Entrepreneurship
Hrsg.: Malte Brettel, Lambert T. Koch, Tobias Kollmann und Peter Witt

Jan Boehm

Entrepreneurial Orientation in Academia

GABLER EDITION WISSENSCHAFT

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Herausgegeben von
Professor Dr. Malte Brettel, RWTH Aachen,
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„Entrepreneurship" ist ein noch relativ junger Forschungszweig, der jedoch in Wissenschaft und Praxis stetig an Bedeutung gewinnt. Denn Unternehmensgründungen und deren Promotoren nehmen für die wirtschaftliche Entwicklung einen zentralen Stellenwert ein, so dass es nur folgerichtig ist, dem auch in Forschung und Lehre Rechnung zu tragen.

Die Schriftenreihe bietet ein Forum für wissenschaftliche Beiträge zur Entrepreneurship-Thematik. Ziel ist der Transfer von aktuellen Forschungsergebnissen und deren Diskussion aus der Wissenschaft in die Unternehmenspraxis.

Jan Boehm

Entrepreneurial Orientation in Academia

With a foreword by Prof. Dr. Malte Brettel

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Foreword

Entrepreneurial firms and new venture creation are important drivers for economic growth. Hence, emphasis is put on the question how to adequately stimulate and support new business creation. The corresponding discussion has not excluded academic organisations such as universities - quite the contrary. In Germany, this discussion was intensified by changes in the Employee Invention Act (Arbeitnehmererfindergesetz), which now obliges researchers to report an invention to the sponsoring university, which in return has to decide how the invention it will be exploited. Subsequently, inventions and patents have emerged as a attractive economic resource for universities. This explains why university administrators have great interest in understanding how the creative and entrepreneurial orientation of researchers or entire research teams can be controlled, steered, and enhanced.

The discussion we are having in Germany today began in the US more than 20 years ago. With the Bayh-Dole-Act of 1980, a shift in the allocation of property took place similar to the introduction of the Employee Invention Act in Germany today. In addition, the notion of entrepreneurial activities in the context of research organisations has a long-lasting tradition in the US, and the current German system could learn a lot from understanding these developments.

This has been the motive for Jan Boehm to look deeper into the field of entrepreneurial orientation in academia, in particular in the US. He pursues the question to what extent entrepreneurial orientation of research organizations contributes to the phenomena of start-up activity and technology transfer.

The author has taken up this question in an interesting way and has developed exiting results: With his literature work, he has provided a solid theoretical basis and presented the revolutionary wave of change being encountered by universities today. On this theoretical framework, he has conducted an empirical study on US universities, and the results demonstrate a number of issues to think about: In light of centralistic

efforts to further align research goals of various institutions, how can academic freedom remain untouched? How can researchers be motivated to develop a more proactive and innovative attitude? How is it possible to encourage researchers to take more risks and develop an entrepreneurial spirit, if this has positive implications on new venture creation and successful technology transfer at universities? This and further questions are illuminated in the dissertation, which therefore provides interesting aspects to the current debate.

This dissertation is recommended to everyone who wants to participate in this discussion.

Malte Brettel

Acknowledgements

For the most part, entrepreneurship research has focussed on the individual as innovator and entrepreneur, or likewise on entrepreneurial companies. The process of entrepreneurship at academic organizations, in particular universities, stood on the sidelines. With the rise of knowledge-based technologies and dynamic developments in fields such as biotechnology and computer science, however, public interest in entrepreneurial activities at universities has increased, driven by a number of examples where university staff founded highly successful start-up companies and transferred technology out of universities into the successful business ventures.

The phenomenon of entrepreneurship at universities has been very visible in the United States, and a number of measures taken there have been discussed and often times introduced in the German context, such as the Employer Invention Act. Hence, developments in the U.S. continue to serve as a source for new ideas and trends for management and administration of research institutions in Germany. For the observer, they provide an ideal field for study and analysis, in particular given the rather broad availability of data. In this respect, I would like to thank all survey participants who made this dissertation possible.

With the present dissertation, my goal was to gain a better understanding about the process of entrepreneurial orientation at research organisations in the US, and the impact this orientation has on technology transfer. The opportunity to spend almost twelve months in the entrepreneurial environment of Stanford University and the Silicon Valley was helpful to understand first sight the processes and behaviors it takes to set the parameters right for successful technology transfer.

A number of individuals have been instrumental to the creation of this study. Firstly, of course, I would like to thank my supervisor and first referee Prof. Dr. Malte Brettel, Professor for Business Administration for Engineers and Natural Scientists at RWTH Aachen University of Technology. He provided me with great guidance and was al-

ways an important source for academic advise, critical and constructive discussion, and personal motivation. Further, my acknowledgements go to my second referee Prof. Dr. Rüdiger von Nitzsch, Professor for Business Administration and General Management at RWTH Aachen, for his valuable comments to this dissertation.

My fellow doctorate students and other academic colleagues at RWTH Aachen and Stanford University were helpful in so many ways. I am indebted to them for all of their great ideas and support. At RWTH Aachen, these include Florian Heinemann, Andreas Kessel, Degenhard Meier, Stephan Hungeling, René Mauer, Ralf Schmelter, Birgit Maassen, Predrag Angelovski, and Marco Hennigs. At Stanford University, Denise Chan, Nadja Dornhöfer, Fiona Kapers, Rachel Freiberg, Ester Hammond, Leandro Saita, and Andrew Nelson. I also thank my long-time mentor Dr. Michaela Sulke-Trezek for her continuous support.

This work would not have been possible without the help of my family and my wife Nadja to whom this work is dedicated.

Jan Boehm

Table of Contents

Exhibits

Tables

Abbreviations

ArbNErfG	Gesetz über Arbeitnehmererfindungen Employee Invention Act
ARD	American Research and Development
AUTM	Association of University Technology Managers
AVE	Average variance extracted
BMBF	Bundesministerium für Bildung und Forschung Federal Ministry for Education and Research
BTG	British Technology Group
CEO	Chief Executive Officer
CMDA	Constrained/Confirmatory Monotone Distance Analysis
CS	Computer Science
CSO	Corporate Spin-Off
CVR	Content validity ratio
DFG	Deutsche Forschungsgemeinschaft German Research Foundation
e.g.	exempli gratia, for instance
ed.	editor
eds.	editors
EE	Electrical Engineering
EO	Entrepreneurial orientation
ESSCA	External single-set component analysis
et al.	et alii, and others
etc.	et cetera, and so on
H	Hypothesis
HMT	Her Majesty's Treasury
i.e.	id est, that is to say
ibid.	ibidem, in the same place
IPO	Initial Public Offering
LISREL	Linear Structural Relationships
LS	Least Square

LV	Latent Variable
MANOVA	Multivariate Analysis of Variance
MD	Medical Doctor
MIT	Massachusetts Institute of Technology
ML	Maximum likelihood
NSB	National Science Board
OSRD	Office of Scientific Research
OTL	Office of Technology Licensing
Ph.D.	Doctor of Philosophy
PI	Principal Investigator
PLS	Partial Least Square
R&D	Research and Development
RWTH	Rheinisch-Westfälische Technische Hochschule Aachen, RWTH Aachen University
SBU	Strategic Business Unit
SEM	Structural Equation Modeling
TLO	Technology Licensing Office
TTO	Technology Transfer Office
U.K.	United Kingdom
U.S.	United States
UC	University of California
USO	University Spin-Off
Var	Variance
VC	Venture Capital, Venture Capitalist
WHU	Wissenschaftliche Hochschule für Unternehmensführung, Otto-Beisheim-Hochschule, Vallendar WHU Otto Beisheim Graduate School of Business, Vallendar
WWW	World Wide Web

1. Introduction

1.1. Background

Universities are in the focus of discussion about innovation-based economic growth in Germany, in the United States, and in other countries of the world.[1] Historically, the university's role in society comprised the functions of higher education and research, following Humboldt's 19th century ideal of combining learning and research in one single institution.[2] More recently, universities have transformed their role and extended their mission to incorporate a more commercially oriented element, based on the successes of technology transfer at universities such as the Massachusetts Institute of Technology ("MIT") and Stanford University.[3] Etzkowitz describes this transformation as the "second academic revolution", which requires universities to act more entrepreneurially and commercially, and serve society not only by educating students, but also by fostering research which can be developed into marketable products and technologies, thereby advancing the public good and economic wealth.[4]

The results of successful academic entrepreneurship in regions such as the Boston and the San Francisco Bay area have nurtured the hopes of policy makers, managers, and

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[1] National education and science ministries, government departments, and agencies in almost all industrialized countries debate this issue. As examples for Germany, the United Kingdom, and the United States, see BMBF (2004b) p. II, HMT (2004) p. I, NSB (2004b) p. 1, respectively. The academic basis for this debate can be found with Arrow (1962), Dasgupta and David (1994), and Rosenberg and Nelson (1994).

[2] See Etzkowitz (2002), pp. 10-11. Etzkowitz classifies the combination of education and science as "first academic revolution", extending the function of medieval teaching institutions in Paris and Bologna, adding the innovative research component. Etzkowitz views the 19th century universities of Göttingen and Gießen in Germany as role models of Humboldt's idea.

[3] See BankBoston (1997), p. 2. In the study "MIT: The Impact of Innovation" prepared by its Economics Department, BankBoston presents the results of a major study on the national economic impact of companies founded by MIT alumni. Among other findings, the study reveals that MIT graduates have founded 4,000 companies, creating 1.1 million jobs worldwide and generating annual sales of $232 billion. It was the first study demonstrating the key role that higher education and research play in the economic vitality of the U.S. See also Etzkowitz (2002), p. 20, and p. 102.

[4] See Etzkowitz (2002), p. 12, and Etzkowitz and Webster (1998), p.1. Also, see Gray (1999), p.1, as it relates to the development in the United Kingdom.

employees for economic progress.[5] Newly developed technologies and products in the areas of bio-chemistry, bio-medical engineering, bio-informatics, nano-engineering, electrical engineering, computer science, and the combination of all of these, are expected to stimulate economic growth and thereby create wealth and employment, in particular in the high-labor-cost countries of the Western hemisphere.[6]

Innovative growth industries are characterized by strong involvement of knowledge-based science, which places them much closer to university-based basic sciences than it is the case in more established industries which rely to a greater extend on applied sciences. As a consequence, a large portion of research and development work is provided by universities, often funded by the industry.[7]

At the same time, universities encounter an environment in which they increasingly have to act entrepreneurially and commercially. Against the backdrop of smaller governmental budgets for research and education, given the general fiscal situation in the United States as well as in Europe and Germany, universities have to search for alternative financial sources to fund their operations. Universities face a competitive situation in pursue of the best professors, researchers and teachers, in pursue of a highly motivated and intelligent student base, and third-party research grants and other endowments. This competition is certainly more pronounced in the United States than in Germany, however, similar trends can be observed amongst German universities, and are currently debated by policy makers.[8]

Close university-industry relationships and commercialization of research can provide alternative sources of financial means for universities. By registering patents and li-

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[5] See Saxenian (1994), p. 7, Roberts and Malone (1996), p. 17, Mansfield and Lee (1996), p. 1047, and Varga (1998), p. 1.

[6] See BMBF (2004b), p. II.

[7] See NSB (2004a), p. 54, for an international comparison of industry sponsored funding over time.

[8] See BMBF (2004a), pp. 1-3. Bund and Länder agreed upon initiating competitive procedures in order to enhance performance and increase quality of universities in Germany.

censing them to companies, or by encouraging and participating in research-based start-up companies, often equipped with former research staff in leading positions, universities can transfer technology efficiently to the public domain and at the same time participate in the economic surplus. Ultimately, the regional environment of universities shares the economic prosperity generated by these new companies.[9]

The Association of University Technology Managers ("AUTM") has collected data about the technology transfer process at U.S. universities since 1991. According to AUTM's data, numbers of invention disclosure, patent filings, and executed licenses by U.S. universities have steadily grown over the last 15 years. One of the drivers of this increase has been the effect of the Bayh-Dole-Act, introduced in 1980. The Bayh-Dole-Act assigned property of rights of government-sponsored research results to universities, thereby encouraging universities to pursue the economic benefits of research.[10] AUTM reported an average annual increase in invention disclosures of 6.8 per cent over a 10-year period from 1993 to 2002, totaling 15,573 new invention disclosures in 2002. During the same time, the number of patent filings and executed licenses rose by 10.3 per cent and 8.6 per cent, respectively, totaling 3,673 new patents and 4,673 executed licenses in 2002. These indicators show that commercialization of university knowledge has significantly grown over the last decade.[11]

Besides licensing, another way of transferring technology from universities to the public is the creation of a university spin-off company ("USO"). Rogers et al. claim that spin-offs "are a particularly effective means of technology transfer, leading to job and wealth creation."[12] In a USO, faculty members leave their research post and start a new company based on the technology they have developed in their research lab. The number of USOs has grown steadily over the last 15 years.

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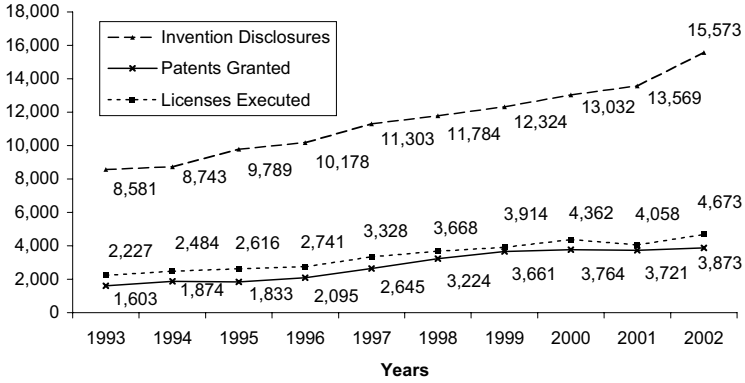
[9] See Saxenian (1994), p. 7, and Roberts and Malone (1996), p. 17.

[10] See Shane (2004), p. 127, Mowery and Ziedonis (2002), p. 399, and Mowery, Nelson, Pampat and Ziedonis (2001), p. 99.

[11] See AUTM (2003), pp. 10-11.

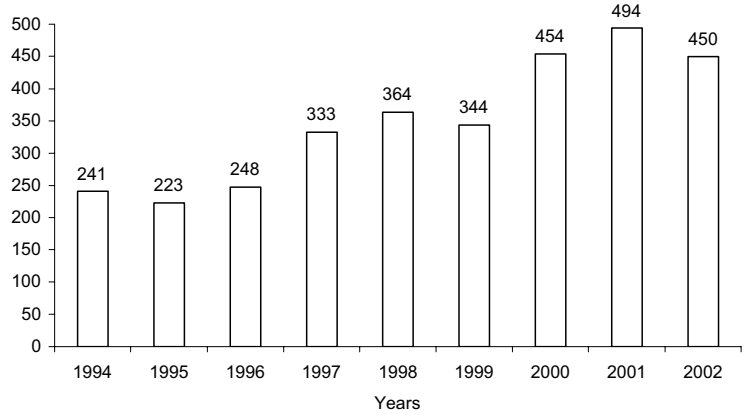
[12] See Rogers, Takegami and Yin (2001), p. 259.

Exhibit 1: Invention Disclosures, Patents Granted, and Licenses Executed by U.S. Universities



Source: AUTM (2003)

Exhibit 2: University Spin-Off Activity from 1994 - 2002



Source: AUTM (2003)

According to AUTM data, there were 450 new university spin-offs created in 2002, up from 223 in 1995, but slightly down from the peak of spin-off activity in 2000 and 2001, when 454 and 494 new spin-offs were created, respectively.[13] Over the period from 1994 to 2002, new spin-off creation increased by 8.1 per cent on average per year. In total, AUTM reported 4,320 companies being started by U.S. universities during a period from 1980 to 2002, of which 2,741 were still operative at the end of 2002.[14]

The universities most active in spin-off activities in 2002 were the University of California System, MIT and Stanford University, with 23, 23, and 13 new companies created, respectively.[15] There are numerous examples, in the United States, in Europe, and in Germany, where universities and politicians tried to mimic the successes of University of California, MIT and Stanford in their respective regions and capitalize knowledge to the benefit of the general public.[16] However, the success of these efforts varies significantly. Until today, it is not clear why some universities create more start-up companies and generate more wealth for their communities than others.

1.2. Problem Statement

The increase in university activity to commercialize scientific discoveries has spawned growing research interest in the phenomena of academic entrepreneurship and technology transfer.[17] However, the literature specifically on university spin-off

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[13] See AUTM (2003), p. 21.

[14] See AUTM (2003), p. 22.

[15] The University of California System reports number for all University of California campuses on a consolidated basis only. Based on anecdotal evidence, it is estimated that the campuses of Berkeley and San Diego are the most active in new spin-off generation, given their relative size and focus on the most relevant research fields such as computer science, biomedical science, and engineering.

[16] See Gray (1999), p. 1, BMBF (2004b), p. III.

[17] See Arrow (1962) and Jaffe (1989) for the foundations of this research stream. Arrow, in particular, elaborated at an early stage on the issue of resource allocation for research and the impact on the economy.

activity is not extensive, and findings are still preliminary. The research field as such is still in a relatively early stage.[18]

In particular, there is still little organizational analysis from the perspective of entrepreneurship research. Traditionally, entrepreneurship research has focused on individual and organizational entrepreneurial behavior in companies, mostly in small and medium sized companies, but also in large corporations. Entrepreneurial and managerial decisions and behavior in for-profit-organizations were in the focus. Only over the last decade, knowledge-based start-up activity has moved into the center of interest, hence, research on the behavior of university staff and organization is still limited. The present dissertation will focus on entrepreneurial activity within the university organization. The key question thereby being addressed is: To what extent is entrepreneurial orientation at the organizational level, i.e. at the level of the research unit,[19] important for start-up creation and technology transfer?

So far, universities have been looked at from perspectives of different economic theories, such as the resourced-based view, resource dependence theory, the theory of social embeddedness, and other economic and management approaches.[20] This dissertation will introduce the concept of entrepreneurial orientation into the discussion of organizational behavior at the research unit level.[21] It should illuminate the question how and why some academic research units are more entrepreneurial than others in a sense that they produce more discoveries, innovations, patents, and ultimately new start-up companies which create jobs and wealth.

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[18] See Clarysse and Moray (2004), Powers and McDougall (2004), and Shane (2004) for most recent findings.

[19] A research unit is defined as a group of researchers, headed by a principal investigator, conducting jointly research in a specific research field, such as research laboratory or a research center.

[20] See the contributions of Powers and McDougall (2004), Powers (2000), Wayne (2003), Clarysse and Moray (2004), Jensen and Thursby (2001), Di Gregorio and Shane (2003), and Bornemann and Mauer (2004).

[21] The theory of entrepreneurial orientation is primarily based on the work of Lumpkin and Dess (1996).

The economic literature has formulated a link between the concept of an entrepreneurial posture and academic research activities in a way that different specificities of entrepreneurial orientation might lead to different, more economically valuable results of research units.[22] This relationship between entrepreneurial orientation and entrepreneurial performance is at the center of this dissertation.

1.3. Purpose of Study and Research Gap

This study aims to provide more insight into the characteristics of a research organization, such as a research lab. These characteristics should enable research lab members, such as principal investigators or Ph.D. students, to act entrepreneurially and potentially enhance the technology transfer activities based on their research findings. The study measures the relationship between entrepreneurial orientation of a research unit, and satisfaction with regard to entrepreneurial performance.

More specifically, the study will measure how certain characteristics of a research organization positively or negatively influence the technology transfer process, or if they do not have any influence. These characteristics include autonomy, competetiveness, risk taking, innovativeness, interdisciplinarity, and proactiveness.

The phenomenon of the "second academic revolution" has provided stimulation for researchers to investigate the commercially oriented aspects of university behavior and commercialization of knowledge. At the same time, there has been progress made in the field of entrepreneurial-orientation research; however, emphasis in this field has been on for-profit-organizations, rather than on non-profit-organizations. This dissertation will apply the concept of entrepreneurial orientation for the first time to research university organizations.

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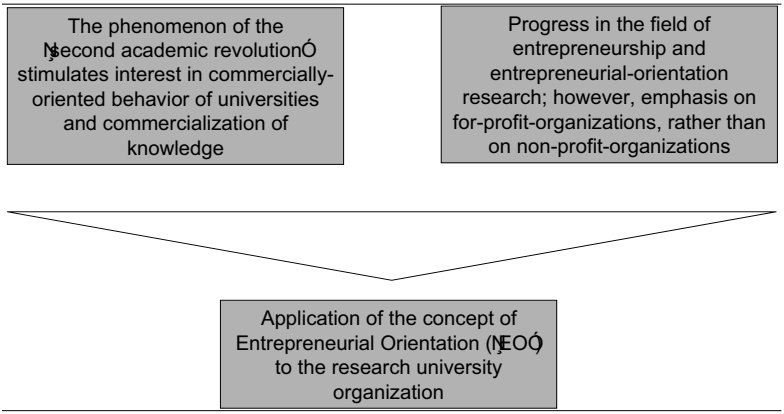
[22] Specificities of entrepreneurial orientation can be organizational characteristics such as autonomy, competitiveness, or risk taking. See Lumpkin and Dess (1996), pp. 138-151.

Murray argues that "while science-based entrepreneurial firms are a key feature of the modern economy, our insights into their organization and productivity remain limited. In particular, our understanding of the mechanisms through which academic investors shape entrepreneurial firms established to commercialize their scientific ideas is based upon a traditional perspective."[23]

Exhibit 3: Research Gap



Source: Own conception

These findings will be embedded in the context of the entrepreneurial role of universities and their contribution to society.

1.4. Plan of Dissertation

Chapter 1 introduces the subject of the dissertation, provides the problem statement, and explains purpose, research gap, and significance of the study. In addition, it presents an outline of the study.

[23] Murray (2004), p. 691.

In Chapter 2, the topic of the dissertation is put into context, and the fundamental terms are limited and defined. The purpose of this section is to introduce the uninitiated into the concepts of research universities, research units and their members, spin-offs and technology transfer. Further, it presents the historical perspectives of the development of entrepreneurial academia in the U.S., which is important for the understanding of the underlying problem. The role of U.S. research universities in the technology transfer process is described, and different aspects of entrepreneurial activities are illuminated.

Chapter 3 provides a review of the relevant literature of academic entrepreneurship, evaluates different theoretical frameworks, and establishes selection criteria regarding a theory for the empirical analysis. On this basis, a suitable theory for the analysis of the problem will be chosen.

Chapter 4 develops the conceptual model of this dissertation, and derives hypotheses. Further, it presents a measurement model for the various constructs, and demonstrates the operationalization of the model indicators.

Chapter 5 presents the statistical methodology of the study, including selection criteria for the model and data selection. It will contain information about different multivariate analytical tools, and assess why variance-based multivariate analysis is used for this dissertation.

In Chapter 6, data collection process and analysis will be described, the survey instrument will be developed, and results of the model will be estimated and tested.

Chapter 7 will ultimately discuss results, and present findings, recommendations, and limitations of the study.

1.5. Significance of Study

The results of this dissertation may provide further insight for decision makers in research labs, universities and government about how to manage and guide research

organizations. The implications are relevant both for organizations in the United States and in Germany. In particular in Germany, higher education is facing tremendous change, and conclusion can be drawn from the experiences in the U.S.

Professionally managed technology transfer, including enhanced patenting and spin-off activity, should be beneficial both for the respective research university, and its region and community. The importance of this study is underpinned by recent endeavors of the German federal government to boost technology transfer activities at German universities. In their 2001 government program "Wissen schafft Märkte", the German government stated its goal to professionalize the patent and technology transfer process. Key elements of this initiative are an improvement of the utilization of academic research results, an enhancement of university spin-off activities, stronger exchange between industry and academia, and more application of research innovation by smaller and medium-sized companies.[24] The efforts of the German government are reflected in the amendment of the employee invention act of 2002, which resembles the U.S. Bayh-Dole-Act and is hoped to create a similar increase in technology transfer as in the U.S. from 1980 onwards.

Technology transfer is of major importance for modern economies. The technology transfer process can be managed, and the goal of this study is to present an approach based on economic theory that can help to manage this process more effectively.

[24] See BMBF (2001), p. 2.

2. Context and Definitions

The purpose of this chapter is threefold. Firstly, it will position the dissertation within the field of entrepreneurship research. Entrepreneurship research has gained in importance over the recent years, and there are numerous areas of entrepreneurship science that have emerged and developed from pure exploration to a more grounded theory.

Secondly, this chapter will provide definitions and limitations of the relevant terms of this dissertation. As a basis for the theoretical and empirical part of the dissertation in Chapters 3, 4 and 5, this chapter will define the objects of investigation, i.e. research universities, research units, and their respective research members, and the processes of investigation, i.e. technology transfer activity and spin-offs.

Thirdly, this chapter will present the historical background of university development and technology transfer in the U.S. It will highlight the role change of higher education institutions from their inception in the 17th century to the introduction of the Bayh-Dole-Act in 1980 and the so-called "second academic revolution". This description is important for the understanding of entrepreneurial orientation and technology transfer at U.S. universities today.

2.1. Positioning

This dissertation aims to contribute to the understanding of the entrepreneurship phenomenon. Despite the increasing interest in general entrepreneurship theory over the last 20 years,[25] and the increasing importance of the industry-university relationships,[26] a common understanding of the notion of entrepreneurship amongst researchers is still lacking. "Entrepreneurship is a multifaceted phenomenon that cuts across

[25] See Shane and Venkataraman (2000), p. 217.
[26] See Mansfield and Lee (1996), p. 1047.

many disciplinary boundaries."[27] This is already reflected in the varying definitions of entrepreneurship: Schumpeter defined entrepreneurship as "carrying out new combinations."[28] Kirzner viewed entrepreneurship closely related to an arbitrage behavior and the ability to correctly anticipate where market imperfections and imbalances will be.[29] Cole saw entrepreneurship as a purposeful activity to initiate, maintain, and develop a profit-oriented business.[30] For Gartner, "Entrepreneurship is the creation of new organizations."[31]

Low and MacMillan commented that "the problem with these definitions is that though each captures an aspect of entrepreneurship, none captures the whole picture. The phenomenon of entrepreneurship is intertwined with a complex set of contiguous and overlapping constructs such as management of change, innovation, technological and environmental turbulence, new products development, small business management, individualism and industry evolution. Furthermore, the phenomenon can be productively investigated from disciplines as varied as economics, sociology, finance, history, psychology, and anthropology, each of which uses its own concepts and operates within its own terms of reference."[32]

An examination of the contents of the most relevant conference on entrepreneurship research highlights the diversity and breadth of topics covered in this field. The annual "Frontiers of Entrepreneurship Research" conference by the Babson College is the most highly regarded meeting of entrepreneurship researchers. In 2002, as much as 23 different areas were covered in the proceedings, ranging from opportunity rec-

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[27] Low and MacMillan (1988), p. 140.
[28] Schumpeter (1934).
[29] See Kirzner (1973).
[30] See Cole (1968).
[31] Gartner (1988), p. 26.
[32] Low and MacMillan (1988), p. 141.

ognition via venture capital to education.[33] In other terms, entrepreneurship research is very scattered and often times dependent on factual or anecdotal topics such as finance and venture capital.

The lack of a comprehensive entrepreneurship theory has been addressed by a number of researchers in the past.[34] More recently, Shane and Venkataraman demanded a conceptual framework of entrepreneurship theory.[35] This is particularly true in the area of entrepreneurship in academia, where research can be found by scholars of social sciences, science history, economics, business administration, and educational science.

