the various capital ratios. The constant is represented by the term α in the formula. The independent variables, here the factor scores, are incorporated into the model by the vector I. The regression coefficient of the vector I is denoted as β. C is the control vector representing control dummies and other controls. The term δ is the coefficient of the vector C. The error term is marked by ε and the subscript index i serves as the firm index.

Results

Figures 3–6 display the combined results of the factor and regression analyses. They present the statistically significant variables that particular factors consist of and the relationship of these factors to the capital structure ratios introduced above. Separate and comprehensive results for both analyses are provided in Tables A2 and A7 in the Appendix A.

Earnings ratio

Figure 3 shows the factors that interact with the earnings ratio. Two out of five factors explained the variation in the ratio significantly, namely factors 1 and 4. Factor 1 represents firms with a well-balanced IC base. All three IC components are present with the CEO's experience embodying human capital, the age of firms representing structural capital, the export ratio standing for relational capital and turnover as well as the product-on-markets indicator representing commercially exploitable intangible assets. At this point, one should point out that factor 1, the only factor representing a well-balanced IC base, is the sole factor comprising commercially exploitable intangible assets.

Firms that are represented by factor 1 display a higher earnings ratio. The coefficient of the regression analysis is positive and statistically significant at the 10% level.

Factor 4 represents firms with an incomplete IC base having only structural capital. In factor 4, structural capital is expressed by the variables indicating the ratio of patent applications of the total patent portfolio and the R&D intensity. Firms represented by factor 4 show a negative relationship to the earnings ratio. The coefficient is significant at the 10% level.

In other words, these findings indicate that the most research intensive and innovative firms have been unable to generate significant cash flows.

External equity ratio

Figure 4 shows the results for the external equity ratio. Factor 2 is the only factor explaining the ratio. It represents an incomplete IC base having only human and relational capital. In factor 2, human capital is expressed by the number of personnel, in-house marketing experience, and the share of doctors of total personnel, where the share of doctors is in a negative relationship to the other variables. Relational capital is expressed by the variables indicating collaboration between a firm and a foreign university. Firms represented by factor 2 have a higher external equity ratio. The coefficient is significant at the one percent level.

The results for factor 2 can also be interpreted inversely, negating all coefficient fore signs. Then factor 2 would represent firms with few personnel, no marketing experience, a high share of doctors, and no collaborative arrangements with foreign universities. Firms represented by this inverse factor 2 have a lower external equity ratio.

One can also argue that those firms, that have obtained financing in terms of external equity have been able to increase their size. Or, investors have steered these firms to recruit people with marketing competencies. Such problems of reverse causality or simultaneity bias will be further discussed below.

Capital loan ratio

Figure 5 presents the results for the capital loan ratio. Again, factors 1 and 4 affect the ratio. Firms with a well-balanced IC base represented by factor 1 are negatively correlated to the capital loan ratio, whereas firms represented by factor 4 have a higher capital loan ratio. The coefficient of factor 1 is significant at the one percent level and the coefficient of factor 4 at the five percent level.

Young and research intensive firms, which have an inexperienced CEO and which have not generated sales or exports, do have relatively high capital loan injections. This stresses the significant role of the Finnish government in the financing of the infant industry given that the government has provided more than half of the industry's capital loans (Hermans & Tahvanainen, 2002; Tahvanainen, 2003; Hermans, 2004).

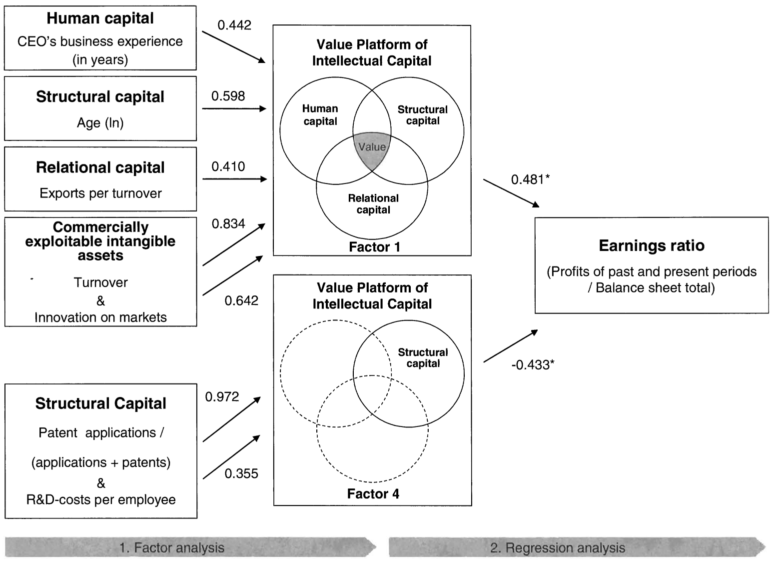

Figure 3 Factors interacting with the earnings ratio.

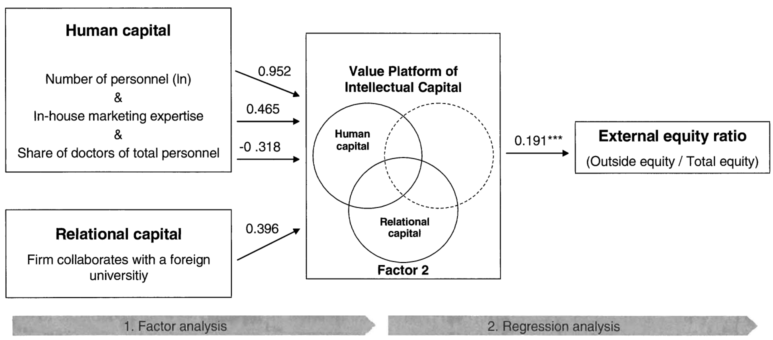

Figure 4 Factors interacting with the external equity ratio.

Debt ratio

Figure 6 shows results for the debt ratio. Factors 1 and 4 are the sole factors with explanatory power. Well-balanced firms show a positive affiliation to the debt ratio with the coefficient being significant at the one percent level. Firms represented by factor four are negatively correlated to the ratio. The coefficient for factor 4 is negatively significant at the 5% level.

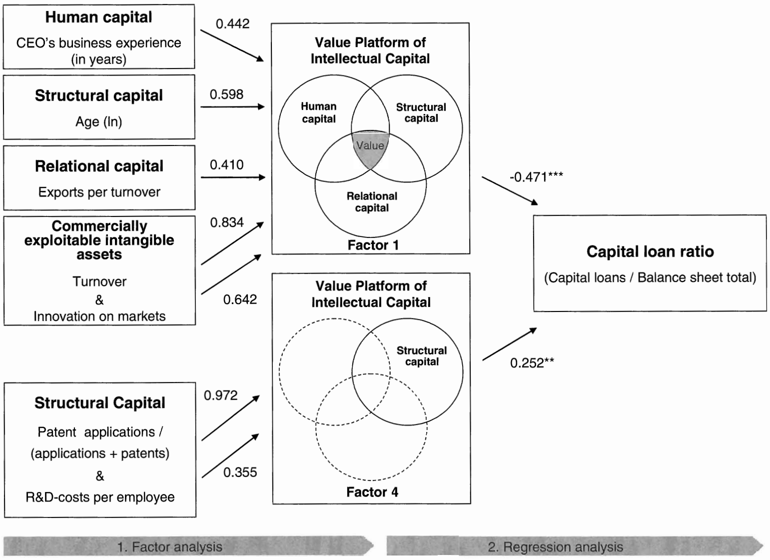

Figure 5 Factors interacting with the capital loan ratio.

When the firm is mature and has already generated sales, it can obtain debt financing. If the firm's only collaterals are based on structural capital, here the research activities, it seems difficult to acquire any debt.

Discussion

Based on the empirical evidence, we find that there is a relationship between the IC and the financial capital structure of a company. In the following sections we discuss two alternative interpretations of this relationship, one of which favors the financial pecking order framework introduced earlier in the paper, whereas the other is in line with empirical research countering the theory.

The results can be argued to be in line with Myers' (1984) pecking order framework insofar that firms of high value displaying a well-balanced IC base (factor 1) shun external equity financing and display higher retained earnings and debt ratios than other types of firms. According to the perspective of the pecking order hypothesis, this behavior aims at avoiding the undervaluation of equity. Also in line with the hypothesis, firms of allegedly lower value (factor 2) utilize relatively more external equity financing as their equity is not as severely undervalued. Firms with only a single IC component, here structural capital related to research intensity and innovativeness (factor 4), prefer capital loans as a source of financing relatively more than other firms. Capital loans are a special feature of the Finnish financial markets and play a decisive role in the financing of the biotechnology industry. Thus, they deserve separate treatment.

Assuming that the pecking order hypotheses is indeed the driving force behind the findings, this implies that the information asymmetry between the sample firms and financial markets truly exists, and that a strong IC base does not positively affect the availability of financing. If the IC base of companies was observable and it revealed the true value of a company by nullifying the information asymmetry, we would be unable to evidence a pecking order-like behavior, as the companies' equity is always priced fairly on markets making firms indifferent between financing sources.

The findings render false our claims concerning the active use of knowledge management metrics. Either (a) intangible assets are unobservable or (b) investors simply do not bother to apply information beyond leadership, management, and tangible assets when evaluating com-

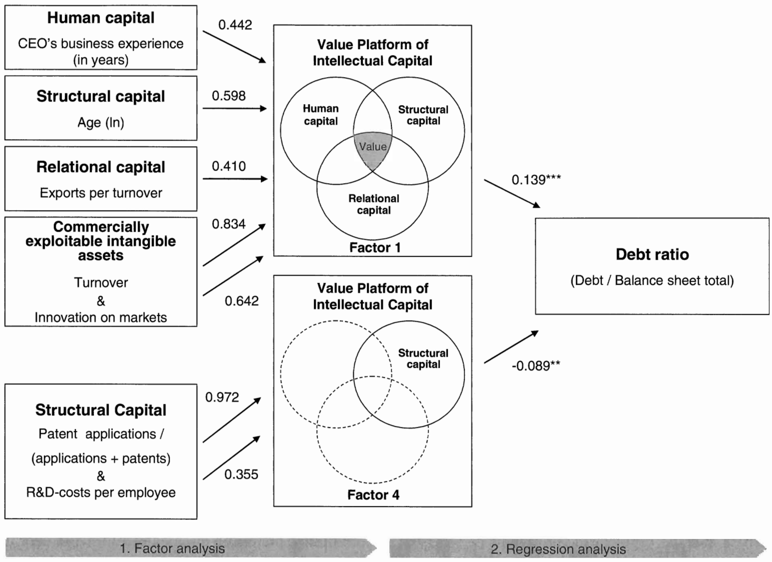

Figure 6 Factors interacting with the debt ratio.

panies, as Hussi (2004) states. As comprehensive knowledge management metrics do exist and are retrievable from target companies in conjunction with the customary Due Diligence analysis prior to investment, the former notion is hardly defendable. 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 towards its application in the field.

Issues of reverse causality

As pointed out above, the study leans on cross-sectional data. This confronts us with a reverse causality problem. We cannot definitely show whether a company's capital structure is determined by its IC base or whether financing comes with constraints that force a company to adapt its IC base accordingly. Thus, the validity of the discussion above rests very much on the validity of the pecking order hypothesis. The theory implies that the decisions from which source and to what extent financing is to be drawn are made actively by the companies that, for their part, optimize the cost of financing. Thus, according to this notion, a company's IC base explains its capital structure as interpreted above.

Nevertheless, blindly taking the theory's perspective as given might oversimplify reality. It is assumable that biotechnology firms, in their infant stage, are not in the position to choose freely from different sources of financing to the extent that knowledge-intensive operations require. In fact, in the start-up phase, companies are usually happy to receive any financing, regardless of the terms with which it comes. As soon as the founding capital is consumed, these companies usually turn to venture capitalists and other external equity sources in the hope of getting financed, as the debt market is still out of reach due to a lack of collaterals and revenue streams (see Graham & Harvey, 2001; Frank & Goyal, 2003). In this situation, the pecking order is reversed (Hyytinen & Pajarinen, 2002). In contrast again, Fama & French (2002) present empirical results on how the debt market can be utilized for the short-term needs of financing even when the external equity financing is preferable in the long run.

The stage in the life cycle of a firm might not have an effect only on the validity of the pecking order theory, but also on the direction of causality between the IC base and the capital structure of a company. Knowing that investors, especially venture capitalists, apply harsh direct regulation on the companies in which they invest, receiving financing from external sources will most probably have an effect on company structures and thereby also on the IC base of companies. Young companies that are dependent on investments can be argued to be affected especially, as guidelines for the development of operations are dictated by investors. It can be argued that in the early stages of the life cycle the IC base of a company is determined to a large extent by financial markets and not the reverse.

Assuming that investors are rational and familiar with the theory of knowledge management, they push the target company's IC base towards a more balanced configuration. Once companies mature under the guidelines of investors and grow more independent of external financing, firms finally start behaving according to the pecking order, as the strengthening IC base is monitored to an ever decreasing level by outsiders, and terms for external equity turn ever more unfavorable. This loosening of control over the development of the IC base by investors can be defended by two separate arguments. First, after a company reaches a certain stage in its life cycle and business success seems more certain, investors actively seek to exit the venture in order to cash in their investment. Thus, they let go of the control over the company. Second, one might argue that the development of the IC base has a momentum of its own beyond the conscious control of investors. If investors monitor the development only in the scope of their own guidelines, then a part of the IC base will be unobserved. Thus, an information asymmetry between the firm and investors arises. At this stage of the life cycle, the causality between the IC base and the capital structure might be reversed again with the IC base dominating the capital structure.

An alternative interpretation

With this more dynamic framework in mind, we can interpret the results in a new light. Factors 1, 2, and 4 can be interpreted to represent firms in different stages of the life cycle. The question remains of whether these firms make static financing decisions according to the principles of the pecking order in their particular stages of the life cycle. Starting with factor 4, firms represented by that factor are probably at a very early stage of their life cycle. They are highly R&D intensive, building a robust IPR portfolio that aims at securing future operations. Value can be expected to be created in the distant future making investments at this stage very risky. Debt financing is not available due to a lack of revenue, and collaterals and operations are still at such an infant stage that external equity investments are regarded as too risky and investment periods too long by investors. This leaves factor 4 companies facing a financing gap. However, this gap is closed by capital loans, a financing instrument designed to support young technology start-ups to overcome the early phases of operations. Our analysis shows that the instrument is working and utilized by the right target group as intended. Over 50% of capital loans are provided by the National Technology Agency of Finland, Tekes, making it a key component in the national innovation system as far as the biotechnology industry is concerned (see also Hermans & Tahvanainen (2002); Tahvanainen (2003)).

Factor 2 companies are already more established, showing human capital and relational capital in their IC base. They have in-house marketing expertise at their disposal, which is very much appreciated by investors. Also, the network to outside research institutions is initiated. Such a company represents a good example of what a growing but still immature, company could look like under the guidance of professional investors. External equity has been injected into the company while debt markets are still not an option, which explains the relatively high external equity ratio (For biotechnology specific discourses on the phenomenon see Parry *et al.*, (1999) as well as Champenois *et al.*, (2004)). At the same time, investors demand the reinforcement of the IC base. At this stage, the information asymmetry between the firm and the financial markets is still relatively small.

Factor 1 companies are the most mature ones and can be placed further up in the life cycle than companies represented by any other factor. They are able to generate internal income, value, already and are thus more independent in terms of financing. Endowed with a well-balanced IC base, these firms are of the highest value according to the knowledge management literature, and are as such prone to suffer from the undervaluation of equity relatively more than other types of firms. As shown by the empirical evidence, factor 1 firms act accordingly, preferring retained earnings and debt financing over external equity.

Conclusions

In this study, we set out to answer the question of whether the intellectual capital base of a company is related to its capital structure. To this end, we utilized a 2001 cross-section of 65 small and medium-sized Finnish biotechnology companies. In the first stage, we resorted to a factor analysis as a method to categorize companies according to their intellectual capital configurations, providing every observation with a factor score for each generated factor. Then in a second stage, the factor scores were used to estimate a number of capital structure ratios derived from the capital structure literature.

We were able to show for the first time that companies with differing intellectual capital bases indeed also exhibit differing capital structures. While companies with well-balanced intellectual capital bases have relatively high retained earnings and debt ratios, companies endued with only structural capital display relatively high capital loan ratios. Companies, the IC bases of which consist of human and relational capital only, show relatively high external equity ratios. In a static framework one can argue that the findings are in line with the financial pecking order hypothesis of Myers (1984), implying that, despite existing knowledge management metrics deliberately created for the measurement of IC, an information asymmetry concerning the IC of companies still persists between sample firms and financial markets.

Owing to the lack of time series data, we were unable to control for a possible reverse causality of results. The dynamic development of the IC base and the capital structure of a company could well be induced by either or both with the direction of effect shifting in the course of a company's life cycle. The unveiling of a dynamic interaction between intellectual capital and capital structures constitutes an attractive area for further research that has a large potential to contribute decisively to the understanding of corporate financial behavior from the perspective of knowledge management. Injecting new interdisciplinary ideas for approaching the matter seems welcome, since the related discussion has followed rather rigid trajectories for the past two decades building incremental additions to existing frameworks (For a comprehensive review of capital structure theories and their development over time see, e.g., Harris & Raviv, 1991). We point out the necessity of using time series data if such research is conducted.

As a policy implication we suggest that IC metrics should be applied in investment decisions. IC metrics could be compared between an individual firm and the entire industry. It seems that IC metrics could stand as a basis for the evaluation of the most promising investment decisions and also as a basis for the strategically meaningful development of companies that have been invested in.

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Appendix A

This appendix includes Tables A1–A7.

Table A1 Correlation matrix for variables included into factor analysis

Variable code	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	1														
2	−0.341**	1													
3	−0.072	0.298*	1												
4	−0.318**	0.500***	0.309**	1											
5	0.134	0.123	0.137	0.173	1										
6	0.055	−0.149	0.085	0.031	−0.028	1									
7	−0.092	0.153	0.419***	0.083	0.036	0.105	1								
8	−0.173	0.230	0.079	0.273*	0.369**	−0.051	−0.184	1							
9	−0.091	0.232	0.099	0.006	0.142	0.018	0.352**	0.075	1						
10	−0.192	0.263*	0.300*	0.318**	0.000	0.351**	0.144	0.082	0.051	1					
11	−0.102	0.346**	0.090	0.212	0.125	0.108	−0.045	0.235*	−0.046	0.360**	1				
12	−0.291*	0.050	0.190	0.104	−0.089	0.094	0.238*	−0.133	0.162	−0.105	−0.134	1			
13	0.189	0.244*	−0.051	−0.045	0.276*	0.176	−0.106	0.202	−0.087	0.139	0.199	−0.326**	1		
14	−0.117	0.154	0.165	0.151	−0.041	−0.026	0.107	−0.152	−0.079	−0.073	−0.088	0.107	−0.094	1	
15	−0.168	0.306*	0.282*	0.088	−0.076	−0.010	0.417***	−0.159	0.349**	−0.189	−0.115	0.534***	−0.187	0.263*	1

***Correlation is significant at the 0.001 level (two-tailed), **correlation is significant at the 0.01 level (two-tailed), *correlation is significant at the 0.05 level (two-tailed).

Variable code legend:

1 doctors/personnel, 2 ln personnel, 3 Ceo's experience in years (ln), 4 full-time marketing expertise, 5 RD/personnel, 6 patents/total personnel, 7 age (ln), 8 patent applications/(patent applications+patents), 9 exports/turnover, 10 share of public support used for university research, 11 collaboration with foreign university, 12 innovation to markets within past 3 years, 13 pharma = 1, 14 sales/personnel, 15 turnover € (ln).

Table A2 Rotated factor matrix

	Factor				
Variable	*1*	*2*	*3*	*4*	*5*
LnTurnover €	0.834				
Innovation to markets within past three years	0.642				
LnAge	0.598				
LnCeoexperience	0.442				
Exports/turnover	0.410				
Sales per personnel					
LnPersonnel		0.952			
Full-time marketing expertize		0.465			
Collaboration with Foreign University		0.396			
Post-graduated personnel/total personnel		−0.317			
Share of public R&D support used in university research			0.887		
Patents/total personnel			0.522		
Patent applications/(patent applications+patents)				0.972	
RDperpersonnel				0.355	
Pharma = 1					0.969

Extraction method: generalized least squares. Rotation method: varimax with Kaiser normalization.

Table A3 Communalities for factor analysis

Variable	*Initial*	*Extraction*
Post-graduate personnel/total personnel	0.367	0.457
LnPersonnel	0.595	0.999
LnCeoExperience	0.347	0.460
Full-time marketing expertize	0.396	0.453
RDPerpersonnel	0.291	0.382
Patents/total personnel	0.340	0.417
LnAge	0.407	0.523
Patent applications/(patent applications+patents)	0.352	0.999
Exports per turnover	0.335	0.478
Share of public R&D support used in university research	0.476	0.861
Collaboration with foreign university	0.308	0.368
Innovation to markets within past three years	0.452	0.586
Pharma = 1	0.432	0.999
SalesPerPersonnel	0.181	0.259
LnTurnover €	0.563	0.779

Extraction method: generalized least squares.

Table A4 Total variance explained (factor analysis)

	Initial eigenvalues			*Extraction sums of squared loadings*			*Rotation sums of squared loadings*		
Factor	*Total*	*% of variance*	*Cumulative %*	*Total*	*% of variance*	*Cumulative %*	*Total*	*% of variance*	*Cumulative %*
1	2.939	19.590	19.590	1.930	12.867	12.867	2.063	13.754	13.754
2	2.413	16.084	35.674	1.035	6.902	19.769	1.646	10.973	24.727
3	1.507	10.045	45.719	1.711	11.409	31.178	1.397	9.314	34.041
4	1.417	9.445	55.164	1.375	9.165	40.343	1.238	8.252	42.293
5	1.139	7.591	62.755	1.526	10.174	50.517	1.234	8.224	50.517

Extraction method: generalized least squares.

Table A5 KMO and Bartlett's test

Kaiser–Meyer-Olkin Measure of Sampling Adequacy		*0.576*
Bartlett's test of sphericity	Approx. χ^2	233.488
	df	105
	Sig.	0.000

The KMO measure of sampling adequacy does not quite meet the limit of 0.600, which is conventionally held as a critical value. However, Bartlett's test of sphericity shows that a factor analysis can be applied on the data at a 0.1 percentage risk level.

Table A6 Goodness-of-fit test

χ^2	*df*	*Sig.*
28.255	40	0.918

The goodness-of-fit test implies that the factor solution is able to explain the variance of initial variables.

Table A7 Results for the regression analysis

Dependent variable:	*Earnings ratio*	*External equity ratio*	*Capital loan ratio*	*Debt ratio*
R^2	0.171	0.325	0.168	0.251
Adjusted R^2	0.083	0.255	0.082	0.174
F-test	1.956*	4.645***	4.126*	3.244***
Variable	β	β	β	β
Constant	−0.773**	0.569***	0.242***	0.330***
	(0.322)	(0.055)	(0.047)	(0.053)
Factor 1:	0.481*	0.041	−0.090**	0.139***
HR+SC+RC+CEIA	(0.258)	(0.045)	(0.038)	(0.042)
Factor 2:	−0.308	0.191***	0.019	−0.002
HC+RC	(0.251)	(0.043)	(0.037)	0.041
Factor 3:	−0.267	0.065	−0.037	−0.022
SC+RC	(0.251)	(0.044)	(0.037)	(0.041)
Factor 4:	−0.433*	−0.021	0.070**	−0.089**
SC	(0.236)	(0.041)	(0.034)	(0.039)
Factor 5:	0.347	0.027	0.001	0.008
Pharmaceuticals	(0.239)	(0.041)	(0.034)	0.039
Tangible assets	−0.549	0.105	−0.036	0.278
	(1.517)	(0.263)	(0.221)	0.250

Standard errors in parentheses. Asterisk labels (*) stand for level of statistical risk of rejecting the null hypothesis incorrectly. (*) 10 per cent, (**) 5 per cent, (***) 1 percent risk level.

About the authors

Antti-Jussi Tahvanainen is a research economist at ETLA, the Research Institute of the Finnish Economy. With a background in technology management and – politics, his current research focuses on economics and managerial perspectives of biotechnology. His prior work deals mainly with financial structures and aspects of academic entrepreneurship in the biotechnology industry.

Raine Hermans is a research economist at ETLA, the Research Institute of the Finnish Economy. His current research interests have focused on economics and management of biotechnology. His dissertation for Helsinki University of Technology deals with international mega-trends and growth potential of the Finnish biotechnology industry. He has published articles in edited books and journals on, for example, forecasts of foreign trade, the Finnish innovation system, and the market structure of the pharmaceutical industry.

APPENDIX 4

CHAPTER 6

THE EFFECT OF TECHNOLOGY SUBSIDIES ON INDUSTRY STRATEGIES AND MARKET STRUCTURE

Raine Hermans – Morton Kamien – Martti Kulvik – Antti-Jussi Tahvanainen

6.1 INTRODUCTION

As discussed in Chapters 2 and 4, governments have shown significant interest in promoting biotechnology in general and pharmaceutical applications in particular. Chapter 5 pointed out why a government might want to support the initial stages of drug development that present a negative net present value.

This chapter assesses how implementation of the infant industry argument (IIA) could affect entrepreneurial strategies via injections of government financing. First, how the IIA-based subsidies and financing extend to a conventional financial pecking order is shown theoretically. Then the Finnish biopharmaceutical industry is investigated empirically. The results of this study reveal the framework to be a relevant tool reflecting IIA-based policies in two primary ways: (1) Government *subsidies* become the most highly preferred financial instrument, even more than companies' internal financing and (2) Government *equity financing* is a last resort and a relevant option only for companies with non-market-oriented technology push strategies; in fact, late stage support tends to cultivate lemons instead of market-oriented vital companies, contrary to the original intentions of any government.

6.1.1 Theoretical background

There has been a clear shift towards free trade, concomitant with the development of new technologies that significantly accelerate the transfer of knowledge and goods. This globalization has forced regions and nations to create the means for restoring and enhancing the competitiveness of their industries: as traditional trade barriers have decreased, other competitiveness-enhancing industrial policies have been created.