Schmoch, for example, analyzes the interdependencies of university research and industry research from a sociological and system-theoretical perspective, and emphasizes the cooperative nature of technology transfer mechanisms.[36] Also from a sociological and urban development perspective, Saxenian elaborates on the regional impacts of entrepreneurship at universities and its influence on regional wealth creation.[37] Different from sociology, however with a great overlap with regard to the object of investigation, Etzkowitz's and Geiger's educational perspective illuminate the phenomenon of academic entrepreneurship. Etzkowitz as an educational researcher elaborates on the development of technology transfer at research universities and entrepreneurial science.[38] Geiger follows a more descriptive path in his historical approach.[39]

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[33] See Babson College (2002). Entrepreneurship topics include Nascent entrepreneurs and startups, Opportunity recognition, Characteristics, Knowledge, Networks, Gender, Ethnic, Family firms, Technology, Strategy, Economic growth and employment, Informal investors/angels, Venture capital, Initial public offerings, Banking/finance, Compensation/incentives, Corporate entrepreneurship, Spinouts/spinoffs, International, Failure/survival, Not-for-profit, Research, and Education.

[34] See Gartner (1988) and Low and MacMillan (1988).

[35] Shane and Venkataraman (2000), p. 217.

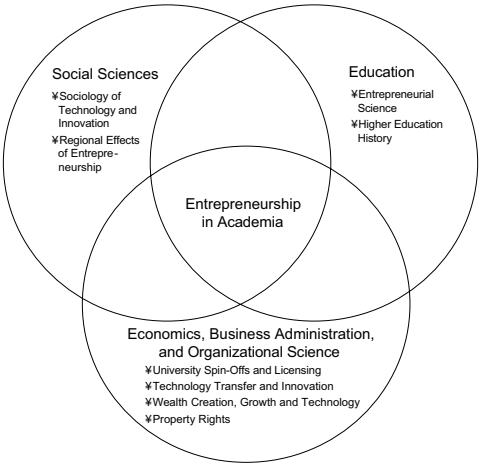
[36] See Schmoch (2003). The author is head of the department of technology analysis and innovation strategies at the Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe.

[37] See Saxenian (1994). Saxenian is dean of the school of information management and systems (SIMS) and professor in the department of city and regional planning at UC Berkeley.

[38] See Etzkowitz (2002), who is director of the Science Policy Institute and associate professor of sociology at the State University of New York at Purchase.

Another angle on entrepreneurship in academia is provided by research in the fields of economics and business. A number of economists have analyzed the impact of resource allocation into research and its effects on wealth creation and technical advancement, such as Arrow, and Rosenberg and Nelson.[40] This analysis was fundamental to more specific research in the field of university spin-off creation and technology transfer and innovation. The aspects of university patenting were, for example, investigated by Hendersen et al., and Jaffe and Lerner.[41] Feldman et al. analyzed the impact of equity participation of universities in spin-off companies, an approach backed by engineering and business researchers.[42]

Exhibit 4: Perspectives on Entrepreneurship in Academia



Source: Own conception

[39] See Geiger (1993) and Geiger (2004). The author is professor of education at Pennsylvania State University. His two principal fields of study are the history of American higher education and research universities.

[40] See Arrow (1962) and Rosenberg and Nelson (1994).

[41] See Henderson, Jaffe and Trajtenberg (1998) and Jaffe and Lerner (2001)

[42] See Feldman, Feller, Bercovitz and Burton (2002).

In summary, research on academic entrepreneurship is very much interdisciplinary, and different perspectives on the object of investigation illuminate different aspects of the phenomenon, adding thereby to a more holistic understanding. Exhibit 4 illustrates these different perspectives on academic entrepreneurship. Research on entrepreneurship amongst academics has grown in particular in the aftermaths of the start-up boom of the 1990s in the computer science, engineering and biotechnology industries.

The present dissertation is based on organizational theory of entrepreneurship. It views entrepreneurship "as the scholarly examination of how, by whom, and with what effects opportunities to create future goods and services are discovered, evaluated, and exploited."[43] Shane and Venkataraman list three sets of research questions representing organizational entrepreneurship research:

(1) Why, when, and how opportunities for the creation of goods and services come into existence

(2) Why, when, and how some people and not others discover and exploit these opportunities, and

(3) Why, when, and how different modes of action are used to exploit entrepreneurial opportunities.[44]

In this respect, the dissertation follows Schumpeter's approach on the entrepreneurial individual, Miller's approach's on the entrepreneurial organization, and Lumpkin and Dess' concept of entrepreneurial orientation.[45] This stream of research views entrepreneurship quite different to Brüderl, and does not solely focus on new companies.[46]

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[43] Shane and Venkataraman (2000), p. 218.

[44] Shane and Venkataraman (2000), p. 218.

[45] See Schumpeter (1934), Miller (1983), and Lumpkin and Dess (1996).

[46] See Brüderl (2004), p. 215. Brüderl defines entrepreneurship as follows: "Mit 'Entrepreneurship' bezeichnet man eine dynamische Form des Unternehmertums, die sich insbesondere (aber nicht ausschließlich) in Gründung und Management von neuen bzw. jungen Unternehmen niederschlägt."

In contrast, organizational entrepreneurship theory believes that entrepreneurship can occur in any organization, not only in newly created ones, and therefore is much more a general theory.[47]

The organizational stream of entrepreneurship research provides a framework for the more functional oriented fields of entrepreneurship research, such as entrepreneurial marketing, or entrepreneurial finance, and, in this sense, is much more related to strategy than to function. The functional approach on entrepreneurship often encompasses a business lifeline of a new company, beginning with the pre-start-up phase, seed, start-up, early growth, expansion, and exit. Entrepreneurship as it is viewed in this study has a more comprehensive perspective, including opportunity generation and organizational behavior aspects.

In summary, the present dissertation is part of the organizational branch of entrepreneurship research, which derives its foundations from the general organizational and strategy literature. Given the nature of the object of investigation – research universities –, there are cross-linkages to the research fields of educational science, social science, and economic science.

2.2. Definitions

In the following sections, key terms of this dissertation will be positioned in context and defined.

This definition bears a number of insufficiencies: Firstly, the terms "Entrepreneurship" and "Unternehmertum" are quite often used interchangeably; therefore, it is dilutive to explain one term using the other. Secondly, this definition focuses on the act of starting a company. There are numerous examples where entrepreneurship occurs unrelated of a new company. Pinchot (1985) showed that entrepreneurship could occur in large, established organizations. Phan (2004) asks for a distinct theory of the entrepreneurial firm, and argues that the largely phenomenological nature of the extant work – venture capital, innovation, network economics, psychology – creates impediments for the development of a general theory.

[47] See Pinchot (1985), p. 1.

2.2.1. Research University

This dissertation examines research universities in the U.S.[48] According to the Carnegie Foundation for the Advancement of Teaching, 3,941 higher education institutions were operative in the U.S. in the year 2000, educating more than 15 million students nationwide. The Carnegie Foundation classifies higher education institutions into the following categories:

- Doctoral or Research Universities
- Master's Colleges and Universities
- Baccalaureate Colleges
- Associate's Colleges
- Other[49]

According to the Carnegie Classification of Institutions of Higher Education, doctoral or research universities typically offer a wide range of baccalaureate programs, and are committed to graduate education through the doctorate. If they award 50 or more doctoral degrees per year across at least 15 disciplines, they are classified as extensive research universities. If they awarded at least 10 doctoral degrees per year across three or more disciplines, or at least 20 doctoral degrees per year overall, they are classified as intensive. Table 1 presents a breakdown of distribution of higher education institutions in the U.S., and their student enrollment.

Based on the Carnegie Foundation data, there were 261 research universities in the U.S. in 2000, of which 151 were extensive, and 110 were intensive. Research universities represent only 6.6 per cent of all higher education institutions, however, more than 28 per cent of students are enrolled with these top tier universities.

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[48] For further explanation of the term "research university", see Steffensen, Rogers and Speakman (2000), p. 96.

[49] See Carnegie (2001), p. I.

Table 1: Distribution of Higher Education Institutions and Student Enrollment by 2000 Carnegie Classification

	Number of Institutions		Student Enrollment			
Category	**Total**	**%**	**Average**	**Median**	**Total**	**%**
Doctoral/Research Universities	261	6.6	16,258	14,319	4,243,433	28.1
of which Extensive	151	3.8	20,672	20,016	3,121,462	20.7
of which Intensive	110	2.8	10,200	8,917	1,121,971	7.4
Master's Colleges and Universities	611	15.5	5,288	3,865	3,230,842	21.4
Baccalaureate Colleges	606	15.4	1,729	1,322	1,039,020	6.9
Associate's Colleges	1,669	42.3	3,785	1,681	6,041,946	40.1
Specialized Institutions	766	19.4	715	349	510,703	3.4
Tribal Colleges and Universities	28	0.7	530	369	13,253	0.1
Total	**3,941**	**100.0**	**3,961**	**1,617**	**15,079,149**	**100.0**

Source: Carnegie (2001)

This dissertation will focus only on a subset of these 261 research universities.

2.2.2. Research Unit

Studies of academic productivity or performance often concentrate on characteristics of individual research team members, such as age, training, or gender.[50] However, Stephan highlighted that such studies have a weak ability to explain research productivity due the collective nature of research.[51] Therefore, some academics suggest investigating academic research performance on an organizational level.[52]

U.S. research universities generally consist of a number of schools, or colleges, of different academic disciplines, such as a school or a college of liberal arts, a school of natural sciences, a school of engineering, etc. Each school or college is organized in different departments. E.g. the school of engineering comprises a department of bioengineering, a department of chemical engineering, a department of computer science, etc.

[50] See Carayol and Matt (2004), p. 1081.
[51] See Stephan (1996), p. 1199.
[52] See Dasgupta and David (1994), p. 487.

Within one department, faculty is responsible for teaching and research. In particular in natural sciences and engineering, where research is often based on experiments, research is conducted in research laboratories, or labs. Research labs often operate under the leadership of a principal investigator.

In contrast to a research laboratory that generally focuses on one single discipline, research centers are university-based entities whose purpose is to conduct scholarly investigation of an interdisciplinary nature. Research centers tend to draw to their faculty from a variety of departments.[53]

For the purpose of this dissertation, we define research unit as any entity that is led by a principal investigator and focuses on a specific research field, be it a laboratories, a research center, or a department.

Focusing on research units has a number of advantages for this study. It is observed that research units operate as firm-like entities, with the difference that research units are not profit-oriented, but rather result-oriented. An experienced professor, who formerly did research, but now devotes more time on organizational, administrative, or representative tasks, leads these units, usually consisting of seven or eight members. Often times, professors consider running their lab similar to "running a small business".[54]

Given the fact that research units have firm-like qualities, it is adequate to apply organizational theory derived from for-profit organizational research on them.

2.2.3. Research Unit Member

Although the emphasis of this dissertation is on organizational as opposed to individual behavior, information supporting the underlying survey is retracted from individ-

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[53] See Steffensen, Rogers and Speakman (2000), p. 96, for a definition on research centers.

[54] See Etzkowitz (2003), p. 111. Etzkowitz further indicates that principal investigators, in order to continue on a competitive level with their peers, maintain an organizational momentum.

ual members of an organization. Therefore, it is important to understand which types of individual researchers operate in biotech or high-tech research labs.

In general, under the leadership of a principal investigator, members of a research unit conduct research in their fields. Typically, research unit members are research associates, postdoctoral fellows, Ph.D. students, graduate students or undergraduate students.

Research associates have a Ph.D. degree and significant experience in doing research. The career path of a research associate is more focused on full-time research, in contrast to a professorial career which also implies a teaching component. Postdoctoral fellows ("post-docs") are researchers who have recently completed their Ph.D. degree and do research in a certain field of expertise for a number of years.

Ph.D. students are researcher who have completed an undergraduate and/or graduate degree, and who follow a curriculum designed to become a researcher with a doctoral degree (Doctor of Philosophy, Ph.D.). The Ph.D. curriculum is the typical education path for a future researcher, and usually lasts between 4 an 7 years.

Graduate students have completed their undergraduate, or Bachelor's, degree and pursue a graduate, or Master's, degree. A Master's degree is typically scheduled to be completed in 2 years. Often times, graduate students work in research labs if they plan to pursue a career in research.

Undergraduate students pursue their first academic degree, a Bachelor's degree. A Bachelor's degree usually takes 4 years. Similar to graduate students, undergraduate students which are interested in research start work in a research lab in parallel to their ongoing studies.

In short, a research unit is led and managed by a principal investigator who guides, instructs and mentors his research staff consisting of research associates, post-doctoral fellows, Ph.D. students, graduate, and/or undergraduate students. All this personnel, we define as members of a research unit for the purposes of this dissertation.

2.2.4. Technology Transfer

A definition of technology transfer should encompass a definition of the terms "technology" and "transfer". Bozeman pointed out that the term "technology" alone comprises definitional controversies, and suggests, with reference to Sahal, to view technology as a configuration including knowledge, processes, subjects and objects.[55]

Accordingly, a definition on technology transfer bears difficulties. Bozeman refers to technology transfer as the movement of know-how, technical knowledge, or technology from one organizational setting to another. At the same time, he acknowledges that definitions on technology transfer differ substantially across academic disciplines.[56]

Larsen and Wigand define technology transfer as "the process through which the results from basic and applied research are communicated to potential users."[57] Jaffe, relating to real effects of academic research, talks about "spillovers" from university research to commercial innovation.[58]

According to Steffensen et al., technology transfer involves (1) a source of technology that possesses specialized technical skills, and (2) the transfer of technology to receptors who do not posses these specialized skills and who cannot create the technology themselves.[59]

The study of the German Fraunhofer Institute and the U.S. National Academy of Engineering finds that universities' primary missions, both in the U.S. and in Germany, are education and research directed at the advancement of knowledge. The principal contribution of universities to the technical needs of industry is the formation of hu-

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[55] See Bozeman (2000), p. 628, and Sahal (1981), p. 2. Alternatively, Schmoch provides definitions and limitation on technology, technique, and science. See Schmoch (2003), pp. 23-35.

[56] See Bozeman (2000), p. 630.

[57] See Larsen and Wigand (1987), p. 587.

[58] See Jaffe (1989), p. 957.

[59] See Steffensen, Rogers and Speakman (2000), p.96.

man capital, i.e. highly educated, skilled science and engineering graduates. Consequently, the most important technology transfer channel from universities to industry is the movement of science end engineering graduates from one sector to the other.[60]

Another aspect of the technology transfer process is the role of a technology licensing office, or technology transfer office, which many universities have established over the last decade.[61] These offices support and assist researchers during the commercialization process of their inventions. According to AUTM, technology transfer activities include those activities associated with the identification, documentation, evaluation, protection, marketing, and licensing of technology and intellectual property management, in general.[62]

Rogers et al. provide a clearer definition of technology transfer and deliver a set of technology transfer mechanisms. They view *technology* as information that is put into use in order to accomplish some task. *Transfer* is the movement of technology via some communication channel from on individual organization to another. A technological innovation is an idea, practice or object that is perceived as new by an individual or some other unit. Therefore, *technology transfer* is the application of information (a technological innovation) into use. The technology transfer process usually involves moving a technological innovation from an R&D organization to a receptor organization. Different mechanisms enable technology transfer. These mechanisms are *spin-offs*, *licensing*, *publications*, *meetings*, and *cooperative R&D agreements*. In short, Rogers et al. view technology transfer as a special type of communication process.[63]

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[60] See Abramson, Encarnação, Reid and Schmoch (1997), p. 11.

[61] The number of technology licensing offices or programs has significantly increased since the introduction of the Bayh-Dole Act in 1980. In 1980, 23 technology licensing programs were active in the U.S. By 2002, a total of 149 programs had been established. See AUTM (2003), p. 7.

[62] See AUTM (2003), p.44.

[63] See Rogers, Takegami and Yin (2001), p. 254.

For the purposes of this dissertation, technology transfer will be defined according to AUTM: "Technology transfer is the term used to describe a formal transferring of new discoveries and innovations resulting from scientific research conducted at universities to the commercial sector".[64]

2.2.5. University Spin-Offs

The process of spinning off a company from a parent organization as part of technology transfer has been investigated by numerous researchers over the recent years. This has led to a number of nuances with regard to the definition of the term "spin-off" in general, and "university spin-off" in particular.[65]

Firstly, the term "spin-off" is often been used synonymously to the term "spin-out". Both hold that a new organization is created based on resources (people, technology, patents) of a parent organization. The term "spin-off" therefore relates to the notion that a parent organization is the origin of a new independent business activity.

Secondly, the term "start-up" is used to describe the phenomenon of new company creation, although it does not reflect the fact that a parent organization is quasi generating a new venture creation process. A start-up in the narrow sense could also be an independently created new company without a parent organization. Although some researchers do not differentiate between the semantics of "spin-offs" versus "start-ups"[66], others draw precise line based on different perspectives on spin-offs.[67]

There are two salient questions with regard to universities and spin-off companies:

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[64] See AUTM (2004)

[65] For a comprehensive review of existing spin-off definitions, see Pirnay, Surlemont and Nlemvo (2003), p. 357.

[66] Smilor, Gibson and Dietrich (1990), and Abramson, Encarnação, Reid and Schmoch (1997), e.g., do not differentiate greatly between these terms, given that most spin-out companies are technology start-ups.

[67] Nicolaou and Birley (2003), e.g., present a review of existing definitions, and further differentiate between orthodox, hybrid, and technology spin-offs. Hague and Oakley (2000), pp. 5 and 7, differentiate clearly between spin-offs and start-ups.

(1) Why are universities so important for spinning-off companies? According to Smilor et al., universities are particularly important as a source of personnel and ideas during formation and development of the company, and as a source of consultants and research expertise as the company grows.[68]

(2) Why are spin-offs so important for the technology transfer process? According to Rogers et al., spin-offs are a particularly effective means of technology transfer, resulting in job and wealth creation.[69]

One angle to specify spin-offs relates to the parties involved in the spin-off process. In this context, Roberts and Malone identified four possibly involved parties: (1) the parent organization from which the technology is extracted, (2) the technology originator who brings the technology from basic research to a point at which technology transfer can begin, (3) the entrepreneur who attempts to create a new venture based on this technology, and (4) a possible investor who provides funding.[70] The roles of the technology originator and the investor are not necessarily required, given that the entrepreneur often times acts as technology originator, and at the same time provides funding. Therefore, the essential actors in a spin-off are the parent organization and the entrepreneur.[71]

With regard to the parent organization, research was initially more focused on spin-off activity resulting from large corporations and national laboratories. Already in the late 1960s and early 1970s of the last century, the first studies point to the spin-off phenomenon. Roberts examined spin-off activity from MIT laboratories.[72] Cooper focused on

[68] See Smilor, Gibson and Dietrich (1990), p. 63.
[69] See Rogers, Takegami and Yin (2001), p. 259.
[70] See Roberts and Malone (1996), p. 1.
[71] See Djokovic and Souitaris (2004), p. 5-6.
[72] See Roberts (1968), p. 249.

corporate spin-off activity in Northern California.[73] Carayannis et al. examine a number of high-tech spin-off processes from U.S. and Japanese government laboratories.[74]

Over the last 15 years, the focus shifted more towards university based spin-off activity.[75] The nature of the parent organization can therefore be used as a first criterion to differentiate between spin-offs. Depending on whether the parent organization is a university, a corporation, or another organization, the literature differentiates between university spin-offs ("USO"), corporate spin-offs, or other spin-offs.

From a general perspective on actors in the spin-off process, Smilor et al. define spin-offs as a new company formed (1) by individuals who were former employees of a parent organization, and (2) which is based on a core technology that is transferred from the parent organization.[76]

More specifically on USOs, Smilor defines a spin-offs in two ways: (1) the founder was a faculty member, staff member, or student who left the university to start a company or who started the company while still affiliated with the university; and/or (2) a technology or technology-based idea developed within the university.

Steffensen et al. agree that the term "spin-off" describes a newly established entity that arises from a parent organization.[77] Typically, an employee leaves a parent organization and takes along a technology that serves as basis for the new company in a high-technology industry.

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[73] See Cooper (1971), p. 2.

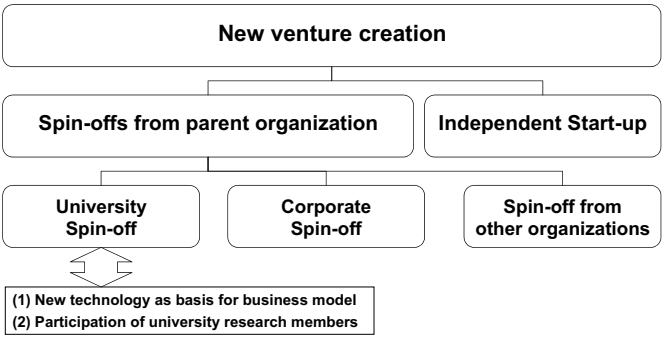
[74] See Carayannis, Rogers, Kurihara and Allbritton (1998), p. 1.

[75] Often times, university focused research is more anecdotal and based on case studies. E.g. Smilor, Gibson and Dietrich (1990) examine the University of Texas at Austin, Chrisman, Hynes and Fraser (1995) focus on the University of Calgary, Steffensen, Rogers and Speakman (2000) assess spin-off activity at the University of New Mexico, and Kenney and Goe (2004) examine professorial entrepreneurship at University of California at Berkeley and Stanford University.

[76] See Smilor, Gibson and Dietrich (1990)

[77] See Steffensen, Rogers and Speakman (2000), p. 96.

Exhibit 5: Definition and Limitation of University Spin-off



Source: own conception, Bornemann and Mauer (2004)

AUTM, however, refers to "start-ups" companies rather than "spin-offs", and claims that "start-ups companies have historically been a major part of the innovation process as established firms frequently are unable to embrace new technologies that have the potential to render their existing investments and technologies obsolete."[78] AUTM defines start-up companies as "companies that were dependent upon licensing the institution's technology for initiation."[79]

Nicolaou and Birley provide a definition of USOs, using the following criteria: (1) transfer of a core technology from an academic institution into a new company, and (2) founding members may include the inventor academics who may of may not be currently affiliated with the academic institution.[80]

For the purposes of this dissertation, the definition of USOs is based on two elements: (1) a new technology that is the basis of the business model of the newly established

[78] See AUTM (2003), p. 21.
[79] See AUTM (2003), p. 44.
[80] See Nicolaou and Birley (2003), p. 340.

company, and (2) participation of university-research members who leave university and start working in a newly established company. The existence of one of the two elements is sufficient to define a new company as a university spin-off.

2.2.6. Summary of Definitions

To conclude this chapter, the following Table 2 summarizes the terms defined for the purpose of this dissertation:

Table 2: Terms and Definitions

Terms	Definition
Doctoral/Research University	Universities that offer a wide range of baccalaureate programs, and are committed to graduate education through the doctorate. Typically, they award 10 to 50 or more doctoral degrees per year across 3 to 15 or more disciplines, they are classified as extensive research universities
Research Unit	Any organizational unit (e.g. laboratory, research center, or department) that is led by a Principal Investigator ("PI") and focuses on a specific research field
Research Unit Member	All members of a research unit including the PI; the PI guides, instructs and mentors the members of his RU; research members are research associates, post-doctoral fellows, Ph.D. students, graduate, and/or undergraduate students
University Spin-Off ("USO")	A newly created company based on (1) a new technology that is the basis of the business model (2) participation of university research members who leave university and start working in the company Existence of one of the two elements is sufficient to define a new company as a university spin-off
Technology Transfer ("TT")	Formal transferring of new discoveries and innovations resulting from scientific research conducted at universities to the commercial sector".

Source: Carnegie (2001), AUTM (2003), own definitions

2.3. Role of U.S. Universities for Technology Transfer

Having defined the key terms of this dissertation, the following section will present an overview of the role of universities in technology transfer and academic entrepreneurship. As already indicated in the introductory chapter, the role of research universities in the U.S. has developed over the course of the last two centuries. In particular, major changes with regard to academic entrepreneurial activity have taken place over the last 25 years.

The following sections will provide a description of the historical development of universities from inception to present, elaborate on the effects of the change in the federal patent act - the Bayh-Dole Act of 1980 -, then examine the notion of the second academic revolution, and illuminate the phenomenon of university spin-offs.

2.3.1. Historical Development of Universities in the U.S.

Technology transfer and industry-university relationships are not an invention of the 1990s. As a matter of fact, these relationships go back to the very first days of university creation in the U.S. Traditionally, universities were organized in colleges, following the English role models of Cambridge and Oxford. Harvard and Columbia, founded in the 17th and 18th century, exemplify classical teaching colleges in its origins. In parallel to these colleges, so called "land grant" universities were created in the 19th century, training students in agricultural science and related mechanical sciences.[81] Agriculture was at that time the leading industry in the U.S. and the biggest sector for employment. The University of Connecticut was one of the first universities established on the basis of land grant.[82]

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[81] The underlying legislation was the Morrill Act of 1862, the "land grant act", that provided federal lands to each state to sell in support of universities. The Hatch Act of 1867 and the Smith Lever Act of 1918 built on the Morrill Act and provided further research funds and technology transfer capabilities.

[82] See Etzkowitz (2002), pp. 24-25.

In addition to traditional colleges and land grant universities, polytechnic institutes were established during the later half of the 19th century, influenced by a similar movement in Europe.[83] In the focus of polytechnic institutes were engineering disciplines, driven by the industrialization of society at that time. Over time, these three streams of higher education (classical teaching colleges representing arts and sciences, land-grant universities representing agriculture, and polytechnic institutes representing engineering), merged into what is today called "research universities". Most of the 151 research universities of the Carnegie Category 1 offer education and research in a broad array of scientific disciplines across liberal arts, sciences and engineering.[84]

Relationships between industry and university existed prior to World War II, mostly based on personal contacts between faculty members and companies who needed scientific advice and hired professors as consultants. Large payments to the university, however, occurred more for philanthropic reasons, rather than based on business reasons.[85] During the 1930s recession, however, industry support further declined, and the importance of government as pre-eminent sponsor of research activities increased.

One of the key personalities for the advance of technology transfer and the emergence of the science-based company in the U.S. was Vannevar Bush, professor and later vice-president and dean of the engineering department at MIT. Bush adumbrated the model of the entrepreneurial academic as consultant, patent holder and firm founder, when he was involved in the creation of companies such as Raytheon Corporation and Spencer Thermostat, which later became part of Texas Instruments. The vision of Vannevar Bush and his Boston academic colleagues led to the creation of "research row", a location for technology firms on Cambridge's Memorial Drive between MIT

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[83] The origins of RWTH Aachen are an example of this movement.

[84] The Carnegie Classification includes all colleges and universities in the U.S. that are degree-granting and accredited by an agency recognized by the U.S. Secretary of Education. See Carnegie (2001), p. 1.

[85] See Etzkowitz (2002), p. 13. An example for strong involvement of an individual sponsor in creating a university is the case of Leland Stanford, former governor of California and railroad businessman. Stanford contributed significant amounts of his personal wealth to found Stanford University in 1891.

and Harvard. In addition, the first U.S. venture capital firm American Research and Development ("ARD"), established by Harvard Professor Georges Doriot, laid the foundation for future availability of funds and expertise to establish a region known as Route 128 that should succeed largely after World War II.

A similar movement was established in California, when Bush's Ph.D. student Frederick Terman arrived at Stanford University in 1925 as a professor of electrical engineering and brought the MIT model for academic-industrial relationship to Stanford. Terman was instrumental in the creation of Hewlett & Packard, a company created by his students William Hewlett and David Packard in 1939, based on Hewlett's Ph.D. thesis in Terman's seminar.[86]

During World War II, Vannevar Bush, then Head of the Carnegie Institute of Washington, and James Conant, President of Harvard University, advocated that academic science could be used to develop technology for military purposes, and successfully lobbied the government to found an agency to support this research. The goal was not to establish a research institute, but rather to use federal resources to support universities. The Office of Scientific Research ("OSRD"), headed by academics, was established to oversee this effort. Several major universities, such as MIT, Johns Hopkins, Chicago, and the University of California, received contracts to administer government laboratories during the war. MIT became one of the main centers of wartime research due to its technical capacity, initiative and administrative experience.[87]

One example of MIT's work is the Radiation Laboratory, the so-called Rad Lab, established under the OSRD in 1940 to improve radar technology. The Rad Lab was the

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[86] See Bygrave and Timmons (1992), p. 239. Terman acted not only as a mentor and motivator to Hewlett and Packard, but also provided them with the intial $538 to start their business, and helped them negotiate a $1,000 bank loan. See Rogers and Larsen (1984), pp. 31-35.

[87] See Etzkowitz (2002), pp. 46-48.

first large-scale interdisciplinary and multifunctional R&D laboratory established at a university, integrating research, development, and production in one site.[88]

The conduct of military research in these times, integrating theorists and engineers from diverse disciplines to accomplish common tasks, transformed organizational structures and policies at major universities. Close cooperation between university, industry and military reshaped the role and function of university. As a result, universities became a major institutional sector of U.S. society.[89] They also benefited economically, with a number of researcher increasing to record levels during war times.[90] Vannevar Bush in his role as leading science administrator put forward the case for a strong permanent support by the federal government for U.S science after the war.[91]

Consequently, after 1945, ties between universities and government were to be renewed. Government research funds spread into health-science in addition to technical and military-relevant fields. Scientists continued to participate in interdisciplinary research and interacted with military officers, industrial managers and policy makers, thereby adopting a more socially responsible role outside the laboratory.

Governmental support was placed on a competitive basis and was decided rather on scientific quality than meeting local needs, as it was aimed at in the land grant model.[92] Agencies like the National Science Foundation and the National Institute of Health were established and act as major sources of funding until today.[93] Federal

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[88] See Etzkowitz (2002), p. 50.

[89] One of the most relevant endeavors was the Manhattan Project, which developed the atomic bomb as a result of a broad interdisciplinary effort. See Rosenberg and Nelson (1994), p. 334.

[90] See Etzkowitz (2002), p. 52. Staff and students at MIT amounted to 680 and 3,100, respectively, in 1939. During war times, in 1945, these number rose to 1,165 and 6,200, respectively.

[91] See Bush (1945), p. 1., in his famous speech to President Roosevelt "Science – The Endless Frontier".

[92] See Etzkowitz (2002), p. 54. As a consequence, government funded academic research found its way mostly to the two coasts, i.e. the North East and California, with some areas in the Mid-West.

[93] See Powers (2000), p. 10.

funding for academic research increased to 73% of total research funding by 1965, when it started to decline slightly.

Table 3: Support for Academic R&D in the U.S., by sector, 1955-2000 (millions of current $)

	Source of Support (in millions of current $ and per cent)											
Year	**Total**		**Federal Gov-ernment**		**State/local government**		**Industry**		**Academic Institutions**		**All other sources**	
1955	342	*100*	191	*55.8*	50	*14.6*	27	*7.9*	42	*12.3*	32	*9.4*
1960	705	*100*	453	*64.3*	90	*12.8*	40	*5.7*	67	*9.5*	55	*7.8*
1965	1,595	*100*	1,167	*73.2*	150	*9.4*	42	*2.6*	136	*8.5*	101	*6.3*
1970	2,418	*100*	1,686	*69.7*	237	*9.8*	66	*2.7*	259	*10.7*	171	*7.1*
1975	3,570	*100*	2,400	*67.2*	348	*9.7*	118	*3.3*	432	*12.1*	272	*7.6*
1980	6,455	*100*	4,335	*67.2*	519	*8.0*	264	*4.1*	920	*14.3*	419	*6.5*
1985	10,308	*100*	6,388	*62.0*	834	*8.1*	630	*6.1*	1,743	*16.9*	713	*6.9*
1990	16,936	*100*	9,936	*58.7*	1,399	*8.3*	1,166	*6.9*	3,187	*18.8*	1,249	*7.4*
1995	22,599	*100*	13,580	*60.1*	1,750	*7.7*	1,547	*6.8*	4,108	*18.2*	1,616	*7.2*
2000	30,154	*100*	17,475	*58.0*	2,197	*7.3*	2,310	*7.7*	5,969	*19.8*	2,203	*7.3*

Source: NSB (2004a)

Rosenberg and Nelson argue that with the strong expansion of funds allocated to university research, and the great role of government sponsoring, the character of university research shifted dramatically from a focus on application orientation during war times, now to a focus on basic research.[94]

Spending on military research during the 1940s and 1950s had resulted in innovations both for civil and military purposes.[95] However, over time up into the 1970s, it became a tacit agreement between the federal government and universities that scientists would be given considerable autonomy to pursue research with little requirement of practical application or economic relevance.[96]

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[94] See Rosenberg and Nelson (1994), p 335. By the 1960s, the U.S. were leading in most of the academic fields as to statistics of Nobel laureates.

[95] See Etzkowitz (2002), p. 53.

[96] See Powers (2000), p. 10.

During the economically sluggish years of the 1970s, lawmakers tried to realign academic research to make their achievements better available to the general public. One of results of these endeavors was the Bayh-Dole Act of 1980.

2.3.2. The Impact of the Bayh-Dole Act of 1980

The Bayh-Dole Act of 1980 allocated intellectual property rights of federal-sponsored research results to the university in which the discovery was made. Prior the 1980, government agencies who funded research owned these rights and were in charge to use or dispose of them, which they occasionally did. Given the notion that government-sponsored research should be made available to serve the public good, however, government agencies where often reluctant to grant companies an exclusive license on a certain discovery, as opposed an open license that could be granted several times. This resulted in companies not acquiring the license at all, given that only an exclusive license would give them a competitive advantage.[97]

The Bayh-Dole Act solved this dilemma, allocated property rights definitively, and provided universities with the opportunity of another source of income. The latter purpose was important given that the portion of federal sponsoring for research had reached historical heights (between 67 and 69% during the 1970s, as per Table 3), and the general fiscal budgetary situation was deteriorating during the 1970s. A monetary incentive should help universities to steer their research more into applied research, thereby creating stimulus for the general economy.[98] In addition, the Act should benefit small companies in particular, stating them as the key target group for the acquisition of university patents, and providing them with privileged access to university research.[99]

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[97] See Etzkowitz (2002), p.113. Etzkowitz calls this dilemma a "classic free-rider effect."
[98] See Powers (2000), p. 10.
[99] See Etzkowitz, Webster, Gebhardt and Terra (2000), p. 318.

In the year following the introduction of Bayh-Dole, university licensing increased significantly.[100] AUTM started recording university licensing data in 1991, and confirms that total patents filed increased from 2,469 in 1991 to 12,929 in 2002.[101] Shane suggests that the Bayh-Dole Act indeed provided incentives to increase patenting in those fields in which licensing is an effective mechanism for acquiring new technical knowledge.[102]

Although on the first glance the arguments speak for a strong success of the Bayh-Dole Act, there is a debate among academics whether the Act truly impacted licensing behavior at U.S. universities. A number of studies argue that the Bayh-Dole Act was not or not to the extent claimed responsible for the increase in academic entrepreneurial activity.[103]

Other countries have followed the underlying idea of the Bayh-Dole Act, such as the United Kingdom in 1985 by changing the law regarding the British Technology Office,[104] and Germany with the Introduction of the Employee Invention Act of 2002.[105] Consequently, the phenomenon of a "dramatic" increase in patenting activity might be observable again in these countries over the next years.

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[100] See Jensen and Thursby (2001), p. 240, describing the increase as "dramatically."

[101] See AUTM (2003), p. 11.

[102] See Shane (2004), p. 127.

[103] See Henderson, Jaffe and Trajtenberg (1998), p. 119, who suggest that rate of increase of important patents was much less than the overall rate of increase in patenting, and Mowery, Nelson, Pampat and Ziedonis (2001), p. 99, who suggest that the Act was only one of several important factors behind the rise of university licensing and patenting activity.

[104] See Etzkowitz, Webster, Gebhardt and Terra (2000), p. 319. In 1985, universities were given the right and responsibility to exploit their intellectual property by securing property rights to ensure government funded work was transferred to the private sector. The devolution of right from the government agency British Technology Group (BTG) to universities was intended to help universities generate income, and to contribute to national wealth creation.

[105] See BMBF (2002), p. 1. Until the recent change in German legislation, the academic inventor had the intellectual rights in inventions based on federal-sponsored research. Under the new legislation, the Employee Invention Act (Arbeitnehmererfindungsgesetz, ArbNErfG), the invention will be intellectual property of the university, however, 30% of economic proceeds will go to the inventor.

2.3.3. The Second Academic Revolution

Increases in the commercial activities of universities, in patenting and spin-offs, and in the research literature covering these issues support the argument that university research policies have undergone fundamental change over the last 25 years. Etzkowitz describes this phenomenon as the "second academic revolution", adding commercialization to the historic pillars of teaching and research to the universities' purpose.[106]

Another term frequently used in this debate is the "triple-helix" by Etzkowitz and Leydesdorff, referring to university-industry-government dynamics. They argue that the future location of research and technology transfer resides in the triple-helix, constituting thereby a "socio-technical world" in the course of invention, innovation, and policy implementation.[107]

One indicator for the fact that universities are embracing the notion of a second academic revolution was the increase in technology transfer programs at universities. According to AUTM data, by 1980, 23 universities in the U.S. had established technology transfer programs. After the introduction of the Bayh-Dole Act, the number increased rapidly by average of 6 programs per year. In 2002, there were 151 active programs with U.S. universities.

Another important argument of the increasing commercialization of academic inventions is the monetary effect of license income and the sale of equity holdings in USOs. Licensing income from patented inventions is a supplementary stream of income to universities, and can provide an alternative in times of reduced government funding. Licensing income is received from companies, most small businesses or new companies, who use the technology developed by university researchers.

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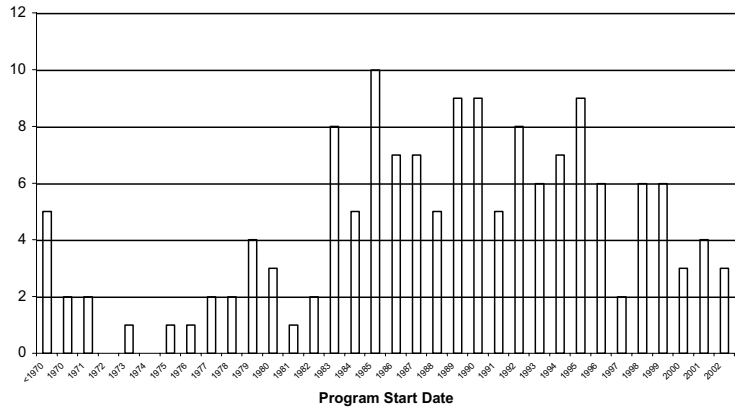
[106] See Etzkowitz (2002), pp. 9-19.
[107] See Etzkowitz and Leydesdorff (1999), pp. 111-112.

Exhibit 6: Technology Transfer Program Start Date of U.S. Universities



Source: AUTM (2003)

A number of universities benefit quite substantially from their license income. Columbia University earned $157 million in 2002 on license income, contributing 8.2 per cent to Columbia's total budget of $1.895 billion. Stanford earned $50.2 million from this source, with a total budget of more than $2 billion in 2002.[108] Based on AUTM data, its 151 reporting U.S. universities received a total of $945 million from licensing revenues in 2002.[109]

However, it is not the case that every university in the U.S. recognizes strong income from its licensing activities. Of the $945 million licensing revenues, the 10 strongest earners gathered 60 per cent of all revenues; the top 20 earned a combined nearly 80 per cent, and the top 50 nearly 95 percent.[110] In other terms, the lower 100 universities

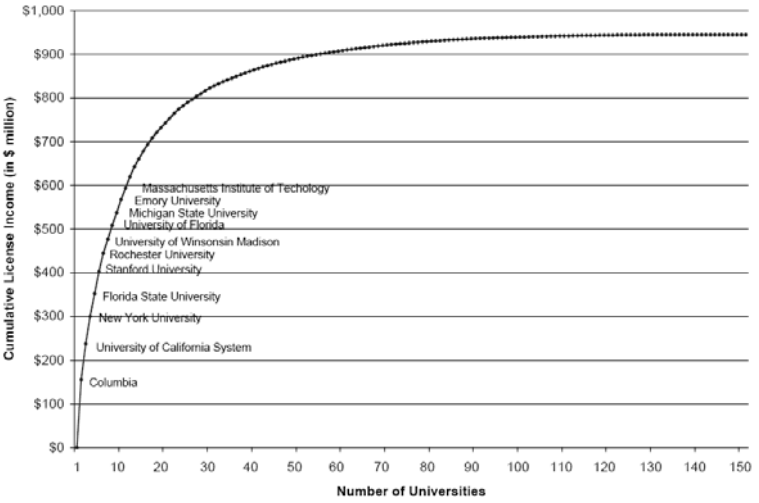
[108] AUTM (2003), p. 113, Columbia (2003), p. 3, and Stanford (2003), p. 26.

[109] Under AUTM's definition, license income received includes license issue fees, payments under options, annual minimums, running royalties, termination payments, the amount of equity received when cashed-in, and software and biological material end-user license fees. AUTM (2003), p. 42.

[110] AUTM (2003), p. 113.

collected only 5 per cent of all licensing income of the U.S. university system. Exhibit 7 illustrates these numbers. Also, to put these numbers into perspective, the bulk of these revenues stem from single so-called blockbuster licenses.[111] AUTM states that of the more than 20,000 active licenses, only 145 licenses generate more than $1 million of annual income.[112]

Exhibit 7: Cumulative License Income of U.S. Universities, 2002



Source: AUTM (2003)

Another income stream for universities is the disposal of equity holdings in university spin-offs. In the first years after Bayh-Dole, universities viewed equity participation

[111] Powers and Campbell (2003), p. 8, list a number of blockbuster licenses, such as the Hepatitis-B vaccine license of University of California, chemo-therapeutic drug Taxol of Florida State University, chemo-theropeutic drug Cisplatin of Michigan State University, and Gatorade formula and trademark of University of Florida. See also Grimes (2004) for a list of recent university inventions.

[112] AUTM (2003), p. 20.

as compensation mechanism of last resort, and generally preferred a cash payment rather than an equity position.[113] Given that these young companies are often cash flow weak, accepting equity positions in these companies has emerged as a technology transfer mechanism.[114]

During the period of depressed stock market in 2001 and 2002, cashing-in these equity holdings was rather subdued. Recent successes, however, such as the initial public offering of Google Inc., raise the hopes that equity participation will provide better returns than license income.[115]

2.3.4. Conflict of Interest between Research and Commercialization

The scope of this dissertation is limited to the relationship between entrepreneurial orientation of universities and technology transfer performance. Hence, one of the basic assumptions of this relationship is that technology transfer and commercialization as such is something that is desirable and beneficiary to society.

This assumption is not undisputed in the general literature. There is a debate between the freedom of research and the intrinsic desire to generate competitive advantage by limiting access to information to those who want to exploit it economically.[116]

In fact, the increase of entrepreneurial activity within academia has raised concerns that the research orientation of universities might become "contaminated" by the application-oriented needs of industry. Van Looy et al., however, argue that empirical evidence on this concern is scarce and ambiguous, and rather suggest that both activi-

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[113] See Feldman, Feller, Bercovitz and Burton (2002), p. 109.

[114] See Feldman, Feller, Bercovitz and Burton (2002), p. 105.

[115] See Grimes (2004). Stanford University owned stock valued at $179.5 million in Google, Inc. Google is a university spin-off that licensed the technology developed by the founders when they were Ph.D. students at Stanford University. Stanford University took an equity position as compensation for the license.

[116] See Press and Washburn (2000)

ties do not hamper each other. [117] Nevertheless, an in-depth discussion about the pros and cons of academic entrepreneurship exceeds the scope of this study.

[117] See van Looy, Ranga, Callaert, Debackere and Zimmermann (2004), p. 425.

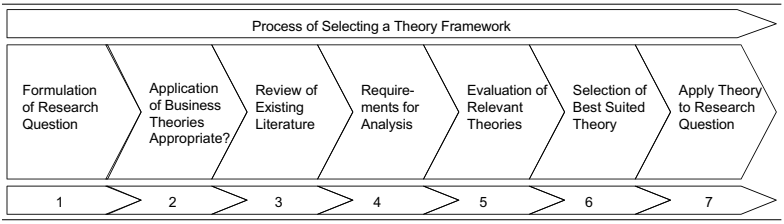
3. Theoretical Framework and Literature Review

3.1. Overview

The previous chapter presented the historic development of the relationship of academia and entrepreneurship in the U.S. and its status quo. In addition, it positioned this dissertation within different perspectives of entrepreneurship and technology transfer research, and defined the relevant terms. In this chapter, a theoretical framework will be derived from the existing literature and identified as a basis for the investigation of academic entrepreneurial behavior. Exhibit 8 illustrates the selection process of the theoretical framework.

The dissertation's underlying question addresses entrepreneurial behavior in academic organizations. Therefore, it will be discussed, as a first step, to what extent economic organizational theory should be applied to academic research institutions, and whether this procedure is well founded. As a second step, the existing literature on the specific issue of entrepreneurship in universities will be presented and analyzed.

Exhibit 8: Theoretical Framework Selection Process



Source: Own conception

The spectrum of theory alternatives how to approach this problem includes theories such as the resource-based view of the firm, resource-dependency theory, organizational contingency theory, theory of entrepreneurial intent, organizational configurative theory, theories of market orientation and of entrepreneurial orientation, theory of

social embeddedness and opportunity recognition theory, and theory of entrepreneurial attitude.

A relevant set of dimensions of these theories will be evaluated and compared. Based on the problem requirements, one theoretical approach will be selected upon which the further investigation will be conducted.

3.2. Application of Entrepreneurial and Organizational Theory to Academic Organizations

By applying entrepreneurial and organizational theory to academic organizations, one immediate concern is the question whether the application as such is appropriate. Above all, academic non-profit research organizations differ quite substantially from profit-seeking capitalist companies from which these theories were initially derived.

The issue of appropriateness can be illuminated from different perspectives. Firstly, the environmental element of universities is of importance for an appropriate theory. Secondly, organizational factors have to be taken into consideration. Thirdly, behavioral aspects of life in an academic research organization compared to business organizations have to be assessed. And finally, a retrospective of the existing literature will provide guidance.

With respect to the operative environment of university organizations, Etzkowitz et al. argue that universities have undergone and will continue to undergo a substantial transformation from the function of knowledge production to a socio-economic function within the contemporary innovation process.[118] Universities will find themselves more than ever involved in R&D efforts coordinated between corporate research centers, government laboratories and universities. In other words, function and demands

[118] See Etzkowitz, Webster, Gebhardt and Terra (2000), p. 326.

have changed, which puts university organizations on a more level playing field with other non-university organizations.

In addition to this change in external demands, competition or competitive behavior between universities will increase. Powers argues that "conceptualizing of universities as being in a competitive environment with their peer institutions is appropriate given current realities. … One manifestation of which is having to compete for reduced financial resources … or for top quality students. … Furthermore, a culture of competition has also emerged attributable to annual rakings published by high profile news magazines."[119] Using resource-focused theories, scholars have tried to explain university's behavior and endeavors to access and secure federal and private funds, industry contracts and tuitions.[120] Consequently, the fact that universities operate in a competitive environment makes it logical that this phenomenon is investigated using business, economic or management theories.

Thirdly, some researchers argue that labor organization in a research lab does not differ significantly from business organizations. In another research piece, Etzkowitz states that "the internal organization of the Research University consists of a series of research groups that have firm-like qualities, especially under conditions in which research funding is awarded on a competitive basis. Thus, the Research University shares homologous qualities with a start-up firm even before it directly engages in entrepreneurial activities."[121] In fact, there is evidence that professors consider heading and administrating a research lab as essentially being similar to leading a start-up company, with the difference that the organization's goal is research, publishing and patenting, rather than profit-maximization.

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[119] Powers (2000), p. 34. Powers also mentions increasing competition from new entrants to the higher education industry, such as online universities.

[120] See Wayne (2003), p. 40.

[121] Etzkowitz (2003), p. 109.

As a final argument why business theory should be applied to university organizational questions, it shows that historically numerous researchers have successfully worked with various business theories and contributed valuably to the overall understanding of higher education organizations.[122]

3.3. Literature Review

In order to derive an adequate theory for the analysis for entrepreneurship, technology transfer, and spin-off activity at universities, the existing literature on the subject was thoroughly reviewed. The review resulted in a selection of articles and publications in entrepreneurship-focused journals, such as the Journal of Business Venturing and Entrepreneurship Theory & Practice, and higher-education-focused journals, such as Research Policy. The review, however, was not limited to these journals, included publications from the U.S., the U.K. and Germany, and published and unpublished dissertations.

A total of 31 relevant publications on this subject were identified and analyzed in detail. Table 4 provides brief summaries of these publications, including information on author names, research method, underlying theory, context of the study, and key findings.

Of these 31 publications, 19 (or 61 per cent) had a U.S. or Canadian analysis background, i.e. the objects of investigation – universities, researchers, or technology officers – were located in the U.S. or in Canada. 9 studies (29 per cent) observed non-U.S./Canadian universities, mostly in Europe, but also in Israel and Australia. 3 studies (10 per cent) examined phenomena both in the U.S./Canada and outside the U.S./Canada.

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[122] E.g. Powers (2000) applied the resource-based view, resource-dependency theory, and the revenue theory of costs, Wayne (2003) applied resource-dependency theory to universities, Lilischkis (2001) applied transaction cost theory.

The bulk of these studies are of very young age. 23 out of 31 (74 per cent) were published between 2000 and 2005, indicating the relatively new state of research in this field. 6 out of 31 studies (19 per cent) were published during the 1990s, whilst only two of the as immediately relevant identified works are dated earlier than 1990 (6 per cent).

The age distribution of the literature reflects that this research field as a whole is still in an early and exploratory phase. Consequently, the theoretical content of the literature is comparably low.

Table 4: Review of Relevant Academic Entrepreneurship Literature

Study	Research Method	Underlying Theory	Context	Key Findings
Autio et al. (1997)	Survey, structural equation modeling	Entrepreneurial intent	1,956 university students from Finland, Sweden, U.S. and Asia	Entrepreneurial conviction is most important determinant of entrepreneurial intent
Bozeman (2000)	Literature review	Typological framework	Technology transfer from U.S. universities and federal laboratories	Technology effectiveness can take a variety of forms, such as "out-the-door", market impact, economic development, political, opportunity cost, and human capital
Bray and Lee (2000)	Survey and interviews	Exploratory study	TLO managers of 10 universities, AUTM data	Taking equity in USOs maximizes financial return
Carayannis et al. (1998)	Case Studies	Exploratory study	Spin-offs from 4 U.S. federal labs in New Mexico and 3 Japanese universities	Too few professional entrepreneurs to manage spin-offs and lack of VC are impediments to USO activity
Carayol and Matt (2004)	Archival data, regression	Exploratory study	80 laboratories at Louis Pasteur University, Strasbourg	Combining researchers and professors preserves incentives; highly publishing labs have more patents
Chrisman et al. (1995)	Survey and interviews	Exploratory study	367 faculty of University of Calgary	USOs have created 723 new jobs; estimated 14 new ventures per year will be created
Clarysse and Moray (2004)	Longitudinal qualitative case study	Exploratory study	1 research-based spin-off of University of	Shocks in the founding team co-evolve with shocks in the development of the business

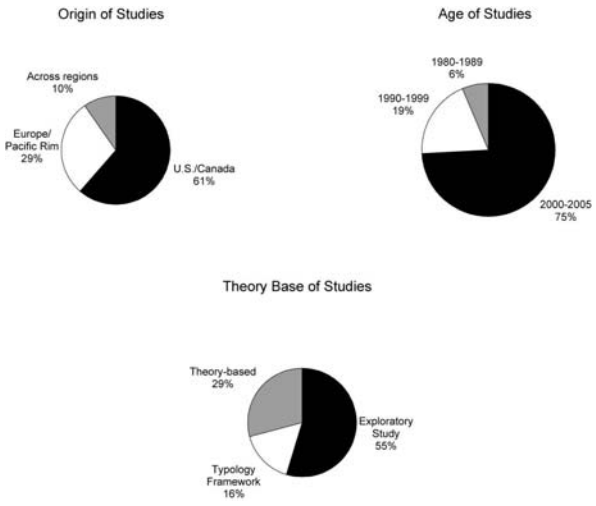
Study	Research Method	Underlying Theory	Context	Key Findings
			Leuven	
Clarysse et al. (2005)	Archival data, case studies	Typological framework	7 spin-out services in 5 European countries; 43 case studies	3 distinctive incubation models of managing USO process: Low selective, supportive, and incubator
Di Gregorio and Shane (2003)	Archival data, negative binomial regression, extension to longitudinal data	Exploratory study	101 U.S. universities from 1994-98 (AUTM data, U.S. Patent and Trademark Office data, survey with TLOs).	Intellectual eminence, policies of making equity investments in TLO start-ups and maintaining low investors share of royalties increase new firm formation activity
Doutriaux (1987)	Survey	Exploratory study	38 USOs of various Canadian universities	USOs created by academics who leave university grow more aggressively than USOs where the founder continues a part time university job
Feldman et al. (2002)	Survey, regression	Exploratory study	67 TTO administrators of U.S. univ.	Equity participation is an attractive mechanism for universities and USOs
Kassicieh et al. (1996)	Survey, regression	Comparative analysis, exploratory study	213 investors and 24 spin-off entrepreneurs from 3 large national laboratories	Inventors at government laboratories are reluctant to leave the lab and become entrepreneurs
Kenney and Goe (2004)	Survey, historical research	Social embeddedness	24 faculty members of Stanford and UC Berkeley	Being embedded in a department that supports entrepreneurial activities can counteract disincentives
Lilischkis (2001)	Survey, interviews, case study	Transaction cost theory	112 individuals at University of Washington and University of Bochum	Lower transaction costs when accessing knowledge, capital and incentives to start a business result in higher number of USOs
Murray (2004)	In-depth interviews, case studies	Social embeddedness	12 USOs at the U.S. East coast	Inventor brings human capital into USO; inventor simultaneously exploits his social capital
Nicolaou and Birley (2003)	Literature review	Typological framework	Social networks of academics and involvement	Trichotomous categorization of USOs into orthodox, hybrid and technology spin-offs
Péréz and	Structured	Exploratory	10 USOs of	Technology transfer and net-

Study	Research Method	Underlying Theory	Context	Key Findings
Sánchez (2003)	interviews and questionnaire	study	University of Aragón, 1990-2000	working at USOs decreased over time, customer relationships increased
Peterman and Kennedy (2003)	Survey, regression	Entrepreneurial intent	112 students at Australian schools	Completing an entrepreneurial education program enhances desirability and feasibility of starting a business
Oliver (2004)	Survey, multiple regression	Exploratory study	291 scientists in Israel	Large laboratories and large number of Ph.D. students indicate more collaboration relationships
Pirnay et al. (2003)	Literature review	Typological framework	Survey of relevant literature	Two key discriminatory factors: (1) status of individuals (researchers vs. students); (2) nature of knowledge transferred (codified vs. tacit)
Powers (2000)	Archival data, regression	Resourced-based view, resource dependency theory, revenue theory of cost	Multi-source archival data of 108 U.S. universities	Federal and industry R&D revenues, status, number of licenses, and TTO size are positive predictors of performance
Powers and McDougall (2004)	Archival data, negative binomial regression	Resource-based view	120 U.S. research universities, multi-source data	Set of university financial, human capital, and organizational resources a significant predictors of USOs and IPOs
Renault (2003)	Interviews and surveys	Exploratory study	89 professors at 12 U.S. universities	Belief about role of university, age, academic quality of professors influence decision about technology transfer
Roberts and Malone (1996)	Case studies and surveys	Exploratory study	TTO administrators from 8 U.S. universities	Parent organizations in regions with strong VC resources and supply of entrepreneurs are more likely to have successful USOs than without VCs and entrepreneurs
Robinson et al. (1991)	Survey, regression	Attitude theory	63 undergraduate students from 1 U.S. university, 54 entrepreneurs, 57 non-entrepreneurs	Attitude is a better approach to identify entrepreneurs than personality characteristics or demographics
Rogers et al.	Case studies, histori-	Typological	Anecdotal evidence from	USOs are particularly effective

Study	Research Method	Underlying Theory	Context	Key Findings
(2001)	cal research	framework	University of New Mexico	in transferring technology
Seashore Louis et al. (1989)	Survey, regression	Explorative study	778 scientists from 40 U.S. universities	Life scientists at research universities are modestly entrepreneurial; the greater the size of research grants, the more they behave entrepreneurially
Smilor et al. (1990)	Survey, archival data	Exploratory study	27 faculty and staff from 23 UT Austin USOs	Pull factors (i.e. opportunities) were more important than push factors (lack of alternatives)
Steffensen et al. (2000)	Case studies	Exploratory study	14 research centers and 19 spin-offs from University of New Mexico	Degree of support from parent organization is important for USO success
Vohora et al. (2004)	Detailed field study	Exploratory study	9 USOs from 7 universities in the U.K.	Growth of USOs is characterized by a number of stages and critical junctures
Wayne (2003)	Archival data, regression	Resource dependency theory	109 U.S. universities (AUTM data, Carnegie Foundation)	Federal and industry R&D funding, state venture capital, and university type are significant indicators of USO creation

17 of the 31 studies (55 per cent) used an exploratory approach to their research and did not base their findings on any theory, which is typical for research studies in early stage science. 5 of the studies (16 per cent) focused on establishing a framework of typology, given that it is essential to a developing research area to establish generally accepted terms and definitions. Only 9 studies (29 per cent) had a defined theory as the basis of the findings.