In place of trade restrictions, innovative activity has become the central driver of local economic growth (Romer, 1986; Suarez-Villa, 1990; Furman et al., 2002). For example, national innovation systems have been created to stimulate and strengthen dynamic interactions among industrial clusters, universities and public institutions (Porter, 1990; Niosi, 1991; Nelson, 1993; Mowery and Nelson, 1999). The aim of such systems is to support the development and commercialization of new technologies. High technology sectors, often while still in their infancies, are expected to provide new growth opportunities for countries in the midst of global competition.

This article mirrors financing tools based on the infant industry argument to entrepreneurial strategies and the theory of financial pecking order. The infant industry argument, first put forward by List in 1841 (List, 1856), has been used to suggest that government support is a prerequisite for the success of an industrial sector in its infancy because such support dramatically increases the sector's potential for competing favorably with mature foreign industries. Traditionally, the infant industry argument's recommendations were carried out via instruments related to trade policy (see Baldwin, 1969; Krueger and Tuncer, 1982). Yet the more current route to nurturing infant high-technology ventures is through sophisticated instruments related to national innovation policies. For instance, Jensen and Thursby (2001) demonstrate that university patent licensing promotes the industrial applications of government-funded research.

The financial pecking order theory (Myers and Majluf, 1984) involves the explicit assumption that companies have exclusive information on the quality of their operations that external investors lack. This information asymmetry makes financing from external sources more expensive than that generated internally, in the spirit of Akerlof's (1970) seminal paper.

6.1.2 Empirical setup

Finland has been rated one of the top countries in international competitiveness (see e.g. WEF, 2002; WEF, 2003; WEF, 2004; WEF, 2005; WEF, 2006; WEF, 2007; WEF, 2008). The success of the Finnish information and communication technology (ICT) sector has been regarded as evidence of effective policymaking (Rouvinen and Ylä-Anttila, 2003). Because the policy was pivotal to the success of the ICT sector, it was seen as the key to the success of the Finnish biotechnology sector (Hermans, Kulvik and Ylä-Anttila, 2005).

In Finland much emphasis has been placed on biotechnology research in both academic and industrial settings; thus the number of companies has grown sharply as a result of active innovation policies. However, the domestic pharmaceutical industry has traditionally played only a minor role in Finland compared, for example, to the role of the industry in neighboring Sweden. Therefore, Finland provides a direct empirical example of the modern infant industry argument in action: government bodies support an industrial sector that would otherwise not be capable of successful competition in global markets. The industrial policies have emphasized science-based entrepreneurship and enabled the creation of over a hundred small biotechnology companies within a decade. Overviews of the Finnish biotechnology industry have been provided elsewhere (e.g. Schienstock and Tulkki, 2001; Hermans et al., 2005).

Hall (2002) empirically identifies under-investment, or a “funding gap” related to R&D-intensive business activity, calling for a “further study of government seed capital and subsidy programmes using quasi-experimental methods”. To tackle this call, the aim of this study is to assess how an implementation of the infant industry argument on a national level can affect corporate strategies and their capital structure.

The issue is approached by mirroring the strategic orientation of the strongly supported Finnish biopharmaceutical sector against their financing strategy. To that end, the financial pecking order theory was used as the analytical framework. Thus the empirical analysis has two phases: 1. To identify the sources of financing for Finnish biopharmaceutical companies. 2. To investigate whether government financing is related to the strategic orientation and other characteristic features of these companies.

In the first phase sources of financing for and the capital structures of the firms, as well as their market and research orientations, are evaluated. In the second phase, principal component and regression analyses are used to evaluate how sources and types of financing are related to the companies’ market- and research-oriented strategies.

The study is organized as follows. Following this introduction, Section 2 provides an overview of the infant industry argument and financial pecking order theory and combines the two frameworks. Section 3 describes the capital structures of Finnish biopharmaceutical companies. Section 4 presents the findings of the empirical analysis and the interconnections between capital structures and strategic orientations of the companies. Finally, in Section 5 the results of the study are discussed.

6.2 THEORY

6.2.1 The Infant Industry Argument

Hamilton and List argued that public support could enable a country's infant industry to achieve a leading position over the industries of other nations (List, 1841/1844; List, 1856); for a comprehensive summary see Shafaeddin, 2000). The infant industry argument (IIA) is based on the temporary need for protection (or support) of an infant industry, if the industry is unable to grow in the context of free trade and foreign rivals. The initially high costs of providing industry support are assumed to be compensated for *via* learning by doing of the industry, thus stimulating excessive profits and economic growth in subsequent stages (Bardhan, 1971). The IIA states that this growth might not have been captured without short-term government support However, the IIA is sometimes tempted to be utilized as justification for exceedingly long-term protection, contrary to List's original view.

One rationale for supporting an infant industry is that it stimulates cumulative learning within the sector through the creation of positive externalities over time. Such Marshallian type (Marshall, 1920; Krugman, 1991) externalities include, for example, the availability of technically competent labor, technological spillovers, and diminishing transport costs of intermediate inputs due to the creation of a local cluster. If these externalities could only be created through government promotion, and if the long-term GDP gains exceeded the initial short-term costs of the promotion, it would be reasonable to provide temporary support for the infant industry. Thus the IIA diverges from static trade restriction schemes, which protect domestic industry through permanent import tariffs, quotas, or similar means.

There are several modern versions of the conventional IIA. Although there is increasing consensus on the need for free trade, many developed and less-developed regions execute industrial programs, for instance, in the name of developing their national innovation systems or of encouraging entrepreneurial ventures. Jensen and Thursby (2001) state that the original inventor should be provided clear economic incentives by the academic institution controlling the intellectual property rights to the invention, as otherwise the relationship between the inventor and the university would lead to a conflict of interests and a potential moral hazard problem discouraging innovation activities.

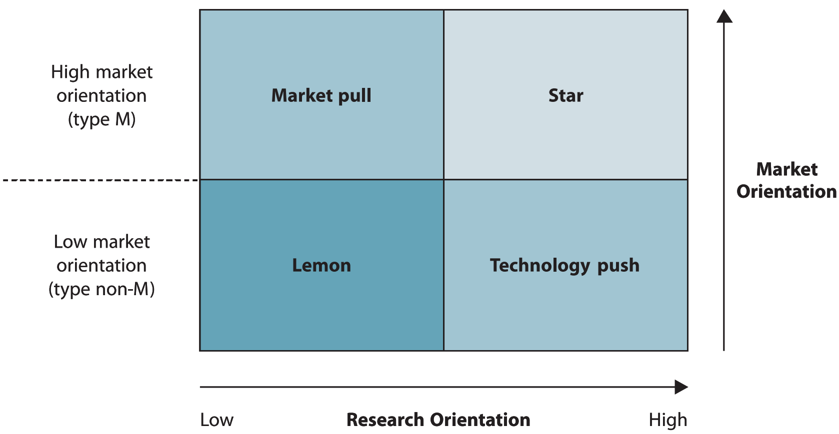
Jensen's and Thursby's statement is also compatible with the most recent interpretation of the IIA: broadly available and relatively inexpensive government services and financing strengthen the industrial base for the latest and most promising industrial branches, such as the business sector based on biotechnological innovations. Here the infant industry argument is utilized and how companies that have received government financing differ from firms with funding from other sources is investigated.

6.2.2 The capital structure literature

There is a vast literature related to capital structure. The capital structure literature mainly analyzes the rationale behind companies' choices of distinctive forms of financing. This study utilizes the pecking order hypothesis presented by Myers and Majluf (1984) and Myers (1984). Harris and Raviv (1990) and Klein, O'Brien and Peters (2002) draw a more comprehensive picture of theoretical perspectives on capital structure choices.

Myers and Majluf (1984) analyze information asymmetry between entrepreneurs and external investors. Information asymmetries may decrease the expressed value of a company. The depreciation may even lead to a rejection of positive net present value (NPV) development projects. Asymmetric information could also provide an incentive for moral hazard behavior. A simplified example is provided below.

Figure 6.1 Definition of strategic orientations



Source: Kamien and Schwarz (1982).

High-technology companies can be divided based on their market and research orientations, respectively. In this classification, corporate strategies, based on the companies' market and research orientations, are divided into star, market-pull, technology-push, and lemon categories, respectively (Figure 6.1).

The companies are divided into two categories of market orientation: those with a market-oriented strategy (**M**), and those with a reasearch-oriented strategy (**non-M**). Both companies can be technologically advanced and stable. Market-oriented companies have a clear strategic aim towards a market place, whereas the research-oriented companies rely on competencies other than the explicit ability to capture the commercial value of their technology. Due to information asymmetries investors are unable to determine whether the target company is of type **M** or **non-M**. This is the starting point for this illustration of the financial pecking order theory as well as for the data analysis.

The financial pecking order theory

Both types of companies, M and non-M, may have a development project that could be realized using external financing by issuing new equity. As investors are unable to distinguish M from non-M companies, they face a haphazard risk: if they value the company as type M, but the company turns out to be type non-M, they would overvalue the company and pay too much for the new equity. This would provide supernormal pay-offs to the current owners of the company, and the managers of the non-M type company would have no incentive to identify their firm as non-M because they aim to maximize the wealth of their current owners.

Anticipating this behavior and an inability to valuate the company, the investor would adjust the overall valuation scheme in order to control for these risks: all companies' equity would be priced to a level corresponding to the non-M value, and hence below the fair value for an M firm.

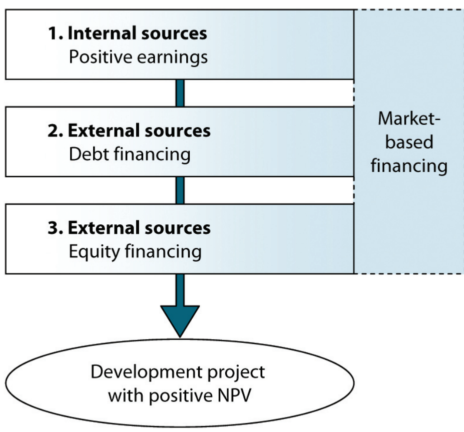
Managers of the M type company would find the situation somewhat contradictory. The current owners of the M company would have to consider whether their net wealth gain still remained positive. If the wealth loss of the current owners did not exceed the overall NPV of the development project, the project should be accepted in economic terms. However, the project could be rejected, even if it had a positive NPV, if the projected wealth decrease of the current owners of the M company exceeded the project's NPV.

The asymmetric information approach implies that an M type company would issue equity only if it had no other project-financing option. In contrast, non-M type companies would have nothing to lose, which would make equity financing an appropriate instrument for them. Based on this reasoning, by issuing new equity, the company signals that it is type non-M.

Consequently, companies follow a financial pecking order as described by Myers and Majluf (1984) (Figure 6.2):

1. The company exploits its internal sources of financing: company revenues, or equity issuance for insiders. Because information asymmetry does not occur among insiders, there will be no wealth losses and equity would not be undervalued. Furthermore, there will be no issue fees or trade costs associated with the internal financing, which implies that it would be economically superior to any other source of financing. Only in cases where no internal financing was available for all the development project(s) with positive NPV would other financial sources be used.
2. Companies prefer debt financing to equity financing because the debt interest is usually tax-deductible and the single bond security is a fixed claim with the same value independent of the type of company. Thus, debt financing is cheaper than equity financing for a type M company and even for a non-M company when issuing equity is more costly than issuing debt.

Figure 6.2 The pecking order of market-based financing at any stage of the company's life cycle



Source: Myers and Majluf (1984).

3. External equity financing is used as a last resort to finance promising development projects, due to the dilution effects mentioned above.

The company makes a new assessment and financing choice for each new NPV project. Typically a well-established company has a real choice among financial instruments as it can have retained earnings, as well as collaterals for a possible loan. For a young company the true choices are very limited. However, the financial pecking order *preferred* by all companies remains the same across situations.

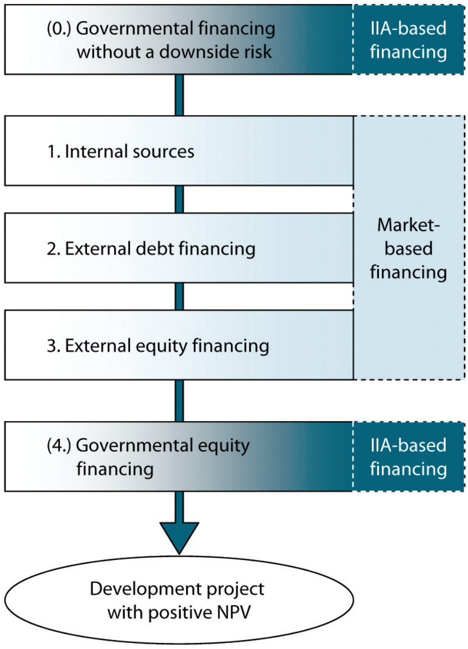
Financing based on the infant industry argument: an extended financial pecking order

The introduction of financial instruments in concordance with the infant industry argument necessitates an extension of the concepts of the original financial pecking order theory (Figure 6.3). If the government loosens the terms of financing, a company's management might prefer government financing to any other financial source in order to minimize the efforts and risks related to the financing. This is the case especially if the loans do not require repayment in the case of project failure. In this case the loans can be viewed as a virtually risk-free source of financing for a company. Such government funding would thus transcend the conventional pecking order to become the first choice for companies.

Government financing organizations specializing in venture capital type financing have an inherent principal-agent problem. The government venture capitalists are by definition not true venture capitalist entrepreneurs as they operate with outside (*i.e.* taxpayers') money, and hence are virtually free from downside risks caused by internal and external factors. Moreover, an upside resulting from successful government investment is not reflected primarily in the wealth of the responsible investment managers. Consequently, government venture capitalists may not have explicit incentives to pursue results in the best interests of the financier or the original owner of the company. A second problem is connected to the political principals of a government venture capital organization:. even if the government venture capitalist provides the same conditions as its private counterpart, there might be a risk of arbitrary decision-making due to changing political climates.

Both the principal-agent problem and the "political risk" should guide the financing provided by a government venture capitalist in the opposite direction of the pecking order than government subsidies. Government equity financing becomes even less preferred and more expensive than equity financing obtained from a private venture capitalist. Consequently, if a company has a strong injec-

Figure 6.3 Infant industry argument (IIA) extends beyond the financial pecking order at any stage of the company's life cycle



Source: Adapted from Myers and Majluf (1984) and List (1841/1844).

tion of government venture capital, it might have a negative signaling effect in the following rounds of financing.

6.3 Data and Empirical Setting

6.3.1 Characteristics of empirical data

The data used in this study are derived from a database compiled by ETLA, The Research Institute of the Finnish Economy, covering financial and business-related information on 84 companies operating in the biotechnology sector. 42 small and medium-sized firms that indicated they are part of the pharmaceutical industry or that their clients or subcontractors are in the pharmaceutical industry were selected from the database. ETLA's biotechnology company database was collected in 2002-2004. Hermans and Luukkonen (2002) and Hermans et al. (2005) present a detailed description of the data. The information from financial statements has been cross-checked with the trade register of the National Board of Patents and Registration of Finland. A comparison of Finnish biopharmaceutical small and medium sized enterprises to all SMEs[1] is presented in Table 6.1. The number of employees in biopharmaceutical SMEs is relatively high when compared to other Finnish SMEs as a whole, but their sales revenues are lower on average than those of companies in other industries. Despite the fairly high number of employees, 45% of the companies show a turnover of less than 200,000 euro, compared to only 15% of other SMEs. The biopharmaceutical sector's sales are oriented more toward foreign markets than sales of all companies on average and the companies are comparatively young. Slightly more than a third of the biotechnology companies were founded in 1997 or afterwards, while the corresponding proportion for all SMEs is 14%.

The biopharmaceutical sector's emphasis on scientific research is evident from examining the companies' outlays on research and development (R&D) as a percentage of their total expenses. Accordingly, 75% of the biopharmaceutical companies have patents or patents pending, while 94 % of all Finnish SMES have neither of these.

R&D activity is typically associated with expectations of future revenues. However, this emphasis on future commercialization increases business risks, which will in turn elevate the yield requirements of investors. Given the revenue expectations of entrepreneurs and the yield requirements of investors, it is understandable that 86% of the biopharmaceutical companies in the sample expect their turnover to rise over the next five years at an average annual rate exceeding 10%, compared to only about 20% of all SMEs.

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1 Below we use the term SMEs to denote small and medium-sized enterprises. A company is called small or medium-sized if two of the following three conditions are met: the company has a maximum of 250 employees, its turnover does not exceed EUR 40 million and its total assets are less than EUR 27 million.

Table 6.1 Comparison of Finnish Biopharmaceutical SMEs and SMEs as a whole

	Bio-pharmaceutrical SMEs (%)	Total SMEs (%)[2]
Number of employees		
< 5	33 %	44 %
5-20	38 %	41 %
> 20	29 %	15 %
Turnover, million euro		
< 0.2	45 %	15 %
0.2-1.5	40 %	56 %
1.6-8.0	12 %	24 %
> 8	2 %	5 %
Exports/turnover		
0 %	43 %	70 %
0-1 %	2 %	22 %
2-5 %	7 %	4 %
6-10 %	0 %	2 %
> 10 %	45 %	3 %
Unknown	2 %	0 %
Age of company, years		
0-2	14 %	5 %
3-4	21 %	9 %
5-24	64 %	70 %
>24	0 %	16 %
R&D expenditures/total costs (total SMEs = R&D expenditures/turnover)		
0 %	5 %	53 %
0-1 %	2 %	23 %
2-5 %	5 %	13 %
6-10 %	7 %	3 %
> 10 %	79 %	6 %
Unknown	2 %	0 %
Company has patents or patent applications		
Yes	74 %	6 %
No	26 %	94 %
Company's expected turnovergrowth over next 5 years (total SMEs = next 3 years)		
< 0 %	0 %	1 %
0-1 %	2 %	31 %
2-5 %	0 %	20 %
6-10 %	10 %	23 %
> 10 %	86 %	21 %
Unknown	2 %	5 %
Total observations in sample	***42***	***754***

Source: Trade register of the National Board of Patents and Registration of Finland, Hermans and Luukkonen (2002), Hermans et al. (2005) and authors' calculations.

[2] Hyytinen and Pajarinen (2003) used sector-specific data on Finnish companies to uncover the real structure of Finnish SMEs. This study weighted the data according to the age of the companies, as in Hermans and Kulvik 2005). The weights are obtained as follows:

$\frac{n_{total(t)}}{n_{sample(t)}}$. The term n denotes the number of companies in the total population and the sample. Term t denotes the three groups (t=1,2,3) in order of age. Group 1, group 2 and group 3 consist of companies founded in 1997-2001, 1991-1996, and earlier, respectively.

6.3.2 Capital structure and financial sources

Types of capital

This section investigates the financing received by biopharmaceutical companies, broken down by type of capital. The empirical handling of capital structures was influenced by a study on the SME sector in the US (Berger and Udell, 1998), a study on the capital structure of Finnish small and medium-sized companies (Hyytinen and Pajarinen, 2003), and a study of capital structures in the biotechnology industry (Tahvanainen and Hermans, 2005).[3]

Equity and capital loans are prominent forms of financing in all biopharmaceutical companies in the sample (Table 6.2). Equity and capital loans are considered part of the total shareholders' equity. Capital loans are a specific version of financing offered by government institutions in Finland. A company pays interest on capital loans only if it has profits to pay out.

The capital loans supplied to biopharmaceutical companies have come almost entirely from the public sector, with the National Technology Agency of Finland (Tekes) accounting for over 80% and the Finnish National Fund for Resarch and Development (Sitra) for 15% of the total amount. The role of Sitra as a source of capital loans is especially pronounced in small companies with less than 20 employees.

Table 6.2 Capital structure by age and size of biopharmaceutical companies

	Equity, %	Capital loans, %	Loans, %	Total financing (million euro)
Total	70.6	18.3	11.1	225.4
0-4 years	77.1	10.5	12.4	134.9
5-8 years	71.0	27.9	1.1	59.3
9-24 years	41.4	33.6	25.0	31.2
Small	49.9	36.5	13.7	20.6
Large	72.6	16.5	10.9	204.8

Source: *ibid*.

[3] Because almost half of the companies showed a loss in the fiscal period evaluated, the realized losses reduced the amount of equity on the balance sheet. Because we want to assess how much has been invested in the companies in the form of equity and capital loans, the realized losses are not taken into account in our study. Thus, the total equity presented in Table 2 does not correspond to the figures obtainable directly from the balance sheets.

As biopharmaceutical companies' assets are mainly based on intangible assets and competencies, they – especially younger companies – seldom have collateral with which to secure loans. Consequently, loans account for 11% of total financing on average. Thus, only older companies with stabilized operations and accumulated tangible assets have traditional bank loans.

Loans provided by Tekes can be given without major collateral and do not require repayment if the financed project fails. Thus the loans provide virtually risk-free project-financing and are highly preferred by companies. Due to the repayment terms, investigators should not consider such financing an ordinary loan, as Tahvanainen and Hermans (2005) did, but more of a subsidy.

The total equity financing of SMEs operating in the pharmaceutical industry is estimated to be slightly less than 160 million euro. The major owners of the companies are actively engaged in the business, private venture capital companies, and government institutions providing venture capital, mainly Sitra. The nominal value of the equity financing of older firms is less than that of their younger counterparts at the end of 2001. This may be explained by inflation and by smaller levels of initial investments particularly in those matured companies that can generate sales and positive profits.

Especially in older companies the owners are likely to be non-financial companies; other companies own over 60% of the shares of biopharmaceutical companies more than 8 years old, whereas private venture capital companies and government institutions have proportionately greater ownership of younger companies.

Capital structure related to companies' financial performance

Most of the equity financing is focused on firms with turnover less than 1.5 million euro (Table 6.3). Those few companies that have succeeded in generating higher sales are mostly owned by non-financial companies. These companies primarily export their products or services.

The time from innovation of a drug to the final product launch may take 10 to 15 years (DiMasi et al., 2003). Hence, a start-up firm's R&D activities and intangible assets are of pivotal importance when assessing the firm's present value from its expected stream of revenues (e.g. Garner et al., 2002). The companies' high levels of R&D activity might reflect the investors' emphasis on the importance of R&D activity as a way of boosting future revenues, or the activity may signal future revenue expectations to investors, making the company a more attractive investment target (Table 6.3, High R&D intensity).

Table 6.3 Equity financing by realized turnover (i.e. sales revenue) and export intensity of biopharmaceutical companies

	People active in the business, %	Other people, %	Private venture capital company, %	Other financial institution, %	Other company, %	Govern-ment institution, %	Other, %	Total share financing, mill. euro
Turnover under 1.5 million euro	26.3	5.1	33.6	2.6	5.9	25.0	1.4	147.6
Turnover over 1.5 million euro	16.8	0.6	7.4	2.3	67.4	5.5	0.1	11.5
Low R&D intensity	4.5	0.2	0.0	0.0	93.8	1.5	0.0	7.5
High R&D intensity	26.6	5.0	33.3	2.7	6.2	24.7	1.4	151.6

Source: *ibid*.

In Table 6.4 the ownership structure is broken down by the sales expectations indicated by the company, with the threshold of a company's own expectation of its sales after 5 years set at 1.5 million euro. People actively engaged in the business own about 25% of the companies with both low and high revenue expectations.

Table 6.4 Equity financing of biopharmaceutical companies by expected turnover in 2006 and expected annual growth in turnover

	People active in the business, %	Other people, %	Private venture capital company, %	Other financial institution, %	Other company, %	Govern-ment institution, %	Other, %	Total share financing, mill. euro
Expected sales in five years below 1.5 million euro	26.4	6.4	36.1	3.3	0.1	27.4	0.2	107.4
Expected sales in five years above 1.5 million euro	23.9	1.4	22.6	1.1	31.6	15.9	3.5	51.7
Expected rate of growth less than 25% per annum	24.1	4.5	38.6	0.3	8.7	23.5	0.3	90.3
Expected rate of growth greater than 25% per annum	27.6	5.2	22.8	5.6	12.5	23.8	2.6	68.7

Source: *ibid*.

Private venture capital firms own on average slightly over a third of companies with revenues anticipated to remain below 1.5 million euro over the next five years, but they account for slightly over 20% of the ownership of companies with higher revenue expectations over the same time. The role of government sources of venture capital, especially Sitra, is high in companies whose turnover is not expected to surpass 1.5 billion by 2006. On the other hand, non-financial companies have invested almost exclusively in companies whose sales expectations are relatively high.

In this section the capital structure of companies in the biopharmaceutical sector have been presented, broken down by characteristics of the biopharmaceutical companies. In the next section a more systematic overview of the above-described capital and ownership structures are presented using statistical means.

6.3.3 Indicator construction

Market orientation of the companies

Six indicators are used to characterize the market-orientation of the companies. Descriptive statistics for the 6 market-orientation variables are presented in Table 6.5.

The first variable represents current value creation by the company, as measured by annual revenues. The second indicator relates to future value creation expectations, estimated by anticipated annual revenues five years after the time of survey. These estimates may include some upward bias because they are disclosed by the companies themselves and thus tend toward more optimistic outcomes. However, the anticipated sales seem to be related closely to the company's actual level of intellectual capital, the foundation for future earnings as demonstrated by Hermans and Kauranen (2005). For the current purposes, the measure was simplified and a dummy created indicating whether the anticipated future sales are above 8 million euro (1) or not (0).

The third indicator of market-orientation, exports intensity, approximates an orientation towards the globalized markets of pharmaceuticals. This indicator is estimated as the exports' share of the total revenues of the company. Such a measure is especially relevant in this study's context: a small open economy of which domestic markets constitute a vanishing share of the global markets.

The fourth indicator, customer dependence, is a dummy variable based on whether the company has a principal customer whose purchases exceed 33% of the company's annual revenues. This indicator provides important information on the company's customer relations as a part of its market orientation.

Table 6.5 Variables indicating market-orientation

Direct market orientation	N	Minimum	Maximum	Mean	Std. Deviation
Current value creation (turnover in million euro)	42	0.00	27.53	1.27	4.28
Future value creation (turnover in 5 years)	41	0.00	204.46	12.21	35.42
Export intensity (export/sales <=10%=0 >10%=1)	41	0.00	1.00	0.46	0.50
Customer dependence (principal customer (>1/3))	42	0.00	1.00	0.43	0.50
Managerial experience (manager's business experience in years)	42	1.00	40.00	10.60	8.42
Auditing expertise (top 5 auditor)	42	0.00	1.00	0.71	0.46

Source: *ibid*.