Exhibit 9: Analysis of Reviewed Literature, by Origin, Age, and Theory Base



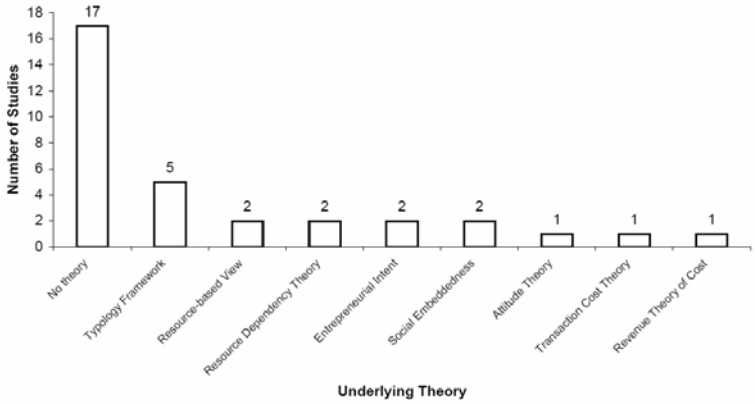
Source: Literature review analysis, own conception

In other terms, interest in the field of academic entrepreneurship, technology transfer and university spin-offs has clearly gained over the course of the last decade. It seems that the literature approaches a phase where based on initial exploratory and typological work, theoretical concepts will be derived in order to reach a profound understanding of the observations. This is reflected in the fact that 7 of the 9 theoretical studies (78 per cent) have been published within the previous 5 years.

A more detailed analysis of the applied theories shows that a broad variety of underlying research streams. Organizational theory like the resource-based view of the firm, or resource-dependency theory, was applied four times. Network-based theory such as the theory of social embeddedness found twice its application. One study was based on neo-institutional transaction cost theory. Three other studies used socio-

psychological approaches, which were focused on individual behavior in contrast to organizational behavior.

Exhibit 10: Analysis of Underlying Theories of Relevant Studies



Source: Own depiction

3.4. Requirements of a Theoretical Framework

As stated in the introductory chapter, the goal of this dissertation is to fill the research gap of entrepreneurial behavior in academic research organizations. This goal determines the requirements of a theory to contribute bridging this gap.

The object of the investigation is the organization. Therefore, one dimension of the theory should be an organizational approach, as opposed to an individual approach. Since the intent is to focus on behavioral issues, the theory should relate to behavior, in contrast to culture, norms, artifacts, or resources. Another dimension will be whether the theory provides an internal or external perspective, and whether it is process or result focused. Since the goal is to gain insight about the behavior inside the organization, an internal view would be preferred. At the same time, emphasis should be more on process, less on result.

Whilst the so far mentioned dimensions demonstrate the perspective of the research object, another important perspective is the functional aspect that is to be investigated. A preferred theory would incorporate the aspects of entrepreneurship, rather than other functional dimensions such as marketing, production, human resource management, or general management.

Why is entrepreneurship important for organizations? In the organizational and management literature, entrepreneurship is presented as a significant factor in organizational effectiveness. Risk taking and accepting responsibility are interdependent and equally important to an organization.[123] Entrepreneurship is linked with invention and innovation, which are causally related with productivity.[124] The relationship of entrepreneurship to organizational performance is not limited to the private sector, and should rather be discussed in the context of higher education.[125]

Consequently, theory alternatives in question will be evaluated by dimensions of:

- organizational focus
- behavior
- process orientation
- internal perspective
- entrepreneurship

The following sections will provide the essentials of relevant theories found during the literature review, and present an evaluation.

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[123] See Benveniste (1987), p. 1.
[124] See Peters and Waterman (1982), p. 1.
[125] See Etzkowitz (1983), p. 198.

3.5. Theory Alternatives

3.5.1. Resource-Based View

The theory of the resource-based view of the firm has its origins in Edith Penrose's classic work about growing firms and their desire to diversify.[126] Penrose asked the question why companies enter into new markets once they have developed a new product, as opposed to selling it to the highest bidder. Her answer was market imperfection, which required firms to develop idiosyncratic skills, or resources. Consequently, companies within an industry are heterogeneous, and have different sets of resources.

Birger Wernerfelt developed Penrose's insight into a theory and named it "the resource-based view".[127] Within the strategic management literature, this theory has received considerable attention, given its attempt to align internal factors, such as skills and resources, with external optimal performance measures, such as profitability, growth rate, market share, return on investment. Wernerfelt's inside-out perspective of the organization became more popular when Prahalad and Hamel started communicating their approach of dynamic capabilities, which is related to Wernerfelt's theory.[128]

Barney developed the theory later into a comprehensive approach.[129] In addition to formulating the underlying assumptions of resource heterogeneity and resource immobility,[130] Barney grouped resources in four categories, namely (1) financial resources, (2) physical resources, (3) human capital resources, and (4) organizational

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[126] See Penrose (1958), p. 1.

[127] See Wernerfelt (1984), p. 171.

[128] See Mintzberg, Ahlstrand and Lampel (1998), pp. 276-277, for a comparison of the approaches of Wernerfelt (1984) and Prahalad and Hamel (1990).

[129] See Barney (1991), p. 15.

[130] Resource immobility relates to the notion that resources are not easy to copy.

resources. Organizational resources comprise the firm's organizational structure, planning, controlling, and coordinating systems, culture, and informal relationships between groups within and outside the firm.

Later research identified specific resources for entrepreneurial activities including expert knowledge and scientific capabilities, access to key personnel, information and support.[131]

Powers uses the resource-based view in his analysis of technology transfer activities of research universities. He argues that "although the resource-based view of the firm was developed from studies of the for-profit sector, its application in higher education is reasonable and sharpens our understanding of an organizational phenomenon such as technology transfer that occurs there."[132]

With regard to the dimensions relevant for this dissertation, the resource-based view is an organizational resource-oriented theory with an internal perspective. It is more result than process focused and relates to a number of managerial functions, but not necessarily to entrepreneurship.

3.5.2. Resource-Dependency-Theory

The analysis of the resource-based view led to conclusions how to approach an organization with an internal perspective. In contrast to an emphasis on internal resource, resource-dependency theory focuses on external resources that influence the behavior of an organization and its subsequent performance.

Resource-dependency theory has its origins in organizational theory of social behavior.[133] One of its basic arguments is that the behavior of organizations is explained

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[131] See Mansfield and Lee (1996), p. 1047.
[132] Powers (2000), p. 34.
[133] See Pfeffer (1987), p. 25.

through the perspective of ongoing interactions with society, and that "organizations are inescapably bound up with the conditions of their environment."[134] In its early form, it was outlined by Pfeffer and Salancik in their book "The External Control of Organizations", stating that "the organization can adapt and change to fit environmental requirements, or the organization can attempt to alter the environment so that it fits the organization's capabilities."[135]

Resource-dependency theory has been used before to study university organizations.[136] Wayne argues that "universities are very dependent on resources provided by externalities. These external resources include federal grants, state government support, private foundations funding, industry contracts, and tuitions from students and their families."[137]

For the purposes of this study, resource-dependency theory provides a number of beneficial characteristics. It is aimed at the organizational behavior level, although resource-oriented. However, the theory is less process-related, has primarily an external perspective, and does not focus on entrepreneurship.

3.5.3. Contingency Theory

The core element of contingency theory is that organizational effectiveness results from fitting characteristics of the organization, such as structure, to its contingencies

[134] See Pfeffer and Salancik (1978), p. 1.
[135] See Pfeffer and Salancik (1978), p. 106.
[136] See Powers (2000). pp. 35-38, and Wayne (2003), pp. 33-45.
[137] See Wayne (2003), p. 40.

that reflect the situation to the organization.[138] Examples for contingencies are the environment, organizational size, and organizational strategy.[139]

In essence, the theory argues that depending on the fit of specific organizational characteristics to its contingencies, an organization delivers better or worse results in performance. In other words, the more an organization is capable of adapting to varying contingencies, the more successful the organization will be.[140] This results in the notion that there is "no best way" to run an organization, but rather best management depends on the circumstances and the environment.[141] Consequently, contingency theory demands an empirical approach to support its research, rather than generally valid system-theoretical approaches.[142]

Contingency theory provides a number of advantages. The fact that the theory is based on empirical research, and that it is open to different environments, makes it a viable alternative for the investigation of behavior of research organizations with regard to performance.

However, contingency theory depends in the first place on external factors. Different environmental states (i.e. stability, complexity, diversity, hostility) are important input factors of the theory. In addition, the theory is more focused on structural elements (like mechanistic organizational structure versus organic structure)[143], which will not be a crucial point with regard to entrepreneurship.

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[138] See Donaldson (2001), p. 1. The origins of contingency theory were formulated by Pugh, Hickson, Hinings, Macdonald, Turner and Lupton (1963), p. 289.

[139] See Burns and Stalker (1962), p. 1, Child (1975), p. 12, and Chandler (1962). p. 1, respectively for the contingencies of environment, organizational size, and organizational strategy.

[140] See Donaldson (2001), p. 2.

[141] See Mintzberg, Ahlstrand and Lampel (1998), p. 289.

[142] See Staehle (1999), p. 48.

[143] See Pennings (1987), p. 223, and Burns and Stalker (1962), p. 1. Alternative terms for mechanistic and organic are hierarchical and participatory, respectively.

Understanding entrepreneurial behavior in research universities requires a more focused approach, which highlights the specificities of entrepreneurship. Therefore, contingency theory is valuable as an underlying element, however, in itself not sufficient to be ideal for this investigation.

3.5.4. Configurational Theory

An enhancement of organizational contingency theory is the configurational approach to organizations, which was developed mainly during the 1970s by a group at McGill University in Montreal around scholars like Pradip Khandwalla, Danny Miller, Henry Mintzberg, and Peter Friesen.

In its origins, configurational theory is based on the achievements of contingency theory. According to Miller and Friesen, configurational theory is not an alternative to contingency theory, but rather a necessary complementation. Whilst contingency theory puts its emphasis on the relationship between environment and structure, and their interdependency, configurational theory is a more holistic approach to the issue of organizational behavior.[144]

It also emphasizes the transitional element of organizations, making change a constant of strategic decision making. In particular, the configurational approach focuses on big changes in the organizational setting, so-called quantum changes. These periods of drastic change, which require stark managerial decision-making, are often followed by periods of relative calmness. "Organizations are treated as complex entities whose elements of structure, strategy, and environment have a natural tendency to coalesce into states or 'configurations.'"[145]

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[144] See Miller and Friesen (1984), pp. 1-8. Miller and Friesen label their holistic approach as "Quantum View" on the organization. The notion of a Quantum View comprises that a relatively limited number of key configurations reflects a high number of combinations of organizational elements. See also Miller (1983) for the archetypes of these combinations.

[145] Miller and Friesen (1984), p. 1.

The achievements of both contingency and configurational theory should be viewed as complementary, more than conflicting. Over the last 25 years, both approaches have been tested in organizational research, and they provide important elements that are useful for the examination of academic research groups. In particular, their perspective on the organization as opposed to the individual and the behavioral view hold a number of advantages.

Both theories provide a basis for a more focused theory, given their ambition as general theories. Therefore, it is useful to study more defined approaches such as marketing or entrepreneurship orientation, which are based on contingency and configurational theory, in order to achieve more specific, higher content results.

3.5.5. Social Embeddedness and Opportunity Recognition

Different to the previously described theories of individual and organizational behavior, the theories of social embeddedness and opportunity recognition belong into the category of network theory, and focus more on social aspects of research activity. Their appeal to problems of university laboratories stems from the fact that researchers tend to work in small groups within their universities, and at the same time have a network of research contacts that is distributed around the globe. In other terms, researchers operate in network structures, locally and globally, which can be modeled by network theory. Various scholars have applied network theory to the issue of academic entrepreneurship, in order to illuminate the importance of personal interdependencies and exchange of ideas.[146]

The theory of social embeddedness goes back to early research by Mark Granovetter in sociological theory in the 1970s. Granovetter addressed the issue that most sociological theories do not span the gap between micro-level interactions and macro-level interactions of individuals. He argued that in contrast to benefits one can gather from

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[146] See the work of Kenney and Goe (2004), and Murray (2004).

close relationships (family and close friends), weaker relationships can be much more valuable for achieving certain personal or professional goals. Hence, focus on weak ties is of much greater interest than focusing on immediate and strong family ties.[147]

Granovetter extended this view into the theory of social embeddedness. In contrast to Oliver Williamson's view of "markets and hierarchies",[148] social embeddedness views economic action as part of social relations, rather than the neoclassical atomized-actor view.

Powell et al. approached the issue from a comparable perspective, arguing that "when the knowledge base of an industry is both complex and expanding and the sources of expertise are widely dispersed, the locus of innovation will be found in networks of learning, rather than in individual firms."[149]

Murray elaborates on the issue to what extent scientists do not only bring their knowledge to a spin-off company, i.e. human capital, but also contribute social capital in form of professional contacts, and how this social capital contributes to the embeddedness of the entrepreneurial firm. [150]

Granovetter's theory of weak ties and embeddedness is one of the pillars of the theory of entrepreneurial opportunity identification and development. Ardichivili et al. developed the so-called "theory of opportunity recognition" and identified five factors affecting the entrepreneurial opportunity recognition process:

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[147] See Granovetter (1973), p. 1360. Granovetter revisits this theory of the strength of weak ties in Granovetter (1983).

[148] See Williamson (1975). Granovetter (1985, pp. 481-482) argues that classical and neoclassical economics assume rational, self-interested behavior affected minimally by social relations, thus invoking an idealized state. His argument of embeddedness captures the opposite, saying that ongoing social relations constrain actors and institutions so much that to construe them as independent is a grievous misunderstanding.

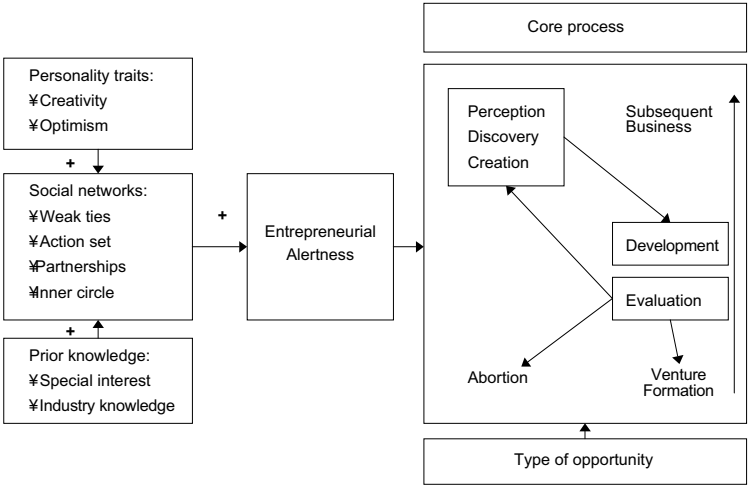
[149] See Powell, Koput and Smith-Doerr (1996), p. 116.

[150] See Murray (2004), p. 645.

- Entrepreneurial alertness
- Information asymmetry and prior knowledge
- Discovery versus purposeful search
- Social network
- Personality traits, including risk taking, optimism and self-efficacy, and creativity[151]

The social component of entrepreneurial activity seems to be of importance in order to gather and develop promising ideas, in particular in the academic context.

Exhibit 11: Concept of Theory of Opportunity Recognition



Source: Ardichvili et al. (2003)

[151] See Ardichvili, Cardozo and Ray (2003), p. 113.

Social embeddedness was used as an underlying theory in two of the examined relevant studies on entrepreneurship in academia. Dimensions missing in this theory, however, are process and entrepreneurial-related aspects. Given its nature as a network theory, both organizational and individual aspects are captured.

3.5.6. Attitude Theory

Attitude theory has its basis in social psychology. By definition, the theory is individual-focused, as opposed to most theories discussed in this chapter that are organization-focused. The theory, nevertheless, seems to be particularly useful to study entrepreneurial orientation of individuals and carries a number of elements important to entrepreneurship research.[152]

Robinson et al. claim that "attitude is presented as a better approach to the description of entrepreneurs than either personality characteristics or demographics,"[153] and propose this theory as an alternative for investigating entrepreneurship. They refer to entrepreneurial behavior as attitudes formed through the strength of an individual's suggestive association and formed values towards certain attributes.[154]

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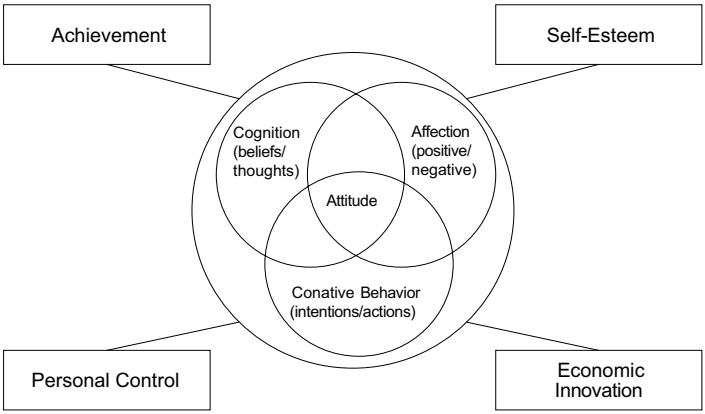
[152] Based on its psychological origins, attitude theory has a substantial history of research. Attitudes are seen as being relatively less stable than personality traits, changing across time and across situations through interactive process with the environment. See Robinson, Stimpson, Huefner and Hunt (1991), p. 18, and Chaiken and Stangor (1987), p. 575.

[153] Robinson, Stimpson, Huefner and Hunt (1991), p. 13.

[154] See Ajzen and Fishbein (1977), p. 888.

Exhibit 12: Concept of Attitude Theory



Source: Robinson, Stimpson, Huefner and Hung (1991)

From a social psychological perspective, the term attitude is defined as the "predisposition to respond in a generally favorable or unfavorable manner with respect to the object of the attitude."[155] Every attitude has an object and exists either on a general or specific level. E.g., attitude toward achievement in general differs from attitude towards achievement in an entrepreneurial setting.

Researchers have taken two different approaches on attitude theory: (1) They have looked at attitude theory as a unidimensional construct consisting of affect (feelings) and reaction, or (2) as a tripartite model, consisting of three types of reactions: affect (feelings), cognition (beliefs/thought), and conative behavioral intentions.[156]

[155] Robinson, Stimpson, Huefner and Hunt (1991), p. 17.
[156] See van Wyk and Boshoff (2004), p. 33.

Robinson et al. applied the tripartite model to undergraduate students and tested four attitude sub-scale:

- Achievement in creating a business
- Innovation in business
- Perceived personal control of business outcomes
- Perceived self-esteem in business[157]

Within their sample, they were able to discriminate between non-entrepreneurs and entrepreneurs.

The requirements of this dissertation differ to some degree from what Attitude Theory offers. In particular, organization-level and process-oriented perspectives are missing.

3.5.7. Entrepreneurial Intent

Early research of the origins of entrepreneurship and the drivers behind starting a business were focused on trait or personality characteristics of the individual entrepreneur.[158] More recently, researchers developed models of intentions, attitudes and their antecedents to better explain the entrepreneurial focus.[159] There are also numerous attempts to investigate the influence of entrepreneurial education on the decision to start a business.[160] However, after more than 10 years of development in the entrepreneurial education literature, strong and rigorous studies are still few in number.[161]

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[157] See Robinson, Stimpson, Huefner and Hunt (1991), p. 19.

[158] See Schumpeter (1934), Brockhaus (1980, 1982); see also Gartner (1988), who argues that individuals seldom behave consistently over time and in different situations, and that personality traits are not good predictors of future actions.

[159] See Bird (1988), Shapero (1975), and Shapero and Sokol (1982). Davidsson (1995), e.g., related personal variables such as gender, education, and experiences to attitudes that influence convictions and entrepreneurial intentions.

[160] See Peterman and Kennedy (2003), Gorman, Hanlond and King (1997), and Young (1997).

[161] See Gorman, Hanlond and King (1997)

Some of the models developed in this field used the construct of entrepreneurial intent, initially proposed by Bird and later developed by Boyd and Vozikis.[162] Shapero concludes that entrepreneurial intent is influenced by perceived desirability, perceived feasibility, and a propensity to act.

Autio et al. enhance Davidsson's model on entrepreneurial intent by including situational variables such as environment and education.[163] Entrepreneurial intent is further moderated by variables such as conviction and social context, and was applied in a university context. The object being investigated is the individual, or more precise, the individual's entrepreneurial behavior. The dependent variable – entrepreneurial intent – is measured and operationalized using an index of three questions.[164]

The intent construct has the advantageous property that it differentiates the dichotomous variable of starting a company. It provides information about the propensity of an individual to act entrepreneurially and therefore provides higher content as a dependent variable. Most researchers have used entrepreneurial intent in the context of individual behavior.

Intent-focused entrepreneurship research emerged after the stream of research focusing on psychological characteristics of entrepreneurs, the so-called trait approach,[165] was viewed as incapable of contributing meaningfully to the question: "Why do people start businesses?" In particular, Gartner redirected the focus of research interested on more behavioral aspects of entrepreneurship, claiming that "the entrepreneur is not

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[162] Different models were developed by Shapero (1982) and Shapero and Sokol (1982), tested by Krueger (1993), and Davidsson (1995), tested by Autio et al. (1997) to the university situation.

[163] See Autio, Keeley, Klofsten and Ulfstedt (1997), p. 2, and Davidsson (1995), p. 4.

[164] Autio et al. (1997) three question index asks for (1) consideration to creating a company, (2) likelihood to start a company in 1 years, and (3) likelihood to start a company in 5 years.

[165] See Hornaday (1982) for a summary of the trait approach.

a fixed state of existence, rather entrepreneurship is a role that individuals undertake to create organizations."[166]

Researcher tried to understand entrepreneurship on a more integrated level, and developed models that take into account not only psychological characteristics of entrepreneurs, but also attitudes, personal background, and situational variables.[167] A particular focus was put on the phase leading to the decision to start a business, a decision that can also be called reasoned action or planned behavior.[168] It has shown that the relationship between intentions and actual behaviors is fairly strong.[169] Boyd and Vozikis, for example, state that "self-efficacy, which has been defined as a person's belief in his or her capability to perform a task, influences the development of both entrepreneurial intentions and actions or behaviors."[170] They refer to Fishbein and Ajzen's model of behavioral intentions, which illustrates the relationship between beliefs and behaviors as:

$$\text{Beliefs} \rightarrow \text{Attitudes} \rightarrow \text{Intentions} \rightarrow \text{Behavior}$$[171]

Davidsson suggests that the "study of entrepreneurial intentions has some distinctive advantages."[172] Firstly, it moves away from the psychological-related focus of minority phenomena, and moves towards more theory-driven, testable models of behavior. Secondly, it avoids identifying actual consequential traits of entrepreneurship as being

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[166] See Gartner (1988), pp. 11-12. Gardner realigned entrepreneurship research and convincingly moved the focus more towards behavioral aspects, referring to the work done by Mintzberg (1973) on managerial behavior.

[167] See Bird (1988), p. 442, and Shapero and Sokol (1982).

[168] See Boyd and Vozikis (1994), p. 63, and Krueger (1993), p. 5.

[169] See Ajzen (1991), p. 179.

[170] Boyd and Vozikis (1994), p. 63.

[171] See Fishbein and Ajzen (1975).

[172] Davidsson (1995), p. 2.

determinants of entrepreneurial activity. Thirdly and importantly, it helps to establish tools for policy making in order to promote future start-up activity.[173]

Autio et al. argue that "practical application of the intent theory have been relatively few."[174] One reason for this observation is that empirical research mostly relies on survey based data, i.e. there is limited secondary data available, as it is often preferred by economics and entrepreneurship researchers.[175]

3.5.8. Market Orientation

The theory of market orientation has been developed over the last 15 years, based on fundamental research by Kohli and Jaworski, and Narver and Slater.[176] In essence, market orientation describes an organization's orientation toward the promotion and support for the collection, dissemination, and responsiveness to market intelligence to serve customer needs.[177]

Market orientation is an important antecedent of product innovation behaviors, activities, and performance.[178] Kohli and Jaworski claim that market orientation "provides a unifying focus for the efforts and projects of individuals and departments with in the organization, thereby leading to superior performance."[179] Narver and Slater assert that market orientation is an "organizational culture that most effectively creates the necessary behaviors for creating superior value for buyers, and thus continuous performance."[180] Atuahene-Gima and Ko summarize that "market orientation engenders

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[173] See Davidsson (1995), p. 2.

[174] Autio, Keeley, Klofsten and Ulfstedt (1997), p. 3.

[175] See Autio, Keeley, Klofsten and Ulfstedt (1997), p. 3.

[176] Kohli and Jaworski (1990) and Narver and Slater (1990) published their fundamental research in the same year in the Journal of Marketing.

[177] See Kohli and Jaworski (1990), p. 1.

[178] See Atuahene-Gima and Ko (2001), p. 55.

[179] See Kohli and Jaworski (1990), p. 13.

[180] See Narver and Slater (1990), p. 21. Homburg and Pflesser (2000) provide a distinction between the cultural and behavioral aspects of market orientation on which this dissertation will not elaborate.

product innovation behavior that focus on understanding the articulated needs of customers. It therefore leads to the exploitation of innovation opportunities that are associated with the current domain of the firm and that take advantage of its currently available learning and experience."[181]

The described characteristics contain a number of elements that make them interesting for the defined problem of this dissertation. However, other elements of market orientation on a stand-alone basis contribute less to a promising application. The focus of the theory, as its name suggests, is the relationship of an organization, typically a for-profit firm, to its marketplace with respect to internal processes and resources. Interdependence between marketplace and organization requires that the organization has identified a market. In the case of a research university, this definition bears some difficulties. One can argue that the university's markets are students, who are provided with education, companies, who are provided with innovation and development, or the general public, who is provided with progressive research. In general, one would have difficulties assigning a concrete market to the behavior of universities.

Furthermore, market orientation focused on the three components of collection, dissemination, and responsiveness to information. This relatively closed approach might exclude some of the underlying behaviors of a research organization that quite often does develop innovation very far away from potential customers.

The entrepreneurial component is not explicitly mentioned in this market orientation approach. However, elements like innovativeness, competitiveness, and exchange play a role in entrepreneurial behavior. In this sense, the approaches of market orientation and entrepreneurial orientation show some overlap.

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[181] See Atuahene-Gima and Ko (2001), p. 56.

3.5.9. Entrepreneurial Orientation

Entrepreneurial orientation as a theory contains promising features for bringing insight into the entrepreneurial behavior of research organizations. This section will present the antecedents of the theory of entrepreneurial orientation, describe its development and its key dimensions. It will close with a critical assessment of the benefits and disadvantages of the theory for this specific investigation.

Antecedents of Entrepreneurial Orientation

The theory of entrepreneurial orientation is part of the organizational branch of entrepreneurship research. Historically, scholars have developed typologies of different perspectives of entrepreneurship, typically depicting these differences as a result of various combinations of individual, organizational, and/or environmental factors. These factors determine when and why entrepreneurship occurs.[182]

One fundamental distinction in entrepreneurship research is the distinction between content and process. In the early strategy literature, scholars focused on the strategic question which business to enter or which opportunity to pursue.[183] This is the question for content. The result would be the essential act of entrepreneurship, which is a new entry into business.[184]

New entry "is the act of launching a new venture, either by a start-up firm, through an existing firm, or via 'internal corporate venturing'".[185] The concept of new entry has been subject to a large part of entrepreneurship research. Its traces go back to Schumpeter's ground laying work about entrepreneurs, invention, and innovation.[186]

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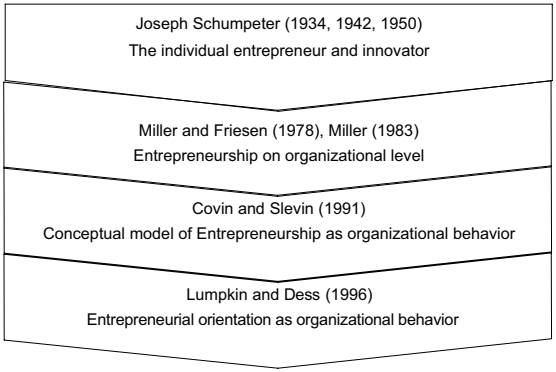
[182] See Lumpkin and Dess (1996), p. 135.
[183] See Bourgeois (1980), p. 25.
[184] See Lumpkin and Dess (1996), p. 136.
[185] Lumpkin and Dess (1996), p. 136. See also Burgelman (1984), p. 154, as to corporate venturing.
[186] See Schumpeter (1934), and Schumpeter (1942).

Another dimension of entrepreneurship research is process, as opposed to content. A concept such as entrepreneurial orientation "refers to the processes, practices, and decision-making activities that lead to new entry … it involves the intentions and actions of key payers functioning in a dynamic generative process aimed at new-venture creation."[187]

Another important aspect in the analysis of entrepreneurship is the organizational level of analysis. Individuals can be entrepreneurial, so can be organizational units, and whole organizations such as companies or universities.

Exhibit 13: Development Stages of Organizational Entrepreneurship Theory



Source: Own conception

Similar to market orientation, entrepreneurial orientation is an organization-focused behavioral approach with respect to a particular functional emphasis. Danny Miller, in

[187] See Lumpkin and Dess (1996), pp. 136-137, with reference to Child (1972) and Van de van den Ven and Poole (1995).

an early attempt to clarify the notion the theory, describes an entrepreneurial orientation as one that "emphasizes aggressive product-market innovation, risky projects, and a proclivity to pioneer innovations that preempt the competition."[188] Three important characteristics describe entrepreneurial orientation:

- a high degree of innovativeness
- risk taking, and
- proactiveness[189]

The theory of entrepreneurial orientation has been further developed over the 1990s, initially by Jeffrey Covin and Dennis Slevin, and later by Tom Lumpkin and Gregory Dess.[190]

The Conceptual Model of Entrepreneurship as Firm Behavior by Covin and Slevin

During the late 1980s until the mid-1990s, researchers tried to identify organizational patterns that should characterize the process of strategic decision-making. These patterns should encompass aspects such as an organization's culture, values, and vision.[191] Continuing Danny Miller's thoughts on entrepreneurship, Covin and Slevin presented their "Conceptual Model of Entrepreneurship as Firm Behavior" in 1991,

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[188] Miller (1983), p. 770.

[189] See Covin and Slevin (1989), pp. 83-85.

[190] Jeffrey G. Covin is Professor of Entrepreneurship at the Kelley School of Business, Indiana University, Bloomington. He received his Ph.D. in Organization Studies and Strategic Planning from the University of Pittsburgh in 1985. Prior, he was Professor of Entrepreneurship and Small Business Management at Georgia Tech. Dennis P. Slevin is Professor of Business Administration at the Katz Graduate School of Business, University of Pittsburgh. He received his Ph.D. in Business Administration (Organizational Behavior) at Stanford University in 1969. Tom Lumpkin is Assistant Professor of Management at the University of Illinois at Chicago. He received his Ph.D. in Strategic Management at the University of Texas at Arlington in 1996. Gregory Dess is Professor of Organization, Strategy and International Management at the University of Texas at Dallas. Prior, Dess was Professor of Leadership and Strategic Management at University of Kentucky. He received his Ph.D. in Business Administration from the University of Washington in 1980.

[191] See Hart (1992) and Miller and Friesen (1978). Miller and Friesen identified 11 strategy-making dimensions, such as adaptiveness, analysis, integration, and risk taking.

depicting "entrepreneurship as an organizational-level phenomenon."[192] They describe entrepreneurship "as a dimension of strategic posture represented by a firm's risk taking propensity, tendency to act in competitively aggressive, proactive manners, and reliance on frequent and extensive product innovation."[193]

The authors also elaborate on the advantages of a behavioral approach on entrepreneurship. A firm-level approach, as opposed to an individual-level approach, is appropriate "because entrepreneurial effectiveness is arguably a firm-level phenomenon."[194] In other terms, the organization's performance will result from both individual and organizational actions, therefore the analysis should be undertaken on the organizational level.

Secondly, "behavior is the central and essential element of the entrepreneurial process"[195], given that neither entrepreneur's psychological profile, nor structure nor culture of an organization as such, make an organization entrepreneurial.

Thirdly, a behavioral theory can be measured reliably, verifiably, and objectively. And fourthly, behavior can be managed, which makes this theory more relevant for practitioners.

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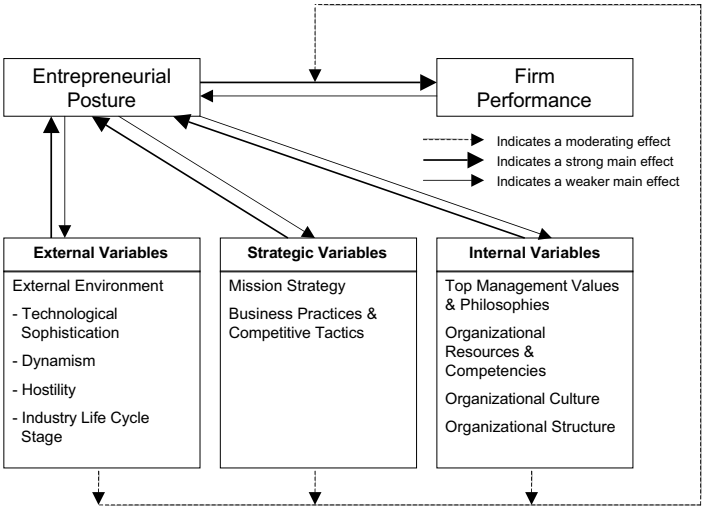
[192] See Covin and Slevin (1991), p. 7. The authors indicate that their model is intended to relate to larger, established firms, but also to smaller firms.

[193] See Covin and Slevin (1991), p. 7.

[194] See Covin and Slevin (1991), p. 8.

[195] See Covin and Slevin (1991), p. 8.

Exhibit 14: Conceptual Model of Entrepreneurship as Firm Behavior by Covin and Slevin



Source: Covin and Slevin (1991)

Exhibit 14 presents the conceptual model of entrepreneurship as firm behavior. The ultimate dependent variable is firm performance. Independent variables consist of environmental, organizational, and individual-level variables. The model also includes both direct and moderator effects, thereby referring to a contingency approach.

The concept was thoroughly reviewed and extended by Zahra. He suggested incorporating intensity, formality, type (locus) and duration of firm-level entrepreneurship.[196]

The Entrepreneurship Orientation Construct by Lumpkin and Dess

Based on the insights of Miller, Covin and Slevin, and further entrepreneurship research, Lumpkin and Dess presented a process-focused concept of organizational en-

[196] See Zahra (1993).

trepreneurship orientation in 1996 that is primarily centered around the five dimension of:[197]

- autonomy
- innovativeness
- risk taking
- proactiveness
- competitiveness[198]

Although prior research indicated that these dimensions may covary, the authors suggest that "autonomy, innovativeness, risk taking, proactiveness, and competitive aggressiveness may vary independently, depending on the environmental and organizational context."[199] They use their model both for small businesses and for strategic business units (SBUs).[200] It will be discussed at a later stage to what extent these dimensions can be applied to research units, or whether adjustment are necessary. For the time being, the focus will be on the firm's aspects of these dimensions.

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[197] See Lumpkin and Dess (1996), p. 139.

[198] Lumpkin and Dess speak initially of competitive aggressiveness, rather than competitiveness. The term "Competitive aggressiveness" wants to emphasize the aggressive and active nature of the dimension. However, the term "aggressiveness" seems redundant, given that a competitive attitude involves per se some elements of aggressiveness. Therefore, the term "aggressiveness" is used in a limited way, and more focus is given towards the term "competitiveness".

[199] Lumpkin and Dess (1996), p. 137.

[200] See Lumpkin and Dess (1996), p. 138. This is an important element, given the discussion about the appropriate level of investigation, analysis, and management. Reviewing the existing literature of entrepreneurial orientation, Zahra pointed out that "(1) entrepreneurship activities occur at (and cut across) multiple levels within a firm, and (2) a generic model of firm-level entrepreneurship – such as Covin and Slevin's – should account for these multiples levels in conceptualizing the entrepreneurship-performance relationship." (Zahra (1993), p. 7). This approach should similarly be used for the examination of universities, which have organization-wide, research unit, and individual levels.

Autonomy

One of the antecedents of entrepreneurship to occur is the "freedom granted to individuals and teams who can exercise their creativity and champion promising ideas. … Autonomy refers to the independent action of an individual or a team in bringing forth an idea or a vision and carrying it through to completion."[201]

Scholars have illuminated the notion of autonomy in two different ways. Firstly, autonomy was described as an entrepreneurial strategy-making mode, where a leader takes decisive and risky actions. This type of autonomy, also labeled as autocratic, is common in smaller organizations where one individual, mostly the firm owner, stands for and decides about the success of the organization.[202]

Secondly, and in contrast to the notion of decisive autonomy at the top of an organization, impetus for new venture creation does not necessarily come from the organization's leadership. Often, lower levels of the organization create and push forward ideas, which emphasizes the importance of autonomy to organizational members, and the freedom to act independently.[203]

Hence, autonomy is a characteristic of both leadership and management style. To be more precise on this notion within larger organizations, Pinchot found that many large firms tried to change organizational structure towards flatter hierarchies and delegation of authorities to operating units, in order to increase autonomy.[204]

Badawy illuminated this autonomy-control dilemma that scientists and engineers in industry encounter during the pursuit of their research agenda.[205] This dilemma is of-

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[201] Lumpkin and Dess (1996), p. 140.

[202] See Mintzberg (1973) and Mintzberg and Waters (1985) on strategy making. A similar approach can be found with Hart (1992), who labels it "command mode", and Bourgeois and Brodwin (1984), who refer to it as "commander model."

[203] See Lumpkin and Dess (1996), p. 141.

[204] See Pinchot (1985), p. 1.

[205] See Badawy (1988), p. 21.

ten defined as one of conflicting loyalties between the researcher's own interested and that of his employer.[206] Debackere et al. examined the autonomy of industrial researchers in the choice and pursuit of their technological research agenda. They argue that a proper balance between autonomy and control is required. It is important for R&D management "to pay particular attention to monitoring the strategic and operational autonomy of their Ph.D.-level research staff as its members become more specialized, rather than providing them with maximal levels of autonomy."[207]

Summarizing, autonomy means the ability and will to be self-directed in the pursuit of opportunities, individually and in the context of an organization that could otherwise constrain ideas.[208] However, there are arguments that too much room for autonomy and lack of guidance can be counterproductive and leads the research work into a direction where its results will not be rewarded.[209]

Innovativeness

The term innovation is naturally connected with the work of Schumpeter, who was among the first to emphasize the role of innovation in the entrepreneurial process.[210] He also coined the terms "creative destruction" and "new combinations", which are essential in the process of new venture creation and entrepreneurship.

Lumpkin and Dess comprehend innovativeness as "a firm's tendency to engage in and support new ideas, novelty, experimentation, and creative processes that may result in new products, services, or technological processes. … innovativeness represents a

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[206] See Blau and Scott (1962).
[207] Debackere, Clarysse and Rappa (1996), p. 73.
[208] See Lumpkin and Dess (1996), 140.
[209] See Bailyn (1985), p. 144.
[210] See Schumpeter (1934), and Schumpeter (1942).

basic willingness to depart from existing technologies or practices and venture beyond the current state of the art."[211]

The concept of innovation is complex in itself. To categorize the term, one can think of product-market innovation on the one side of the spectrum, and technological innovation on the other.[212] Whilst Miller's concept of product-market innovation might be too narrow, Zahra and Covin tried to focus more on the technology policy aspect.[213]

Risk taking

The dimension of risk taking is more complex, because it is related to various internal and external factors. The term "risk" itself varies in meaning, and is generally difficult to measure. Dess and Lumpkin provided the following definition of risk taking: "Risk taking refers to a firm's willingness to seize a venture opportunity even though it does not know whether the venture will be successful and to act boldly without knowing the consequences."[214] Following Baird and Thomas' typology, there are three different types of risk:

- venturing into the unknown
- committing a relatively large portion of assets, and
- borrowing heavily[215]

Miller and Friesen argue in the context of strategy formulation that risk taking is "the degree to which managers are willing to make large and risky resource commitments, i.e., those which have a reasonable chance of costly failures."[216]

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[211] Lumpkin and Dess (1996), p. 142.
[212] See Miller (1983), and Miller and Friesen (1982).
[213] See Zahra and Covin (1993), p. 452.
[214] See Dess and Lumpkin (2005), p. 152.
[215] See Baird and Thomas (1985), pp. 231-232.
[216] Miller and Friesen (1978), p. 923.

Proactiveness

Already since the early stages of entrepreneurship research, proactiveness has been identified as a key element in the entrepreneurial process.[217] Proactiveness leads to first mover advantages as the best strategy to capitalize on market opportunities. A first mover can exploit market asymmetries and capture unusually high profit margins.[218] The initiative to anticipate and pursue opportunities is an important ingredient to entrepreneurship.

Miller and Friesen associate proactiveness with shaping the environment by introducing new products, technologies, or administrative techniques.[219] Venkataraman's definition of proactiveness refers to processes aimed at anticipating and acting on future needs.[220]

Lumpkin and Dess are of the opinion that there is a profound distinction between proactiveness and competitiveness.[221] Whilst Covin and Slevin often use these terms interchangeably,[222] Lumpkin and Dess feel that "proactiveness refers to how a firm relates to *market opportunities* in the process of new entry. It does so by seizing initiative and acting opportunistically in order to 'shape the environment,' that is, to influence trends, perhaps, even create demand. Competitive aggressiveness, in con-

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[217] See Schumpeter (1934) and Penrose (1958).

[218] See Lieberman and Montgomery (1998), p. 41.

[219] See Miller and Friesen (1978), p. 923.

[220] See Venkatraman (1989), p. 949.

[221] For matters of consistency, the term competitiveness will be used in this context, rather than the term competitive aggressiveness. Without engaging into the semantics of these two terms, one should also consider that aggressiveness in its German translation bears a rather negative connotation. This is not the case in its original English meaning, where it also relates to speediness, impetuousness, and pertinacity.

[222] See Covin and Slevin (1989), p. 79. The authors relate to aggressive competitive orientation as a defining element of proactiveness.

trast, refers to how firms relate to *competitors*, that is, how firms *respond* to trends and demand that already exists in the marketplace."[223]

Competitiveness

Competitive aggressiveness, or competitiveness, relates to "a firm's propensity to directly and intensely challenge its competitors to achieve entry or improve position, that is to outperform industry rivals in the marketplace."[224] It is characterized by "responsiveness, which may take the form of head-to-head confrontation, … , or reactive."[225]

Amongst all the dimensions identified by Lumpkin and Dess, competitiveness is clearly the one which is most related to profit-seeking companies operation in a free capitalist marketplace. Whilst the other behavioral attitudes can be better generalized across organizations (proactiveness, innovativeness, autonomy, and risk taking), competitiveness requires market competition.

Integrating the Five Dimensions into One Model

The construct of Lumpkin and Dess raises two obvious questions with regard to its dimensions:

(1) Do these dimensions operate independently from each other?

(2) Does an organization have to show strong signs in any of these dimensions in order to act entrepreneurially?

With regard to the first question, Lumpkin and Dess theorize that salient dimensions may vary independently of each other, depending on the given context.[226] Arguing

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[223] Lumpkin and Dess (1996), p. 147.

[224] Lumpkin and Dess (1996), p. 148. The authors refer to MacMillan (1982) and Porter (1985) in their definition.

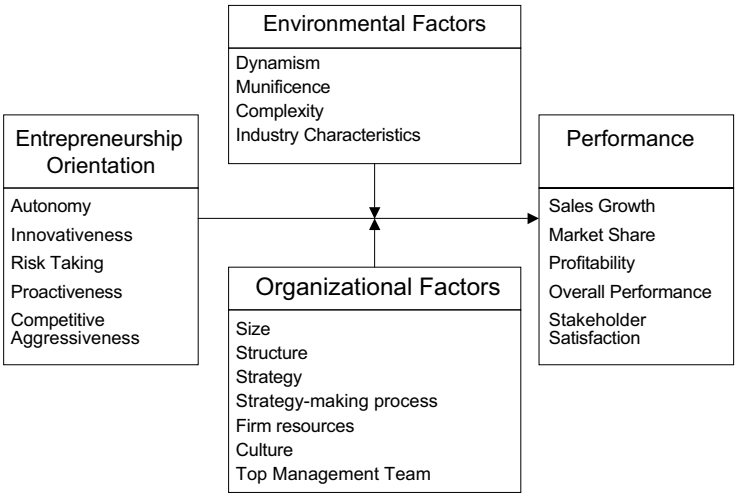
[225] Lumpkin and Dess (1996), p. 149.

[226] See Lumpkin and Dess (1996), p. 151.

with anecdotal evidence, the authors present situations in which one dimension shows strong evidence, other dimensions appear less pronounced, but the overall organizational behavior can be described as entrepreneurial oriented. Hence, one of their propositions is that the dimensions to not covary.[227]

This relates to the second question, and proves that in order to be entrepreneurial oriented, an organization does not have to show strong signs in any of these dimensions, but only in some of them, depending on the context.

Exhibit 15: Conceptual Framework of Entrepreneurial Orientation by Lumpkin and Dess



Source: Lumpkin and Dess (1996)

[227] Anecdotal evidence by Sony and Matsushita is presented, claiming that Sony operates entrepreneurial based on its innovativeness, proactiveness, and competitiveness given its R&D efforts and its efforts to be a first-mover, whilst Matsushita as the classical second-mover acts entrepreneurially by waiting how markets develop, but then putting money at risk and being intensly competitive. Consequently, entrepreneurial orientation can have various specificities, very much depending on the circumstances. See Lumpkin and Dess (1996), pp. 150-151.

As a next step, Lumpkin and Dess position their model into the framework of contingency theory, referring to Miller's approach that key variables such as environment, structure, and strategy, are key to obtain optimal performance.[228] Exhibit 15 depicts the conceptual framework of entrepreneurial orientation.

Lumpkin and Dess further analyzed the relationship of their model with the key contingencies, discussed key performance measures, and compared their approach with other existing models using their dimensions.[229]

3.6. Evaluation of Theory Alternatives

Given the relatively young age of entrepreneurship research, only few relevant studies are based on a theoretical framework. Most studies are exploratory. Of the ones that are theory-based, the underlying theories were measured against the requirements for this dissertation. It results that none of the analyzed theories complies with all the requirements of an organizational behavioral theory focused on the internal processes of entrepreneurship.

Entrepreneurial orientation is the theory matches all requirements to the stated problem. Interestingly, it has not been applied in the context of research organizations and entrepreneurship yet, although the focus of many researchers in this field is to understand how researcher behave when they act entrepreneurially, and how the behavior of entrepreneurial academics differs from non-entrepreneurial academics. That is why entrepreneurial orientation should serve as a theoretical framework for this study.

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[228] See Miller (1983).

[229] See Lumpkin and Dess (1996), pp. 152-161. For the purposes of this dissertation, further details of the contingencies will note be discussed here. It is refereed to the original text for further information.

Table 5: Evaluation of Theory Alternatives

Selection Criteria/ Perspective	Resource-based view	Resource Dependency Theory	Contingency Theory	Configura-tional Theory	Social Em-beddedness	Attitude Theory	Entrepreneu-rial Intent	Market Ori-entation	Entrepreneu-rial Orientation
Literature	Penrose (1959), Wernerfelt (1984), Barney (1991)	Cyert and March (1963), Pfeffer and Salancik (1978), Mintz-berg (1982)	Pugh et al. (1963, 1968), Van de Ven (1979), Miller et al. (1988)	Chandler (1962), Khand-walla (1970), Miller (1976, 1982), Mintz-berg (1979, 1983), Miller and Friesen (1984)	Granovetter (1973, 1983, 1985), Powell et al. (1996), Ardichvili et al. (2003)	Ajzen and Fishbein (1977), Robinson et al. (1991)	Shapero (1975), Bird (1988), Davidsson (1995), Autio et al. (1997)	Kohli and Jaworski (1990), Narver and Slater (1990)	Miller (1983), Covin and Slevin (1989, 1991), Lumpkin and Dess (1996), Lyon, Lumpkin and Dess (2000)
Organization	✓	✓	✓	✓				✓	✓
Behavior			✓	✓	✓	✓	✓	✓	✓
Process			✓	✓				✓	✓
Internal	✓		✓	✓		✓	✓	✓	✓
Entrepreneur-ship						✓	✓		✓
Number of Matched Re-quirements	**2**	**1**	**4**	**4**	**2**	**3**	**3**	**4**	**5**

Source: Own conception, based on literature review

3.7. Conclusion

In this chapter, an overview of the existing literature on entrepreneurial activity in an university context was presented, the underlying theories were analyzed and tested according to the requirement of this dissertation, and entrepreneurial orientation was selected as being the most suited for approaching the problem of entrepreneurial behavior in research groups at universities.

It became evident that the entrepreneurial orientation framework of Lumpkin and Dess encompasses many advantages as to why it should be applied to this problem. As the only theory presented, entrepreneurial orientation fulfilled the criteria of an organizational behavioral perspective combined with a process-focus on internal entrepreneurship activities. This combination makes entrepreneurial orientation the preferred theory for this dissertation.

In the following chapter, the theoretical framework of entrepreneurial orientation will be tailored to the requirement of investigating university research units. A model of academic entrepreneurship orientation will be presented, and variances in its dimensions will be explained.

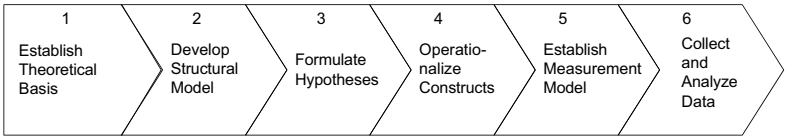
4. Conceptual Model and Hypotheses

4.1. Overview

After having discussed alternative theories available to illuminate the question why some academic research units achieve more technology transfer results than others, this chapter will design a conceptual research model on the basis of the theory we identified as best suited to analyze the problem.

Lumpkin and Dess' theory of entrepreneurial orientation will serve as underlying research framework. On this basis, a structural model will be developed that encompasses the relationship of entrepreneurial orientation and its dimensions, and technology transfer performance. We will use the model to formulate hypotheses for the research question. Furthermore, constructs of the model will be designed, and a measurement model will be developed, consisting of indicators. The combination of the conceptual and measurement model will result in a survey tool to enable data collection and analysis procedure. Exhibit 16 depicts the next steps of this study.

Exhibit 16: Research Steps



Source: Own conception

4.2. Structural Model and Derivation of Hypotheses

The structural model will encompass the key relationship of this study, which is the relationship between entrepreneurial orientation and technology transfer performance. Analogous to the strategic management literature, it is suggested that entrepreneurial

orientation improves an organization's performance.[230] According to Wiklund and Shepherd, "there is also reason to believe that EO [Entrepreneurial Orientation] as an overarching construct can have universal positive performance implications."[231] A number of empirical studies have supported this positive relationship: Wiklund studied 420 Swedish small and medium-sized companies with respect to the sustainability of entrepreneurial orientation over time found that there is a positive relationship between entrepreneurial orientation and performance;[232] the results of Zahra's study of 119 Fortune 500 firms indicate that corporate entrepreneurship activities are associated with financial performance;[233] Covin and Slevin suggested that entrepreneurial top management style has positive effect on the performance of organically-structured firms.[234] However, the underlying assumption is not undisputed, given that other researchers were unable to find such a relationship: Smart and Conant, e.g., tested 599 business people and did not detect any significant relationship between entrepreneurial orientation and performance;[235] and Hart argued that entrepreneurial-type strategies under certain circumstances may even be associated with poor performance.[236]

Atuahene-Gima and Ko provided an alternative approach, linked the concept of entrepreneurial orientation to market orientation, and argued that a maximum positive effect on performance is achieved when market and entrepreneurial orientation are aligned.[237] This approach is put into a different perspective by Bhuian et al., who examine 231 not-for-profit hospitals and suggest that the entrepreneurship-performance relationship is actually curved, showing an initially positively impact when an organi-

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[230] See Covin and Slevin (1991), pp. 19-20. Performance is viewed as revenue generation and profitability, given that the authors designed their concept for the private sector.

[231] Wiklund and Shepherd (2005), p. 75.

[232] See Wiklund (1999), p. 37. Zahra and Covin (1995), examining 109 firms across sizes and industries, also found a positive relation between entrepreneurship orientation and performance.

[233] See Zahra (1991), p. 259.

[234] See Covin and Slevin (1988), p. 217.

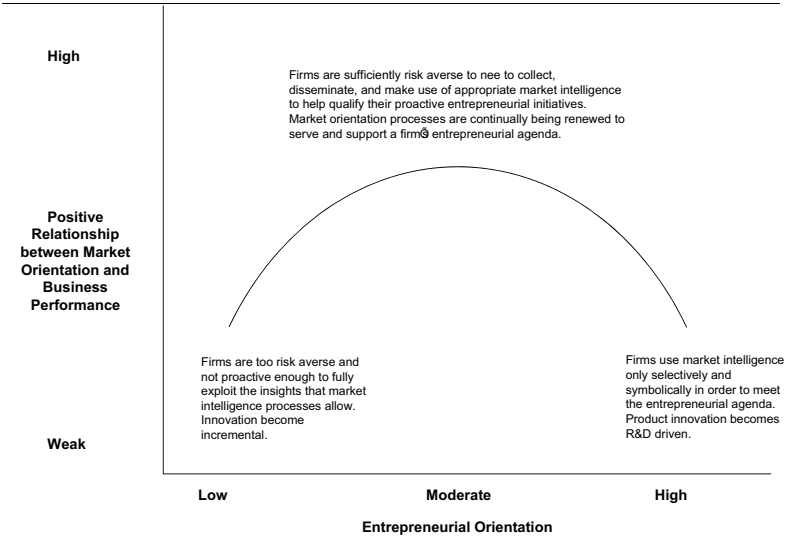
[235] See Smart and Conant (1994), p. 28.

[236] See Hart (1992), p. 346.