The fifth indicator for market orientation approximates the company's business and management experience, as measured by how many years a chief executive officer (CEO) has been active in managing businesses.

The last indicator is based on whether or not the company has retained the services of one of the five largest international auditing companies. This might relate to the company's reliability in the eyes of potential international business partners.

Research orientation of the companies

Research activity is the heart of any business in the field of drug discovery. The initial research leading to an innovation may be conducted within academia or a company. 74% of the biopharmaceutical companies within the data set state that their origin stems from an academic biotechnical research idea, and 19% of the companies are spin-offs of other companies. Thus, the industry as a whole can be expected to be extremely research-oriented, with business based almost entirely on R&D activity. Table 6.6 lists four variables used as indicators of company research orientation.

The first indicator estimates the research intensity as a ratio of R&D costs to total costs of the company. If the ratio is close to 100%, it means that the company has no in-house sales activity: it either has no sales or has out-licensed its distri-

Table 6.6 Variables indicating research-orientation

Research orientation	N	Minimum	Maximum	Mean	Std. Deviation
Research intensity (R&D costs per total costs)	42	0 %	100 %	0.51	0.36
Education intensity (Share of employees holding PhD degree out of total labor)	42	0 %	100 %	0.35	0.31
Research productivity (patent applications + patents/labor)	42	0.00	21.43	2.06	4.45
Research collaboration (collaboration with foreign academic institutions)	42	0.00	1.00	0.26	0.45

Source: *ibid*.

bution efforts. In both cases, the company's research intensity remains the main driver of value creation.

The second indicator measures formal research education intensity of employees as the ratio of the number of employees holding a PhD degree to the total number of employees.

The third indicator relates to research productivity in terms of intellectual property rights as output from R&D activity (Suarez-Villa, 1990; Furman et al., 2002). This indicator is measured as the ratio of number of patent applications and patents to the number of total number of employees. The size of the patent portfolio is often related directly to earnings prospects, especially in a high-tech industry such as drug development (Hermans and Kauranen, 2005). However, the number of approved patents will usually be substantially lower than the number of patent applications. As pharmaceutical companies are assessed in part based on their relatively high number of approved patents, small biotechnology companies will also attempt to produce a significant patent portfolio (Nikulainen et al., 2006). Thus, their patent portfolio becomes biased towards patent applications. The conclusion is that using the number of patent applications as an indicator of research productivity provides a valid proxy for research orientation of the biopharmaceutical company.

The fourth indicator for research orientation describes international academic collaboration as measured by a dummy variable based on whether the company collaborates with a foreign academic institution (1) or not (0). A reflection of the very unique research-oriented nature of the industry is that 95% of the companies collaborate at least with one domestic academic institution and 26% with at least one foreign institution.

Table 6.7 Control Variables indicating size, age, and location of companies

Controls	N	Minimum	Maximum	Mean	Std. Deviation
Size (employees)	42	1.00	82.00	16.48	19.21
Matureness (age of firm)	42	0.00	21.00	6.69	4.47
Hub location (Helsinki)	42	0.00	1.00	0.36	0.48
Hub location (Turku)	42	0.00	1.00	0.36	0.48

Source: *ibid*.

Four control variables were used in the empirical analysis to detect any potential effects or correlations specific to size, age, or location of the companies (Table 6.6). Company size is estimated by the total number of employees, maturity is measured by the age of the company, and two dummy variables represent location: Helsinki and the Turku region each house 36% of the biopharmaceutical companies in the sample, and the location dummies reveal whether distinctive investor groups demonstrate any geographic preferences.

6.4 Empirical models

The empirical analysis was conducted in two stages. First, the depth of market and research orientation of the companies was described and measured, and then these measures were related to the sources of financing. In The second stage estimated how the market and research orientations of the companies are configured when they are financed by distinctive government and private sources of financing using a logistic regression model. The results of the regression analysis reveal the interaction, if any, among the strategic orientations of the companies, the infant industry argument and the modified pecking order hypotheses related to the biopharmaceutical business.

The first stage compresses the information hidden in the overall and partial co-variations within the initial data to form uncorrelated linear combinations of the observed variables. It was possible to identify between-variable groups of loadings representing distinctive indicators of the market orientation and research orientation of the companies. Some companies might be leaning on exceptionally high current R&D expenses in order to create abnormally high future earnings. This would be expressed both as research and market orientation in a single principal component. More generally, the principal component loadings provide information on how market-orientation and research-orientation of the companies interact within the data set.

The results of the first stage of analysis provide solid grounding for the second stage analyses: the resultant principal component scores are used as independent variables in the regression model. Using principal component scores in place of the original individual variables reduces risks for multi-collinearity of the independent variables within the model because the principal components measure co-variation of the initial variables but are uncorrelated to one another.

6.4.1 Results from the first stage: principal components and strategic orientations

Principal components were formed to assess the different strategic orientations of the biopharmaceutical companies within the sample. The varimax rotation method simplified the interpretation of the principal components by minimizing the number of initial variables that correlate with any principal component. The method seeks to produce a rotated final result where each variable is prominent in only one principal component.[4] The rotated principal components analyzed explain slightly over half of the variance of the selected variables. The principal components are distinguished according to whether the correlation between the selected variable and the principal component is over 0.3, which corresponds roughly to the correlation level that differs significantly from zero, taking into account the sample size and assuming a normally distributed population. Six principal components, the eigenvalues of which are greater than 1, are named.

This method produced six principal components with eigenvalues greater than 1. The resulting components all represent a certain composition of strategic orientations. The rotated principal components are shown in Table 6.8. To assess the companies' strategic orientations, the components were divided into type M (market-oriented strategy) and type non-M (non-market oriented strategy) using the strategy matrix described earlier.

Component 1, "Established business": This reflects an ongoing business strategy; the CEO is experienced, the company protects its intellectual property by patents, has established solid export channels, and shows high current sales. This is a type **M**

[4] Sharma (1996), for example, provides a detailed technical presentation of principal component analysis.

Table 6.8 Principal components depicting strategic orientations within the biopharmaceutical business

Rotated component matrix [a]	Component 1	2	3	4	5	6
Ln age (Control)	**0.801**	-0.025	0.068	-0.135	0.023	0.065
Export/sales >10% (**M**)	**0.707**	*-0.320*	0.167	-0.103	-0.294	0.045
Patents per labor (**non-M**)	**0.632**	**0.336**	-0.180	0.189	0.037	-0.203
Principal customer (**M**)	0.115	*-0.807*	0.047	0.239	0.106	0.262
Collaboration with foreign academic institutions (**non-M**)	0.083	**0.681**	0.262	0.173	-0.087	0.082
Anticipated sales >8meur (**M**)	0.008	0.156	**0.848**	-0.160	0.025	0.090
Ln revenues (**M**)	**0.443**	-0.275	**0.583**	-0.111	0.114	*-0.388*
Ln employees (Control)	-0.042	**0.527**	**0.554**	0.001	-0.225	0.212
Turku (Control)	-0.097	0.154	-0.097	**0.882**	0.151	-0.052
Helsinki (Control)	0.039	0.204	0.150	*-0.829*	**0.306**	0.058
Top 5 auditor (**M**)	0.106	0.291	0.013	0.125	*-0.811*	0.153
Ln CEO's business experience (**M**)	**0.495**	0.268	0.202	-0.083	**0.564**	0.284
PhDs per total labor (**non-M**)	-0.095	-0.111	*-0.428*	0.119	**0.477**	0.124
R&D costs per total costs (**non-M**)	0.015	-0.085	0.034	-0.094	0.003	**0.913**

Extraction method: principal component analysis.
Rotation method: varimax with Kaiser normalization.
M = market oriented strategy.
non-M = non-market oriented strategy.
[a] Rotation converged in 16 iterations.

Source: *ibid*.

strategy, showing high scores for both market and research orientation. According to this study's classification, companies showing such a strategy are Potential Stars. The reversed component 1 is an "Infant stage" strategy revealed by companies lacking an experienced CEO, international market relations, a patent portfolio, and current sales. This strategy is associated with Lemon companies of type **non-M**.

Component 2, "International scientific collaboration": This strategy lacks exports and a principal customer, but has established foreign academic collaboration, a critical mass of employees and many in-house patents. This is a type **non-M**, Research Oriented Strategy. The reversed component 2 strategy in this study is called "Foreign customer focus", a type **M**, Market Oriented Strategy.

Component 3, "Sales Orientation": This describes a strategy that has led to high current sales along with high anticipated future sales, and a significant critical mass of employees, but a relatively low number of PhDs. This is a type **M**, Market

Oriented Strategy. The reversed component 3, “Scientific competence” strategy is associated with no present nor anticipated future sales and few employees, but a relatively high number of PhDs. This is a purely Research Oriented Strategy of type **non-M**.

Component 4, “Location in Turku”: This component has a reversed component, “Location in Helsinki”. The locations were control variables, and the result suggests that corporate strategies do not vary according to company location. Consequently, this component cannot be placed in any specific category of this classification.

Component 5, “Human resources”: This is a type **M** strategy showing both a market and research orientation. The strategy includes both a high ratio of PhDs to total employees, as well as a CEO with significant business experience. Moreover, it is located in Helsinki. According to this classification, this should be a Potential Star. Strategies characterized by a reversed component 5 comprise a Top 5 auditor but lack internal human resources, and this strategy is called “External control”, and as such it is a Lemon strategy within this classification.

Component 6, “R&D”: Strategies associated with this component show a high R&D intensity but low current sales. This is clearly a Research Oriented Strategy of type **non-M**. The reversed component 6 is associated with a low R&D intensity but high current sales, and is consequently named “Sales” -a Market Oriented Strategy of type **M**.

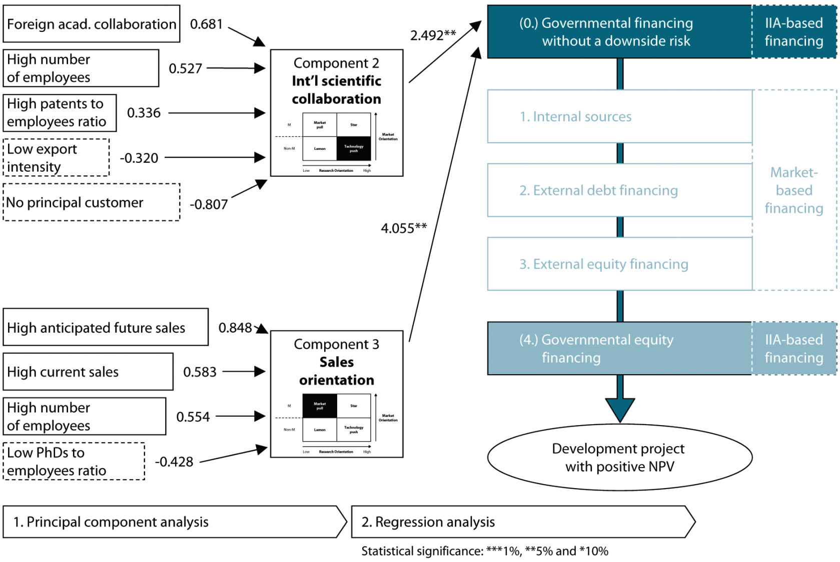
6.4.2 Second stage results: logistic regression analysis

A standard logistic regression model is utilized to reveal the types of strategic orientation with which companies at each stage of the extended financial pecking order framework are associated. The dependent variables are dummies indicating whether the company has received financing from a financial source related to a specific stage of the pecking order. The logit regression model is of the following form:

$$\text{logit } P_t = \alpha_i + \beta_i X + \varepsilon_i, \quad (6.1)$$

where the left hand of Equation 6.1 depicts the odds ratio of a probability (P) to obtain funds from the i^{th} source of financing. Term α is a regression constant. The vector X represents the principal components derived in the analysis above, and the regression coefficient of the vector X is denoted by β, measuring to what degree the strategies revealed by principal components can be related to financing from the i^{th} source (the results are presented also in Appendix 6.2 in table format).

Figure 6.4 The strategic orientations of companies receiving government subsidies and loans as part of IIA policies



Government financing without a downside

Government financing without a downside refers to risk-free subsidies and loans provided by Tekes. 96% of the companies applied for such direct or indirect subsidies, with 65% of the companies ultimately receiving this financing from Tekes. Consequently, the strategic orientations depicted in Figure 6.4 mainly reflect the selection criteria of Tekes. The company profiles show both market-driven and research-oriented strategies (Figure 6.4). As the majority of companies have received 0-type government financing risk-free, the logistic regression results suggests that it is sufficient to show either of the following to receive Tekes funding:

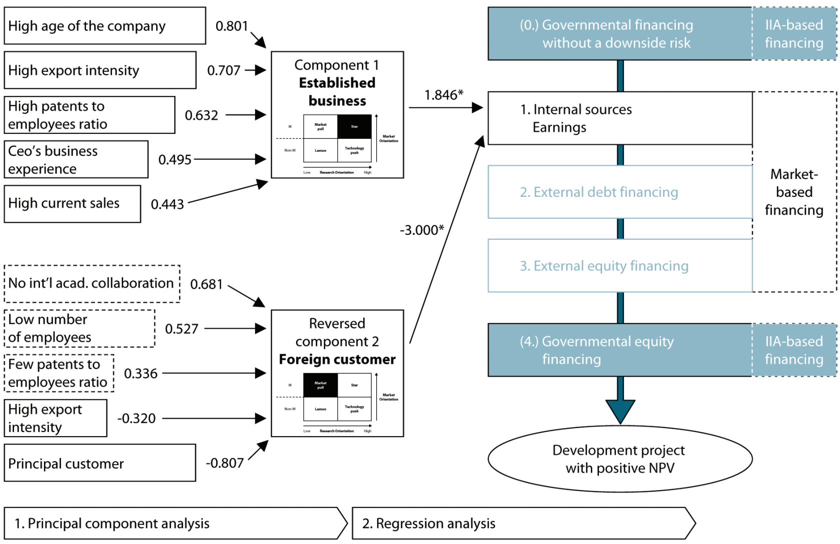
1. A large international research network (see Kamien and Tauman (2002) for a deeper comparison of the most profitable modes of licensing by an inventor who is an industry incumbent with one who is an outsider).
2. High sales, either disclosed by the company itself as high anticipated future sales, and/or high present sales.

This leads to the conclusion that the strategic orientations of the preferred companies can be either type **M** or type **non-M**.

Internal sources: earnings

Market-based internal financial sources are clearly related to a type **M** corporate strategy. As Finland is a small open economy, high current sales typically relate to a high export intensity. Moreover, success in international markets seems to be associated with a higher age or later stage of the company or, in the case of a younger company, with the establishment of a strong relationship with a foreign principal customer (Figure 6.5). Himmelberg and Petersen (1994) show that internal sources are a significant form of R&D financing for publicly listed companies in the USA.

Figure 6.5 The strategic orientations of companies generating positive earnings



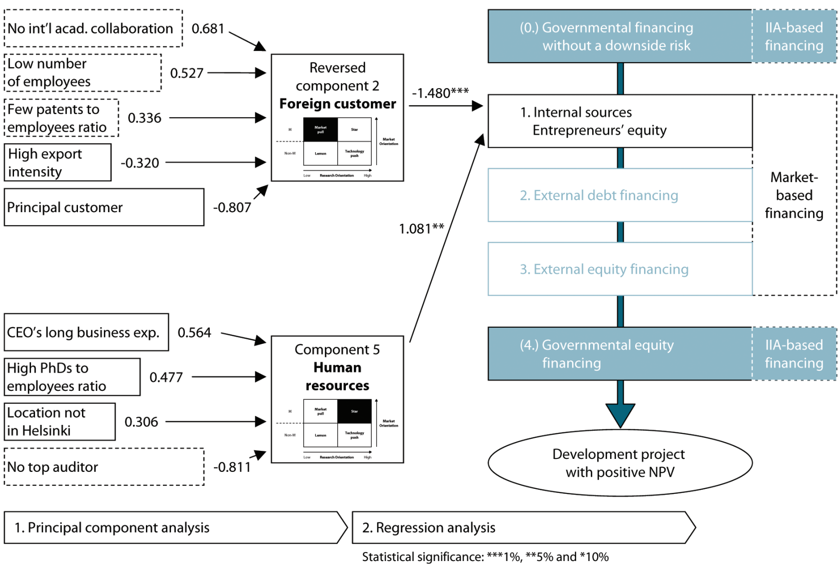
Statistical significance: ***1%, **5% and *10%

Internal sources: entrepreneurs

The term "entrepreneurs' equity" refers to ownership of more than 50% of the shares of the company by individuals who are active in the company's business. These employee-driven companies seem to implement clear internationally oriented strategies, having based their niche and combination of market and research orientation on the business experience and scientific knowledge of their employees (Figure 6.6). Moreover, the companies show high dependence on single foreign customers – equal to that of the companies with internal sources of financing stemming from earnings – thus warranting their status as having a type **M** corporate strategy. However, even though this dependence on a single customer may provide some stability of cash inflows, the loss of such a customer may be insurmountable for a small enterprise.

The market orientation of these entrepreneur-driven companies is parallel with the findings of the literature assessing agency costs. Agency costs reflect the costs of shareholders to monitor manager's behaviour and decision-making, and consequently agency costs are zero if the manager owns 100% of the equity. In the entrepreneur-driven companies managers own at least one half of the equity, which seems to lower agency costs in terms of market orientation (e.g. Ang et al., 2000).

Figure 6.6 The strategic orientations of companies with entrepreneurial ownership and financing

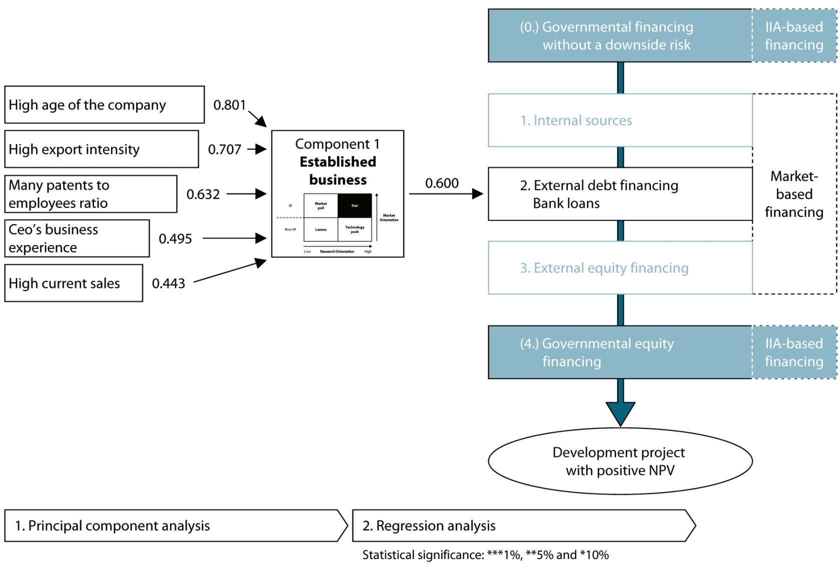


External debt: bank loans

In this study the bank loans consisted of only 2.5 million euro, and thus formed only a minimal portion of the total financing. This is likely the reason no strategic orientation was able to characterize this financing entity. However, Component 1, "*Smooth business*", predicted most significantly (p<.25) the reception of bank loans (Figure 6.7). This suggests that older and more proven type **M** companies had been able to attain debt financing.

No significant relation was found between strategic orientations of the companies and the external debt financing provided by banks. Bhagat and Welch (1995) argue that this relationship depends on cultural context: R&D activity seems to be financed by debt rarely among U.S. firms, but more often in Japan.

Figure 6.7 The strategic orientations of companies receiving bank loans



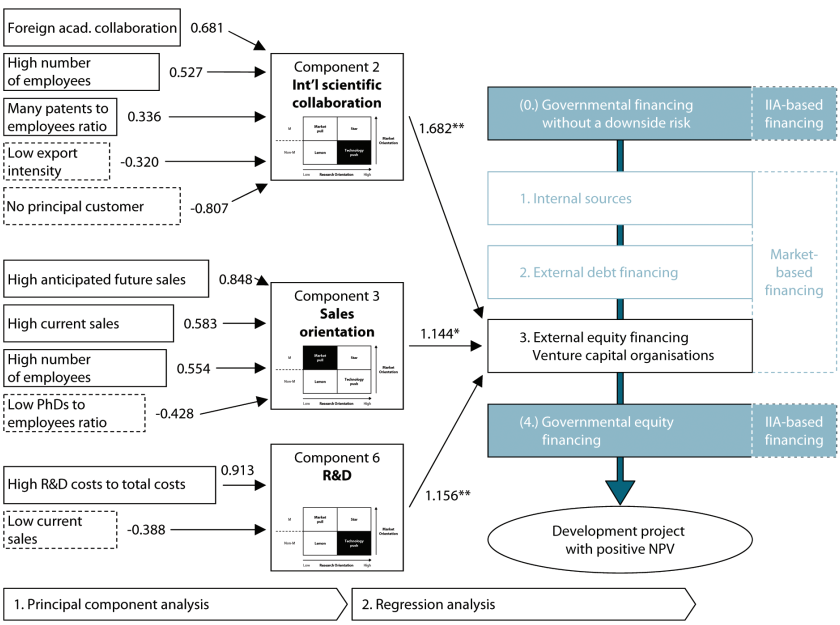
External equity financing: venture capital organizations

Companies that have been unable to obtain financing from earlier-stage sources in the pecking order generally seek external equity financing for their positive NPV projects. The probability of receiving financing from venture capital companies is higher when the firm shows any combination of the following strategic orientations (Figure 6.8):

- International scientific collaboration (**type non-M**)
- Sales orientation (**type M**).
- Intensive R&D activity (**type non-M**)

The simultaneous appearance of high current sales in component 3 and low current sales in component 6 is in line with the findings of Hermans and Kauranen (2005), where high anticipated future sales were not related to the current sales of the company but instead to a large patent portfolio, intensive R&D activity, uni-

Figure 6.8 The strategic orientations of companies receiving equity financing from venture capital companies



Statistical significance: ***1%, **5% and *10%

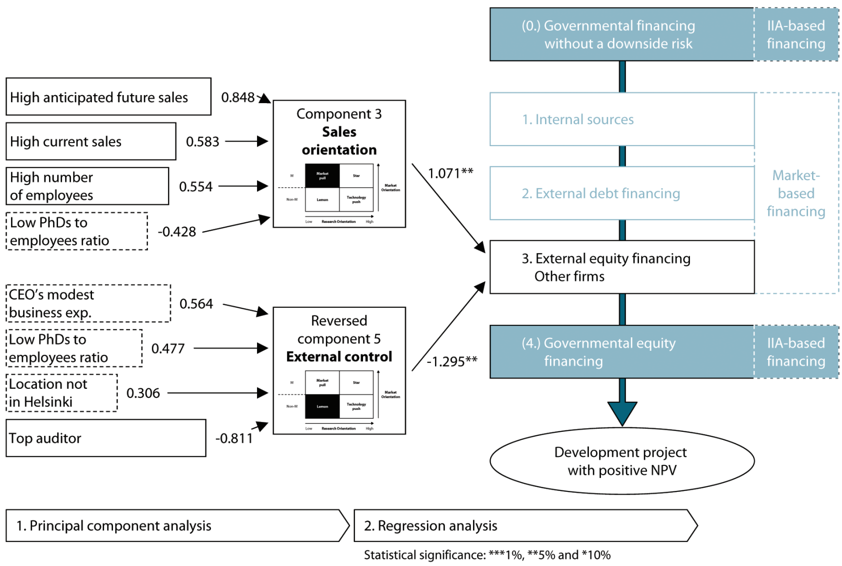
versity collaboration, company size, CEO experience, and equity financing from venture capital companies and other firms. High current sales seem to provide provide an important source of financial injections for R&D activity – as suggested by Kamien and Schwarz (1978) – although the Sales orientation strategy within the data seems to refer specifically to high anticipated future sales, rather than to high current sales.

Interestingly, the pattern of financial inputs of venture capital companies and high R&D intensity (component 6) is in line with the findings of Baysinger, Kosnik and Turk (1991): they concluded that high ownership stakes of institutional investors imply high R&D intensity.

External equity financing: other firms

Figure 6.9 presents results for companies financed by other firms as shareholders. Capital injections from other companies reflect an intensive market orientation with high current and anticipated sales closely related to type **M** companies. The

Figure 6.9 The strategic orientations of companies receiving equity financing from other firms



companies have a relatively large but non-research oriented employees. As described earlier, component 5 indicates a Lemon with type **non-M** corporate strategies, as it lacks both research orientation and market orientation, at least in terms of internal human resources. However, this is the case only when we consider component 5 an isolated phenomenon.

Companies owned by other firms can function in a very specific part of the parent firms' value chain. Consequently, the IPR portfolio and marketing functions can be transferred to any other part of the group as corporate functions (see Hermans and Kulvik, 2004). A company owned by another firm should hence be considered within the context of the entire group rather than as a sovereign entity.

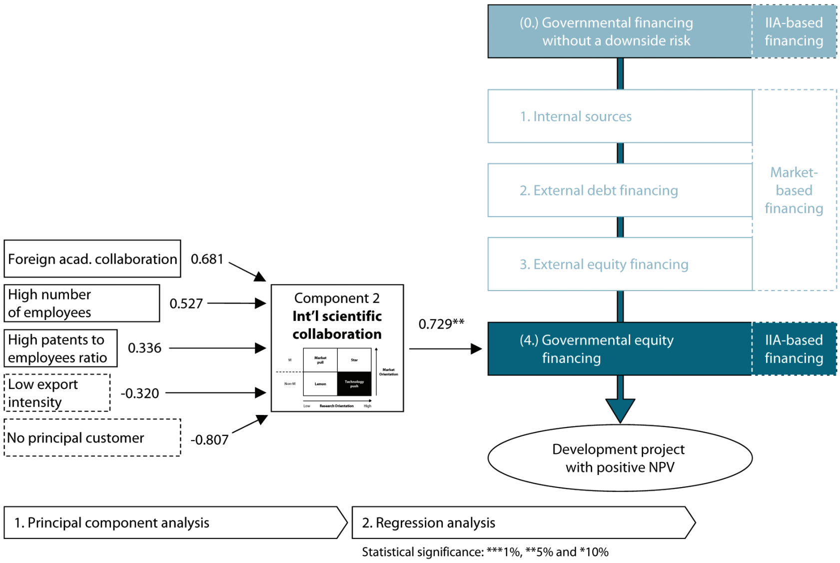
The difficulty that Finnish biotechnology companies faced raising money from initial public offerings at the beginning of this century links our findings to the work of Lerner, Shane and Tsai (2003). They suggest that during periods of limited external equity financing, US biotechnology companies were too compliant, shifting a large share of control to large outside partners. Reversal component 5 in our data is related to equity financing provided by other firms; it reflects a form of external control and monitoring similar to that found by Lerner, Shane and Tsai (2003).