[237] See Atuahene-Gima and Ko (2001), p. 68.

zation begins to act entrepreneurially, and then a declining relationship when the organization becomes too entrepreneurial.[238]

Exhibit 17: The Effect of Entrepreneurship on the Market Orientation-Performance Relationship



Source: Bhuian et al. (2005), p. 11

In order to build the constructs of entrepreneurial orientation and technology transfer performance, the existing literature on both constructs will serve as a basis, using on the one hand the theory of entrepreneurial orientation concept following Lumpkin and Dess,[239] and on the other hand the concepts of performance satisfaction in relation to Wiklund and Shepherd,[240] and Homburg and Pflesser.[241] The underlying assumption

[238] See Bhuian, Menguc and Bell (2005), p. 3.

[239] See Lumpkin and Dess (1996), p. 135.

[240] See Wiklund and Shepherd (2005), p. 80.

[241] See Autio, Keeley, Klofsten and Ulfstedt (1997), and Homburg and Pflesser (2000), p. 449.

is that there is a positive relationship between entrepreneurial orientation and technology transfer performance.

4.2.1. Entrepreneurial Orientation

A key element of effectiveness of the construct lies in the associated operationalization. Lyon et al. reported in 2000, four years after the initial publication of the entrepreneurial orientation construct, about the strengths and weaknesses of three different approaches how to operationalize entrepreneurial orientation. These approaches are: (1) managerial perceptions, (2) firm/organizational behavior, and (3) resource allocation.[242] Based on an analysis of the literature, the authors suggested a triangulation of research methods.

Triangulation comprised an approximation of different research methods. While approaching the subject of entrepreneurial orientation from three different angles, researchers would receive best insight into the nature of the construct. Depending on the specific context of the research question, it might be useful to work with surveys in order to capture individual perceptions. Alternatively, one might decide to move away from the perception level and work from a neutral distance away from the organization, thereby trying to analyze organization specific data. As a third alternative, an archival analysis of the allocation of resource could provide the most unbiased perspective. These alternatives should be assessed versus the goals of construct validity, construct reliability, and practicality. The following passage will assess advantages and disadvantages of the three alternatives.

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[242] See Lyon, Lumpkin and Dess (2000), p. 1055.

Managerial Perceptions

Managerial perceptions are often used in entrepreneurship research, involving aspects such as strategy, decision-making processes, or performance.[243] Perceptions can be obtained from interviews or surveys using questionnaires with organizational leaders, given that they can best comment on the situation of the entire organization. Surveys for this purpose have been developed by Miller and Friesen in the strategic management literature,[244] and have been further specified with respect to entrepreneurship orientation by Miller[245] and Lumpkin and Dess.[246]

One of the advantages of a managerial perception approach using surveys is the relatively high level of validity, because "researchers can pose questions that address directly the underlying nature of the construct."[247] They also measure current conditions within an organization with a high degree of specificity. Interviews, in contrast, are more difficult to handle than surveys given that open-ended responses might induce interviewer error, measurement error, and room for interpretation.

The disadvantages of managerial perceptions are grounded in the technique of self-reporting, as opposed to using objective data sources such as financial reports, statistical data, or other archival measures. Collecting self-reported leadership perceptions on organizations creates subjective data.[248] However, in entrepreneurship research, self-reporting is frequently used, in particular with executives, general managers, or in the case of this dissertation by principal investigators. These individuals in leadership positions are most knowledgeable about organizational structure, set-up and behavior, and can communicate general opinions. Furthermore, in particular in small organiza-

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[243] See Naman and Slevin (1993), p. 137.
[244] See Miller and Friesen (1978), pp. 922-923.
[245] See Miller (1983), pp. 773-774.
[246] See Lumpkin and Dess (1996), pp. 153-155.
[247] Lyon, Lumpkin and Dess (2000), p. 1058.
[248] See Boyd, Dess and Rasheed (1993), p. 226.

tions such as research labs, the view of the respondent often reflects those of the organization.[249] However, one should be aware that reliance on a single respondent could increase the possibility of common method variance.[250]

Another problem associated with perceptual measures is functional biases. Boyd et al. explain that different top management members perceive dimensions of entrepreneurship differently.[251] Similarly, in the case of research units, it is possible that a principal investigator in an electrical engineering department has a very different perception of any of the entrepreneurial orientation construct dimensions compared to those of his colleague in biochemistry. Furthermore, it is possible that the information provided by a principal investigator reflects solely his personal perceptions that may vary substantially from those of the other members in his lab. Post-docs and Ph.D.s might have a different perception.

In essence, retrieving information about leaders' perceptions by means of a survey carries a number of advantages: (1) it achieves a high degree of response validity, (2) it can focus on the key elements of the research problem, and (3) it achieves a high degree of specificity. On the negative side, asking for perceptions is influenced by errors within the technique of self-reporting, which ultimately results in subjective data. However, in the case of one self-reporting single-respondent per organization, validity remains high.

Organizational Behavior

An alternative approach available to researchers to study entrepreneurial orientation of a research unit is the observation of organizational behavior. In particular, in order

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[249] See Hambrick (1981), p. 260. Other advantages named by Glick, Huber, Miller, Doty and Sutcliffe (1990), p. 303, are reduced cost by examining just one respondent per organization, and increased likelihood that an organization will participate if only one individual is asked.

[250] See Podsakoff and Organ (1986), p. 531, who discuss problems in self-reporting such as common method variance, consistency motif, and social desirability.

[251] See Boyd, Dess and Rasheed (1993), pp. 215-216.

to avoid problems of dealing with unobservable variables, researchers can focus on those elements of behavior that are observable. Most approaches on measuring organizational behavior come from the strategic management literature.[252]

Measuring organizational behavior, however, is subject to particular challenges for the researcher. As an example might serve the dimension of competitiveness: The literature provides potential approaches to measuring competitiveness by, e.g., content analysis of news headlines or article abstracts. By counting events such as reaction on competitor behavior of a, e.g., another laboratory which has published an important research finding, or the release of a new patent by another university, and the subsequent reaction of the laboratory, e.g. publishing another article referring to the original finding, a researcher could measure the kind of response, time of response, number of responses, etc.[253] However, coding events like the publication of an article and linking it directly to the action of another party will prove difficult. In the majority of cases, a taken action is not a reaction to one single event, but are much more likely to have a number of influencing factors.

In previous entrepreneurship studies, dimensions such as competitiveness and innovation were operationalized using an organizational behavior approach.[254] Advantages are that source data, such as headline news, is independent of the researcher and reproducible. Also, error sources such as respondent or interrogator error can be excluded, provided that coding and interpretation of the source data are accurate.

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[252] See Covin and Slevin (1991), p. 8. The authors argue that the issue of measurability gives advantage to a behavioral model, given that behavior is overt and demonstrable. However, it has to be noted that the causes for a behavior, e.g. an orientation, are not easily observable and measurable. Therefore, by limiting measurement to observable behavior variables, a researcher limits his access to available information.

[253] See Jauch, Osborn and Martin (1980), p. 517, who describe this approach of content analysis in more detail.

[254] See Chen and Hambrick (1995), p. 453, and Chen and MacMillan (1992), p. 539, who applied these methods to the U.S. airlines industry, and compared reactions of smaller and larger companies.

Admittedly, this inherent neutrality makes the organizational behavior approach compelling. There are a number of aspects, though, that diminish its usefulness. First and foremost, only few institutions or organizations are covered so closely by the media or other third parties that headline news are continuously available. In most cases, neutral information is not readily available in a satisfactory manner. Media coverage of large airlines might be sufficient to allow conclusions about their marketing measures and reactions of competitors. For most small businesses, and in particular, for small research laboratories, this is clearly not the case. In this regard, a neutral observation of organizational behavior is simply not feasible, and the researcher ends up in a situation where the patterns he wants to study are in fact unobservable.[255]

Second, even if actions are observable and countable, it is difficult to bring them into an order as it relates to timing and causality. Some responses might occur very rapidly after the initial action, others might take a long lead-time to implement them.[256] Whether these observations are causally linked is not part of the observation.

In summary, the advantages of this approach are the directness of observation and measurement, and the comparability. The disadvantages are the accuracy and meaningfulness of data codification, data identification, the dependency of third parties who provide the data, and ultimately availability of data. In the context of small firms, Lyon et al. conclude that "the usefulness of normative theory developed from studies of large firms may not be generalizable to the competitive situation of smaller firms."[257] This statement is similarly true in the case of research units.

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[255] See Lyon, Lumpkin and Dess (2000), p. 1061.
[256] See Ferrier, Smith and Grimm (1999), p. 375.
[257] Lyon, Lumpkin and Dess (2000), p. 1061.

Resource Allocation

A third alternative how to approach operationalization of entrepreneurial orientation is to study the allocation of resources in organizations,[258] aimed at the dimensions of entrepreneurial orientation, i.e. innovativeness, risk taking, proactiveness, autonomy, and competitiveness. For example, a company's innovativeness could be measured by the ratio of scientists and engineers relative to its total number of employees, or by the ratio of research & development expenditures relative to the firm's total expenditures.[259] Measures of a company's risk taking could be financial leverage.

Reliability of archival data is high, however, there are a number of problems associated with this method. Firstly, in the concrete case of research laboratories, one has to transfer these indicators away from a company environment. Figures like research & development expenditures and number of research personal had to be transferred into another context. As a result, most of these indicators lose parts of their meaning. E.g., in a research lab, hundred per cent of employees work in research, apart from some administrative staff. Similarly, the available budget is usually hundred per cent spent on research. Therefore, a researcher had to search for different indicators, such as research funds spent on new or risky projects, in order to examine innovativeness and risk taking. Similarly, financial leverage generally does not exist in a university environment.

Secondly, even if data is available, and reliability is high, construct validity is not always given.[260] Quite the contrary, available and easily obtainable data can only very roughly estimate the nature of a construct. Most of the elements of entrepreneurial orientation, such as innovativeness, are much more complex as they could be identi-

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[258] See Miller and Friesen (1978), p. 922.

[259] See Hitt, Hoskisson and Kim (1997), p. 778.

[260] E.g. Hambrick and MacMillan (1985), p. 535, and Hitt, Hoskisson and Kim (1997), p. 778, both work with the indicator of research & development spending per unit as a proxy for a company's innovativeness.

fied or measured with one single number. Van de Ven views innovation as a multidimensional construct and comments that "the process of innovation is defined as the development and implementation of new ideas by people who over time engage in transactions with other within an institutional context."[261] In other terms, innovation and innovativeness are complex constructs, and can only be approximated by means of measuring allocated resources.

In summary, the approach of resource allocations is advantageous with respect to data objectiveness, data replicability, data comparability, and reliability. However, in particular the validity aspect turns out to be one of the major disadvantages of this approach. Lyon et al. support the argument that resource allocation in general might be a valid proxy, however, consistent with the tradeoffs between judgment, generalizability, simplicity, and accuracy, additional efforts to establish the validity of such measure may be necessary.[262]

Managerial Perceptions as Preferred Approach

In the previous three sections, the advantages and disadvantages of managerial perceptions, organizational behavior, and resource allocation as research approaches with respect to the goals of construct validity, construct reliability, and practicability were discussed. Exhibit 18 summarizes this discussion.

It shows that the approach of testing perception of individuals in managerial and leadership positions, such as the principal investigator in the context of a research laboratory, is most advantageous, because it provides the highest construct validity, the highest degree of specificity, and can be tailored in order to focus on the key elements of entrepreneurial orientation. Its practicality can still be high, depending on how the

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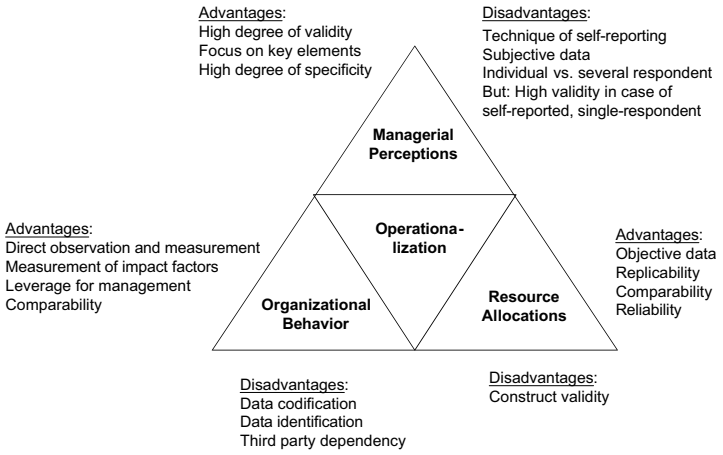
[261] van den Ven (1986), p. 591.

[262] See Lyon, Lumpkin and Dess (2000), p. 1063.

actual surveying activity is structured. By concentrating on a self-reported single respondent, the researcher can limit the impact of data subjectiveness.

Exhibit 18: Three Approaches to Measuring Entrepreneurial Orientation



Source: own conception, following Lyon et al. (2000), p. 1064.

4.2.2. Technology Transfer Performance

A crucial element in the establishment of any entrepreneurial orientation-performance construct is the definition of the performance component of the construct. Whilst in the case of for-profit organizations variables such as profitability or revenues can serve as proxies for performance, it is more difficult to find an appropriate variable for non-profit research units. In the entrepreneurship and strategic management literature, performance is usually defined by indicators such as profitability, revenue growth, market share, return on equity, shareholder value creation, or economic value added.[263] In the case of research universities, the nature of output and goals are differ-

[263] See Lyon, Lumpkin and Dess (2000), p. 153.

ent and change the performance component. Referring to Powers, performance for the purposes of this dissertation will contain elements of the technology transfer process.[264] Another important aspect is the view of Wiklund and Shepherd, who argue that "performance is multidimensional in nature, and it is therefore advantageous to integrate different dimensions of performance in empirical studies."[265]

Following the work of Powers[266] and Rogers et al.,[267] technology transfer includes items such as number of university spin-offs created, number of patent licensed, number of publications, number of meetings, number of industry co-operations.[268] A performance measure that accounts for and reflects these items can be retrieved by the approach of subjective performance satisfaction, as it was formulated by Dess and Robinson.[269]

Table 6: Forms of Technology Transfer Performance Items

Construct	Technology Transfer Performance Item
Performance Satisfaction	Satisfied with number and quality of: • university spin-offs • patents licenced • publications • meetings at conferences • industry cooperations

Source: Powers (2000)

Collecting meaningful performance data on small organizations has early been identified as a difficult task. Dess and Robinson pointed out that "strategic management

[264] See Powers (2000), p. 14.
[265] Wiklund and Shepherd (2005), p. 80.
[266] See Powers (2000), p. 67.
[267] See Rogers, Takegami and Yin (2001), pp. 253-255.
[268] See Rogers, Takegami and Yin (2001), p. 254.
[269] See Dess and Robinson (1984).

researchers often encounter problems obtaining objective measure of selected aspects of organizational performance that are reliable and valid. With privately-held firms, such data are frequently unavailable. With conglomerate business units, all or parts of such data are inextricably interwoven with corporate-wide data."[270] This problem does not only apply to small firms or start-up companies, but similarly to academic research units which resemble a lot to small firms with regard to disclosure and availability of data and performance indicators.

Perceptual measures carry a number of advantages compared to objective performance measures. Firstly, often times objective performance measures such as financial performance (return on assets, return on investment, return on equity) are simply not available on the level for research units. Secondly, even if some form of objective performance measure is available, it is questionable whether the objectivity of this measure applies across all respondents in a way that a comparison of the responses is possible. Thirdly, even if they were available and a comparison was possible, principal investigators might be reluctant to provide this information given its confidential nature.[271]

Therefore, collecting subjective data, often based on a relative comparison with other research units, seemed to be a more suitable approach for performance measurement. In support of this approach, Dess and Robinson found that "a researcher might consider using a subjective perceptual measure of at least two aspects of organizational performance (return on assets and growth on sales) under two specific conditions: (1) accurate objective measures are unavailable, and (2) the alternative is to remove the consideration of performance from the research design."[272] The two criteria are met in the case of this study.

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[270] Dess and Robinson (1984), p. 265.

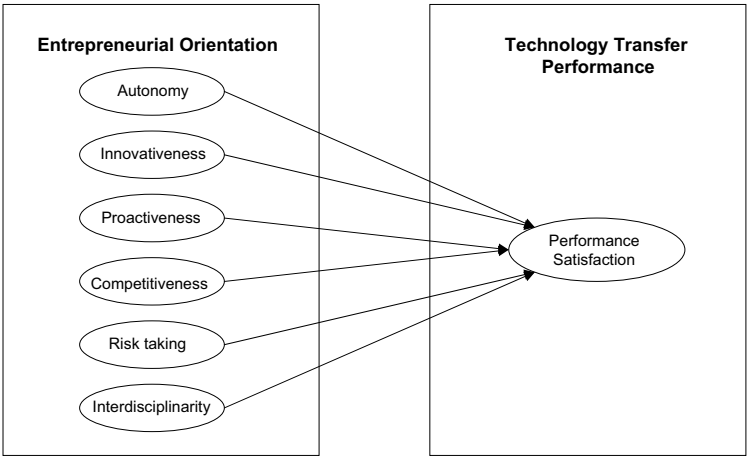
[271] Homburg et al. have encountered similar problems in their study of 2,610 strategic business units. See Homburg, Krohmer and Workman (2004), p. 1335.

[272] Dess and Robinson (1984), p. 271.

4.2.3. Summary of the Structural Model and Development of Hypotheses

The structural model of this study consists of the entrepreneurial-orientation construct as exogenous variable, and technology transfer performance as endogenous variable. The exogenous variable is derived primarily based the work done by Lumpkin and Dess,[273] the endogenous variable draws from the concepts of technology transfer performance satisfaction.[274] The below Exhibit 19 depicts the relationship.

Exhibit 19: Structural Entrepreneurial Orientation-Technology Transfer Performance Model



Source: Own conception

Based on this model and the theoretical framework outlined in Chapter 3, the following relationships are developed, and seven hypotheses are derived.

[273] See Lumpkin and Dess (1996).

[274] See Rogers, Takegami and Yin (2001).

Autonomy-Performance Relationship

A researcher's individual freedom to determine the focus of his/her research, and a research unit's liberty to determine how to allocate resources, and to choose which opportunities to follow, are key elements of opportunity recognition and entrepreneurial behavior.[275] Autonomy to act and do research on an individual, but coordinated basis within a research group seems to be an important ingredient for successful venture creation and technology transfer, because it emphasizes the gain the researcher and his team can achieve if the personal effort is successful.

The first hypothesis, therefore, claims that autonomy has positive impact on technology transfer, performance satisfaction, and ultimately business creation.

H 1 *A higher degree of autonomy within a research unit will impact performance satisfaction more positively.*

Innovativeness-Performance Relationship

Innovation is one of the key elements of successful research, as it is for successful new venture creation.[276] Innovativeness of a research unit is a posture how researchers approach their tasks, if they are open for new ideas and methods, and to which degree they dare to try new paths and experiments. In this regard, innovativeness is closely related to creativity, as Schumpeter already pointed out.[277] The degree to which researchers behave innovatively will impact their technology transfer performance. A positive relationship between innovativeness and performance is expected.

H 2 *The more innovatively a research unit behaves, the more it will be satisfied with its performance.*

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[275] See Lumpkin and Dess (1996), p. 140.
[276] See van den Ven (1986), p. 590.
[277] See Schumpeter (1934).

Risk taking-Performance Relationship

A risk-friendly posture should enable researcher to explore new opportunities more radically, which should be reflected in the allocation of resources such as time, co-workers, money, and materials on a specific projects. This follows the argument of Miller and Friesen that any large commitment of resources encompasses the possibility of failure.[278] The hypothesis between risk taking and performance is that there is a positive relationship between the two variables, i.e. a risk-friendly posture fosters technology transfer performance.

H 3 *The more a research unit is open for taking risks, the more it will be satisfied with its technology transfer performance.*

Proactiveness-Performance Relationship

A proactive researcher is expected to be more successful in his/her research activity, but at the same time also more successful in transferring technology, and possibly in developing an intention to create a new company. This follows from Schumpeter's and Penrose's basic assumption that proactiveness is a key element of entrepreneurial activity.[279] A positive relationship between proactiveness and performance will be tested.

H 4 *The more a research unit is proactive about its research, the more it will be satisfied with its technolgy transfer performance.*

Competitiveness-Performance Relationship

The willingness to compete with others and survive in a marketplace is a basic entrepreneurial element. It is assumed that research units that have the desire to try new ideas in the marketplace and to promote their ideas aggressively act similarly aggres-

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[278] See Miller and Friesen (1978), p. 923.

[279] See Schumpeter (1934) and Penrose (1958).

sively in their research work. Again, a positive relationship between competitiveness and performance is expected.

H 5 *The more a research unit works competitively, the more it will be satisfied with its performance.*

Interdisciplinarity-Performance Relationship

Interdisciplinarity is the only component of the construct that is not developed by Lumpkin and Dess. Given the importance of interdisciplinary exchange between researchers for the purpose of opportunity recognition, this element is implemented in the model, and positive relationship between interdisciplinary activity and technology transfer performance is postulated.

H 6 *The more a research unit works on an interdisciplinary basis, the more it will be satisfied with its technology transfer performance.*

Relationship between Exogenous Variables

Lumpkin and Dess already proposed that "the salient dimensions of entrepreneurial orientation – autonomy, innovativeness, risk taking, proactiveness and competitive aggressiveness – may vary independently of each other in a given context",[280] because a company can avoid innovativeness, but be on the other hand extremely competitive, and therefore these variables can move independently from each other. This proposition will be followed.

H 7 *The variables of autonomy, innovativeness, risk taking, proactiveness, competitiveness, and interdisciplinarity, do not have a causal relationship between each other and do not covary.*

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[280] Lumpkin and Dess (1996), p. 151.

4.3. Development of Measurement Model and Operationalization of Indicators

A number of studies using the elements of the entrepreneurial orientation construct were conducted over the course of the last fifteen years. From a statistical perspective, it is important to note that many of these studies, however, lack or do not report on reliability or validity testing, nor were they based on second-generation structural equation modeling. In this regard, the present study will be conducted under high modeling standards.

4.3.1. Operationalization of Entrepreneurial Orientation Construct

In their article "Enhancing Entrepreneurial Orientation Research: Operationalizating and Measuring a Key Strategic Decision Making Process", Lyon et al. provide guidance about the operationalization of the entrepreneurial orientation construct.[281]

Autonomy

In the context of a questionnaire measurement, the autonomy construct was tested several times in earlier studies, mostly involving entrepreneurship situations. Chaganti et al., for example, asked 903 small venture entrepreneurs about their capital structure decisions. The autonomy component was measured using original scale items, and showed that individual entrepreneurs influence capital structure decisions. Reliability or validity tests were not reported in the study.[282]

Lerner et al. investigated 220 women entrepreneurs on individual motivations and goals, social learning, network affiliation, human capital, and environmental influences, using scale items developed by Hisrich and Brush.[283] Revenues were chosen as

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[281] See Lyon, Lumpkin and Dess (2000).
[282] See Chaganti, DeCarolis and Deeds (1995).
[283] See Hisrich and Brush (1982), Hisrich and Brush (1985).

of the performance measures, thereby showing that autonomy motivation was negatively related to performance. Lerner et al. tested reliability of the construct; validity, however, was not reported.[284]

In another study, Shane et al. also applied original scale items to examine cultural differences of 1,128 individuals from 30 countries with regard to national preferences for innovation championing strategies, and to find that different degrees of autonomy result in different innovation champion behavior across different countries. Reliability of the study was tested, validity was not reported.[285]

For the autonomy dimension, no generally accepted construct that could be broadly applied has been developed yet. Earlier studies have tailored their measurement tools to the specific context of their investigation. The present study will pursue a similar approach, given that this will be the first study connecting entrepreneurial behavior of academics and performance measurement.

In this study, an original items scale consisting of six indicators will measure the autonomy construct: "Individual research freedom", "resource allocation responsibility", "research focus adjustment", "individual grant application", "personal accountability", and "relative perceived autonomy".

Table 7: Item Source of "Autonomy" Construct

AUTONOMY CONSTRUCT		
Label	*Indicator*	*Source*
AUTO1	Individual research freedom	Original item
AUTO2	Resource allocation responsibility	Original item
AUTO3	Research focus adjustment	Original item
AUTO4	Individual grant application	Original item
AUTO5	Personal accountability	Original item
AUTO6	Relative perceived autonomy	Original item

[284] See Lerner, Brush and Hisrich (1997).

[285] See Shane, Venkataraman and MacMillan (1995).

Innovativeness

The innovativeness dimension has received greater research interest than the autonomy dimension. Next to the proactiveness dimension, innovativeness is the most investigated of the five original dimensions of the entrepreneurial orientation construct. The literature on innovativeness and innovation in various contexts is broad; therefore the selection of studies presented here is limited to those relevant to entrepreneurial orientation.[286]

The most widely used scales on innovativeness go back on scale items developed by Miller and Friesen,[287] Covin and Slevin,[288] and Hart.[289] Although these scales reflect different perspectives on innovation, they operate in comparable fashion, often using 7-point bipolar Likert scales, and targeting at entrepreneurial organizational behavior in firms.

Becherer and Maurer, for example, in their investigation of innovativeness, risk taking and proactiveness of 147 entrepreneurs who had started or purchased a business, used scale items based on the Covin and Slevin scale. They found that an entrepreneurial orientation, comprising these three dimensions, is directly related to changes in performance, represented in their study by profits.[290] Sapienza and Grimm also worked with the Covin and Slevin scale, thereby investigating 70 CEOs of shortline railroad companies. In their organizational-level study, they could not find a relation between

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[286] Articles discussed in this passage are limited to those following a managerial perception approach, i.e. data and results are obtained mostly based on surveys. Those articles following a firm behavior or a resource allocation approach are not discussed. These articles would include the works of Hitt, Hoskisson and Kim (1997), Hundley, Jacobson and Park (1996), Kelm, Narayanan and Pinches (1995), Kochhar and David (1996), and Kotabe and Swan (1995).

[287] See Miller and Friesen (1982), p. 24. The authors view innovativeness from a product innovation perspective.

[288] See Covin and Slevin (1989), p. 86. Covin and Slevin's approach in more focused on the strategic posture element of an organization, therefore being more applicable to the problem of entrepreneurial orientation in research organizations.

[289] See Hart (1991). Other scales used in this context were developed by Khandwalla (1977) and Robinson, Stimpson, Huefner and Hunt (1991).

[290] See Becherer and Maurer (1997).

entrepreneurial orientation and performance.[291] Barringer and Bluedorn applied the scale to 169 manufacturing firms and found a positive relationship between organizational entrepreneurship and five strategic management practices.[292]

Koberg et al. adapted Miller and Friesen's measure and developed a three-item composite measure, anchored on a five-point scale with paired statements to investigate 326 CEOs of non-diversified firms in a firm-level study. They found that the life cycle stage is a contingency factor in organizational innovation.[293]

The range of scales to measure innovativeness is not limited to developments of Covin and Slevin, and Miller and Friesen. In a cross-cultural entrepreneurship survey of 258 CEOs in English and French-speaking countries, Knight used a scale for innovativeness and proactiveness based on Khandwalla's work in the 1970s, and showed its validity and reliability across cultures.[294] The study of Barney et al. deals with new venture teams and their assessment of learning from venture capitalists. The authors investigated 205 new ventures and analyzed managerial perceptions on innovativeness.[295] The scale used was based on suggestions by Porter[296] and Sandberg and Hofer.[297] In a comparative study of entrepreneurial incidence among inventors in national laboratories, Kassicieh et al. surveyed 237 inventors and applied the entrepreneurial attitude orientation scale of Robinson et al. to investigate the dimension of innovativeness.[298] The authors tested the construct on an individual level, and found

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[291] See Sapienza and Grimm (1997).

[292] See Barringer and Bluedorn (1999). The five strategic management practices include scanning intensity, planning flexibility, planning horizon, locus of planning, and control attributes.