Government equity financing

According to this study's hypothesis, companies are expected to turn to IIA-based government venture capital equity financing only as a last resort for positive NPV projects. Government venture capital organizations have financed companies showing a strong penchant for research but lacking a clear market orientation – type **non-M** companies (Figure 6.10). This is in clear contrast to the preferences of market-based venture capitalists (Figure 6.9). The empirical analysis shows, moreover, that the companies with market-oriented strategies have received all their financing from preceding market and non-market sources within the extended financial pecking order framework.

Lerner and Merges (1998) found that among US biotechnology alliances the partners with greater financial resources tended to have significantly more control rights within the relationship. In light of their finding, it is interesting to note that the companies that obtain significant government equity financing, as well as private venture capital financing, generally have control over a large patent portfolio. As Table 7.3 presents, government and private venture capital financing constitutes two thirds of the total equity financing. Therefore, it seems that IPRs are related to the firm's financial resources *per se*, rather than to the financing source.

Figure 6.10 The strategic orientations of companies receiving equity financing from government venture capital organisations



6.4.3 Sensitivity analyses

The study utilizes a relatively small set of cross-sectional data. This is associated with two potential problems:

1. Reverse causality between the dependent and independent variables.
2. Higher levels of sensitivity of results due to our limited number of observations.

First, the reverse causality issue suggests that it may be difficult to assess whether a company's strategic orientation is determined by its owners or whether the owners have been attracted by the company's existing strategic orientation, or some combination of these. Therefore, the validity of the implications based on the results above is directly related to the validity of the pecking order hypothesis. The pecking order theory assesses the financial decisions are made primarily by the companies, which aim to optimize the cost of financing. According to this reasoning, a company's strategic orientation should predict the sources of financing on which it will rely.

Second, the problem of increased sensitivity of results may be assessed by comparing the results produced here to those of alternative technical analyses. To that end, (1) a conventional principal component analysis without any rotation and (2) a generalized least squares (GLS) approach with the same rotation method as used above were employed. These alternative tests generated results aligned with those above, with a few exceptions (described below).

When the variable indicating whether the the company has received financing from Tekes on the unrotated principal component scores was regressed, four significant components were found, instead of only the two that emerged from the original analysis. This is due in part to the unrotated model's inability to simplify the components: the sensitivity analysis results in two components with high loadings on current and anticipated future sales. In addition, the first of these components had a high loading on the Helsinki region and another on the Turku region, whereas the rotated model was able to simplify the sales loadings within single components, with no loadings on a geographic location.

The clearest difference between the GLS model's results and the original ones was linked to the government venture capital institution. In this model, features associated with the research-oriented factor included collaboration with international academic institutions and the number of employees as above. The research-oriented factor also showed high loadings on anticipated future sales but not on any other measure of market-orientation. Thus, according to the GLS model companies financed by the government VC expect high earnings in the future from their internationally oriented research.

6.4.4 Discussion on empirical findings

Government institutions in Finland, as in many other countries, have placed strong emphasis on advancing the biotechnologies as a basis for drug development, although the pharmaceutical industry has not been historically one of the industrial pillars in Finland (Hermans and Kulvik, 2005). Finland's existing policies imply that the government has based its industrial and innovation policies on the conventional infant industry argument, with high hope pinned on business opportunities in the pharmaceutical markets.

The government institution (i.e. Tekes, in the data) provides direct subsidies. Tekes also provides loans without requiring collateral, and if the project fails, the loan becomes null and void. According to the extended financial pecking order, such a financier should become a primary source of financing for any kind of company. This was indeed confirmed by the fact that nearly all the companies in the sample applied for government direct subsidies, though only 65% of the companies ultimately received them. Furthermore, principal component analysis suggested that 65% of the subsidized companies express both market and research orientations, and thus represent both types **M** and **non-M** companies.

The government takes on the business risk for the companies, and thus enables them to seek higher earnings by developing their products through later stages. The financial pecking order is not distorted, but it could have a detrimental effect on the company's commercialization strategy as it weakens the quest for early sales and thus the drive for commercialization. This notion was supported by this study's findings,[5] specifically where component 2, "*International scientific collaboration*", seemed to increase the probability of obtaining government subsidies, but to decrease the probability of generating any internal sources of financing when named as "*Foreign principal customer*". Accordingly, the (international) market orientation, rather than the (international) research orientation, seemed to boost the company's positive earnings and equity financing from entrepreneurs involved in the business activity.

The government institution willing to perform equity financing (i.e. Sitra, in the data) was expected to remain the last resort in the financial pecking order for any type **M** or type **non-M** company. The reasoning underlying this prediction was related to the additional risk of arbitrary decision-making on the part of the government VC due to the disconnection of power, responsibility and changing political climates, leading to a negative signaling effect. This could discourage the most promising type **M** companies from even applying for any government VC financing; and consequently the government VC equity financing would attract only **non-M** companies, which are often unable to obtain adequate financing from any other source. This seemed to be the case in the empirical analysis. Sitra was connected only with a research-oriented component, and thus with **non-M** companies.

The findings might also reflect an explicit strategy on the part of Sitra, such that the organization had decided to support promising high-risk companies that would otherwise not survive. As **non-M** research companies are inherently associated with high hopes and high risks, effective risk management requires the investor to be involved with a sufficient number of companies in order to offset the technical failure of a single project. Sitra is an early-stage investor; the typical success rate for a pharmaceutical product in preclinical testing is 0.4% (DiMasi et al., 2003). This would require 250 projects to yield one success, on average. Suc-

5 This was confirmed also by the simpler measures: the Pearson correlation between the zero-phase government financing vs. internal financing was negative ($p<.05$).

cessful pursuit of such high-risk ventures requires a very solid investment capacity and an enduring strategy.

This study's theory-based assertions and empirical findings point to potentially inefficient use of tax-payer money: when the government VC provides equity financing directly to companies. In such a case, the attractiveness of investee companies may be damaged, as government VC equity financing may signal to other (private) investors that the company is incapable of convincing market-based financiers to invest, given that taxpayer money represents a significant stake in the company.

A potential remedy could be a network of financiers. If the government VC acted as a part of the financiers' community, then it might co-invest with private counterparts.[6] The second, potentially more sustainable cure could be to acknowledge these structural shortcomings and realign interests. A government VC could act as a fund of other external private funds and outsource direct ownership to private players, while it could still direct the financing selectively to those fields that fall under the infant industry argument.

In the industry's point of view, Kamien and Zang (2000) showed that a creation of a competitive research joint venture reduces the level of technological improvement and increases prices compared to when firms conduct R&D independently. Their findings direct further analysis to assess the significance of collaborative patterns between the companies more thoroughly.

6.5 Conclusions

The infant industry argument aims at generating new, economically significant industrial clusters that will provide a competitive edge for firms entering global markets. This study analyzed the impact of public financial instruments implemented in accord with the infant industry argument.

The hypothesis was that an infusion of government financing into infant-industry companies extends the financial pecking order and thus modifies company strategies for two primary reasons:

1. If free government subsidies are available or if repayment conditions of government debt financing are not as stringent as those of other loan providers, the government subsidies and loans could be the first-preferred financial

[6] In our data, this was often the case. The basis for such cooperation is probably the origins of Finnish private VCs active in the biotechnology business: there are two private VCs active in the field and both are spin-offs of the government VC, Sitra, which has a stake in the private VCs. Therefore, one can expect close collaboration between the institutions, at least on a temporary basis.

instruments even over companies' internal financing, and hence would occupy the first rank in the pecking order. As the government takes on risk for the companies, the companies can strive for higher earnings by developing their products into later stages.

2. If a government institution provides equity financing and aims at being a company shareholder, this could impact the opposite end of the pecking order. This is due to principal-agent problems, and the potential threat of political climate fluctuation directing the behavior of government institutions as shareholders with the negative signaling effects resulting from such changes of behaviour. This should discourage entrepreneurs from applying for equity provided by government sources. In such a scenario the entrepreneur would prefer private equity investors over the government, placing the government last in the financial pecking order.

In order to assess the extended financial pecking framework, the capital structures of small and medium-sized Finnish biopharmaceutical companies were analyzed and the empirical findings viewed. The Finnish biopharmaceutical sector was chosen because it represents a specific infant industry where public financial instruments have been implemented.

The findings indicated that government interventions do affect the financial pecking order and corporate strategy. The results confirmed the extension of the financial pecking order as a relevant tool reflecting IIA-based policies in two regards. First, government subsidies and loans without stringent repayment conditions become the most preferred financial instruments, even over companies' internal financing. Second, taking on the government venture capital organization as the owner seems to be the last resort and a relevant option only for companies with clearly non-market oriented research-based strategies.

Based on this study's findings, government equity financing seems biased towards supporting non-market strategic orientations of the companies. As an alternative, one could ask whether temporary tax reliefs could encourage the more market oriented private equity investments into the infant industry.

From a corporate perspective, the extended financial pecking order framework has some important applications and implications. Corporate managers may find the framework useful when comparing the distinct forms of private and public financing. Second, due to its transparency, the framework helps to create a dynamic plan for initial or further corporate finance. This, in turn, may adduct or even pair the corporate finance planning with IIA-based technology policy.

Appendix 6.1
Principal component analysis

KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.408
Bartlett's test of sphericity	Approx. chi-square	160.342
	df	91.000
	Sig.	0.000

Communalities	Initial	Extraction
Lnperson	1	0.6819
post-graduated labor per total labor	1	0.4614
Lnceoexp	1	0.7641
rdcost/total cost	1	0.8511
patent applications + patents / labor	1	0.6224
Lnaget	1	0.6704
principal customer (>1/3)	1	0.8035
collaboration with foreign academic institutions	1	0.5831
Top5 auditor	1	0.7923
Lnto	1	0.7887
export/sales <=10%=0 >10%=1	1	0.7284
anticipated sales <8meur=0 >8meur=1	1	0.7773
Helsinki	1	0.8499
Turku	1	0.8465

Extraction method: principal component analysis.

Source: *ibid*.

Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumu-lative %	Total	% of variance	Cumu-lative %	Total	% of variance	Cumu-lative %
1	2.730	19.497	19.497	2.730	19.497	19.497	2.035	14.538	14.538
2	2.164	15.458	34.955	2.164	15.458	34.955	1.948	13.917	28.455
3	1.700	12.144	47.099	1.700	12.144	47.099	1.759	12.565	41.020
4	1.371	9.790	56.889	1.371	9.790	56.889	1.701	12.150	53.170
5	1.245	8.894	65.783	1.245	8.894	65.783	1.491	10.651	63.821
6	1.011	7.224	73.007	1.011	7.224	73.007	1.286	9.187	73.007
7	0.926	6.613	79.621						
8	0.814	5.815	85.436						
9	0.691	4.934	90.370						
10	0.413	2.949	93.318						
11	0.341	2.439	95.758						
12	0.273	1.948	97.705						
13	0.202	1.446	99.152						
14	0.119	0.848	100.000						

Extraction method: principal component analysis.

Source: *ibid*.

Component matrix[a]

	Component					
	1	2	3	4	5	6
Anticipated sales <8meur=0 >8meur=1 (anticipated sales of the company in 2006 over 8 million euro, then 1, otherwise 0)	0.666	-0.166	-0.221	-0.153	-0.009	0.483
Lnto (sales, log)	0.540	0.406	0.212	-0.055	-0.375	0.379
Lnaget (age of the company, log)	0.539	0.399	0.375	0.126	0.138	-0.212
export/sales <=10%=0 >10%=1 (export per sales >10% then 1, otherwise 0)	0.463	0.437	0.451	-0.305	0.065	-0.150
Post-graduated labor per total labor (%)	-0.434	0.252	-0.129	0.387	0.205	-0.027
Principal customer (>1/3) (sales to a single customer exceeds 33% of the total sales)	-0.250	0.636	0.146	-0.344	0.300	0.326
Collaboration with foreign academic institutions (if yes then 1, otherwise 0)	0.370	-0.592	0.123	0.240	0.140	0.057
Lnperson (number of employees, log)	0.528	-0.575	-0.076	-0.090	0.157	0.184
Top 5 auditor (big int'l auditor 1, otherwise 0)	0.175	-0.531	0.374	-0.461	0.132	-0.331
Helsinki (location in Helsinki region 1, otherwise 0)	0.511	0.178	-0.659	0.199	-0.139	-0.255
Patent applications + patents/labor (number of patents and pat. appl per capita)	0.246	0.005	0.559	0.438	-0.016	-0.239
Turku (location in Turku region 1, otherwise 0)	-0.448	-0.314	0.482	0.313	0.204	0.419
Lnceoexp (Ceo's business experience in years, log)	0.506	0.229	-0.045	0.556	0.366	0.102
Rdcost/total cost (R&D expenditure to total cost ratio, %)	0.110	0.089	-0.288	-0.225	0.832	-0.075

Extraction method: principal component analysis.
All the indicators reflect the situation in 2001 if not other quote.
[a] 6 components extracted.

Source: *ibid*.

Rotated component matrix[a]

	Component					
	1	2	3	4	5	6
Lnaget (age of the company, log)	0.801	-0.025	0.068	-0.135	0.023	0.065
Export/sales <=10%=0 >10%=1 (export per sales >10% then 1, otherwise 0)	0.707	-0.320	0.167	-0.103	-0.294	0.045
Patent applications + patents/labor (number of patents and pat. appl per capita)	0.632	0.336	-0.180	0.189	0.037	-0.203
Principal customer (>1/3) (sales to a single customer exceeds 33% of the total sales)	0.115	-0.807	0.047	0.239	0.106	0.262
Collaboration with foreign academic institutions (if yes then 1, otherwise 0)	0.083	0.681	0.262	0.173	-0.087	0.082
Anticipated sales <8meur=0 >8meur=1 (anticipated sales of the company in 2006 over 8 million euro, then 1, otherwise 0)	0.008	0.156	0.848	-0.160	0.025	0.090
Lnto (sales, log)	0.443	-0.275	0.583	-0.111	0.114	-0.388
Lnperson (number of employees, log)	-0.042	0.527	0.554	0.001	-0.225	0.212
Turku (location in Turku region 1, otherwise 0)	-0.097	0.154	-0.097	0.882	0.151	-0.052
Helsinki (location in Helsinki region 1, otherwise 0)	0.039	0.204	0.150	-0.829	0.306	0.058
Top 5 auditor (big int'l auditor 1, otherwise 0)	0.106	0.291	0.013	0.125	-0.811	0.153
Lnceoexp (Ceo's business experience in years, log)	0.495	0.268	0.202	-0.083	0.564	0.284
Post-graduated labor per total labor (%)	-0.095	-0.111	-0.428	0.119	0.477	0.124
Rdcost/total cost (R&D expenditure to total cost ratio, %)	0.015	-0.085	0.034	-0.094	0.003	0.913

Extraction method: principal component analysis.
Rotation method: varimax with Kaiser normalization.
[a] Rotation converged in 16 iterations.

Source: *ibid*.

Component transformation matrix

Component	1	2	3	4	5	6
1	0.555	0.318	0.638	-0.417	-0.069	0.074
2	0.430	-0.760	-0.119	-0.257	0.397	-0.004
3	0.616	-0.034	-0.100	0.652	-0.343	-0.257
4	0.208	0.515	-0.258	0.118	0.760	-0.183
5	0.147	0.044	-0.072	0.272	0.091	0.943
6	-0.251	-0.228	0.705	0.497	0.367	-0.075

Extraction method: principal component analysis.
Rotation method: varimax with Kaiser normalization.

Source: *ibid*.

Appendix 6.2
Logistic regression results

Independent variables:	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6	Constant
	Established business (+)	Int'l scientific collaboration (+)	Sales orientation (+)	Location in Turku (+)	Human resources (+)	Research and development (+)	
	Lemon (-)	Foreign customer (-)	Scientific experts (-)	Location in Helsinki (-)	External control (-)	Sales (-)	
Dependent variables:							
Infant industry argument-based financing							
(0.) Governmental financing without a downside risk	-0.097 (.683) **non-M**	**2.492**** (1.092) **M**	**4.055**** (1.601)	-0.909 (0.746)	-0.459 (0.568)	1.891 (1.174)	**3.302**** (1.266)
Market-based financing							
1. Internal sources: positive earnings	**1.846*** (1.024) **M**	**-2.998*** (1.759) **M**	0.370 (0.344)	-0.227 (0.511)	1.377 (0.908)	-3.203 (2.052)	**-2.303*** (1.255)
1. Internal sources: entrepreneurs' equity financing	-0.207 (0.452)	**-1.480***** (0.545) **M**	-0.712 (0.452)	-0.673 (0.487)	**1.081**** (0.506) **M & non-M**	0.235 (0.442)	-0.013 (0.428)
2. External debt financing: debt from banks	0.600 (0.492)	-0.021 (0.492)	0.273 (0.447)	-0.338 (0.509)	-0.607 (0.529)	-0.264 (0.454)	**-1.840***** (0.523)
3. External equity financing: venture capital companies	0.501 (0.504)	**1.682**** (0.674) **non-M**	**1.144*** (0.635) **M**	1.202 (0.733)	-0.559 (0.770)	**1.156**** (0.505)	**-2.278***** (0.838) **non-M**
3. External equity financing: other firms	0.540 (0.486)	-0.349 (0.496)	**1.071**** (0.479) **M**	-0.348 (0.494)	**-1.295**** (0.608) **non-M**	0.069 (0.412)	**-1.372**** (0.534)
Infant industry argument-based financing							
4. Governmental equity financing	-0.113 (0.343)	**0.729*** (0.378) **non-M**	0.064 (0.340)	0.219 (0.356)	0.007 (0.377)	0.453 (0.346)	-0.567 (0.357)

Statistical significance: *** 0.1%, ** 1%, * 10%.

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APPENDIX 5

ETLA

ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 358-9-609 900
Telefax 358-9-601 753 World Wide Web: http://www.etla.fi/

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Antti-Jussi Tahvanainen – Raine Hermans

AGGLOMERATION AND SPECIALISATION PATTERNS OF FINNISH BIOTECHNOLOGY – On the Search for an Economic Rationale of a Dispersed Industry Structure

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ABSTRACT: This study sets out to inspect empirically whether existing theory in Geographical Economics (GE) is able to provide a rationale for the controversial and much debated structure of the highly knowledge- and research-intensive biotechnology industry in Finland. In addition to providing evidence of GE in action, we integrate the effects that active public technology policy might have on geographic structures of industries into our analysis as a novel discourse. The results provide evidence of a theory based rationale that is able to deepen our understanding of the roles that different regions have enacted in the development of the case industry. Simultaneously, however, the rationale also reveals several challenges that different types of regions still have to overcome in order to steer on a track of sustainable economic development in the future. Based on the results we argue that public sector funding has enabled certain regions to develop in ways that otherwise would not be sustainable.

KEYWORDS: Geographical economics, regional agglomeration, regional specialisation, regional integration

1 Introduction

1.1 Objectives and Empirical Setting

This study sets out to inspect empirically whether existing theory in Geographical Economics (GE) is able to provide a rationale for the controversial and much debated structure of the highly knowledge- and research-intensive biotechnology industry in Finland. In contrast to its extensive theoretical contributions the GE literature seems to suffer from scarce empirical research. In addition to providing evidence of GE in action, we integrate the effects that active public technology policy might have on geographic structures of industries into our analysis as a novel discourse. Very active public innovation policies characteristic of most of the Scandinavian economies enable us to analyse its interaction with the studied GE framework.

While variables proxying the traditional phenomena of GE will be mainly derived from theoretical discourses by Krugman (1991a), Krugman and Venables (1996), Brezis and Krugman (1997), as well as Duranton and Puga (2001), the distribution of corporate financing from different public and private institutions function as an expression of implemented technology policy.

Our empirical focus on biotechnology is grounded in the above-cited discourses that award a vital role to the intra-industry trade of intermediate inputs in determining geographical location. With knowledge being a critical value-driver and a disproportionately central input in the business of biotechnology as a knowledge-intensive business, we expect the industry to react especially sensitively to the effects of intra-industry trade of knowledge that we capture by observing R&D collaboration patterns in our data. Thus, we expect the biotechnology industry to provide us with a formidable testing-ground for the GE literature.

Once a rationale for the geographic structure of our case industry has been established, we will be able to discuss its economic justification. In pursuing this objective, we particularly aim to identify conditions under which knowledge-intensive businesses can be expected to thrive in locations of dense agglomeration, on the one hand, and in significantly smaller geographical peripheries on the other. The results will enable us to form implications that can be applied in public innovation policy design.

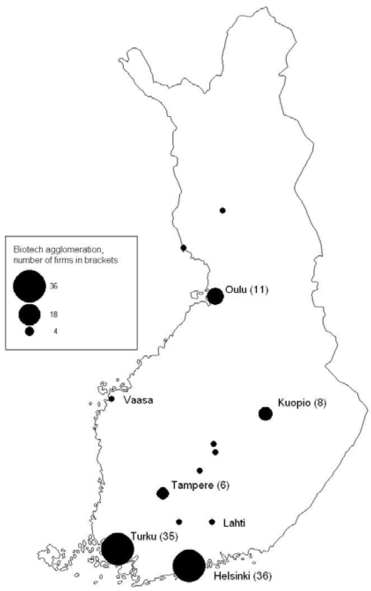
Our analysis is based on data retrieved from a population of 111 Finnish small and medium sized companies active in various sectors of the biotechnology industry. This population-wide data encompasses information on company size and location. To answer our research agenda we additionally employ a more detailed subsample of 62 companies encompassing a much broader scope of data. An overview of the data is provided in Hermans, Kulvik and Tahvanainen (2006). The Finnish biotechnology industry is chosen for its pronouncedly dispersed and multi-centred geographical structure that enables us to observe firms in very dissimilar locations and conditions within the same sample (Hermans and Tahvanainen, 2006). Moreover, the quality of firm level data and precise information on firm co-ordinates necessary to construct measures for spatial agglomeration speak in favour of reverting to Finnish data sets.

To enrich the background of our empirical setting, Section 1.2 proceeds with a brief discourse on the key aspects of the geographical structure of the sample industry. Section 2 encompasses the treatment of literature that this study leans on, and proposes estimates for the industry structure that we expect to confirm by means of a principal component analysis (PCA) in Section 3. Preceding the PCA, however, Section 3 also provides extensive descriptive results highlighting the relevant specificities of the underlying data regarding the phenomena of agglomeration, specialisation and public funding. In Section 4 we deliver the results of the analysis and discuss them. Section 5 provides conclusions pointing out potential public policy impacts and prospective avenues for complementary research.

1.2 Background – The Finnish Biotechnology Industry on the Map

Finland's small and medium sized biotechnology industry is agglomerated around several geographically dispersed locations. These are the Helsinki, Turku, Tampere, Kuopio and Oulu regions, of which the Helsinki and Turku regions alone account for two thirds of the industry's ca. 120 firms including large biotechnology companies. All five regions boast universities active in biotechnological research. Figure 1.1 shows their geographical distribution.

Figure 1.1 Geographical Distribution of Finnish Biotechnology SMEs



There is an obvious discrepancy between the relatively small size of the country, that of the resident biotechnology industry and the relatively large number of agglomerated hubs. These hubs also all feature biotechnology centres providing facilities and services to the resident companies. These centres are the outcome of the national innovation policy of the early 1990s that focused strongly on regional development. A decade later criticism has been heard of the establishment and maintenance of five separate hubs as being inefficient in the sense that the industry is dispersed across the country impeding the formation of a critical mass needed to spur the industry's so far modest internally generated growth (e.g. Kafatos et al. 2002).

To make the discrepancy more plastic and tangible, we can compare the ratio of country/industry size and the number of established hubs to that of the USA, the world leader in biotechnology. In raw numbers, the USA has a surface area 30 times larger than that of Finland, a GDP 74 times larger than the Finnish equivalent[1], and a biotechnology industry ten times the size of Finnish biotechnology measured by the number of firms. In terms of total sales the US biotechnology industry outweighs the Finnish by a factor of 118 (Nationmaster, 2006). Given these numbers, the USA has only two major and seven minor regions of agglomeration in the biotechnology industry with the former being Boston and the San Francisco Bay Area. Resources are more concentrated and single hubs constitute by far larger units than those in Finland. A critical mass of companies forming a self-nourishing cluster can be envisioned with ease in this setting. In the light of the figures the criticism of the multicentred structure of Finnish biotechnology seems reasonable at first glance.

While it is argued to be a disadvantage for the competitiveness of the Finnish biotechnology industry, the spatial dispersion together with emerging regional patterns of specialisation discussed further below provide a fascinating opportunity for testing GE based theories that, although fragmented in their foci, deal in-depth with these phenomena. In this study we will draw from a broad range of approaches present in the contemporary GE literature in an attempt to capture the rationale of the industry structure under study in all its facets.

1.3 Approach

One potential approach for the analysis is first to explore the reasons behind the spatial structure of industrial activities as driven by market structure. Agglomeration and specialisation are two key dimensions thereof. Once we are able to establish an economic rationale for the phenomena of agglomeration and specialisation, we are able to argue whether our sample industry's geographical structure is economically justifiable in the light of these results.

The Geographical Economics literature to be reviewed shortly suggests several economic drivers behind the agglomeration and specialisation of industries that have to be integrated into the analysis. These drivers, based on the assumption of a monopolistically competitive market structure, comprise regional labour pooling and knowledge spillovers, intra-industry linkages, transaction costs, regional market size, the degree of regional specialisation and the degree of integration between regions. Taking these drivers into account, firms choose their respective locations in an attempt to maximise their profits. In a fully dynamic setting, so the literature argues, the industry will find an equilibrium in which the empirical observer should be looking at a geographical structure that features diversified, densely agglomerated but innovative centres co-existing with peripheral, small but highly specialised hubs.

In order to test whether the GE based theories are able to explain the spatial structure of the industry under study in this paper we need to analyse the interaction of the above-mentioned drivers and examine to what extent these interactions correlate with the phenomena of agglomeration and specialisation in our data. To this end we will revert to a principal component analysis detailed in Section 3.

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[1] The USA spends 0.77 % of GDP on R&D compared to 0.93 % in Finland.

From the perspective of the policy maker there are two questions that need to be addressed in detail. First, given that supernormal profits will not be sustained in the long-run due to free entrance as well as uninhibited mobility of companies and labour between regions, what is the penalty for not locating in or close to either type of hub? And second, how does the Scandinavian type of active regional innovation policy as a major provider of financing affect the formation of the hubs as predicted by theory? By freezing the industry's movement towards its equilibrium distribution using a static cross-sectional data set we should be able to empirically observe differences in the typology of firms that already reap the theory-predicted benefits of locating in agglomerated or specialised regions, on the one hand, and those that are established in more peripheral or unspecialised regions, on the other. That should give us the tools to answer to the first question. Complementarily to the purely Geographical Economics-based framework we will also test how active public policy affects the location decision in the sample by using public funding provided to companies in different regions as a measure. This should give us the answer to question number two. We will return to the detailed discussion of our approach later. Now we proceed with the theoretical background of the study.

2 Theoretical background – The Geographical Economics Literature

To be able to establish an economic rationale for the geographical structure of a given industry we first need to understand the economic rationale behind the underlying drivers of the structure.

In building a comprehensive framework that provides such a rationale we are able to revert to extensive existing literature. Krugman (1991a) serves as a suitable starting point that we will extend by complementing it with aspects presented in other recognised theoretical works in the field of Geographical Economics (GE).[2] We begin by reviewing studies related to the drivers of spatial agglomeration in the next subsection. In the subsequent sub-section we will turn to literature dealing with drivers of regional specialisation. With this said, agglomeration and specialisation will be the two main aspects used in explaining the geographical structure of the Finnish biotechnology industry. As already mentioned above, a third but not minor aspect will be the influence of public financing flowing into the different geographic regions of the industry. We do not provide an explicit theoretical foundation for its role but content ourselves with its purely empirical analysis.

2.1 Spatial agglomeration

Krugman (1991a) sets out to compose a model that provides the economics for the phenomenon of agglomeration of manufacturing in particular regions of countries. In building his model Krugman splits production in any given centre-periphery setting into manufacturing characterised by increasing returns to scale (IRS), on the one hand, and local production with constant returns to scale (CRS), on the other. The IRS sector tends to concentrate in certain regions, provided that key parameters of

2 A comprehensive and cumulative review of the Geographical Economics, also known as New Economic Geography, is presented by Duranton and Puga (2000).

Krugman's (1991a) model obtain critical values, while the local CRS sector is dispersed over all regions.

The distinguishing feature of the CRS sector impacting the model is the usage of immobile, local resources. It follows that the spatial distribution of CRS production coincides with the distribution of these resources. In contrast, IRS manufacturing does not require as much of these resources with increasing production. To reap the benefits of the resulting scale economies, production will already tend to concentrate and locate near large markets in an attempt to minimise transportation costs and other trade barriers. Thus, the geography of demand plays a crucial role in determining the location of IRS manufacturing production.

To make things more dynamic, total demand for manufacturing is affected not only by the demand from the CRS sector, but also by that from the manufacturing sector itself. It follows, according to Krugman (1991a), that demand is determined by backward and forward linkages in a circular fashion. According to the concept of *backward* linkage, manufacturing prefers the vicinity of large markets, because they provide a sufficient base of economic activity for purchasing inputs and selling outputs. The size and attraction of such markets increases with additional IRS companies agglomerating around them. The concept of *forward* linkage implies that the concentration of manufacturing production will attract additional demand other than that created by manufacturing itself, since the costs of purchasing products provided by the agglomeration are minimised by settling close to it. These circular linkages work in the same direction and self-reinforce the spatial distribution of manufacturing towards agglomeration.

In the end, the strength of the circularity depends on fundamental parameters of the economy. To roughly summarise the essence of his discourse, Krugman (1991a) identifies three central parameters.

First, since the IRS sector labour is mobile over regions, *the share of the population employed in the IRS sector* determines the sensitivity of the formation of agglomerated centres. A high share of the IRS sector labour of the total labour population increases the potential backward linkage effect and supports the formation of agglomerated centres. With wage levels being high in these centres, additional labour is constantly encouraged to migrate to them. However, with constantly increasing wage levels companies will be discouraged from locating in the agglomerated regions at a point where high wage levels and other crowding-out effects outweigh the benefits of locating in a centre. At this point, companies will find manufacturing to be more profitable in the periphery again.

Second, the degree to which manufacturing is characterised by *economies of scale* affects its opportunities to reap the benefits of locating close to a large market. For a sector with low potential scale economies a large market is not necessarily any better than a smaller one. According to the original model of monopolist competition by Dixit and Stiglitz (1977), large economies of scale imply, by definition, high sunk costs (e.g. R&D costs), which, in turn, have an impact on the entire market structure. Dixit and Stiglitz state that high IRS, here high development, costs indicate a smaller number of active companies in a given sector. Thus, while high sunk costs tend to increase companies' tendencies to agglomerate, on the one hand, they also limit the number of active companies to start with, on the other.

Finally, *transportation costs and other trade barriers* between regions counteract with the benefits of locating in an agglomerated area, since a share of products equal to the reciprocal share of demand of a company's local market still has to be transported to the peripheries if one chooses to locate centrally. Once transportation costs fall below a critical level the benefits of concentration outweigh and it is more profitable to serve the periphery from the agglomerated location. In Krugman's (1991a) model trade costs take the form of Samuelson's (1954) "iceberg" costs with high costs implying low *actual* consumption of *initially* produced goods.

In his model, Krugman (1991a) operationalises these three parameters and defines their critical values at which self-reinforcing agglomeration sets in. For our purposes it is not necessary to review the formal details of Krugman's (1991a) model. We content ourselves with the intuition of the model to form implications for our empirical analysis.

In a complementary discourse, Martin and Rogers (1995) and Monfort and Nicolini (2000) examine the effect that public infrastructure has on companies' propensity to agglomerate in a model combining domestic and international settings. Differentiating between domestic and international infrastructure, deficient public infrastructure generates costs affecting trade within and among countries negatively. Like transport costs or other trade barriers in Krugman's (1991a) work, Martin and Rogers (1995) assess the costs imposed by domestic infrastructure that affect the location choices of internationally mobile companies and labour. Infrastructure itself is defined as "comprising any facility, good, or institution provided by the state which facilitates the juncture between production and consumption" (Martin and Rogers, 1995, p. 336).

In their work Martin and Rogers (1995) argue that companies seek to maximise their profit by minimising costs related to infrastructure. To do so, companies in an IRS industry will seek to locate in a country with the best possible infrastructure since it translates into a lower price and a superior relative demand for those goods that have been produced in that particular country. To put it simpler, companies locating in a country with superior infrastructure are able to benefit from economies of scale more than companies in countries with inferior domestic infrastructure. Good international infrastructure is argued to strengthen the effect as it enables even distant markets to be serviced from a locally optimal location, which leads into even stronger agglomeration of economic activity in countries with superior public infrastructures.

Monfort and Nicolini (2000) investigate how economic integration (reduction of trade barriers) affects the location decision of the companies within a country. They find that, in some circumstances, economic integration favours the regional agglomeration of the IRS industry within a country.

In yet another seminal study that provides a complementary part of the background for our purposes Venables (1995, 1996), too, examines the effects that economic integration can have on spatial agglomeration of economic activity. The new perspective in Venables' (1995, 1996) model is that all companies in a given region utilise each other's output as intermediate input in their vertically linked production processes. This in turn gives rise to demand and cost linkages among the companies. These linkages act as centripetal forces and cause regional agglomeration once trade costs (analogous to Krugman's (1991a, 1991b) transport costs and trade barriers) fall below a critical level. To provide the intuition in brief, demand linkages emerge because a portion of any company's costs is spent on intermediate products provided by the other companies in the same region. Thus, establishing or relocating an additional company in a region will add to the demand of all existing companies in that region. This is equivalent to Krugman's (1991a) concept of backward linkages. The cost- or forward linkages emerge, because establishing or relocating a company in a region lowers the trade costs for its intermediate products as borne by the existing companies in the region and *vice versa*. Venables (1995) concludes that, given a low enough level of trade costs *or* a large enough initial number of companies in a region, the linkages set a self-reinforcing agglomeration in motion. A large enough existing company base is needed for agglomeration to set in if trade costs approach the critical level but are still too high for companies to relocate. Since economic integration of regions lowers trade costs by definition and purpose, *ceteris paribus*, it should lead to regional agglomeration of economic activity.

Krugman and Venables (1995) extend on Venables' (1995, 1996) frameworks by showing in a formal model that the effect of decreasing trade costs is not necessarily linear at all. According to their argumentation, falling trade costs entail spatial agglomeration to a certain level as presented by Venables (1995, 1996), after which further decreasing trade costs invoke spatial convergence again. This inverted U - shaped progress of agglomeration is a function of labour costs that are an integral part of Krugman and Venables' (1995) model. The model shows that labour costs rise constantly with progressing agglomeration, because the demand for labour in the agglomerating region grows. These costs start feeding on the benefits resulting from agglomeration. At the same time, labour costs in the waning peripheries decrease constantly. At some point, labour costs in the peripheries fall below a critical level and, with ever-decreasing trade costs between the agglomerated core and the peripheries, production in the peripheries becomes favourable again. This is because low enough labour costs and low enough transport costs to the core region's market offset the declining benefits accruing to companies via forward and backward linkages in the agglomerated region. At this point production shifts towards the peripheries again.

2.2 Regional specialisation effects

Having established a theoretical backdrop for the phenomenon of agglomeration, we will now turn to the effects of specialisation.

According to Krugman and Venables (1996) as well as Forslid and Wooton (2003) agglomeration and specialisation are, in fact, phenomena closely linked to each other. While Krugman and Venables (1996) build their framework to model specialisation on the international level between countries, it is easily transferable to our national scenario with regions in lieu of countries. For instance, Martin and Rogers (1995), as well as Monfort and Nicolini (2000), extend the approach to an intra-country framework.

In Krugman and Venables (1996) vital preconditions for the specialised co-location of economic activities are, as in the case of agglomeration, the presence of intermediate input linkages among firms of an industry and low trade costs between regions. When both conditions are satisfied, a region with an initially large number of intermediate input and final goods producers in a given sector (e.g. drug development, diagnostics, biomaterials) might gain a self-energising advantage over other regions, because final goods producers in that particular sector prefer the region due to the relatively larger base of intermediate producers capable of supplying them with relevant sector-specific input. When trade costs are low enough, the benefits of locating near the intermediate producers as opposed to final markets outweigh the costs of exporting goods outside the region. The result is a strengthening of specialisation of the industrial activity in the region. Intermediate input producers in the same sector, in turn, prefer to locate near final goods producers to minimise costs. It follows that each sector of the industry will tend to concentrate in some region.

Krugman and Venables's (1996) argumentation will lead to an industry structure, in which all regions are specialised in a certain sector of the industry with no two given regions specialising in the same sector. Due to an extreme degree of economic integration and almost non-existent regional differences in trade costs[3] that prevail within the boundaries of a single country, even the most peripheral hubs of the industry can exist profitably while benefiting from regional intra-sector externalities. In other words, such a structure is justified given that all regions specialise in some sector. From the point of view of a single firm, then, locating in a region that is specialised in the firms own production is profitable, as the firm is able to benefit from forward and backward linkages resulting from the closeness and inter-connectedness of relevant intermediate and end product producers.

Another argument in defense of a geographically dispersed and specialised industry structure is provided by Brezis and Krugman (1997). They argue that the emergence of a new technology, which renders the accumulated technological experience of established older centres irrelevant, creates a situation, in which the established centres will rather stick to the incumbent technology than abandon it for the emerging one, because they are more efficient in applying the older technology. New, younger and more peripheral centres, on the other hand, will adopt the new technology despite its still undeveloped state, as land rents and wages in these more peripheral centres are lower and compensate for the initially lower returns on the new technology. Given time, the emerging technology will be developed further in the new centres surpassing the old technology in absolute returns at some point. When this occurs, the younger centres will start attracting human capital from the incumbent ones resulting in a gradual decay of the older centres.

Brezis and Krugman's (1997) concept justifies the existence of multiple peripheral centres, assuming that every single one of them specialises in the development of a technology, which has sufficient commercial potential in the future and is based on knowledge outside the knowledge base accumulated in older and more established centres. In other words, peripheral centres need to be specialised in the development of cutting edge technologies, and, in doing so, always be one step ahead of the larger and established centres to justify their existence and fulfill a purpose that these older centres cannot. These pre-conditions clearly set high demands on the innovative and commercial performance of companies in peripheral regions and serve as a reminder that their justification is far from self-evident.

It is appropriate to note at this point that in a multi-region scenario the two distinct discourses, spatial agglomeration, on the one hand, and specialisation, on the other, predict diverging outcomes in equilibrium[4]. While the agglomeration literature predicts divergence of regions once the agglomeration process has started, the specialisation literature predicts convergence of regions in terms of density of activities with the type of production differing from region to region. To be more precise, both of the latter two specialisation related frameworks (Krugman and Venables, 1996 as well as Brezis and Krugman, 1997) predict a geographically dispersed structure of an industry with regionally specialised hubs of commercial activity, just as it is observed to be

[3] Hermans (2004) labels the level of integration within a single country extreme integration, a level of integration at which trade costs are minimal. At this stage we should point out, however, that in the Finnish case the state of extreme integration is affected to some extent by the active regional policy of the 1990s subsidising technology development activities in the geographical peripheries of the country. This has left core areas, situated mainly in the south of the country, at a relative disadvantage by elevating relative trade costs from core areas to peripheries.

[4] Except for very low trade costs as argued by Krugman and Venables (1995).

partially the case in our data set depicted further below. Neither of the models, however, can provide a rationale for the existence, and more importantly, perseverance of large and diversified centres that, too, exist in the data. Krugman and Venables (1996) predict that diversified centres disperse their activities into specialised centres according to the sectors that those centres are specialised in, while Brezis and Krugman (1997) do not assume the existence of diversified centres in the first place differentiating only between specialised incumbent and emerging centres.

Backed by empirical findings from Feldman and Audretsch (1999), Duranton and Puga (2001) bridge this theoretical gap by suggesting a dynamic model that justifies diversified as well as specialised and more peripheral centres. According to their proposition, diversified and large centres are the birthplace of companies that, in a first step, are able to innovate and learn quickly and efficiently because of the plethora of different technologies available in a diversified centre through knowledge spillover and other technology transfer mechanisms. Once these start-ups have learnt enough to move to the production stage in their lifecycle, they relocate their activities to more peripheral and specialised regions close to other companies based on similar technologies. They do so to avoid the "crowding-out effects" of larger diversified centres (e.g. resource competition, higher wages, elevated rents) and benefit from positive intra-sector externalities that arise when locating in the vicinity of peers basing their activities on a similar, or better, complementary knowledge base.

Thus, Duranton and Puga (2001) see large diversified centres as creative factories facilitating the conceptualisation of innovative technologies based on the multi-disciplinary knowledge base that can be tapped into. At the same time, peripheral and specialised centres are the locations for efficient development, production and marketing of these technologies. In this sense Duranton and Puga (2001) predict a very similar geographic industry structure as Krugman and Venables (1996) and Brezis and Krugman (1997), but allow also for the existence of large and diversified centres.

3 Analysis

3.1 Data

The empirical evidence of this study is based on data gathered in the 2004 ETLA Survey. The survey encompasses data from the Finnish biotechnology industry collected via a telephone questionnaire in late autumn 2004. It is supplemented by financial statement data from The National Board of Patents and Registration of Finland (NBPR). All data describing the current state of the companies represent 2003 figures. In some individual cases financial statement data from NBPR originates from periods before 2003, as 2003 statements were not submitted to NBPR by all sample companies at the time of collection. However, no data from NBPR is used that originates from periods before 2001.

The survey covers the majority of small and medium sized companies[5] that operated in the Finnish biotechnology sector at the end of 2004. As the survey focuses on

5 SMEs in this study are defined according to official definitions of the EU excluding companies with over 250 employees and match additionally at least one of the following criteria: (i) Annual turnover > 50 mill. EUR, (ii) balance sheet total > 43 mill. EUR. Departing from the official EU definition, we include in our SME sample those daughter companies owned by large parent companies that match the above definition in every other aspect.

dedicated biotechnology companies only, cluster companies specialising solely on distribution, import, consulting, and other support functions are excluded from the survey. Our sample includes 72 SMEs out of 123 then active dedicated biotechnology companies of all sizes. The total population of SMEs was 111. Thus the response rate was 65%. Reasons for not obtaining data covering the complete population include no response, incoherent data and no exhaustive list of companies active in the sector at the time of the survey[6]. Although firms of all ages are represented by the sample fairly evenly, very young firms, on the one hand, and very old ones, on the other, are slightly better represented than adolescent or middle aged ones. Regarding NBPR data on financial statements the sample is almost identical to the total number of Finnish dedicated biotechnology companies, as financial statements could be retrieved from 117 companies (95%) altogether. Analyses based on this data are therefore highly representative. The same is true for data concerning the size and location of companies used to construct variables related to agglomeration and specialisation patterns among regions. The identification of the population was facilitated by Finnish Bioindustries, Finland's biotechnology industry association.

The companies in the final sample are independent businesses, partnerships or subsidiaries of bigger corporations. In the latter two cases the businesses had to be independently responsible business units in order to be included in the sample. If the criteria were not fulfilled, the data was collected from the parent company.

The final number of companies included in the principal component analysis in Section 3 is 62. This final sample is smaller due to missing data.

3.2 Descriptive findings – Empirical Evidence on Agglomeration, Specialisation and Public Funding Patterns

In section 2 we have elaborated in-depth on the theoretical background of factors that we expect to affect the geographical structure of the sample industry. This subsection provides initial descriptive findings on the three factors under special scrutiny: agglomeration, specialisation and public funding. The section serves to shed more light on the actual empirical setting and provide a concrete basis for interpreting the results of the actual analysis later on.

3.2.1 Agglomeration

Figure 1.1 in section 1.2 placed all Finnish small and medium sized biotechnology companies on the map. The size of the dots in the figure represents the number of companies resident in the particular regions. The multi-centred structure of the industry is plainly visible with local agglomerations in the Helsinki, Turku, Tampere, Oulu and Kuopio regions. In the following, we will present the spatial patterns of employment that can then be related to the number of firms in each region. Thereby, it is possible to deduce information on the true volume of business activities in the regions instead of relying on mere firm frequencies as a proxy. At this point, we want to emphasise again that the underlying figures are, as throughout this study, based on the small- and medium sized biotechnology industry excluding all large biotechnology

6 In autumn 2004 the Finnish Bioindustries Association Index was updated. During that time the definite number of companies active in the Finnish Biotechnology sector could not be determined. Our sample of 123 firms is based on the Index as valid in September 2004, but includes additional firms tracked down from a variety of sources.

related companies resident in Finland. Being extreme outliers, the inclusion of large companies in the sample would render the results senseless. For instance, some of the large corporations excluded from the analysis employ more than twice as many employees than the SME industry as a whole. Also sales figures of single large corporations exceed the total sales of the entire SME industry many times over. This must be kept in mind while interpreting our results.

Figure 3.1 below is a graphical illustration of the employment distribution of the Finnish SME biotechnology industry[7]. The Helsinki and Turku regions clearly account for the majority of employment with Lahti, Tampere and Kuopio following.

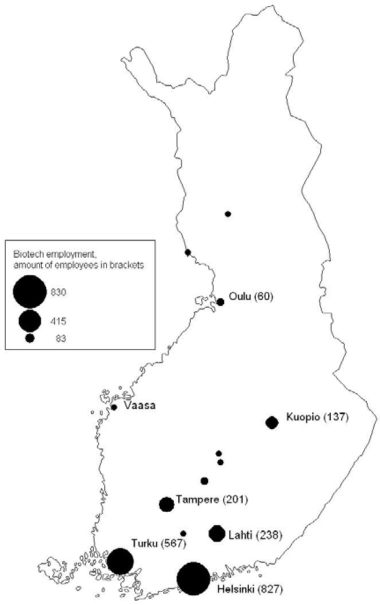

Figure 3.1 Spatial distribution of employment in the biotechnology industry 2003/4

Although the Oulu region has over 10 % of companies, more than Tampere, Kuopio or Lahti, the number of employees in the region is comparatively low. This implies that the average company size is rather small as corroborated in Table 3.1.

7 The N of Table 3.1 is considerably higher than the N in our actual survey sample, because of broader access to data concerning employment figures through the NBPR database. We used all available information to generate descriptive findings in order to maximise accuracy.

Table 3.1 Average size of companies (number of employees) by region

Region	N	Mean	Std. Deviation	Skewness	Kurtosis
Helsinki	35	25	40.229	2.406	5.903
Turku	31	16	16.513	1.653	2.136
Tampere	6	34	34.703	0.435	-2.408
Kuopio	7	11	9.798	1.246	2.071
Oulu	9	6	6.333	1.063	-0.125
Other	9	43	75.090	2.709	7.570
All	97	22	36.046	3.650	16.483

Given that the Lahti region is not considered a hotspot of Finnish biotechnology in terms of firm frequency, one might be surprised by the size of the workforce in the region. Lahti is the home of a few old and well-established companies of considerable size, which explains the finding. The Lahti region is aggregated into the category "Other" in all descriptive tables in this section.

The average age of companies (Table 3.2) in none of the five observed regions deviates to a significant extent from the industry average ($p > 0.1$ in t-test). The average age of companies located outside these regions (designated as "Other" in Table 3.2) is the only exception, as it deviates significantly from the overall average age ($p < 0.01$ in t-test).

Table 3.2 Average age of companies by region

Region	N	Mean	Std. Deviation	Skewness	Kurtosis
Helsinki	37	11	10.041	3.031	11.879
Turku	35	8	5.387	1.504	4.094
Tampere	7	11	5.900	0.656	-1.246
Kuopio	8	11	5.263	0.745	-0.747
Oulu	12	9	5.006	0.395	-1.663
Other	9	25	36.586	2.895	8.537
All	108	11	13.015	6.311	50.388

3.2.2 Specialisation

This section will complement the picture with further details by determining the regions' local specialisation patterns. We will show descriptively whether and how the five regions of agglomeration show signs of specialisation. All of the constructed indices measure different aspects indicating the degree of a region's specialisation in any of the sectors of the biotechnology industry. We will go through each of the indices separately before combining them into a single concise index.

The following two tables depict specialisation as measured by two different *labour input* shares. In Table 3.3 the grey background indicates that a given sector employs a higher proportion of the labour in a region than the *sector* (e.g biomaterials) does on average in Finland[8]. For instance, drug development employs 26.8 % of labour of

8 The formal condition for flagging a quotient is $\frac{L_{ij}}{L_j} > \frac{L_i}{L_{Total}}$, where L is labour, i denotes the sector of the biotechnology industry and j indicates the region.

the small biotechnology industry in Finland. 37 % of the Turku region's labour force in biotechnology is involved in drug development and, thus, the region is specialised in that sector in terms of labour input.

Table 3.3 Labour specialisation by sector

	Finland	Helsinki	Turku	Tampere	Kuopio	Oulu
Total	100.0 %	41.9 %	24.3 %	8.6 %	5.9 %	2.5 %
Drug developm	26.8 %	26.4 %	37.0 %	19.9 %	46.0 %	33.6 %
Diagnostics	37.3 %	46.0 %	41.5 %	22.9 %	80.3 %	31.1 %
Biomaterials	11.0 %	6.5 %	3.4 %	75.6 %	4.4 %	25.2 %
Bioinformatics	3.8 %	7.2 %	3.1 %	0.0 %	0.0 %	0.0 %
Enzymes	19.4 %	27.5 %	12.7 %	0.0 %	0.0 %	0.0 %
Food and feed	19.7 %	2.2 %	25.9 %	0.0 %	0.0 %	1.7 %
Agroforest	1.5 %	1.9 %	0.0 %	0.0 %	0.0 %	15.1 %
Environment	2.4 %	1.5 %	4.5 %	0.0 %	0.0 %	0.0 %
R&D services	15.9 %	8.7 %	26.0 %	19.9 %	35.8 %	43.7 %

In Table 3.4 the grey background signifies that a region employs a higher proportion of labour of a specific sector than the *whole industry* does on a national level[9]. For instance, the Helsinki region employs 41.3 % of the labour active in drug development in Finland, whereas the Turku region employs only 33.5 %. However, with Helsinki employing 41.9 % of the labour in the entire biotechnology industry, it is not specialised in drug development (41.3 % < 41.9 %). By contrast, the Turku region is specialised in drug development (33.5 % > 24.3 %).

Table 3.4 Labour specialisation by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Helsinki	41.9 %	41.3 %	51.8 %	25.0 %	80.2 %	59.5 %	4.8 %	54.3 %	26.5 %	22.9 %
Turku	24.3 %	33.5 %	27.1 %	7.4 %	19.8 %	15.9 %	32.0 %	0.0 %	45.1 %	39.7 %
Tampere	8.6 %	6.4 %	5.3 %	59.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	10.8 %
Kuopio	5.9 %	10.1 %	12.6 %	2.3 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	13.2 %
Oulu	2.5 %	3.2 %	2.1 %	5.9 %	0.0 %	0.0 %	0.2 %	25.7 %	0.0 %	7.0 %

The second set of tables measures specialisation with two different *sales output* shares. In Table 3.5 the grey background indicates that a sector's sales share of a region's total sales exceeds that sector's sales share of the total sales of the *entire industry*[10]. For instance, biomaterial-based sales are about 4.2 % of the total sales of the small biotechnology industry while constituting a staggering 93.6 % of the sales of the Tampere region. According to this measurement, Tampere region is specialised in the production of biomaterials.