[293] See Koberg, Uhlenbruck and Sarason (1996).

[294] See Knight (1997).

[295] See Barney, Busenitz, Fiet and Moesel (1996).

[296] See Porter (1980).

[297] See Sandberg and Hofer (1987).

[298] See Kassicieh, Radosevich and Umbarger (1996) and Robinson, Stimpson, Huefner and Hunt (1991) which both are part of the relevant set of studies listed in Chapter 4.3.

that lack of support from laboratories did not appear to affect entrepreneurial attitudes of investors. Reliability of the construct was tested, validity was not reported.

The variety of approaches demonstrates how difficult it is at this stage to compare methods and results across different studies, given that no standardized measures for dimensions have been developed yet. Most researchers tend to develop their own scale because this is presumably more appropriate for their specific context of research.

For example, Hitt et al. surveyed 250 mid-sized and large industrial firms on the perception of external innovation. Their study focused on the mergers and acquisitions element of corporate strategy, i.e. how to gain corporate control of other firms and incorporate their innovations. In this case, it was more appropriate to create a new scale, given that the traditional approach of Covin and Slevin was not adequate for this research question.[299]

Similarly original approaches were taken by Rajagopalan in his study of innovativeness of 50 large utility firms,[300] Tan in his survey of 53 Chinese business owners,[301] and Zahra's studies of 138 large manufacturing companies and 176 CEOs.[302] In these cases, the authors decided to utilize original scale items in order to tailor their survey instruments to the specific needs of their respective research questions.

For the purposes of this dissertation, the dimension of innovativeness will be measured using eight items, anchored on a seven-point Likert scale. Thereby, a mixed approach of already established measures and original measures is chosen. The novelty

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[299] See Hitt, Hoskisson, Johnson and Moesel (1996). Primary variables in this study were acquisition intensity, divesture intensity, financial controls, strategic controls, external innovation, and internal innovation. A seven-point Likert scale, asking for managerial perceptions, measured external innovations. Internal innovations were measured as resource allocation in form of R&D intensity over sales, and as firm behavior in form of the mean of new products introduced over the last two years.

[300] See Rajagopalan (1997).

[301] See Tan (1997).

[302] See Zahra (1996b) and Zahra (1996a).

of this study in the field of academic entrepreneurship requires that some indicators have to be newly developed. However, for the major part, Miller and Friesen's and Covin and Slevin's scales can be used.

The first two items of the innovativeness construct – "emphasis on established methods" and "emphasis on technological leadership" – relate to Covin and Slevin's bipolar item of true and tried products versus R&D leadership. In this sense, the bipolar items were modified to test them separately. Items 3, 4, 5 and 6 – "differentiation in research", "radically new methods", "past success" and "willingness to adjust" – are adopted from Covin and Slevin and modified into a measurement format directly tailored at academic scholars. It is important to understand that some of the business terms of the original scale had to be adjusted in order to make them relevant for academics. Item 7 "incorporation of external methods" is taken from the proactiveness section of the Covin and Slevin's instruments. Item 8 "general innovativeness" operates as a summarizing item and incorporates a verification function.

Table 8: Item Source of "Innovativeness" Construct

INNOVATIVENESS CONSTRUCT		
Label	*Indicator*	*Source*
INNO1	Emphasis on established methods	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO2	Emphasis on technological leadership	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO3	Differentiation in research	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO4	Radical new methods	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO5	Past success	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO6	Willingness to adjust	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO7	Incorporation of external methods	Barringer and Bluedorn (1999), Covin and Slevin (1988)
INNO8	General innovativeness	Original item

Proactiveness

The proactiveness component of the entrepreneurial construct has received a relatively high degree of research interest, similar to innovativeness, and relatively more than risk taking, autonomy, and competitiveness. The nature of proactiveness has been linked to entrepreneurship already by Schumpeter in 1934 and Penrose in 1958, capturing the importance of initiative, vision, and anticipation within the entrepreneurial process.[303]

A number of authors have investigated the proactiveness construct. In case that their studies are based on Covin and Slevin's "Conceptual Model of Entrepreneurship as Firm Behavior",[304] it is likely that researcher combined the approaches of proactiveness and innovativeness, given that the firm's entrepreneurial posture is describes as being "represented by a firm's risk taking propensity, tendency to act in competitively aggressive, proactive manners, and reliance on frequent and extensive product innovation."[305] In other terms, Covin and Slevin see a relationship between proactiveness, risk taking, and innovativeness.[306]

As a matter of fact, most of the studies mentioned in the previous section on innovativeness also investigated proactiveness in the same survey, using Covin and Slevin's scale. This is the case in the studies of Barringer and Bluedorn,[307] Becherer and Maurer,[308] and Sapienza and Grimm.[309] Similarly, Knight used the Khandwalla scale

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[303] See Schumpeter (1934) and Penrose (1958).

[304] See Covin and Slevin (1991).

[305] See Covin and Slevin (1991), p. 7.

[306] The following will only present studies that focus on managerial perceptions, i.e. conducted surveys. For other studies focusing on firm behavior or resource allocation in the context of proactiveness, please refer to Chen and Hambrick (1995) and Smith, Grimm, Wally and Young (1997).

[307] See Barringer and Bluedorn (1999).

[308] See Becherer and Maurer (1997).

[309] See Sapienza and Grimm (1997).

to test proactiveness in combination with innovativeness,[310] and Zahra and Covin used the Miller and Friesen scale.[311]

Other authors preferred to develop an original scale to measure proactiveness. Aragón-Correa questioned 105 CEOs of firms in 10 different industry sectors in an original scale survey, and tested the results on reliability and validity. He found that strategic proactiveness relates to efforts to safeguard the natural environment. The focus of this investigation made an original scale approach necessary.[312] Similarly, Tan and Zahra worked with original items.[313]

The items of the present study developed for the investigation of proactiveness of research units in the context of entrepreneurial orientation adopt elements of Covin and Slevin and Miller and Friesen. However, both author teams focused less on the dimension of proactiveness, and Covin and Slevin used the term even interchangeably to "competitiveness". Therefore, other items based on work by Chen and Hambrick were added.[314] Chen and Hambrick emphasized the proactive element of firm behavior and stated that "a firm should be both proactive and responsive in its environment in terms of technology and innovation, competition, customers, and so forth. Proactiveness involves taking the initiative in an effort to shape the environment to one's own advantage; responsiveness involves being adaptive to competitors' challenges."[315] In addition, in order to emphasize the anticipation element of proactiveness, an influence from research done the field of market orientation seemed appropriate, given that market orientation operates close to customer or users of products and inventions.

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[310] See Knight (1997).

[311] See Zahra and Covin (1995).

[312] See Aragón-Correa (1998).

[313] Both authors were already mentioned in the previous section, referring to Tan (1997), Zahra (1996b), and Zahra (1996a).

[314] See Chen and Hambrick (1995).

[315] Chen and Hambrick (1995), p. 457.

The proactiveness dimension was surveyed using eight items on a seven-point Likert scale. Items 1 to 4 – "anticipation of research trends", "relevance of research fields", "anticipation of future needs", and "alignment of research efforts" – are designed as an original scale with strong reference to Chen and Hambrick's notion of proactiveness.[316] In particular, the anticipatory element was taken into account, as being crucial to a proactive posture. Items 5 and 6 – "responsiveness" and "leadership" – are adopted from Covin and Slevin. Again, their semantic differential items were transformed into Likert rating scale items. Items 7 and 8 – "discussion and feedback" and "dissemination" – are taken from the market orientation literature. Given the importance of reacting to and distributing information, as it is pointed out by Kohli and Jaworski,[317] and Narver and Slater,[318] for proactive behavior, these items should add considerably to the proactiveness construct. The items were phrased in a way comparable to its six predecessors, and adopted language from Homburg and Pflesser.[319]

Table 9: Item Source of "Proactiveness" Construct

PROACTIVENESS CONSTRUCT		
Label	*Indicator*	*Source*
PRO1	Anticipation of research trends	Original item, Chen and Hambrick (1995)
PRO2	Relevance of research fields	Original item, Chen and Hambrick (1995)
PRO3	Anticipation of future needs	Original item, Chen and Hambrick (1995)
PRO4	Alignment of research efforts	Original item, Chen and Hambrick (1995)
PRO5	Responsiveness	Covin and Slevin (1988)
PRO6	Leadership	Covin and Slevin (1988)
PRO7	Discussion and feedback	Homburg and Pflesser (2000)
PRO8	Dissemination	Homburg and Pflesser (2000)

[316] See Chen and Hambrick (1995).

[317] See Kohli and Jaworski (1990), p. 3.

[318] See Narver and Slater (1990), pp. 21-22.

[319] See Homburg and Pflesser (2000), p. 459. The authors work with four items on the construct of "openness of market-related internal communication."

Competitiveness

Lumpkin and Dess extended the canon of dimensions of entrepreneurial orientation from initially three (innovativeness, risk taking, proactiveness) by another two (competitiveness and autonomy).[320] There has been debate whether the additional two dimensions actually reflect postures different from the initial three, and the argument can be made that competitiveness is part of a proactive attitude versus markets and competition. Miller, for example, suggests that an entrepreneurial firm is one that "engages in product market innovation, undertakes somewhat risky ventures, and is *first* to come up with 'proactive' innovations, beating competitors to the punch."[321] In other words, Miller sees the competitiveness as part of proactiveness. The competitive element on a stand-alone basis, however, finds strong support by the strategic management literature, in particular by Porter.[322]

The competitiveness component of the entrepreneurial construct has received a relatively low degree of research attention. In the relevant literature on entrepreneurship, only one article by Zahra and Covin was identified as dealing with the competitiveness construct.[323] In this article, the authors worked with data collected from 108 companies across various industries, and concluded that corporate entrepreneurship becomes more effective, i.e. translates more effectively into performance, over time. [324] Reliability and validity of the construct were tested. The analysis was conducted on a firm level using the Miller and Friesen index.[325]

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[320] See Lumpkin and Dess (1996), p. 139.

[321] Miller (1983), p. 771.

[322] See Porter (1985).

[323] Other articles dealing with competitiveness, however not on the basis of managerial perceptions, are the ones of Dess, Lumpkin and Covin (1997), and Smith, Grimm, Wally and Young (1997), using observable firm behavior.

[324] See Zahra and Covin (1995), p. 51.

[325] See Miller and Friesen (1982), p. 17-24.

The competitiveness construct used in this dissertation encompasses six items, all on a seven-point Likert scale. Because the notion of competitive behavior between academics somewhat differs from competitiveness between competing firms, the term competitiveness should be viewed in a broad sense.

Items 1 and 2 – "competition measurement" and "competition observation" – were created in adoption of Covin and Slevin's questions on competitiveness.[326] The original semantic differentials were converted into normal Likert scales. Similar to items of the proactiveness construct, items 3 and 4 – "ambition" and "communication" – refer to questions used in the context of market orientation. Thrive for quality and ambition, as well as openness of internal communication, have been part of Homburg and Pflesser's shared basic value construct.[327] The items were modified to fit the questionnaire used for academics. In order to focus on the element of competitiveness, industry exchange and industry interaction, two original scale items were created, "industry interaction" and "transfer obligation." They should reflect the competitive nature of cooperation with a for-profit company that relies on translating research into marketable products.

Table 10: Item Source of "Competitiveness" Construct

COMPETIVENESS CONSTRUCT		
Label	*Indicator*	*Source*
COMP1	Competition measurement	Covin and Slevin (1988)
COMP2	Competition observation	Covin and Slevin (1988)
COMP3	Ambition	Homburg and Pflesser (2000)
COMP4	Communication	Homburg and Pflesser (2000)
COMP5	Industry interaction	Original item
COMP6	Transfer obligation	Original item

[326] See Covin and Slevin (1989), p. 86.

[327] See Homburg and Pflesser (2000), p. 459.

Risk taking

Risk taking had been identified already by Covin and Slevin as one of the key components of an entrepreneurial orientation. A number of authors tried to obtain a better understanding of the construct using questionnaire technique.

In addition to the studies of Barringer and Bluedorn,[328] Becherer and Maurer,[329] and Tan,[330] which were already mentioned in the context of proactiveness and innovativeness, Busenitz and Barney studied the behavior of 124 entrepreneurs and 95 managers with regard to their posture of risk taking, using the Jackson Personality Inventory.[331] They found that entrepreneurs have a different decision-making process than employed managers.[332]

Palich and Bagby, in a 1995 study of 92 entrepreneurs and non-entrepreneurs, surveyed individual risk taking using a scale developed by Gomez-Mejia and Balkin,[333] and argued that entrepreneurs do not perceive their actions as risk-friendly, but nevertheless tend to assess business situations more positively than others.[334] In contrast, Sitkin and Weingart developed their own scale in a study of 38 MBA students regarding risky decision-making behavior, and argued that risk propensity and perception are mediating factors.[335]

The present study used seven items to test the construct of risk taking, on a seven-point Likert scale, mostly adopting items for the Covin and Slevin scale. Items 1 and 2 – "commitment of resources" and "prudent resource allocation" – are variations of the

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[328] See Barringer and Bluedorn (1999).
[329] See Becherer and Maurer (1997).
[330] See Tan (1997).
[331] See Jackson (1976).
[332] See Busenitz and Barney (1997).
[333] See Gomez-Mejia and Balkin (1989).
[334] See Palich and Bagby (1995).
[335] See Sitkin and Weingart (1995), p. 1592.

strategic posture scales, one emphasizing a strong proclivity for high-risk projects, the other testing a proclivity for low-risk projects. The issue of failure is an important element of entrepreneurial risk taking. Without the acceptance of failure, entrepreneurial risk taking activity is hampered. "Failure should be regarded as a learning experience and firms must permit it. There is no success without risk. Taking no risk is the surest way to fail."[336] Therefore, items 3 to 5 test academics on "encouragement after failure", "acceptance of failure", and "acknowledgment of failure." The concluding items 6 and 7 are again based on Covin and Slevin's scale and check on general "risk-friendliness" and "eagerness for new methods."

Table 11: Item Source of "Risk taking" Construct

RISK TAKING CONSTRUCT		
Label	*Indicator*	*Source*
RISK1	Commitment of resources	Covin and Slevin (1988)
RISK2	Prudent resource allocation	Covin and Slevin (1988)
RISK3	Encouragement after failure	Original item
RISK4	Acceptance of failure	Original item
RISK5	Acknowledgement of failure	Original item
RISK6	Risk-friendliness	Covin and Slevin (1988)
RISK7	Eagerness for new methods	Covin and Slevin (1988)

Interdisciplinarity

The construct of interdisciplinarity has originally not been part of the entrepreneurial orientation construct of Lumpkin and Dess. Interdisciplinarity is a term typical for the academic environment, rather than a firm environment. In the context of this study, however, interdisciplinarity carries a number of important features.

Interdisciplinary collaboration between academics and faculties of different disciplines is generally viewed as necessary and fruitbearing. In its mission statement, the

[336] Badawy (1988), p. 21.

German Research Foundation (Deutsche Forschungsgemeinschaft, "DFG") defines the promotion of cooperation between researchers as one of the foundation's core responsibilities: "An important goal of the DFG's research support is to provide measures to promote the exchange of information between scientists and academics and collaboration between researchers from various disciplines. This is why the foundation focuses particularly on strengthening interdisciplinarity and networking in the scientific communities."[337]

Governments have incorporated the support of interdisciplinary academic work as policy goals. These policies include enhancing communication and exchange between research institutions, creating competence centers and networks, and supporting cross-organizational and interdisciplinary research projects.[338]

From a general economic policy perspective, interdisciplinary research projects are expected to contribute to the creation of innovative high-tech companies, which in itself should nurture economic growth and development of future research. Governments refer in the context to the successes of Silicon Valley, where the combination of local research institutions plus companies plus venture capital providers has led to an innovation-friendly climate.[339]

Universities in the U.S. have recognized the importance of interdisciplinary exchange, and invested heavily in infrastructure of interdisciplinary life science. Stanford University, for example, invested more than $150 million to build the Clark Center of Bio-Science, which will host more than 40 faculty members from various bio-related research fields such as bio-engineering, bio-computation, and bio-physics, and fosters interdisciplinary research.[340] Cornell University started a $600 million new life sci-

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[337] DFG (2004).
[338] As an example of the German federal governmental policies, see BMBF (2004b), p. XIII.
[339] See BMBF (2004b), p. VI.
[340] See Baker (2003).

ence initiative to advance university-wide life science research, the largest single initiative ever in the history of the university.[341]

The impact of interdisciplinary research work on new venture creation is beyond the scope of this dissertation. However, a number of researchers suggest that interdisciplinarity has positive impact on the effectiveness of research efforts. Liebeskind et al. examine how new biotechnology firms source their most critical input – scientific knowledge, and find that scientists "enter into a large number of collaborative research efforts with scientists in other organizations, especially universities."[342] Oliver states "Inter-institutional scientific collaboration in biotechnology are now known to be the vehicle that drives the industry forward. Since networks of collaboration become crucial for biotechnology research, academic and industrial scientists act as entrepreneurs by expressing dedication to the potential commercial value of their intellectual capital."[343]

The impact of interdisciplinarity on technology transfer performance in the context of entrepreneurial orientation at research institutions has not been investigated yet. Consequently, the measurement scale had to be originally drafted. It encompasses eight original measurement items. Items 1 to 3 – "interdisciplinary exchange", "receipt of ideas", and "incorporation of ideas" – capture three steps of idea generation and incorporation, from communication via cognition to action. Items 4 and 5 – "incentives" and "informal meeting" – test means that universities provide in order to contribute to the interdisciplinary discourse between researchers. Items 6 to 8 – "participation in interdisciplinary projects", "observation of inter-disciplinary projects", and "degree of interdisciplinary knowledge" – refer to projects already conducted at an institution, and the degree of tacit knowledge. All items were operationalized using a seven-point Likert scale.

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[341] See Brand and Segelken (2002).
[342] Liebeskind, Oliver, Zucker and Brewer (1996), p. 428.
[343] Oliver (2004), p. 583.

Table 12: Item Source of "Interdisciplinarity" Construct

INTERDISCIPLINARITY CONSTRUCT		
Label	*Indicator*	*Source*
INTER1	Interdisciplinary exchange	Original item
INTER2	Receipt of ideas	Original item
INTER3	Incorporation of ideas	Original item
INTER4	Incentives	Original item
INTER5	Informal meeting	Original item
INTER6	Participation in interdisciplinary projects	Original item
INTER7	Observation of interdisciplinary projects	Original item
INTER8	Degree of interdisciplinary knowledge	Original item

4.3.2. Operationalization of Technology Transfer Performance

In the previous section, the exogenous variables were operationalized using a combination of existing measures plus modifications of these measures for research universities plus original measures if no precedents were available. This section now will operationalize the endogenous variable. The endogenous construct of technology transfer performance consists of the elements of technology transfer performance satisfaction.

Performance Satisfaction

In the literature, there has been debate about the extent to which subjective performance perception is a valid proxy for performance measurement. On the one hand, several researchers state that subjective performance measures may be appropriate given the restrictions imposed by objective measures.[344] Other researchers, in contrast, reported less satisfaction with the subjective performance measure.[345] The advantage of subjective measures is strong internal consistency, which eliminates some of the prob-

[344] See Cooper (1984); Dess and Robinson (1984); Gupta and Govindarajan (1984).

[345] See Covin et al. (1990), and Sapienza (1989, 1992), who modeled after an instrument developed by Gupta and Govindarajan (1984) to estimate the performance of organization sub-units.

lems associated with the multidimensionality of traditional performance measures. In order to eliminate any potential shortcomings with regard to the subjective performance satisfaction construct, it was attempted to build the construct as closely as possible to existing precedent. With regard to different technology transfer items, Rogers et al.'s study served as a template: Technology transfer is expressed in items such as research results, research publications, patents being registered, companies being spun-off, presentations being held at conferences, and meetings being attend with industry counterparts.[346] These items where combined with the satisfaction approach outlined by Dess and Lumpkin, thereby creating a set of indicators that reflect the performance satisfaction of the research unit.[347] It is important to note that these indicators were established in a reflective format, as opposed to formative.

Table 13: Item Source of "Performance Satisfaction" Construct

PERFORMANCE SATISFACTION CONSTRUCT		
Label	*Indicator*	*Source*
PERF1	Research results	Original item
PERF2	Publications	Original item
PERF3	Patents	Original item
PERF4	Company spin-offs and start-ups	Original item
PERF5	Presentations at conferences	Original item
PERF6	Industry meetings	Original item
PERF7	Entrepreneurial activity	Original item
NB: All items were developed with reference to Rogers et al. (2001) and Dess and Lumpkin (2005).		

The performance satisfaction construct represents itself as a set of original items, because the performance construct has not yet been tested in the literature in the context of academic research units. Nevertheless, existing precedents have impacted its construction.

[346] See Rogers, Takegami and Yin (2001), pp. 254-255.
[347] See Dess and Lumpkin (2005)

4.3.3. Control Variables

The research method of a surveying perceptions via a questionnaire allows for sorting and evaluating the data according to certain control variables. The questionnaire was designed to capture criteria which are useful to differentiate across all respondents, such as research discipline, position of respondent, size of research unit, and budget of research unit.

The first control variable "area of research" categorizes the respondents into the research disciplines electrical engineering, computer science, biology/biochemistry, bioinformatics, bioengineering, medical science, other life science research areas, and other. The second control variable "position of respondent" allows differentiating across various respondents by position, such as principal investigators, research associates, post-doctoral fellows, Ph.D. candidates, graduate students, or undergraduate students. The third control variable "size of research unit" encompasses the number of members within the research unit, starting from small units of 1 to 3 members and ending with large units of more than 30 members. The forth control variable "budget of research unit" captures the annual research budget of the research units, which is distributed in seven items starting with less than $250,000 and ending with more that $10 million.

More insight about the relative implications of the control variables is desirable in order to shed more light on the phenomena of technology transfer at universities. In particular, this analysis will be meaningful in comparison to the resource-based and contingency studies conducted i.a. by Powers.[348] However, given the limitations of the dissertation, we will abstain from this analysis at this point. It will be referred to at a later stage with regard to future research opportunities.

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[348] See Powers (2000), p. 14.

4.4. Conclusion

In summary, the measurement model consists of seven constructs, of which six measure the entrepreneurial orientation part of the model (the exogenous variables), and one measures the performance part (the endogenous variable). The exogenous variables are autonomy, innovativeness, proactiveness, risk taking, competitiveness, and interdiscipliarity; performance satisfaction forms the exogenous variable.

5. Methodology

5.1. Overview

Multivariate research techniques are powerful and well-suited tools to analyze strategic management or organizational behavior constructs such as entrepreneurial orientation.[349] This chapter will firstly present multivariate techniques of the so-called "first generation", and discuss their strengths and weaknesses. Secondly, it will introduce and discuss further advanced "second-generation" multivariate research techniques, in particular variance-based and covariance-based structural equation modeling.[350] A comparison of the techniques across generations will lead to the assessment that second-generation multivariate research techniques are more suitable to contribute as a methodology to the problem of influence of entrepreneurial orientation on technology transfer performance.

The earlier analysis of the existing literature on entrepreneurial orientation and technology transfer at universities demonstrated the exploratory stage of this research field. Consequently, only little technically structured research that might serve as reference for this study has been conducted so far. Most research is descriptive in nature and based on case studies. However, it is observable that the research field moves from an exploratory towards a more confirmatory stage, which makes it sound to introduce the application of confirmatory second-generation structural equation model-

[349] See Shook, Ketchen, Hult and Kacmar (2004) as to the development of multivariate research techniques and structural equation modeling in strategic management literature. The authors present an analysis of 92 strategic management studies published from 1994 to 2002. Despite the relatively widespread usage of multivariate research techniques, the authors critically comment that this usage has often been less than ideal, though, and that researchers might draw erroneous conclusions about relationships among variables.

[350] See Hoyle (1995b) for a general introduction into the concept of structural equation modeling.

ing.[351] This methodology will be a valuable contribution to the research field, and will further elucidate the field of academic entrepreneurial behavior.

5.2. First-Generation Multivariate Research Techniques

The rapid development of computer-supported research methods and data analysis software in the 1960s "represented the beginning of a shift in research orientation for many social sciences: from abstract theory, often void of empirical fact, toward increasing empiricism, not often without the justification of or interest in making abstract claims."[352] Empirical research tools such as regression analysis, factor analysis, cluster analysis, multidimensional scaling, multivariate analysis of variance (MANOVA), and discriminant analysis were developed, and are now categorized as "multivariate techniques of the first generation."[353] These methods were rapidly diffused amongst researchers, given that they provided a major step forward from earlier univariate or bivariate methods, and required fewer statistical assumptions. This resulted in an increase in empirical research, fueled by the large amount of data that was already available and could now be handled.

First-generation multivariance techniques, however, carry a number of shortcomings: Firstly, analysis of data is limited to observable variables only, i.e. variables like age, number of employees, earnings, revenues. More complex variables such as entrepreneurship orientation, marketing orientation, or attitudes are generally not directly observable, and hence cannot be captured by these models.[354] Secondly, with respect to

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[351] Anderson and Gerbing (1988), pp. 411-412, argue that "although it is convenient to distinguish between exploratory and confirmatory research, in practice this distinction is not as clear-cut. … Rather then strict dichotomy, then, the distinction in practice between exploratory and confirmatory analysis can be thought of that as an ordered progression."

[352] Fornell (1982), pp. 1-2.

[353] See Fornell (1982), p. 2. In addition, Sheth (1971), pp. 13-17, and Kinnear and Taylor (1971), pp. 56-59, provide classifications of multivariate methods.

[354] See McDonald (1996), p. 239. McDonald states that "a random variable is observable if and only if its values can be obtained by means of a real-world sampling experiment."

measurement error of observable variables, most first-generation techniques assume that variables are measured without measurement error. This is a strong limitation, given that various factors cause measurement errors, be it wrong accounting measures for corporate figures, the respondent's error in understanding and answering the question, or the surveyor's error is asking the question incorrectly.[355] Thirdly, multivariance of most first-generation methods is restricted to only one side of the model's equation, i.e. either predictor or criterion variables, thereby restricting true multivariate analysis. Fourthly, due to the relaxations of statistical assumptions, these methods are better suited for descriptive or exploratory application, rather than confirmatory application.[356]

In other words, first-generation multivariate techniques can be usefully applied in particular during the exploratory stage of a theory. In fact, 11 of the 31 relevant publications analyzed in Chapter 3 used first-generation regression models. In contrast, only one out of 31 study relied on a second-generation structural equation model.[357]

Second-generation methods are more advanced and remedy the shortcomings of the first-generation methods, in particular when it comes to testing unobservable variables, as it is the case in this dissertation. Entrepreneurial orientation captures primarily constructs that are not directly observable, but rather require other indicators to provide more information about them.

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[355] See Bagozzi, Yi and Phillips (1991), p. 459, and Fornell (1982), p. 3. Fornell argues that "very few, if any, measures in the social (or natural) sciences are free from error. Variables such as earnings or sales, population growth, and age are subject to error because of inaccurate statistics, faulty record keeping, or imperfect coding. In ignoring these errors, the analyst runs the risk of obtaining biased parameter estimates."

[356] See Fornell (1982), pp. 2-3, and Anderson and Gerbing (1988), pp. 411-412.

[357] See Autio, Keeley, Klofsten and Ulfstedt (1997), who examined the entrepreneurial intent construct using SEM.

5.3. Second-Generation Multivariate Research Techniques

The development of second-generation multivariate research techniques followed during the 1970s, addressing the weaknesses of first-generation models. In particular, focus was laid on the issue of the nature of abstract variables, their theoretical relationships, and their empirical connections. Chin states that "essentially, second- generation multivariate techniques such as SEM involve generalizations and extensions of first-generation procedures."[358]

Enhancing the capabilities of the first generation, second-generation techniques have the capability (1) to incorporate abstract and unobservable constructs, (2) to model measurement error, and (3) to combine and confront *a priori* knowledge and hypotheses with empirical data.[359] These properties are required for the analysis of entrepreneurial orientation for the following reasons.