9 The formal condition for flagging a quotient is $\frac{L_{ij}}{L_i} > \frac{L_j}{L_{Total}}$, where L is labour, i denotes the sector of the biotechnology industry and j indicates the region.

10 The formal condition for flagging a quotient is $\frac{S_{ij}}{S_j} > \frac{S_i}{S_{Totall}}$, where S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

Table 3.5 Sales specialisation by sector

	Finland	Helsinki	Turku	Tampere	Kuopio	Oulu
Total	100.0 %	59.6 %	15.9 %	2.9 %	1.3 %	0.8 %
Drug developm	30.5 %	41.8 %	20.2 %	1.3 %	32.5 %	33.6 %
Diagnostics	19.2 %	24.6 %	16.3 %	6.4 %	70.5 %	13.5 %
Biomaterials	4.2 %	1.6 %	2.5 %	93.6 %	1.9 %	13.0 %
Bioinformatics	0.3 %	0.3 %	1.1 %	0.0 %	0.0 %	0.0 %
Enzymes	46.7 %	36.4 %	53.9 %	0.0 %	0.0 %	0.0 %
Food and feed	25.4 %	3.1 %	61.7 %	0.0 %	0.0 %	3.3 %
Agroforest	1.4 %	1.1 %	0.0 %	0.0 %	0.0 %	2.6 %
Environment	1.1 %	0.2 %	1.4 %	0.0 %	0.0 %	0.0 %
R&D services	4.5 %	1.8 %	10.5 %	1.3 %	19.3 %	44.9 %

Table 3.6 depicts regional specialisation as approximated by regional sales shares of the total sales of *a given sector*[11]. For instance, the Tampere region generates only 2.9 % of the total sales of the biotechnology industry in Finland. Nevertheless one could say that the region is highly specialised in the production of biomaterials, as it generates 64.7 % of the sales in this sector on a national level.

Table 3.6 Sales specialisation by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Helsinki	59.6 %	81.7 %	76.1 %	22.7 %	48.7 %	46.4 %	7.3 %	44.0 %	10.8 %	23.1 %
Turku	15.9 %	10.5 %	13.4 %	9.5 %	51.3 %	18.3 %	38.5 %	0.0 %	18.7 %	36.6 %
Tampere	2.9 %	0.1 %	1.0 %	64.7 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.8 %
Kuopio	1.3 %	1.4 %	4.9 %	0.6 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	5.6 %
Oulu	0.8 %	0.9 %	0.6 %	2.5 %	0.0 %	0.0 %	0.1 %	1.5 %	0.0 %	8.0 %

While Tables 3.3 and 3.4 observed specialisation as measured by input factors, more precisely labour shares, and Tables 3.5 and 3.6 by output, namely sales, Table 3.7 combines these two and measures specialisation by labour productivity as indicated by sales per worker. The grey flagging denotes that the per head sales in a particular region and a particular industrial sector exceeds that sector's average per head sales[12]. For instance, sales per worker in drug development is 196 061 euros on average in Finland. The corresponding measure of productivity is 310 547 euros in the Helsinki region. Consequently, the region is specialised in drug development in terms of productivity.

Table 3.7 Labour productivity by region

	Total	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Finland	138 032	156 805	71 279	53 300	11 927	333 240	178 165	133 441	65 498	39 444
Helsinki	196 061	310 547	104 589	48 451	7 234	259 666	270 630	108 041	26 661	39 850
Turku	90 141	49 261	35 316	68 312	30 971	382 548	214 400	0	27 150	36 400
Tampere	46 936	3 097	13 184	58 076	0	0	0	0	0	3 097
Kuopio	31 208	22 086	27 408	13 381	0	0	0	0	0	16 829
Oulu	43 838	43 816	19 041	22 549	0	0	85 649	7 579	0	45 090

11 The formal condition for flagging a quotient is $\frac{S_{ij}}{S_i} > \frac{S_j}{S_{Total}}$, where S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

12 The formal condition for flagging a quotient is $\frac{S_{ij}}{L_i} > \frac{S_i}{L_i}$, where L is labour, S stands for sales, i denotes the sector of the biotechnology industry and j indicates the region.

Now that we have obtained a fairly detailed and broken-down depiction of the regional specialisation patterns, it is valuable to combine the above indices into one single index that draws us a more concise picture. To get one coherent composite index of specialisation, we transform the single indices as follows.

We first assign the value one (1) to all flagged observations in every single index. Those observations, that are not flagged, are assigned the value zero (0). As a result, we obtain a matrix for each single index that indicates whether a region is specialised in any of the sectors regarding the particular index. Combining all five matrices by simply adding the transformed values, we obtain a compound index of regional specialisation. The index values range from zero to five, with 5 indicating strong specialisation and meaning that the particular region is specialised in the particular sector as measured by all five single indices. Table 3.8 exhibits the compound index.

Table 3.8 Composite Index of Specialisation

Region	Drug dev.	Diagnost.	Biomat.	Bioinf.	Enzymes	Food&feed	Agroforest	Environm.	R&Dserv.
Helsinki	op 3	5	0	ip 2	ip 2	1	ip 2	0	1
Turku	ip 2	ip 2	1	op 3	op 3	5	0	4	4
Tampere	0	0	5	0	0	0	0	0	ip 2
Kuopio	4	4	0	0	0	0	0	0	4
Oulu	4	0	4	0	0	0	4	0	5

As revealed by Table 3.8, one can indeed observe specialisation patterns among the regions, especially when only sectors of highest specialisation are regarded. The Helsinki region is specialised in diagnostics, Turku in food and feed, Tampere in biomaterials and Oulu in providing R&D services to other companies. Kuopio does not exhibit a field of strongest specialisation, but has a fairly strong focus on drug development and diagnostics in addition to R&D services. The Turku region is the most versatile with fairly strong indices in environmental applications and R&D –services as well as significant indices in bioinformatics and enzymes. Also drug development and diagnostics are sectors of focus as measured by input based specialisation.

At this point it must be pointed out that R&D services cannot be regarded as a sector of its own, as it can encompass services of any of the other sectors. It is rather a mode of business. Nevertheless, companies specialising in R&D services operate a distinct business model and distinguish themselves often strongly from companies focusing on proprietary R&D. They deserve, therefore, separate treatment in the index.

In addition to showing the regional sectors of specialisation, Table 3.8 can be interpreted as a cross-section of the development cycles of regional industry structures in the chronological dimension. With the figures marked with “ip” indicating specialisation as measured by input and those marked with “op” indicating output specialisation, we can infer the regions’ alleged directions of development. Helsinki is strongest in diagnostics investing heavily in it and simultaneously creating relatively large revenues in an efficient manner as measured by per head sales. Helsinki’s drug development sector is mature in the sense that it generates relatively large sales volumes utilising efficient processes that increase the per head in-flow of cash although it is not specialised in terms of input. Bioinformatics, enzymes and the agro-forest sectors can be assumed to have great priority in the region as it has invested heavily in them in terms of labour. However, returns on the investments have not yet materialised leaving these sectors a promise for the future. One might argue that they are in an early stage of their lifecycle.

Turku has a very strong food and feed sector and comparatively mature environmental, bioinformatics and enzymes sectors. Additionally, the region invests heavily in drug development and diagnostics displaying above average employment shares. Having said that, Turku's biomaterials and enzymes sectors are doing comparatively well as sales are generated efficiently without investing super-normally in terms of the number of people employed.

Kuopio is strengthening its drug development and diagnostics sectors that do not seem to be productive yet compared to the entire sectors' averages. Oulu has invested in biomaterials, drug development and agro-forestry creating expectations for the future in these sectors while leaning heavily on R&D services at the moment. It should be emphasised at this point that most biomaterial companies in Oulu develop solutions that are not perceived to represent biomaterials as defined according to the current conception, which encompasses mainly *in vivo* products. As the categorisation of activities in biotechnology is often a rather ambiguous task, Oulu's biomaterial companies could just as easily be assigned to the sectors of food and feed and agriculture. Be that as it may, for a region quite isolated in the geographical sense and rather small in terms of size, Oulu spreads resources over a relatively wide sector base. In contrast, Tampere stands out from all the regions by focusing very determinedly on biomaterials having already created success stories in this sector.

Table 3.9 Krugman's (1991b) Regional Divergence Index within the small and medium-sized biotechnology industry

SME Personnel	Helsinki region	Turku region	Tampere region	Kuopio region	Oulu region
Helsinki region		0.399	0.767	0.648	0.581
Turku region	0.399		0.576	0.285	0.413
Tampere region	0.767	0.576		0.644	0.495
Kuopio region	0.648	0.285	0.644		0.37
Oulu region	0.581	0.413	0.495	0.37	
Other regions	0.629	0.748	1	0.995	0.886
Average	**0.605**	**0.484**	**0.696**	**0.588**	**0.549**

To conclude the descriptive discourse on specialisation patterns, we compare the regions' degree of specialisation based on the Regional Divergence Index by Krugman (1991b)[13]. The index measures how different the industry structures of any two regions are. Here, we apply the index to measure the regional differences within the Finnish biotechnology industry. Table 3.9 cross-tabulates the index over all five regions with the value zero indicating a non-existent difference and the value one indicating a large difference in industry structures. It is possible to calculate the average deviation of industry structure for all regions separately. The averages support our prior findings. Tampere is the most specialised region of all with Helsinki following close behind. On the other extreme, Turku most resembles the average structures of Finland as its activities are quite extensive in most of the sectors.

A final comment concerning specialisation must be made here. Specialisation in a given sector does not mean specialisation in, for example, general drug development. There might still be considerable differences in the research substance of two distinct regions focusing on the same sector as measured by our indices, because both regions are probably specialised in specific niches of a certain sector. While one

13 $\sum_i \left| s_i - s_i^* \right|$, where s_i is the share of sector i in total biotechnology manufacturing employment in some region and * indicates refers to some other region. In addition, we have standardised the index outcomes to range between 0 and 1.

region might conduct research related to health care solutions in cardiovascular diseases, the other could be specialised in neurological disorders. Furthermore, research in one sector can have positive externality effects on other sectors nearby through knowledge spillovers. For instance, in this example first-rate medical research does not necessarily create large-scale pharmaceutical industry plants in the region, but it can contribute extensively to the development, growth and success of some other closely related sectors with strong, even matured, local industries such as diagnostics or enzymes. This potential scenario would serve as a good example for Duranton and Puga's (2001) line of argumentation justifying the existence of innovative diversified centres introduced earlier.

3.2.3 Public policy

Before turning to the actual analysis in section 3.3 we present the patterns of financing that has been directed to the companies and universities in the different regions. Although not anchored to any particular literature, we expect that public sector financing as the epitome of public innovation policy potentially has the power to alter location incentives as predicted by GE theories through the infusion of resources unrelated to market mechanisms that these theories rely on.

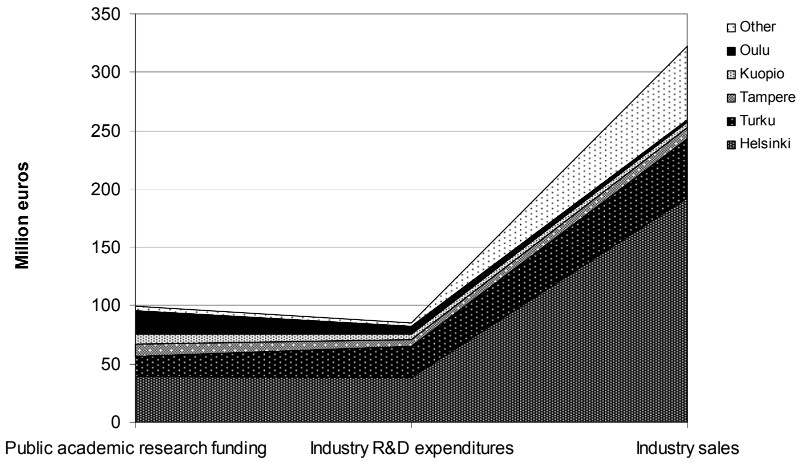

Figure 3.2 Comparing public research funding, industry R&D and sales by region

Figure 3.2 relates the region specific shares of total governmental funding provided for academic research to industry R&D expenditures and industry sales. It gives rise to two possible interpretations. According to the first interpretation, one could say the figure displays a continuum at the beginning of which there is the amount of public money spent on basic research that then, in a second phase, induces industrial R&D that is commercialised in the third and last phase. Following this line of interpretation, the Helsinki region has done quite well in transforming publicly financed research into growing private product development and succeeding in commercialising the development by conquering close to 60% of markets reached by Finnish biotechnology companies. The relation between public sector funding infused into the academic sector, the private R&D emerging from that and the sales generated by these efforts is always positive from one phase to the other. The Helsinki region seems to create value.[14] Turku is actively transforming publicly financed research into corporate R&D activities but seems to perform less well in commercialising it with a share of just below 16% of total sales of the industry. Kuopio and Tampere are similar to Turku albeit displaying much smaller volumes. Oulu seems to perform poorly, as public sector money flowing rather generously into academic research in the region does not lead to industry performed R&D, which, comparatively speaking, is commercialised to an even lesser degree.

Another way of interpreting the figure is to look at it as a cross-section in time. One might say, for example, that the Helsinki region is already in a more mature state having had time to go through all three stages and having set up the necessary down-stream assets and tapped into the markets. Following this interpretation, Oulu might still be in an infant state of development just building up the necessary infrastructure and company base necessary for successful R&D, to say nothing of commercialisation. Given time, the region might then very well create value. Thus, the figure might simply be showing regions in different stages of development and growing towards the markets.

However, it has to be stated clearly that the data presented in Table 3.2 is unsupportive of the latter avenue of interpretation, as the average age of companies in the Oulu or any other given region does not deviate to a significant extent from the industry average ($p > 0.1$ in t-test).

Thus, it seems indeed that there are differences in the performance of single regions when comparing the funding of the regional research, the employment created thereby and the output the regions have generated. To check our results for sensitivity, it is interesting to mirror the outcomes presented above to outcomes based on different sampling policies. The exclusion of subsidiary companies from the sample, for instance, has a fairly great influence on the distribution of regions' sales shares. For example, companies that are part of larger corporations generate in the Helsinki region close to 75% of all sales. In Turku, subsidiaries are responsible for 56% of sales. The distribution of total SME industry sales shares among the regions changes slightly when only independent companies are included in the analysis. Helsinki still leads with 55% of markets followed by Turku with 26%. Tampere, Kuopio and Oulu regions contribute 2%, 5% and 1% respectively. Altogether subsidiary companies make 73% of the SME industry sales with a compound 235 million Euro in 2003.

In addition to public sector funding of academic research it is also relevant to observe public sector funding that has gone directly to companies in a form or another. Direct public support of companies in different regions can be expected to affect their location decisions strongly. It is especially interesting to see whether certain types of region rely relatively more on public funding than others. Since our data does not include all companies active at the time of data collection, the funding variables used to produce Tables 3.8 - 3.10 have been weighted based on company size to obtain a representation as close to the original population as possible.

14 It has to be stated here that sales figures are a measure of output, not profitability. Whether companies in the region actually generate net profit is a separate issue and is not touched on here. The focus is on examining the extent to which the companies in different regions have been able to tap into markets. Sales figures are the appropriate measure for this purpose.

Table 3.10 Shares of equity funding by source in each region

Source	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Staff	10%	9%	5%	26%	35%	8%
Oth. indv.	10%	9%	5%	2%	31%	75%
Sitra	4%	22%		21%	18%	
Gov. VC		7%			1%	
Priv. VC	10%	16%	84%	21%	15%	6%
Oth.comp.	54%	25%		29%		11%
Other	12%	11%	5%	1%		
Total t€	*160,924*	*137,073*	*39,987*	*4,389*	*3,351*	*35,924*

Table 3.10 presents the breakdown of equity funding by source in each region. Before proceeding with its analysis, however, one should notice the rather large differences in total equity between regions. In regions with very limited amounts in equity, such as Oulu or Kuopio, the inclusion or exclusion of single companies might have a significant impact on the distribution of equity over different sources. One is advised to caution when drawing strong conclusions of the results presented. With that being said, the distribution of equity differs radically from one region to another. Companies in the Helsinki region receive their equity primarily from other private companies. Over 50 % of equity is owned by other businesses. Another combined 30 % is owned by private instances be they individuals or venture capitalists. Ownership by governmental instances such as Sitra, the Finnish Innovation Fund, is of negligible significance. In contrast, companies in the Turku region are owned to almost 30 % by governmental institutions. Private VCs and other private companies make up just over 40 % of the ownership base while individuals provide close to 20 % of the remaining equity. Thus, Turku relies most extensively on public ownership in relative terms. The Tampere region is distinctively owned by private venture capitalists. Public funding is non-existent. Oulu, on the other hand, draws its equity from a very heterogeneous base of equity sources with no single source being of overwhelming importance. Companies around Kuopio are owned mainly by individuals and private VCs while governmental ownership makes up close to a fifth of the total.

Summarising, governmental equity based funding has served as a major pillar for two of the most peripheral regions, Oulu and Kuopio, but in both relative and total terms it seems to have played the most significant role in the Turku region, one of the two major hotspots of Finnish biotechnology. As Oulu is a non-specialised region, it seems that the public policy directing equity funding to regions has not been based on a strategy prioritising the specialisation of peripheries as advocated by the literature utilised in this study.

Table 3.11 Shares of capital loans by source in each region

Source	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Tekes	68%	60%	86%	61%	4%	
Sitra	8%	23%		13%	39%	
Oth.gov.		1%	11%		24%	23%
Priv.VC				13%		77%
Fin.inst.		4%			13%	
Oth.comp.	6%	1%	3%			
Other	18%	10%		13%	20%	
Total t€	*36,613*	*56,457*	*26,945*	*542*	*4,363*	*1,869*

Table 3.11 displays the distribution of capital loans by source in each region. As capital loans are the primary financing tool of governmental institutions such as Tekes, the Finnish Funding Agency for Technology and Innovation, it is not surprising to see governmental sources accounting for the majority of capital loans. All of the observed regions draw over 70 % of their capital loans from governmental sources. Tampere is the region with the highest share of publicly provided capital loans on the balance sheet. It is evident that capital loans constitute a major component of funding in the Finnish biotechnology sector as a whole when set in relation to other forms of financing. None of the regions can be pointed out to serve as a distinctive example. Again, there is little evidence of a dominant regional strategy of public policy in the distributions.

Table 3.12 Shares of debt by source in each region

Region	Helsinki	Turku	Tampere	Oulu	Kuopio	Other
Staff	1%					
Oth.indv.						
Banks	11%	31%	16%	66%	38%	80%
Oth.fin.inst.	24%		7%	24%		
Oth.comp.		35%				2%
Bonds						
Tekes	29%	7%	16%			3%
Oth.gov.	33%	18%	29%	9%	62%	10%
Other	1%	9%	32%			5%
Total t€	*8,906*	*4,229*	*15,252*	*1,770*	*1,092*	*6,197*

Also the distributions debt from governmental sources presented in Table 3.12 fail to offer distinct patterns of a clear regional strategy. Regions like Helsinki being the most agglomerated and one of the most heterogeneous centres of Finnish biotechnology reverts to governmental debt to the same extent as more specialised and peripheral regions such as Kuopio or Tampere. At the same time Turku as an agglomerated and diversified hub draws its debt financing to an equal extent of private sources as the most peripheral region of Oulu.

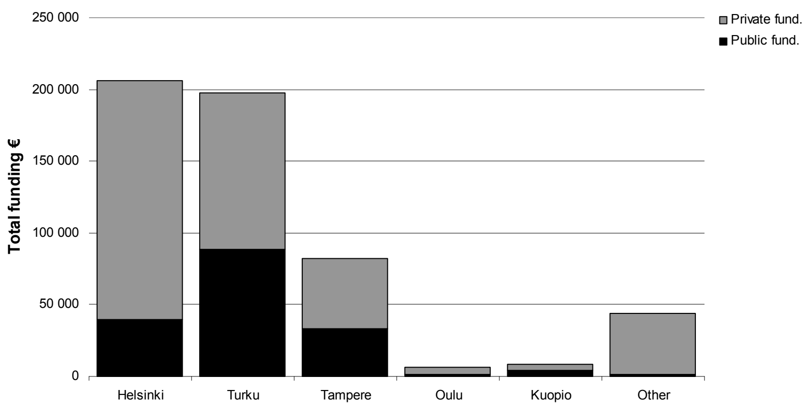

Figure 3.3 Private *vs*. public funding by region

Figure 3.3 crystallises our central findings on the distribution of public sector funding provided to companies in different regions. All three types of financing discussed above have been aggregated in Figure 3.3. The bulk of governmental funding has been injected into the most southern regions, which leads us to two interpretations that complement our previous descriptions. First, the public sector has supported the diversification strategy of the Turku region which is in line with Brezis and Krugman's (1997) notion of a younger emerging diversified centre that, focusing on new technologies, challenges the incumbent diversified centre, the Helsinki region. Second, the government has substantially funded the Tampere region that displays a highly specialised pattern of biotechnology business *á la* Duranton and Puga (2003) who provide justification for specialised peripheries. However, there is little evidence that specialisation has been pursued consistently in all peripheral regions.

Having established a detailed descriptive picture of our empirical setting it is time to turn to a more rigorous analysis of the data.

3.3 Principal Component Analysis (PCA)

As already discussed in earlier sections of this study, the geographic structure is determined by the interplay of many different drivers that interact with each other as opposed to the interaction of independent drivers with a single type of outcome represented by a single variable. The same drivers might be more or less part of the equation in many different kinds of outcomes. Furthermore, it is not clear *ex ante* what kind of outcomes to expect in the first place. The descriptive findings provide us with some initial ideas but fail to convey information on their statistical significance and unobserved interaction of drivers. Our methodological approach to the empirical analysis is built around a PCA due to its ability to address these issues and reveal the multiple and simultaneous interactions of variables as described in the underlying literature.

Moreover, we want to approach our research question on a company level, not on a regional level, a fact that has not been overly stressed earlier on in the study for the sake of being able to present the research setting in its broader context. We chose the company as the level of analysis mainly for one reason. It is our view that regions do not have a consciousness and do not have a decision-making organ with the help of which they would lay out and determine the best geographic structure. It is single companies deciding where to locate and what to produce that implicitly determine the structure of the regions. It is also single companies that trade intermediate inputs and benefit from local infrastructures. By operationalising the reviewed drivers of geographic structure onto the company-level we will obtain a micro-level picture that will provide us with a richer and more detailed picture of the determinants of location and specialisation than a region-level analysis could.

With this said, we expect to find several distinct configurations of geographic drivers that characterise different companies active in different kinds of regions. It is the strength of the PCA to find such configurations and, thereby, outline distinct company types out of a mass of data. We use un-rotated results for drawing conclusions, because it is in our interest to enable single variables to be correlated with several components. Using the popular Varimax algorithm that results in a rotated component matrix would unnecessarily force each variable to correlate with only one component. Thus, although a rotated solution would give us simpler and more illustrative results than the basic solution without rotation, the rotated results might potentially suppress much information that could contribute important nuances to the larger picture. A major weakness of the PCA, on the other hand, is related to the difficulty of interpreting causal relations. A PCA resembles a correlation analysis in the sense that it does not provide built-in references to causalities between the predictors in any given model. The causalities have to be carefully interpreted into the results by leaning heavily against the theoretical backdrop.

In the following we introduce the variables used in our analysis and briefly clarify how they are operationalised from theory.

3.3.1 Agglomeration index (*AggInd*)

As one of the three main aspects of geographic structure the degree of agglomeration needs to be carefully modeled. Since we intend to conduct a company-level analysis the variable measuring the degree of agglomeration needs to express the phenomenon from a company's perspective. The idea is to build a measure indicating the density of economic activity of other biotechnology companies around each of the sample companies[15]. Using exact geographic coordinates of the sample companies, their multilateral distances to each other were determined first. Next, the distances were multiplied with the average cost per time-unit of traveling the given distances in order to capture non-linear agglomeration effects that might emerge with ever growing distances[16].

Then separately, for each sample company, the cost-corrected company-specific distances were used as a discount factor to discount the number of personnel of all other active biotech companies in Finland. The number of personnel served as a proxy for economic activity that was considered more accurate than the number of companies, as it quantifies true company size. In a last step, the discounted numbers of personnel of all companies were aggregated for each sample company to form the final variable Agglomeration Index, *AggInd*. The agglomeration index is of the same form as originally suggested by Harris (1954) and more recently Hanson (1998). Equation 1 shows the formal construction of the variable for firm *i*:

$$\text{AggInd } i = \sum_{j=1}^{N} \frac{L_j}{cd_{ij}}, i \neq j, i = [1, n], j = [1, N], n \in N,$$

where *N* is the population of all active biotechnology companies in Finland, *n* is our sample, *c* represents the travel costs per time-unit over all distances, *d* denotes the distance between firm *i* and *j*, and *L* is the number of personnel in company *j*.

One should point out that, since $i \neq j$, the discounted number of personnel of any firm *i* is not part of its own agglomeration index. Instead, the effect of economic activ-

15 To this end we had to use all 123 biotechnology companies active in Finland, since important activity outside the sample might otherwise be left unheeded and distort the measure of real agglomeration.

16 Although distances are always linear by definition, the costs and times related to bridging them might not. Since the utilized theory base related to intermediate input trade, forward and backward linkages, as well as knowledge diffusion, presume that companies interact with each other concretely, we have to consider real costs related to distances if we attempt to model agglomeration. To calculate travel costs per time-unit we utilised prices and travel times obtained from airlines, railway companies, bus companies and calculations based on using a car. We determined that, in fact, travel costs per time-unit are rather linear over all distances. Thus, the cost multiple of distances merely constitutes a fixed factor.

ity of firm *i* is captured by all other companies in its environment only and *vice versa*. The size of firm *i*, thus, cannot dominate its own index and render *AggInd* an index of mere size rather than surrounding agglomeration.

3.3.2 Specialisation index (SpecInd)

The construction of the *compound* specialisation index was already covered in section 3.2.2. For the purposes of the PCA, however, we only use the labour specialisation –related components of the index and discard the sales specialisation –related ones. The decision to do so is grounded in the argument that factually deployed specialised labour is a true indicator of what companies are doing and to what extent they are doing it. In contrast, sales based indicators might be influenced not only by differences in the respective total volumes of different industrial sectors, but also by the stage of company-specific life-cycles. The inclusion of sales based specialisation indices into our compound index could distort the measure in favor of older and more established companies that do not necessarily specialise in a certain sector. Thus, the compound index shown in Figure 3.8 was used for the earlier descriptive conclusions only with the specialisation index *SpecInd* in our final PCA being a stripped version of it. To operationalise the region-level specialisation index on the company-level, we recoded it into a dummy variable indicating whether a particular company locates in a region that as a whole specialises in the company's own sector in terms of labour inputs.

Following Krugman and Venables' (1996) argumentation, we should expect to see a two-fold relationship between *SpecInd* and *AggInd*. As detailed earlier, Krugman and Venables (1996) suggest a geographical structure, in which there are several hubs that each specialise in a certain industrial sector. Duranton and Puga's (2001) line of argumentation, on the other hand, gives rise to opposite or less strong expectations regarding the two indices, because, in their framework, specialised and diversified agglomeration hubs both have their justification.

3.3.3 Public and private financing

The two variables *PublVC* and *Tekes* proxy the funding received from governmental sources. As elaborated on earlier, we feel that public sector funding is a major incentive that might have a significant effect on geographic location, especially, as it is the embodiment of active regional innovation policy. If public innovation policy has implemented a strategy for supporting certain geographic areas, we should find a positive relationship between agglomeration and public funding. With this said, one could argue that regional public sector funding is a form of publicly provided infrastructure very much along the lines of Martin and Rogers' (1995) argumentation, as it lowers the costs of operating in any given region that receives this funding. Companies are expected to agglomerate in an area where public infrastructure, here public funding, is sufficiently advanced.

Public VC financing proxied by *PublVC* is mainly provided by Sitra, the Finnish Innovation Fund, that has strategically invested in Finnish biotechnology for nearly 20 years. Biotechnology has been one of Sitra's main focus areas receiving up to a third of all annual investments of the fund. Despite exit difficulties after the burst of the technology bubble at the turn of the new millennium, Sitra still continues to provide VC financing to its now streamlined portfolio. Despite being a public institution, Sitra's funding comes with roughly the same claims as private VC funding. The important difference to private VCs is that Sitra invests out of its own balance sheet instead of pooling funds from external investors. It also invests the funds according to current public policy guidelines determined by the government. The variable *PublVC* measures the Euro amount of Sitra financing on a company's balance sheet. In the construction of the variable, the equity mitigating effects of accrued losses from past accounting periods were eliminated in an effort to measure the aggregate amount of public sector VC financing that the companies have received during their entire lifecycle.

The major source of non-equity governmental financing (grants, loans and capital loans) in Finland is Tekes, the Finnish Funding Agency for Technology and Innovation. Tekes' funding is represented in our analysis by the variable *Tekes*. Tekes provides funding for industrial R&D projects, as well as projects in universities and research institutes, by focusing on promoting innovative, risk-intensive projects. The agency proclaims that its "primary objective […] is to promote the competitiveness of Finnish industry and the service sector by assisting in the creation of world-class technology and technological know-how. Specifically, Tekes' activities aim to diversify production structures, increase production and exports, and create a foundation for employment and social wellbeing".[17] Biotechnology has been a major focus area since the mid-eighties and still continues to be a focal area of commitment. Very many biotechnology companies founded since the eighties have received funding from Tekes in one form or the other. Since Tekes financing is not equity based, it is difficult to estimate the accumulated Tekes funding in sample companies. Thus, our dummy-type proxy simply indicates whether a particular company has received any Tekes funding in one form or another. The variables receives a value of one (1), if this is the case, and the value zero (0) if the company has not received financing.

Corporate financing (*CorpFin*). The variable indicates the Euro amount of loss-corrected equity provided by other companies. It is included to map interactions with public financing patterns, on the one hand, and whether companies in agglomerated and/or specialised regions are seen as attractive investment targets on the other. Interaction of corporate financing with public financing is of interest here, because Tekes, for instance, requires 50 % of a company's project to be financed from private sources. Thus, there might be a linkage between private and public funding that needs to be possibly addressed when interpreting the results.

Employee financing (*EmplFin*). The loss-corrected Euro amount of investments provided by companies' employees represents another source of private financing that has to be controlled for the same reasons as *CorpFin*. In the economics of finance literature the amount of internally provided equity financing also serves as a signal for a company's internally perceived quality (Leeland and Pyle 1977). Although controlling the interaction of *EmplFin* with the public funding measures is the actual reason for including the variable in the analysis, the signaling discourse provides the interesting possibility to observe whether there is a connection between the internally perceived quality of business and the location in agglomerated and/or specialised regions.

Private VC financing (*PrivVC*). The loss-corrected Euro amount of financing provided by private venture capitalists is indicated by this variable. Showing the effects of the small size of the country, historically common organisational backgrounds with Sitra might affect the funding behaviour of major Finnish VCs specialising in biotech-

17 http://www.tekes.fi/eng/tekes/ , accessed on July 26th 2007.

nology. There might be interconnectedness between Sitra as well as private VCs and *vice versa*. Again, this is of potential importance when interpreting results.

3.3.4 Collaboration indicators

With a 90 % share of its sales being exports the Finnish biotechnology sector is very export intensive. Thus, Krugman's (1991a) initial argument of industrial agglomeration emerging merely due to the vicinity of large local markets applies in our empirical setting only to a limited extent. While the initial phases of biotechnology development might well locate in Finland, Krugman's argument predicts the later development phases to relocate outside the country in the vicinity of larger markets, especially with ever decreasing trade costs on globalising markets. The relatively high export intensity of the sample industry, as well as the significant presence of adolescent and old companies in the population, are at odds with such predictions. Therefore, we need to revert to Krugman's (1991a) broader framework including the dynamic linkages between production and demand. As depicted earlier, Krugman (1991a) states that strong enough local demand linkages are a requirement for agglomeration to begin. In our analysis, we approximate demand linkages by capturing R&D collaboration patterns among companies in the same region. Collaboration, among other means of technology transfer, is one of the most efficient ways of exchanging knowledge, the substance of technology, and arguably the most valuable goods produced and sought after by biotechnology companies. R&D collaboration is defined very broadly in our data and includes all kinds of collaboration arrangements from contract R&D to joint research projects. With this said, established local demand linkages are represented by the dummy-type variable *ColLO* indicating whether a company is in a collaborative relationship with companies in its own region. Based on Krugman and Venables (1995) we expect to find a positive relationship between demand linkages proxied by *ColLO* and the agglomeration index *AggInd*.

Additionally, *ColLO* also represents intermediate input trade among local companies along the lines of Venables (1995). Active intermediate input trade adds to the demand of the local company base and results in similar demand linkages as in Krugman (1991a). Venables' (1995) framework implies the same positive relationship between *ColLO* and *AggInd*.

ColLU, collaboration with a local university, is an approximation of established links to regional public infrastructure. According to Martin and Rogers (1995) and Monfort and Nicolini (2000), good public infrastructure that facilitates interaction in the interface of production and consumption is expected to correlate positively with economic agglomeration regionally. Active links to universities' basic research can be argued to maintain an organisation's understanding of current developments in relevant generic technologies. Know-how in basic research, in turn, enhances an organisation's technological absorptive capacity that is key in tapping into other organisations' more specialised knowledge and sharing it (Cohen and Levinthal 1990). Thus, links to basic research at universities facilitate the interaction of production and consumption of relevant technological knowledge and is, thereby, to be considered a vital component of public infrastructure providing incentives for geographical agglomeration in the same region. *ColLU* is a dummy variable indicating whether a company collaborates with a local university or not.

Collaboration with a foreign university (*ColFU*) and collaboration with other foreign organisations (*ColFO*) both represent established links with partners abroad. In relation to Martin and Roger's (1995) framework, they both approximate international infrastructure that is factually being exploited. Good international infrastructure enhances local agglomeration tendencies as it enables serving distant foreign markets in an efficient manner by lowering trade costs. *ColFU* is a dummy variable indicating whether or not a company is engaged in R&D activities with a foreign university. *ColFO* is a discrete measure taking values between zero (0) and three (3). The value increases by one for each major continent (EU, US and Asia) that a company has collaborative arrangements on with any type of organisation other than a university. We distinguish university partners from others in an attempt to obtain a more precise picture of the nature of foreign collaboration. We expect both variables to correlate positively with the agglomeration index.

Although not being a collaboration indicator *per se*, the export ratio (*ExpR*) of a company quantifies the number of business transactions with international partners and, at the same time, characterises the type of relationship indicated by *ColFO* further. By including *ExpR* into the analysis, we obtain a more detailed picture of what kind of collaboration the international infrastructure is utilised for.

3.3.5 Innovation indicators

The number of patents per employee (*PatE*) and the turnover share of products or services that have entered markets in the past three fiscal periods (*InnoS*) are both indicators of the innovative capability of a company. While *PatE* measures the actual innovative capacity of a company (see *e.g.* Furman et al. 2002), *InnoS* gives an idea of how much innovations have impacted company sales and to what extent the market appreciates the value of the innovations.

According to Brezis and Krugman's (1997) framework we should see a positive correlation between specialisation and *PatE*, but not necessarily between specialisation and *InnoS*. This is because newly emerging and specialised peripheral centres are expected to surpass incumbent centres in terms of innovativeness, as they embrace novel technologies aiming at substituting the incumbents' conventional technology. Initially, this should be visible in patenting activity with the younger centres performing better than the incumbent centres. But it is not until much later that the new technologies start to become viable on markets. Until then incumbent technologies have to provide the income flow even in newly established companies. Thus, we do not necessarily expect to find any correlation between *InnoS* and *SpecInd*. With this said, we expect to find a negative correlation between *InnoS* and the age of a company, as older incumbent companies rely on proven technologies that provide them with steady income flows. Should there be a positive correlation between *InnoS* and *SpecInd*, however, then it would serve as an even stronger indicator of a focus on novel technologies than *PatE*, since it would measure the technology directly rather than indirectly through *PatE*.

In contrast to Brezis and Krugman (1997), following Duranton and Puga's (2001) framework we should expect rather different findings for both *InnoS* and *PatE*. Given that diversified agglomerations are argued to function as hotspots of innovation due to local knowledge spillovers between sectors, we should find a positive correlation between the agglomeration index and *PatE*. Since Duranton and Puga (2001) predict a relocation of production into less expensive, specialised peripheries once a viable technology has been conceived, there should be a positive relationship between the specialisation index and the share of innovations of total sales.

3.3.6 Sunk cost indicator

The absolute annual amount spent on research and development serves as a measure of sunk costs invested into a business that is characteristic of increasing returns to scale industries like biotechnology. R&D expenses are invested upfront, usually long before generating the first revenue streams, and are not variable with the volume of subsequent production. Krugman's (1991a) line of argumentation is based on the assumption of existing sunk costs that, together with the other factors, drive agglomeration. We expect to find a positive correlation between the sunk cost variable (*SC)* and agglomeration.

Furthermore, *SC* might be correlated to the stage in a company's lifecycle. Since the initial earnings in the research intensive biotechnology industry are generated relatively late, the costs related to the research and development phase are considerably high in the first few years of a company's existence. The variable *SC* might be strongly correlated with public funding indicators, as the majority of public resources are directed towards supporting the early research and development phase and, thereby, the emergence of new technologies that are not yet ripe for market introduction. Thus, in addition to serving as a sunk cost measure, *SC* has to be included into the analysis in order to be able to distinguish between public funding supporting regional development and that supporting new technology development.

3.3.7 Employee compensation indicator

Salaries and wages per employee (*EmplC*). As an implicit result of Krugman's (1991a) and Krugman and Venables' (1996) frameworks agglomeration always entails higher employee expenses as qualified labour becomes a scarce resource within the growing regions. We include *EmplC* in the analysis to test this aspect of theory empirically and expect the variable to be positively correlated with the agglomeration index.

3.3.8 Control variables

Number of personnel (*Staff*). *Staff* measures the number of personnel employed by a particular company. It is a straightforward measure of organisational size.

Age (*Age*). This variable is self-explanatory and controls for age effects. It provides information on the characteristics of companies in agglomerated and/or specialised regions.

Annual Turnover (*AT*). Where *Staff* proxies the organisational size of a company, AT measures the volume of business that a company generates. It is the reported turnover of the fiscal year 2003.

Sector controls *Drug*, *Enzs* and *Biom*. The dummies respectively indicate whether a company is active in the drug development, enzymes or biomaterials sectors of the biotechnology industry. They control for sector-specific effects that might be strong, as each of the sectors of the industry is characterised by very distinct business models, development times, approval procedures etc. The three sector controls do not represent the entire biotechnology industry exhaustively, but are chosen for their large differences in the features mentioned. Other sectors include forestry, food and feeds, agriculture, diagnostic services, and health care instruments amongst others.

Location within major economic centre (*LHub*). As economic activity in general is highly agglomerated in the triangle formed by the Helsinki, Turku and Tampere regions, we have to control for the regions' effects on location incentives if we aim at singling out theory related intra-industry aspects clearly. By including location dummies for the three hubs in the analysis we control for effects that economic activity outside the biotechnology industry in these hubs might have on sample companies. In addition to its controlling function, *LHub* serves as a geographical anchor for the agglomeration index that does not independently provide any information on where exactly agglomeration tends to be high. With this said, we expect to find a very strong correlation between the agglomeration index and the dummy *LHub* indicating whether a company locates within one of the major economic centres of Finland.

Share of Ph.D.s of personnel (*PhDs*). The share of personnel holding a PhD degree is a control related to the sunk cost measure *SC*. It controls for effects that might emerge due to differences in the business models of companies and affect the sunk cost measure. Depending on the established business model, companies are very diverse in their R&D intensities with some focusing solely on developing novel technologies based on new science (e.g. drug production in genetically modified plants) while others build their business on less research intensive product development (e.g. utilisation of known bacteria in functional foods) that requires smaller investments in highly qualified human resources. In order to negate the effect on the *SC* variable we include the share of PhDs, people with scientific expertise, in the analysis as a proxy for the intended business model. The underlying assumption implies that the more scientific personnel a company employs the more it is research focused. Table 3.13 summarises all variables included in the analysis.

Table 3.13 Summary of variables

Variables	Operationalisation	Purpose
Agglomeration and specialisation indices		
AggInd	Agglomeration Index based on the number of personnel.	Degree of agglomeration in company's vicinity.
SpecInd	Specialisation Index based on labor input.	Company locates within a region specialised in company's own sector.
Public policy indicators and interaction controls		
PublVC	The € amount of public VC funding received by a company.	Indicator of active public innovation policy.
Tekes	Company has received funding from Tekes.	Indicator of active public innovation policy.
CorpFin	The € amount of loss-corrected equity provided by other companies.	Control for public funding indicator interaction.
EmplFin	The € amount of loss-corrected investments provided by a company's employees.	Control for public funding indicator interaction.
PrivVC	The € amount of loss-corrected financing provided by private venture capitalists.	Control for public funding indicator interaction.
Intermediate input trade indicator		
ColLO	Collaboration with companies in the same region.	Proxy for intra-industry intermediate input trade.
Public and international infrastructure indicators		
ColLU	Collaboration with a university in in the same region.	Indicator of public infrastructure quality.
ColFU	Collaboration with a foreign university.	Indicator of international infrastructure quality.
ColFO	Collaboration with a foreign organisation other than a university.	Indicator of international infrastructure quality.
ExpR	Export ratio.	Indicator of type of international infrastructure.
Innovative capacity indicators		
PatE	Patents per employee.	Indicator of innovative activity.
InnoS	Turnover share of products or services launched in the past 3 yrs.	Indicator of innovative activity with commercial potential.
Sunk cost indicator		
SC	Annual R&D expenditure.	Indicator for sunk costs.
Wage level indicator		
EmplC	Salary or wage per employee.	Indicator of the level of compensation.
Control variables		
Staff	Number of personnel.	Size control.
Age	Age of company in years.	Age control.
AT	Annual turnover.	Volume control.
Drug	Company active in drug development sector.	Industry control.
Enzs	Company active in enzymes sector.	Industry control.
Biom	Company active in biomaterials sector.	Industry control.
LHub	Company locates in one of three main centres of economic activity.	Economic environment control.
PhDs	The number of personnel with PhD degree.	Business model control.

Table A6 in the appendices presents the concise descriptive statistics and Table A3 displays the results of the correlation analysis for all variables included.

4 Results and discussion

Table 4.1 displays the results of our final un-rotated PCA.[18] We obtained nine distinct components, each of which represents a configuration of variables that co-vary, or present high loadings, with each other. The model explains 72 % of the variance in the data.

Variables that are loaded above the threshold level defined critical for our sample size and show a co-efficient above .3 are flagged with a single asterisk, while strongly loaded variables with coefficient values above .4 are flagged with a double asterisk. The configurations of loaded variables can be interpreted as company typologies depicting characteristics that go hand-in-hand in the underlying data. Although none of the components, as a whole, are correlated with each other by methodology, they are not exclusive in the sense that any single company can show characteristics defined by several different components. These typologies just do not co-vary on the level of the whole sample.

Table 4.1 Component matrix

Variables	**Components**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Agglomeration and specialisation indices									
AggInd	-0.073	** 0.543	* 0.364	**-0.611	*-0.301	0.021	0.011	-0.106	-0.105
SpecInd	0.117	* 0.303	-0.112	* 0.376	-0.174	-0.117	** 0.550	0.065	*-0.366
Public policy indicators and interaction controls									
PublVC	0.144	** 0.524	-0.264	0.135	-0.143	0.024	**-0.462	* 0.311	-0.131
Tekes	0.284	0.228	0.005	0.043	0.237	-0.184	-0.236	0.134	** 0.621
CorpFin	** 0.413	0.033	** 0.688	* 0.394	-0.218	0.272	-0.082	0.175	-0.009
EmplFin	** 0.433	0.046	-0.270	*-0.304	-0.138	0.144	** 0.504	0.104	0.293
PrivVC	0.195	0.240	*-0.369	0.014	0.030	** 0.590	-0.151	-0.244	0.065
Intermediate input trade indicator									
ColLO	-0.210	0.118	** 0.616	-0.252	** 0.466	0.041	-0.072	-0.042	-0.080
Public and international infrastructure indicators									
ColLU	-0.126	** 0.476	0.211	* 0.394	0.181	*-0.362	-0.103	0.052	0.079
ColFU	** 0.603	* 0.329	0.063	0.058	** 0.468	-0.042	0.016	-0.281	-0.095
ColFO	** 0.554	0.170	-0.077	0.073	** 0.454	-0.252	-0.089	*-0.326	-0.162
ExpR	** 0.402	-0.009	** 0.713	* 0.385	-0.182	0.282	-0.028	0.110	0.010
Innovative capacity indicators									
PatE	*-0.318	0.223	0.035	0.176	* 0.325	0.296	0.218	0.229	0.089
InnoS	-0.214	0.173	-0.210	* 0.304	* 0.300	** 0.424	0.016	-0.234	*-0.339
Sunk cost indicator									
SC	** 0.563	* 0.399	-0.226	-0.032	-0.009	-0.045	0.068	-0.103	0.208
Wage level indicator									
EmplC	** 0.408	0.189	*-0.358	0.163	*-0.381	0.027	-0.263	0.077	-0.041
Control variables									
Staff	** 0.733	-0.096	-0.072	-0.316	0.282	0.180	0.107	* 0.314	-0.089
Age	* 0.354	**-0.406	0.015	*-0.329	* 0.315	0.034	-0.120	** 0.459	*-0.302
AT	** 0.688	-0.178	0.183	0.045	0.026	0.078	0.236	-0.064	0.115
Drug	-0.114	** 0.557	-0.219	0.290	0.044	-0.080	0.176	* 0.394	-0.084
Enzs	0.210	*-0.361	0.099	** 0.479	-0.179	-0.092	0.102	-0.288	0.114
Biom	*-0.361	0.003	-0.103	0.081	0.132	** 0.644	-0.058	-0.014	0.235
LHub	0.031	** 0.670	* 0.310	**-0.478	*-0.303	0.104	0.049	-0.175	-0.056
PhDs	**-0.508	* 0.313	0.149	0.043	0.299	-0.059	0.281	0.115	0.237

Extraction Method: Principal Component Analysis.
9 components extracted.

18 A rotated component matrix is provided in Table A4 in the appendices. KMO and Bartlett's test are displayed in Table A1 showing the adequacy of the analysis in relation to the utilised data. The total variance explained is reported in Table A2. Communalities can be found in Table A5.

With this said, we will proceed with describing and discussing each of the components one by one and, in doing so, try to rise to our initial challenge of fleshing out the rationale behind the geographic structure of the sample industry.

4.1 Component 1: Internationally oriented heavyweights

Component 1 depicts established and thriving companies. These companies enjoy large revenues, are relatively independent of domestic markets as indicated by a large export ratio, they look back at a long history in business and employ a large staff that enjoys relatively high compensation. It also displays high sunk costs, as it invests heavily into R&D engaging mainly in foreign R&D collaboration with diverse instances including universities. At the same time, the companies do not employ many PhDs nor do they show a high per head patent count, both of which indicate a business model based on a more generic or incumbent technology. With the ownership of the company being mainly in private hands of other corporations and its own employees it is relatively independent of public support.

What does this tell us in the light of our research question? How do these characteristics relate to geographic structure? First, it is notable that neither the agglomeration nor the specialisation indexes seem to be loaded with the component in any significant way. This implies that a company endowed with the above characteristics could locate virtually anywhere in Finland. One could find it in the most distant periphery just as well as in the country's most dense economic hotspots. Also the location's regional sector of specialisation does not really matter with a highly specialised region being equally probable to host a company depicted by component 1 as a highly diversified region. Clearly, also public support plays only a trivial role in the company's businesses, as the bulk of funding is provided by private owners and internal revenue generation. With this said, it seems that component 1 reflects important interrelational features of the industry that exist independently of geographic location. Neither Krugman's (1991a, 1991b) notions nor Duranton and Puga's (2001) or Brezis and Krugman's (1997) alternative intuitions relating to the role of incumbent regions fail to provide a rationale for companies characterised by component 1, as the agglomeration and specialisation indices simply do not correlate with the component.

One possible avenue of explanation could be opened by Martin and Roger's (1995) notion of international infrastructure. Looking at component 1 it seems that the companies in question rely heavily on foreign collaboration both in terms of sales and product development, while connections to local markets or collaboration partners seem insignificant for running a successful business. This could signify that the international infrastructure between a company's country of origin, here Finland, and those of its partners is of such a high quality that serving these markets and maintaining collaborative relationships from a great distance do not pose a disadvantage. Compared to the significance of these foreign linkages the gains achieved by optimising location *within* the country of origin then seem to be trivial. This is actually rather intuitive, since most of the reviewed studies emphasise the role of local demand linkages as a precondition for any emerging benefits of agglomeration and specialisation. Given that, according to component 1, even R&D collaboration, a measure of intra-industry demand linkages, is mainly conducted jointly with instances abroad and not locally, local intra-industry linkages simply do not exist. Thus, companies characterised by component 1 are rather indifferent in terms of location *within* Finland, as there are no gains to be made by locating near domestic partners that do not provide any relevant input.

We stress this as one of the central findings that will have major implications on regional policy design.

4.2 Component 2: Agglomerated drug developers

Companies characterised by component 2 are relatively young R&D-intensive drug development companies that are located in agglomerated regions, mainly the general economic hotspots in Finland, specialising in the same sector.

As opposed to component 1, component 2 conforms to the underlying theories very well: High sunk costs proxied by R&D expenses are correlated positively with the agglomeration index in accordance with Krugman (1991a), which attests to an attempt to reap the benefits of increasing returns to scale by locating within an economic centre close to potential demand for the companies' services, on the one hand, and the pool of knowledge provided by other companies in close vicinity that can be tapped into through intra-industry linkages, on the other. The high sunk costs are a function of the business model that is characterised by intensive scientific development of technology in the early phase of the organisational life-cycle. A high share of personnel with PhDs and the relatively young age of companies characterised by component 2 support this interpretation.

In accordance with Krugman and Venables (1996), component 2 shows that agglomeration has gone hand in hand with specialisation, here drug development, providing resident companies with the opportunity to take advantage of intra-industry linkages. However, these opportunities have not been exploited to an extent that would be statistically significant. Thus, companies characterised by component 2 may or may not engage in intra-industry trade. They might even engage in harsh competition instead of collaborating with each other. Moreover, the theory-predicted innovativeness of companies in agglomerated areas lacks statistical significance as expressed by variable *PatE*. These two evident weaknesses of some companies can be argued to be interrelated. The heightened innovative capacity of agglomerated regions is based on co-operation between companies that allow for knowledge spillovers or other mechanisms of technology transfer. Since there is a lack of systematic intra-industry activity between companies in regions characterised by component 2, it is not surprising to also see an equal lack of systematic innovativeness. Thus, intra-industry co-operation is a central challenge to be conquered by companies in these regions, because costs related to crowding-out effects in agglomerated centres might otherwise not be offset and the strength of the economic justification of the regions might deteriorate.

While intra-industry linkages fail to manifest themselves in a statistically significant fashion among companies characterised by component 2, links between agglomeration and public, as well as international infrastructure are evident in the component. Along the lines of Martin and Rogers' (1995) framework, companies depicted by the component utilise both local and international infrastructure to achieve further gains by maintaining co-operation with local and foreign universities. Agglomeration is strengthened as the local university attracts related economic activity in its vicinity while good international infrastructure enables necessary contacts to foreign universities without having to relocate.

The fact that collaboration is maintained mainly with academic institutions provides a further indication for the companies' young age and early stage in their lifecycle. The finding is corroborated by the statistically insignificant turnover measure and export share indicators. These companies are probably still in a pre-market phase. The decision of location is most likely based on the existence of relevant public infrastructure and the vicinity of potential future markets.

Public VC funding is also correlated with the component. Although we cannot pinpoint the exact variable that *PublVC* co-varies with most within a single component because the coefficients indicate only correlation with the component as a whole, comparing component 2 to other components discussed in the following reveals that public VC funding seems to be more frequently associated with the drug development sector than with agglomeration. This might hint at a more substance related investment strategy than one based on regional policy. To be more precise, according to component 2 public sector VC funding has been invested to a relatively large extent especially in those drug development companies that locate in regions characterised by both a relatively dense agglomeration and a company base specialised in drug development.

4.3 Component 3: Internationally competitive subsidiaries

Companies characterised by component 3 are again somewhat at odds with our theoretical background. While locating in agglomerated areas within one of the three major economic centres of the country, these companies compensate their employees relatively poorly. This runs opposite to what we expected to find to be the case in agglomerated areas that usually have to compete over qualified labour. It is especially odd, as the companies in our biotechnology based data run businesses that usually demand very highly qualified individuals. The low compensation of employees might be explained by a very generic business model that does not rely on highly skilled personnel. Companies characterised by component 3 might serve as a more production and distribution oriented organisation, for instance. As these organisations are mainly owned by other companies, such a specialised function could be envisioned with ease to fit into the larger structure of a conglomerate. The story would further explain why both innovativeness measures and collaboration with local and foreign universities are insignificant in contrast to expectations based on the theories. R&D related functions are performed elsewhere in the larger conglomerate (see also Markusen 1998).

At this point it is important keep in mind, however, that pure logistics companies, as well as all other companies providing similar support services, were excluded from the data from the onset because we were primarily interested in businesses dedicated to biotechnology. Thus, none of the sample companies focus solely on production or distribution functions. They might, however, emphasise such functions more than others.

On the other hand, component 3 shows a positive relation between agglomeration and local co-operation with instances other than universities, as well as with the export ratio indicator. These findings are both in line with the theory base. Local co-operation indicates active local intra-industry trade that enhances agglomeration. Locating within an agglomeration, in turn, provides access to a large base of intermediate input producers in very close vicinity. Assuming that the business model of companies characterised by component 3 is really based on generic technology as discussed above, the key to profitable operations is in efficient procurement. In such a setting the ideal location is within an agglomeration. With a high export ratio indicating exploitation of a well-established international infrastructure, it is sensible to tap into the companies' main markets abroad from the agglomerated location in Finland.

4.4 Component 4: Specialised periphery

Component 4 represents a model example of a company in a specialised periphery. Being in congruence with Duranton and Puga's (2001) and Brezis and Krugman's (1997) notions, the component characterises companies locating in a peripheral region that is specialised in the companies' industrial sector with the specialisation index being positively and the agglomeration index being negatively correlated with the component. Further in line with both theoretical discourses, the companies in the region are focused on developing novel technologies as indicated by a positive correlation of the *InnoS* variable proxying the sales share of innovations. Companies characterised by component 4 locate in a highly specialised periphery that focuses its activities on cutting edge niche technologies that do not compete on the same markets with agglomerated centres. Locating in the periphery, these companies avoid crowding-out effects and compensate, thereby, for the lower returns on innovations still in an early phase of their market lifecycle. The young age of companies indicated in component 4 supports this interpretation. In the light of Brezis and Krugman (1997), these technologies represent future technology paradigms that will eventually displace those promoted by older incumbent centres. Interpreting component 4 inversely supports this notion, as the agglomeration and innovation proxies are loaded negatively with each other. The sales share of innovations is lower in the case of centrally located companies characterised by the inverse component 4. Duranton and Puga's (2001) interpretation of the finding differs from those of Brezis and Krugman (1997) to the extent that it does not spell doom for agglomerated centres. According to their view, centres serve the role of innovation engines, while peripheries perform the task of developing those innovations to products and bringing them to the markets. The results back this notion in the sense that it provides evidence of the peripheries' role in action.

In compliance with Martin and Rogers (1995), the development of technologies in the periphery depicted by component 4 is facilitated among other things by taking advantage of the well-established public infrastructure represented by co-operation with local universities. A well functioning international infrastructure proxied by a relatively high export ratio additionally facilitates benefiting from externalities of specialisation by lowering trade costs to the extent that serving foreign markets from the periphery becomes viable.

However, there are also some concerns. According to Krugman and Venables' (1996) argumentation, the most significant externalities of specialisation emerge through intra-industry trade of specialised intermediate inputs concentrated in the location of specialisation. Tapping into a common pool of specialised resources generates synergies that attract further activities of similar specialisation into the area. Thus, active intra-regional trade is key to the region's success and a requirement for the justification of its peripheral location. In the case of biotechnology, which is a highly R&D intensive business, the most significant input can be argued to be knowledge. Knowledge, in turn, is traded through collaborative arrangements such as R&D collaboration. Unfortunately, the measure for intra-regional R&D collaboration is statistically insignificant. It follows that some of the companies characterised by component 4 are engaged in intra-regional collaboration while some are not. Those companies will be unable to tap into the synergies offered by the specialised environment they are embedded in and forfeit significant benefits. This poses a challenge not only to the companies in question, but also to the region as a whole because forfeiting collaborative opportunities by some companies impacts the total size of the resource pool that companies in the region can tap into.

4.5 Component 5: Collaborative periphery

Component 5 depicts another model example of companies that take advantage of lower labour costs in the geographical peripheries to develop novel technologies. Their sales share of innovations and the per-head-count of patents are relatively high while wages and salaries paid to employees are relatively low at the same time. The share of highly educated personnel is another indication of the companies' focus on developing innovations as a business model.

In contrast to component 4, active local co-operation with diverse partners implies the existence of established intra-industry linkages that could serve as a basis for emerging agglomeration in the long-run. Most importantly it is evidence of companies taking advantage of the specialised knowledge pool available in the region.

A functioning public and international infrastructure further reinforce the foundation for future growth of the region. Thus, speculating slightly, these regions might represent the seed of future centres of agglomeration.

However, there is again a major concern. In the current cross-section there is no significant sign of agglomeration or specialisation in component 5 yet. Leaning on the discussed literature, the success of growth and economic potential in the future has to be based on regional specialisation in these peripheral regions. As component 5 does not indicate such a development, one could argue that regions inhabited by companies characterised by the component are at a critical crossroads in their evolution. To be sustainable in the long run, these regions need to develop a genuine focus.

The lack of a geographic focus by some public sector funding discussed earlier does nothing to push the development in the right direction, because unfocused funds can be used to keep businesses on life-support despite being at odds with their particular region's specialisation.

With that being said, component 5 draws a coherent picture that is in congruence especially with Brezis and Krugman's (1997) framework, which bestows peripheral centres with the burden of being the locomotives of innovation and future growth. Meanwhile, incumbent centres are destined to decay slowly, as they stick to conventional technology trajectories. With this in mind, interpreting component 5 inversely provides us with the first signs of decay of incumbent centres, as companies characterised by the inverse component show low innovative activity and reliance on established technology (low sales share of innovations) while locating in the midst of economic hotspots. These companies do not exploit local or international infrastructure and suffer from crowding-out effects of intense agglomeration in the form of high salaries.

4.6 Component 6: Geographically dispersed biomaterials

Component 6 is a residual component that basically describes companies active in the biomaterials sector of the biotechnology industry. It does not provide further implications related to the geographical structure of the industry. All we can infer is that companies focused on developing biomaterials show a relatively high sales share of innovations and are privately owned. As neither the agglomeration index nor the specialisation index correlate significantly with the component, companies active in biomaterials could be found in any geographic location.

4.7 Component 7: Entrepreneurial specialisation

Component 7 provides us with one central message: Public equity financing as provided by Sitra has not been a factor leading to specialised regions with the two indicators being loaded negatively with each other. Instead, public VC funding has favoured companies in diversified regions. When these regions locate in the peripheries component 7 tells a rather gloomy story, as the bulk of the literature serving as the theoretical backbone of this study justifies the existence of peripheries only if they are specialised. Where these regions are simultaneously centres of agglomeration this is good news, as especially Duranton and Puga (2001) accord the vital role of innovation engine to diversified larger centres.

Since component 7 shows no significant correlation with the agglomeration index, however, we have to conclude that public equity funding has been equally provided to both agglomerated and peripheral regions and, thus, being invested with no clear strategy related to the economic aspects of geography. Instead, companies in these specialised regions are entrepreneurial in the sense that they finance their operations internally.

4.8 Component 8: Experienced drug development with significant public equity funding

As touched on earlier, this component establishes the positive relationship between the drug development sector of the biotechnology industry and public equity financing provided by Sitra. Combining the finding with that of component 7, it seems that Sitra's investment strategy is more related to the substance of technology than its geography. The question arises whether investing partly against the forces of the economies of geography resembles swimming against the stream. To make a certain sector thrive in a region that does not provide the right environment in terms of the necessary intra-industry linkages associated with specialisation necessitates continuous subsidies. In contrast, investments in companies that locate in regions conducive to their business in terms of specialisation or other relevant inputs could lead to the acceleration of the virtuous circle of specialised agglomeration, as each thriving member in the region adds to the success of others in its vicinity.

4.9 Component 9: Tekes encouraging regional multi-functionality

In accordance with its rather broadly defined mission, Tekes provides financing to incorporated R&D activity still in the early phases of development and would not survive independently on commercial markets. Component 9 correlates negatively with the age and the sales share of innovations. As already discussed in conjunction with Sitra's equity financing, such a broadly defined mission might have significant adverse effects. While providing initial support for emerging technologies will potentially lead to success in some instances, some support will inevitably flow to endeavours unable to strike roots in soil that cannot provide them with the necessary externalities. Once public support ends, companies that locate in less conducive regions from the perspective of their expertise and substance are forced to re-locate or risk failure.

5 Conclusions

This study set out to answer the question whether contemporary literature in the field of Geographic Economics is able to provide a justifying rationale for the much- debated geographic distribution of a science-driven industry, such as the Finnish biotechnology industry, which, according to opposing criticism, is said to be overly dispersed.

Concluding, our results indeed provide evidence of a theory-based rationale that is able to deepen our understanding of the roles that different regions have enacted in the development of the focal industry. The analysis is able to explain 72 % of the variance in our sample. Simultaneously, however, the rationale also reveals several challenges that different types of regions still have to overcome in order to keep on the track of sustainable economic development in the future. With that being said, the current course of regional evolution of the industry cannot be fully justified.

5.1 Agglomerated centres - Lack of regional co-operation and innovative capacity

The analysis clearly exposed the distinct pattern of a centre-periphery setting that is also supported by our descriptive findings. Large returns to scale are a strong incentive to locate in agglomerated centres. Companies in agglomerated centres take advantage of a well-built public infrastructure by co-operating with local universities and increasing their absorptive capacity thereby. However, these young and highly research intensive companies fail to link themselves to the regional network of intra-industry trade that could provide them with valuable channels to access complementary assets in the form of interdisciplinary knowledge provided by partners within the agglomeration. Such knowledge, in turn, is the seed for breakthrough innovations. The lack of such innovations is evident in the data. In the long run the lack of innovations entails the decay of agglomerated regions as hotspots of economic activity. Moreover, if partners are sought mainly outside one’s own region, the demand linkages necessary to spur the growth of a strong local cluster fail to emerge. This has strong inhibitory effects on the growth of the regional economy that each company is a part of. Thus, failing to seek regional collaboration initiates a vicious circle in many ways.

Companies that run a more generic business model and are less research intensive seek agglomerated areas due to the closeness of intermediate input producers. The data reveals that this type of company is closely interlinked with partners in the same region. They choose an agglomerated location to minimise procurement costs and sell their products on foreign markets. From the perspective of economic justification this company type is rather favourable, as it benefits from local demand linkages and strengthens the growth of the region at the same time.

5.2 Innovative peripheries – Missing intra-industry linkages and focus

Peripheries need to meet two interrelated critical success factors to achieve necessary efficiencies through economies of scope that, in turn, compensate for the lack of agglomeration related benefits. Firstly, it is paramount to specialise strongly in some sector of the industry. Krugman and Venables (1996) predict that a periphery's economic growth becomes self-energising once a sufficiently large base of companies specialised in the same sector exists in any given region. Secondly, for this virtuous circle to set in, companies in peripheries need to establish strong intra-industry linkages in the region, as these linkages enable the exploitation of specialised complementary resources and spur demand that, in turn, attracts new sector-specific economic activity and accelerates the growth of the specialised region.

While still 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, were widely met among different types of peripheral companies, very many of them failed to meet at least one of the two aforesaid critical success factors. They were either not located in a region specialised into their own sector or links to the local industry were insignificant. In the long run this might impact the development of these peripheries negatively, because a self-sustaining and self-energising critical mass of specialised economic activity will be difficult to reach. Peripheries too diversified relative to their sise do not provide sufficiently large local markets to justify any single company's decision to establish a business in that region as opposed to locating in a strongly agglomerated region with far larger markets.

5.3 Strong international collaboration and the irrelevance of location

One of the central findings of our analysis indicates that very strong emphasis on international ties in R&D collaboration and sales renders the choice of domestic location irrelevant from the perspective of success. Companies that perform R&D to a large extent in co-operation with foreign partners and export a significant share of their products and services generate considerable turnover, employ a large staff and pay high salaries despite a seemingly random domestic location. It seems that local demand and intermediate input linkages are not of relevance to these companies because international infrastructure is utilised to access demand and intermediate inputs abroad. Thus, given low enough trade costs facilitated by infrastructure, the choice of domestic location becomes irrelevant.

5.4 Public policy implications

The study establishes that public funding, the primary implementation mechanism of innovation policy in Finland, has seemingly not been coordinated based on a regional strategy that would recognise the unique features and criteria that different types of regions need to meet in order to develop in a sustainable way. Instead, there are weak indications that public funding has rather been supportive of certain industrial sectors like drug development. In the worst case, regionally aimless public sector funding provides artificial life-support to companies strongly at odds with their regional environment in terms of specialisation and co-operation. This, in turn, can potentially inhibit the evolution of the region as a whole, which is dependent on the emergence of a critical mass of companies with shared complementary and synergetic assets.

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

Whether unfocused public funding has been the single major factor that has displaced incentives to specialise and co-operate in peripheries remains a question to be answered in further studies.

In terms of regional innovation policy, the irrelevance of location in the presence of strong international collaboration implies that efforts to activate companies to reach out and network internationally are an effective means to boost macro-economic development and regional vitality irrespective of the location of companies.

5.5 Contribution to geographical economics

As a contribution to the existing body of knowledge the study shows that the Geographical Economics literature indeed provides an effective tool for evaluating the challenges faced by industries in terms of their 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. Implicitly, we have shown that the operationalisation of the GE literature is feasible and that it can serve as a basis for drawing implications on the development of single regions.

With this being said, our study serves as a useful basis for future empirical analyses that scrutinise specific questions arising from our results more in-depth. One promising avenue of research could be built around the question of how public funding and other types of public innovation policy affect the location decision of companies. In an attempt to improve the efficiency and effectiveness of public policies we need to understand in depth how the evolution of industries is affected by geography and what role public sector funding and other mechanisms of policy play in determining it. Our results merely point at the relevance of that question, while a rigorous study attempting to answer it would necessitate more extensive time-series data that preferably encompasses several countries for the purposes of benchmarking results and controlling for country effects.

Another effort with promising potential would consist of relating different regional agglomeration and specialisation patterns to firm performance indicators. In such a setting it would be possible to actually test the validity of implications of the geographical economics literature itself by asking whether location matters after all. Such an endeavour would pose considerable requirements to data. The choice of performance measures has to be made with care, because many of the younger research-intensive industries such as biotechnology, for example, still struggle with being profitable, not because they necessarily perform poorly but because of their early stage in the characteristically long development cycle of products. Moreover, effects of location on firm performance can be observed more effectively with changes in geographic patterns of the given industry over time and, therefore, would greatly benefit from the utilisation of time-series data as a basis for analyses.

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8 Appendix

Table A1 KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.488
Bartlett's Test of Sphericity	*Approx. Chi-Square*	661.477
	df	276
	Sig.	0.000

The KMO measure of sampling adequacy does not quite meet the limit of .600, which is conventionally held as a critical value. However, Bartlett's test of sphericity shows that a factor analysis can be applied on the data at a 0.1 percentage risk level.

Table A2 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.622	15.091	15.091	3.622	15.091	15.091	2.334	9.724	9.724
2	2.619	10.914	26.005	2.619	10.914	26.005	2.305	9.603	19.327
3	2.290	9.543	35.548	2.290	9.543	35.548	2.260	9.417	28.744
4	2.070	8.625	44.173	2.070	8.625	44.173	2.077	8.656	37.400
5	1.726	7.192	51.365	1.726	7.192	51.365	1.962	8.177	45.577
6	1.523	6.347	57.712	1.523	6.347	57.712	1.803	7.513	53.089
7	1.210	5.040	62.752	1.210	5.040	62.752	1.703	7.095	60.184
8	1.151	4.797	67.549	1.151	4.797	67.549	1.643	6.846	67.030
9	1.101	4.589	72.138	1.101	4.589	72.138	1.226	5.108	72.138
10	0.956	3.982	76.120						
11	0.809	3.372	79.492						
12	0.798	3.327	82.819						
13	0.669	2.786	85.605						
14	0.605	2.521	88.126						
15	0.582	2.424	90.550						
16	0.492	2.050	92.601						
17	0.458	1.907	94.508						
18	0.337	1.402	95.910						
19	0.319	1.328	97.238						
20	0.273	1.137	98.375						
21	0.217	0.903	99.278						
22	0.112	0.467	99.745						
23	0.045	0.186	99.931						
24	0.017	0.069	100.000						

Extraction Method: Principal Component Analysis.

Table A3 Correlation matrix

	InnoS	PatE	SC	AT	Staff	EmplC	AggInd	SpecInd	Age	ExpR	PhDs	ColFO	ColFU	ColLO	ColLU	Drug	Enzs	Biom	EmplFin	CorpFin	PrivVC	PublVC	Tekes
PatE	0.204																						
SC	-0.118	0.056																					
AT	-0.143	-0.068	0.107																				
Staff	-0.073	-0.144	**.344	**.580																			
EmplC	-0.010	-0.063	*.263	**.290	0.208																		
AggInd	-0.159	0.038	0.119	-0.134	-0.081	-0.116																	
SpecInd	0.138	-0.083	0.050	0.005	0.005	0.069	-0.085																
Age	-0.097	-0.089	0.005	0.138	**.647	-0.047	-0.083	-0.131															
ExpR	-0.061	-0.044	0.041	**.352	0.151	0.045	0.004	0.075	0.024														
PhDs	0.115	*.277	-0.098	*-.270	*-.282	*-.277	0.049	-0.036	*-.246	-0.109													
ColFO	0.018	0.051	**.387	**.315	*.244	0.197	-0.025	-0.062	0.102	0.020	-0.126												
ColFU	0.104	-0.083	**.418	**.382	**.408	0.158	-0.004	0.082	0.131	0.191	-0.036	**.588											
ColLO	0.068	0.075	-0.220	-0.095	-0.031	**-.361	0.224	-0.161	0.049	0.141	0.215	0.047	0.102										
ColLU	0.049	0.148	0.153	-0.168	-0.191	-0.077	0.016	0.153	-0.176	0.075	0.180	0.058	0.162	0.214									
Drug	0.113	0.120	0.109	-0.160	-0.081	0.070	-0.010	**.323	-0.200	-0.071	*.236	0.029	0.065	0.005	0.209								
Enzs	-0.052	-0.148	0.064	0.198	-0.041	0.030	*-.257	0.093	-0.062	*.232	-0.122	0.048	-0.021	*-.247	-0.109	-0.007							
Biom	0.133	**.322	-0.067	-0.155	-0.171	-0.112	-0.072	-0.194	-0.120	-0.070	0.173	-0.210	-0.146	-0.049	-0.042	0.006	-0.039						
EmplFin	-0.122	-0.096	*.244	**.328	**.436	0.154	0.034	0.102	0.032	-0.038	-0.138	0.048	0.146	-0.174	*-.238	0.021	-0.072	-0.075					
CorpFin	-0.105	**.312	**.320	0.123	0.014	0.084	0.114	-0.120	-0.001	**.419	-0.140	*.234	-0.003	-0.026	0.130	-0.092	0.028	0.159	-0.068				
PrivVC	0.223	0.070	**.325	-0.052	0.149	0.139	-0.024	0.005	-0.071	-0.023	-0.111	0.176	0.143	-0.168	-0.118	0.023	-0.113	*.277	0.137	0.221			
PublVC	0.093	-0.029	0.177	-0.074	0.094	**.342	0.113	0.042	-0.093	-0.029	-0.075	0.085	0.109	-0.146	0.193	**.351	-0.174	-0.056	-0.013	0.002	0.172		
Tekes	-0.084	-0.001	*.235	0.023	0.096	0.070	0.063	0.012	-0.003	0.055	0.004	0.087	0.159	-0.019	0.170	0.063	-0.005	-0.060	0.104	0.076	0.100	0.116	
LHub	-0.027	0.026	0.180	-0.035	-0.016	0.051	**.903	0.058	-0.191	0.068	0.009	0.012	0.078	0.176	0.042	0.063	*-.271	-0.057	0.092	0.104	0.112	0.157	0.060

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table A4 Rotated component matrix

Variables	Components								
	1	2	3	4	5	6	7	8	9
CorpFin	** 0.973	0.023	0.047	0.069	0.021	-0.044	0.039	-0.026	0.027
ExpR	** 0.969	0.045	0.029	-0.015	-0.018	-0.016	0.010	-0.012	0.010
ColFU	0.143	** 0.855	0.072	0.001	0.058	0.092	0.098	0.071	0.066
ColFO	-0.033	** 0.852	-0.081	0.073	-0.046	-0.026	0.085	-0.083	0.040
SC	0.015	** 0.466	0.146	* 0.346	0.091	** 0.419	-0.066	0.009	0.207
AggInd	0.011	-0.043	** 0.949	-0.049	-0.030	0.019	-0.048	-0.104	-0.027
LHub	0.084	0.076	** 0.929	0.041	0.042	0.101	-0.151	0.009	-0.024
Enzs	** 0.336	0.090	**-0.462	0.024	-0.246	0.088	*-0.356	-0.139	-0.105
EmplC	0.073	0.087	-0.012	** 0.744	-0.012	0.113	-0.015	0.004	0.024
PublVC	-0.003	0.067	0.196	** 0.680	* 0.348	-0.234	0.119	0.102	0.162
ColLO	0.151	0.147	* 0.347	**-0.620	0.034	*-0.359	0.186	0.044	0.129
Drug	-0.073	0.009	0.044	0.224	** 0.771	0.014	-0.036	0.024	-0.048
ColLU	0.116	0.237	0.031	-0.023	** 0.518	*-0.339	*-0.300	-0.179	0.222
PhDs	-0.148	-0.126	0.108	**-0.480	** 0.514	-0.053	-0.205	0.088	0.158
PatE	0.023	-0.111	-0.038	-0.293	** 0.491	-0.010	0.026	* 0.376	0.030
EmplFin	-0.063	0.037	0.092	0.081	0.002	** 0.842	0.118	0.010	0.041
AT	** 0.433	* 0.350	-0.133	-0.009	-0.212	** 0.465	0.144	-0.106	0.024
Age	0.021	0.055	-0.137	-0.037	-0.155	0.007	** 0.864	-0.140	-0.012
Staff	0.140	* 0.352	0.001	0.094	-0.073	** 0.447	** 0.721	0.006	0.068
Biom	-0.006	-0.293	-0.055	-0.139	0.038	-0.021	-0.060	** 0.716	0.106
PrivVC	-0.040	0.195	0.087	* 0.330	-0.103	0.168	-0.033	** 0.687	0.017
InnoS	-0.082	0.201	-0.111	-0.028	0.188	-0.236	-0.071	** 0.601	*-0.367
Tekes	0.055	0.234	-0.052	0.082	0.144	0.122	-0.036	-0.051	** 0.760
SpecInd	0.115	0.159	-0.047	0.150	** 0.501	0.240	-0.182	-0.163	**-0.559

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 12 iterations.

Table A5 Communalities

Variables	Initial	Extraction
InnoS	1.000	0.652
PatE	1.000	0.484
SC	1.000	0.590
AT	1.000	0.621
Staff	1.000	0.882
EmplC	1.000	0.580
AggInd	1.000	0.920
SpecInd	1.000	0.744
Age	1.000	0.815
ExpR	1.000	0.944
PhDs	1.000	0.622
ColFO	1.000	0.757
ColFU	1.000	0.788
ColLO	1.000	0.733
ColLU	1.000	0.626
Drug	1.000	0.657
Enzs	1.000	0.560
Biom	1.000	0.638
EmplFin	1.000	0.746
CorpFin	1.000	0.960
PrivVC	1.000	0.668
PublVC	1.000	0.732
Tekes	1.000	0.684
LHub	1.000	0.912

Extraction Method: Principal Component Analysis.

Table A6 Descriptive statistics

Variables	N	Minimum	Maximum	Sum	Mean	Std. Deviation
InnoS	75	0	1	14	0.18	0.337
PatE	77	0	10	41	0.53	1.406
SC	95	0	7 200 000	69 654 842	733 208.87	1258850.561
AT	103	0	34 941 568	242 505 420	2 354 421.56	6692446.116
Staff	97	0	238	2 093	21.58	36.055
EmplC	89	0.00	160 586	3 112 279	34 969.43	25356.989
AggInd	104	7.38	47.88	3 643	35.03	12.908
SpecInd	77	0.00	1.00	55	0.71	0.455
Age	77	1	121	824	10.70	15.102
ExpR	76	0	98	124	1.64	11.208
PhDs	75	0	100	2 285	30.47	29.708
ColFO	77	0	3	70	0.91	0.934
ColFU	77	0	1	22	0.29	0.455
ColLO	77	0	1	29	0.38	0.488
ColLU	77	0	1	54	0.70	0.461
Drug	77	0	1	21	0.27	0.448
Enzs	77	0	1	15	0.19	0.399
Biom	77	0	1	18	0.23	0.426
EmplFin	71	0	6 168 400	22 760 657	320 572.63	813721.534
CorpFin	71	0	32 877 589	59 791 060	842 127.61	4320725.955
PrivVC	71	0	20 947 056	47 101 107	663 395.87	2710336.163
PublVC	71	0	5 693 250	23 597 627	332 360.95	997524.004
Tekes	108	0	1	67	0.62	0.488
LHub	77	0	1	59	0.77	0.426
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