Table 14: Comparison of First- and Second-Generation Multivariate Research Techniques

	First-Generation Techniques	**Second-Generation Techniques**
Types of Variables Analyzed	Typically observable variables	Observables and unobservable variables
Measurement Error	Not considered	Explicitly modeled
Model Structure	Typically only one criterion variable	Multiple criterion and predictor variables
Confirmatory Applications	Mostly exploratory	Hypothesis can be empirically confirmed

Source: Meier (2004)

[358] Chin (1998), p. 296.

[359] It is beyond the scope of this dissertation to provide in-depth detail about the alternative multivariate techniques. Much more, this introduction serves to present a very brief general framework. The interested reader is referred to Hänlein and Kaplan (forthcoming), p. 2, and Fornell (1982), pp. 3-4, for a more comprehensive introduction to these methods. In the following, only the models of LISREL and PLS will be examined to a greater extend.

Firstly, the dimensions of autonomy, innovativeness, proactiveness, risk taking, and competitiveness represent the nature of the entrepreneurial orientation construct, according to Lumpkin and Dess.[360] None of these dimensions, however, can be observed directly in the real world, nor can they be assigned a certain value. Instead, these dimensions are unobservable and have to be estimated by a number of indicators.

Secondly, these indicators will be measured by a specifically designed questionnaire. By asking questions to individual respondents, the answers to these questions, and subsequently measurement of indicators, will evidently be accompanied by measurement error, given the relatively subjectiveness of the understanding the questions, and of providing answers.

Thirdly, the construct is based on the underlying theory of entrepreneurial orientation, i.e. *a priori* knowledge, and therefore carries a much more confirmatory than exploratory element.[361]

Second-generation techniques include canonical analysis, redundancy analysis, external single-set component analysis (ESSCA), the LISREL (analysis of Linear Structural Relationships) factor analytic structural equation model, the PLS (Partial Least Square) component structural equation model, and the CMDA (Constrained/Confirmatory Monotone Distance Analysis) confirmatory multidimensional scaling mode. The different nuances of these methods can be assessed by the nature of the theoretical construct, the nature of construct relationships, and the nature of epistemic relationships.[362]

According to Fornell, "a theoretical construct is a variable (explanatory of criterion) that is of interest to the substantive context under examination. Constructs are related, via various rules of correspondence, to one or more empirical indicators (sometimes

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[360] See Lumpkin and Dess (1996), p. 152.
[361] See Fornell (1982), pp. 3-4.
[362] See Hänlein and Kaplan (forthcoming), p. 5, and Fornell (1982), p. 10.

called manifest variables)."[363] Measurement errors are modeled, and depending on how they are treated, one can differentiate between defined and indeterminate constructs.

A defined construct is a composite of its indicators, as opposed to an indeterminate construct which is a composite of its indicators plus an error term. A defined construct is completely determined by its indicators and assumes that the combined effect of the indicator is free from measurement error. However, the effect of each individual indicator can be less than perfect, i.e. variance of the indicator not shared by the construct is considered an error in measurement. In contrast, an indeterminate construct would allow for the possibility that the combined indicator effect contains error.[364]

Another differentiating criterion is the nature of construct relationships. Linear relationships of constructs can be described as orthogonal, symmetric, unidirectional, bidirectional, or causal. Orthogonality means zero correlation between variables, thereby implying the absence of any relationship. Symmetry suggests there is no distinction in direction of the relationship. Directional relationships refer to a change of the dependent variable given a change of the independent variable. Unidirectional relationships represent one-way effects, whilst bidirectional relationships show reciprocal effects. Directional parameters contribute to scientific explanation, but do not permit inferences about causal relationships. Ultimately, the researcher always assumes causal laws.[365]

Epistemic relationships, also known as rules of correspondence, describe the link between theory and data. As abstract concepts, they cannot be directly observed, and are

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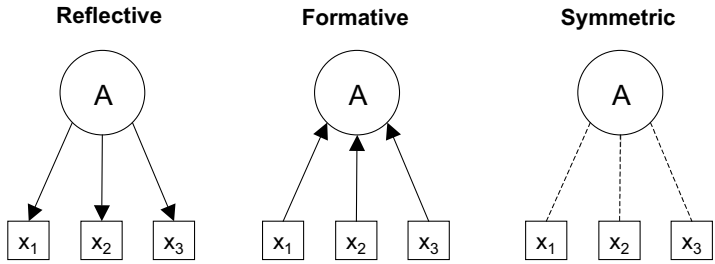
[363] Fornell (1982), p. 5.
[364] See Fornell (1982). p. 5.
[365] See Fornell (1982), pp. 6-7.

linked the empirical world via indicators. There are three types of indicators: reflective indicators, formative indicators, and symmetric indicators.[366]

Exhibit 20: Nature of Epistemic Relationships



Source: Fornell (1982), p. 8.

Exhibit 20 shows possible relationships between abstract constructs, labeled "A" and empirical data, labeled "x_1", "x_2", and "x_3". Reflective indicators are caused by the unobservable construct, i.e. the construct affects the indicator. A typical construct that is often measured via reflective indicators are personality traits or attitudes, given that these variables cannot be measured directly, however, they cause certain behavior or values that can be measured.

Formative indicators, in contrast, give rise to the unobservable construct. In this case, the empirical indicators create of contribute to the latent variable. An example of a formative relationship is, e.g., "social status". Social status can be defined as a combination of occupation, personal income, location of residence, and education.

Ultimately, symmetric indicators do not imply any directionality or causality between construct and indicator. The indicators are used when the research does not want to create a functional relationship between the indicator and the latent variable.

[366] See Fornell (1982), p. 7.

Multivariate research techniques of the second generation mentioned before can be classified according to the criteria of a theoretical construct's nature, construct relationship and epistemic relationship. Table 15 provides this classification.

Table 15: Classification of Second-Generation Research Techniques

Methods	Nature of Theoretical Constructs	Relationships among Theoretical Constructs	Epistemic Relationships
Canonical correlation	Defined	Orthogonal Symmetric	Formative
Redundancy analysis	Defined	Orthogonal Symmetric	Formative (exogenous constructs) Reflective (endogenous constructs)
ESSCA	Defined	Orthogonal	Formative Reflective
LISREL	Indeterminate	Orthogonal Symmetric Unidirectional Bidirectional Causal	Reflective (Formative)
PLS	Defined	Orthogonal Symmetric Unidirectional (Bidirectional) Causal	Formative Reflective
CMDS	Defined	Symmetric	Symmetric

Source: Fornell (1982), p. 18.

The first three methods of Table 15 – canonical analysis, redundancy analysis, external single-set component analysis –, although they are capable to include multiple variables on both sides of the equation, are limited in their capability to analyze systems of relationships. In contrast, LISREL, PLS and CMDS are not only capable of

handling multiple criteria and predictors, but are particularly appropriate for systems analysis, because these methods are more general.[367]

In summary, it shows that the characteristics of the entrepreneurial orientation construct demand a second-generation multivariate research technique approach, given that the variables are abstract and unobservable, they contain measurement errors, and combine *a priori* knowledge and hypotheses with empirical data. The following section will present the structural equation method and assess the advantages and disadvantages of covariance- versus variance-based multivariate methods.

5.4. Structural Elements of Covariance- and Variance-based Structural Equation Modeling

As a result of the breakthrough in developing a numerical method for the simultaneous maximization of several variable functions by Jöreskog in the early 1970s,[368] researchers have overcome the limitations of first-generation multivariate techniques, and have increasingly turned to second-generation structural equation modeling ("SEM") such as covariance-based LISREL or variance-based PLS.[369] "Structural equation modeling (SEM) is a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables,"[370] and consists "of a set of linear equations that simultaneously test two or more relationships among directly observable and/or unmeasured latent variables."[371]

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[367] See Knapp (1978), pp. 410-416, for an introduction into canonical correlation analysis, van den Wollenberg (1977), pp. 207-219 for an introduction into redundancy analysis, and Fornell (1979), pp. 323-338, for an introduction into ECCSA.

[368] See Fornell and Larcker (1981), p. 39, who refer to Jöreskog (1967) and Jöreskog (1970) for the foundations of structural equation modeling.

[369] See Hänlein and Kaplan (forthcoming), p. 4.

[370] Hoyle (1995a), p. 1.

[371] Shook, Ketchen, Hult and Kacmar (2004), p. 397.

Amongst SEM techniques, covariance-based methods in general are the most widely known, and the LISREL software in particular is the most widely used.[372] Covariance-based techniques resulted from works of Jöreskog, Keesling and Wiley.[373] "Typically using a *maximum likelihood* (ML) function, covariance-based SEM attempts to minimize the difference between the sample covariances and those predicted by the theoretical model. Therefore, the parameters that are estimated by this procedure attempts to reproduce the covariance matrix of the observed measures."[374]

As an alternative to covariance-based techniques, there are variance-based techniques such as the partial least squares technique ("PLS") that focus on maximizing the variance of the dependent variables explained by the independent ones instead of reproducing the empirical variance matrix. Compared to other structural equation models, PLS also estimates case values for latent variables using weight relations.[375] For a better understanding of the differences between a covariance- and a variance-based approach, the structure of the PLS structural equation model will be briefly explained.

Structural equation models usually consist of two parts: (1) the structural model (also called the inner model, inner relation, or substantive theory) which reflects the relationship between latent variables, and (2) the measurement model (also called the outer model, or outer relations) which reflects the relationship between latent variables and its indicators.[376] Exhibit 21 depicts a structural equation model and its two components.

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[372] Examples for covariance-based methods are LISREL, EQS, AMOS, SEPATH, and RAMONA. See Chin (1998), p. 295.

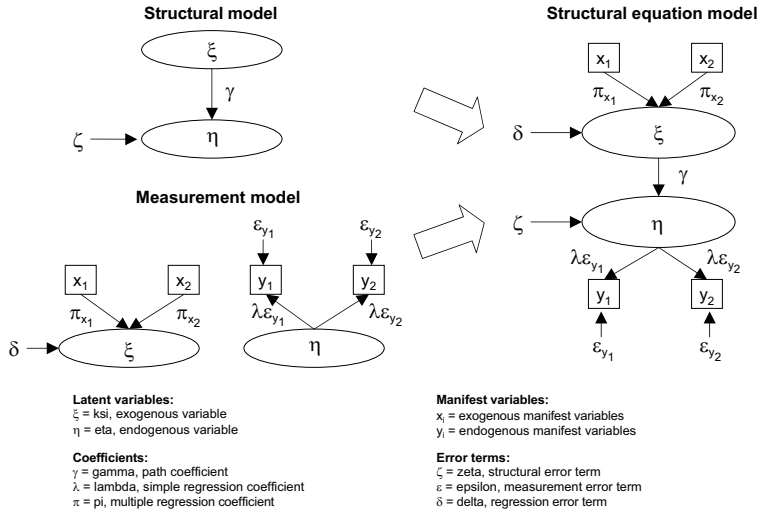
[373] See Jöreskog (1970), Keesling (1972), and Wiley (1973) for the foundations of this approach.

[374] Chin (1998), p. 297.

[375] See Chin and Newsted (1999), p. 307. See also Diamantopoulos (1994) for an introduction into LISREL.

[376] See Meier (2006), p. 73.

Exhibit 21: Structural Equation Model



Source: Chin (1998), p. 298.

Firstly, within the structural model, actual unobservable constructs are represented by latent variables. A regression relationship, indicated by the unidirectional arrow, consists between the exogenous, independent variable ξ ("ksi") and the endogenous, dependent variable η ("eta"). A path coefficient γ ("gamma") indicates the strength of the relationship between the two latent variables. Given that SEM incorporates an error estimate on the level of the structural model, the structural error term ζ ("zeta") contributes the error term of the relationship. In mathematical terms, this relationship can be described as:

$$\eta = \gamma\xi + \zeta \tag{1}$$

Secondly, within the measurement model, the actual constructs are estimated. The measurement model consists of a manifest variables, or indicators, which are observable data points related to the respective latent variable. Manifest variables relating to

the exogenous latent variable are labeled x_i, manifest variables relating to the endogenous latent variable are label y_i.

Epistemic relationships between manifest variables and the latent variable ξ in the exogenous construct are depicted as formative ones, i.e. manifest variables influence the latent variable. This relationship is estimated using multiple regression, with π_{xi} ("pi") being the multiple regression coefficient, and δ ("delta") accounting for the error term of the regression. Hence, the exogenous construct is represented by the equation:

(2a) $$\xi = \pi_{x1} x_1 + \pi_{x2} x_2 + \delta$$

Within the endogenous construct, the epistemic relationship between manifest variables and the latent variable η is reflective, i.e. manifest variables are a reflection of the latent variable. The relationship is estimated using a simple regression, with λ_i ("lambda") being the simple regression coefficient. PLS accounts for measurement errors, hence, the manifest variables contain a measurement error term ε_i ("epsilon"). The equation for each single relationship between manifest variables and the endogenous variable is:

(2b) $$y_i = \lambda_{yi} \eta + \varepsilon_{yi}$$

Finally, with the structural and measurement model providing the specifications for the PLS algorithm, weight relations are defined and estimated as follows:

(3) $$\hat{\xi}_h = \Sigma_{kh} w_{kh} x_{kh}$$
$$\hat{\eta}_i = \Sigma_{ki} w_{ki} y_{ki}$$

where w_{kh} and w_{ki} are the k weights used to form the latent variable estimates of ξ_h and η_i. Thus, the latent variables are linear aggregates of the observed indicators whose

weights are obtained via the PLS estimation procedure as specified by the structural and measurement models.[377]

Based on this description of the core elements of a structural equation modeling, the next section will depict the difference between covariance- and variance-based methods.

5.5. Properties of Covariance- and Variance-based SEM

5.5.1. Properties of Covariance-based SEM

Covariance-based SEM carries four major statistical problems that are relevant for the analysis of the construct of entrepreneurial orientation. Firstly, one of the basic assumptions of a covariance-based technique is multi-normality and interval scaling of measurement variables.[378] In general, estimations under covariance-based SEM apply maximum-likelihood procedure and assume a multi-normal distribution and interval scaling of manifest variables – a strong and relatively unrealistic assumption for the application of organizational behavior constructs.[379]

Secondly, with regard to the fit of the model, covariance based techniques are assessed under the χ^2 ("chi square") test method.[380] This method bears three problems: (1) In conjunction with the assumption of multi-normal variable distribution, the χ^2 test is sensitive to departures from multi-normality.[381] (2) The statistical power of the χ^2 test is not known, which might be misleading in the case of non-significant results.[382] A researcher might fail to reject the null hypothesis even when it is false

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[377] See Chin (1998), p. 314.
[378] See West, Finch and Curran (1995), pp. 56-75, for issues regarding nonnormal variables.
[379] See Jöreskog (1967), p. 443.
[380] See Hu and Bentler (1995), pp. 76-99, for an introduction into model fit.
[381] See Jöreskog and Sorbom (1982), p. 408.
[382] See Kaplan (1995), p. 100.

given that the χ^2 test signals a non-significant result caused by good fit or low power.[383] (3) Sample size has a strong impact on the χ^2 test. Given that the χ^2 test is proportional to the size of the sample, any model is likely to be rejected as long as sample size is sufficiently large.[384]

Thirdly, sample size matters for covariance-based techniques, in particular when it comes to small samples. Estimations on small samples will be affected by the problems of non-convergence and improper solutions.[385] Non-convergence comprises that the maximum likelihood algorithm fails to converge within a reasonable number of iterations. A solution is improper if the estimated variance is negative, or correlation coefficients are greater than 1. Non-convergence and improper solutions are more likely to occur with decreasing sample size.[386] In light of these problems, researchers have provided guidance with regard to sample size under covariance-based multivariate techniques, and recommended a minimum of 100 to 200 samples.[387]

Fourthly, and most importantly for the construct of entrepreneurial orientation and performance, covariance-based approaches struggle with the formative indicators for latent variables. Incorporating formative indicators might cause identification problems, occurrence of implied zero covariances among indicators, and existence of equivalent models. The resolution of these problems may involve altering the original model in terms of its substantive meaning or parsimony.[388]

In summary, covariance-based SEM techniques carry a number of statistical insufficiencies which might cause difficulties in the context of this investigation of entrepreneurial orientation: (1) multi-normality of measurement variables is assumed, (2) un-

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[383] See Bielby and Hauser (1977), p. 153. Not rejecting a false hypothesis is a type II error.
[384] See Bagozzi (1981a), p. 380, and Fornell and Larcker (1981), p. 39.
[385] See Bollen (1987), p. 375.
[386] See Boomsma (1985), p. 345.
[387] See Marsh, Hau, Balla and Grayson (1998), p. 187.
[388] See MacCallum and Browne (1993), p. 540.

known statistical power of χ^2 test and its sensitivity to samples size, (3) samples size between 100 and 200 as minimum required, and (4) insufficiencies with formative indicators.

5.5.2. Properties of Variance-based SEM

In contrast to covariance-based techniques, variance-based techniques have the capabilities to compensate for some of the mentioned insufficiencies.[389] The main difference lies in the underlying optimization algorithm, which in the case of variance-based SEM aims to minimize residual variance, as opposed to residual covariance. As a consequence, variance-based SEM addresses some of the shortcomings of the covariance techniques.

Firstly, with regard to underlying distribution assumption, variance-based SEM does not require a specific distribution nor interval scaling of measurement variables. This is a more realistic assumption and makes variance-based techniques more applicable for organizational behavior constructs where variables are not scalable.

Secondly, model fit is tested differently for a variance-based technique. The coefficient of determination, named R^2, is used in the case of a variance-based construct, as opposed to the χ^2 test. This bears a number of advantages, such as (1) there is no impact of the sample size on the test, and (2) the statistical power of the test is determined and not unknown.[390]

Thirdly, with regard to minimum sample size, variance-based techniques such as PLS are in a position to deal with relatively small samples sizes. [391] This feature is suppor-

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[389] McDonald (1996), p. 240, states that "Partial Least Squares appears to be, currently, the most fully developed general system for path analysis with composites."

[390] See Bollen and Long (1992), p. 128.

[391] See Wold (1989), p. vii.

tive in the analysis of large, complex models with latent variables, given that the PLS algorithm only involves a part of the structural equation during each iteration step.[392]

Finally, variance-based techniques have the ability to work both with reflective and formative constructs. Chin states that "because LV scores are determinate, we can also model what have been termed *cause* or *formative* indicators where the observed indicators are assume to cause or form the LV (Bollen, 1989). In this situation, with arrows directed toward the construct from their indicators, the PLS algorithm provides LV weight estimates such that the LV score is maximally predicted by its block of indicators."[393]

Of course, variance-based methods contain also a number of shortcomings. E.g., parameter estimates are biased by the underlying true parameters, given that latent variables are estimated as weighted aggregates of their corresponding indicators and their respective measurement error.[394] Consequently, "the estimates of loadings and structural coefficients for the latent variable relationships are biased, being overestimated and underestimated, respectively."[395]

In contrast, covariance-based methods do not estimate latent variables in their algorithm; hence, their parameter estimates are always consistent with respect to the model postulated, no matter how poor the indicators and the data are. Another aspect is that the bias of variance-based parameter estimates decreases as the number of observations in the samples and/or the number of indicators increases, a property that is called "consistency at large."[396]

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[392] See Chin (1998), p. 311.
[393] Chin (1998), p. 303.
[394] See Anderson and Gerbing (1988), p. 412.
[395] Fornell and Cha (1994), p. 66.
[396] See Chin, Marcolin and Newsted (1996), p. 31.

In summary, variance-based SEM remedies some of the insufficiencies of covariance-based methods. Based on an algorithm to minimize residual variances, variance-based methods (1) do not require a specific distribution nor interval scaling of measurement variables, (2) can be tested using R^2, (3) can be applied to small samples, and (4) work with both formative and reflective indicators.

5.6. Comparison and Discussion

So far, this chapter has provided an overview about the development from first- to second-generation multivariate research techniques, presented the foundations of structural equation modeling, and analyzed the properties of both covariance- and variance-based techniques.

The decision which research approach to take is very much based on the underlying research question, and depends on the researcher's objectives. Chin argues that "the level of theoretical/substantive knowledge that the researcher brings to the study is a major factor [in the decision process]."[397] If a researcher, based on strong substantive knowledge, believes that the underlying structural model is correct, then he/she should tend to use covariance-based methods. If, on the other hand, a researcher is not as confident in the underlying structural model and, in addition, has a focus on prediction rather than causality, then a variance-based approach might be recommendable.[398] Fornell and Cha comment that "there is a choice between parameter accuracy and prediction accuracy. We cannot have both."[399] Table 16 summarizes the comparison of covariance- and variance-based structured equation modeling techniques.

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[397] Chin (1998), p. 332.
[398] See Chin (1998), p. 304.
[399] Fornell and Cha (1994), p. 74.

Table 16: Selection Criteria of Covariance- and Variance-based SEM

Selection criteria	Covariance-based SEM / LISREL	Variance-based SEM / PLS
Statistical assumption	Multi-normality Interval scaling	No assumptions about population or scale of measurement
Indicators	Reflective only Usually a handful per construct	Formative and reflective Large numbers (>500) per construct possible
Sample size	>100-200	Suitable for sample size <100
Parameter estimates	Consistent	Consistent
Focus	Causality	Prediction

Source: Meier (2004)

The underlying theoretical framework of this dissertation has not been applied in the context of academic entrepreneurship yet. As it was demonstrated in Chapter 3, the theoretical basis of entrepreneurship orientation in academic organizations is limited, and most research is done on an exploratory basis rather than being theoretically grounded. The construct of entrepreneurial orientation has not been tested yet on academic research laboratories. Therefore, it would be too early to test the construct with regard to causality. Much more, a prediction-oriented method would be appropriate in this context. This is the principal reason why a variance-based technique should be used as the preferred methodology.

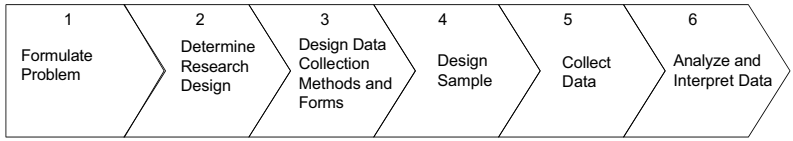
Other factual reasons support this decision: (1) the construct of entrepreneurial orientation can encompass both formative and reflexive indicators, (2) the samples size does not surpass a recommended number of 200 for a covariance-based methods, and (3) multi-normality and interval scaling do not apply to the measurement variables. These factors in combination with the overall framework of the dissertation make a variance-based approach more plausible.

6. Data Collection and Analysis

The purpose of the previous chapters was to establish a theoretical and methodological framework for this dissertation. As a next step, this chapter will present how empirical data was collected and analyzed. The goal of this investigation is to obtain a representative picture of entrepreneurial activity in research units, i.e. research laboratories and centers, at U.S. universities, and draw respective conclusions.

This chapter outlines the data collection process, includes definitions of research design and methods, develops a research instrument, identifies a representative sample, and describes the analysis of the data obtained. In this first step, the research process will flow as suggested by Churchill and Iacobucci,[400] and Böhler.[401] Exhibit 22 depicts the research process conducted in this chapter.

Exhibit 22: Empirical Research Process



Source: Adapted from Churchill and Iacobucci (2002) and Böhler (1995).

As a second step, the entrepreneurial orientation-performance construct will be tested with respect to representativeness, non-response and informant bias, validity, reliability, and significance of constructs, and the construct will be estimated.

[400] See Churchill and Iacobucci (2002), p. 56.
[401] See Böhler (1995), p. 1770.

6.1. Research Design

As a fundamental research decision, a researcher has to choose between an exploratory and a confirmatory research approach at the beginning of a research project. Based on the identification of the underlying theory in Chapter 3, a confirmatory approach was chosen. The operational alternatives about how to conduct this research were also developed in Chapter 4 and led to the conclusion that a managerial perception approach, as opposed to observation of organizational behavior, or analysis of resource allocation, was most suited for this study. In other words, primary data about behavior and attitudes of research units is required. This data was gathered using a survey method. An appropriate structural model in form of the partial-least squares method was determined in Chapter 5.

6.2. Data Sample

As a basis for this study, research units of major U.S. universities were examined. In 2003, 148 U.S. universities reported about their technology transfer activities in the AUTM Licensing Survey 2002.[402] These 148 universities were selected as the basis of the study's sample. Of these 148 universities, 122 universities fall into the category "Doctoral/Research University-Extensive" according to the Carnegie Foundation, 23 are classified as "Doctoral/Research University-Intensive", and 3 universities belong into the category "Master's Colleges and Universities."[403] Bearing in mind that there were only 151 extensive doctoral universities, in particular the coverage of the top tier category of universities of 80.8 per cent is strong.[404] By focusing on the top tier of research institutions, it is intended to capture the most important part of the nation's academic research activities.

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[402] See AUTM (2003), pp. 30-31.
[403] See Carnegie (2001), pp. 35-41.
[404] See Carnegie (2001), p. 21.

So far, the majority of existing university technology transfer research has mostly covered biotechnology related disciplines, for various reasons:[405] Oliver, for example, focusing on the collaborative aspects of entrepreneurial scientists, states that "biotechnology can now be characterized as the industry in which scientific and product development process are collaborative. Every single organizational, sociological or science policy research that has focused on this industry has shown how collaborations (of any kind and form) are crucial to the maintenance, development, and survival of the industry, … , and of different scientists working in the industry and in related fields in universities."[406] Powell et al. argue that "The large-scale reliance on interorganizational collaboration in the biotechnology industry reflects a fundamental and pervasive concern with access to knowledge."[407] Therefore, biotechnology and life science related research fields like biology, biochemistry, bioinformatics, bioengineering, and medical science, appeared appropriate to be tested about technology transfer, since these fields are most exposed to the phenomena.

In addition, electrical engineering and computer science are of particular interest for technology transfer, although the research literature has focused less on these disciplines in the recent past. Murray noted that "one possible explanation of the relative neglect [of research interest] of university-industry relations in electronics could be that the electronics industry, despite the numerous spin-outs, has been less directly dependent upon university research than was biotechnology."[408] Nevertheless, the precedents of successful USOs in the computer science and electronic engineering areas, such as Google and Sun Microsystems from Stanford, but also those mentioned in the AUTM survey (Akustica from Carnegie Mellon, broadband wiring from Vir-

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[405] For a selection of other research articles dealing with biotechnology and university technology transfer, see Owen-Smith, Riccaboni, Pammolli and Powell (2002), Zucker, Darby and Armstrong (2002), Oliver (2001), Zucker, Darby and Brewer (1998), and Liebeskind, Oliver, Zucker and Brewer (1996).

[406] Oliver (2004), p. 583.

[407] Powell, Koput and Smith-Doerr (1996), p. 116.

[408] Murray (2004), p. 693.

ginia Tech, and software company Teoma Technology from Rutgers University),[409] provide evidence that the computer science and electrical engineering disciplines should be included in a study on university technology transfer.

Based on these parameters, the sample of this study was determined as research units in the fields of biotechnology/life science, electrical engineering, and computer science of the 148 universities reporting to AUTM.

As a next step, research units in these disciplines were searched via the internet on the respective university websites. In order to manage the quantity of data to a bearable maximum, it was determined to target 3 research units each in the fields of life science, computer science, and electrical engineering. Approaching 9 research units of 148 universities would result in a target number of 1,332 research units.

Research units were identified randomly by searching the respective university websites, identifying departments and research activities, locating faculty lists, and identifying principal investigators of research units. Principal investigators were mainly chosen as contact person, given that they would be best equipped to respond to answer about behavior of their research unit.

Not all universities, however, are active in all three research fields, nor have research operations in all fields. If a research unit could not be identified, no replacement was sought. This resulted in a lower total number of identified survey target. In total, 1,195 research units were selected, including information about their university, the academic department, and their email address, each representing one distinct research unit.

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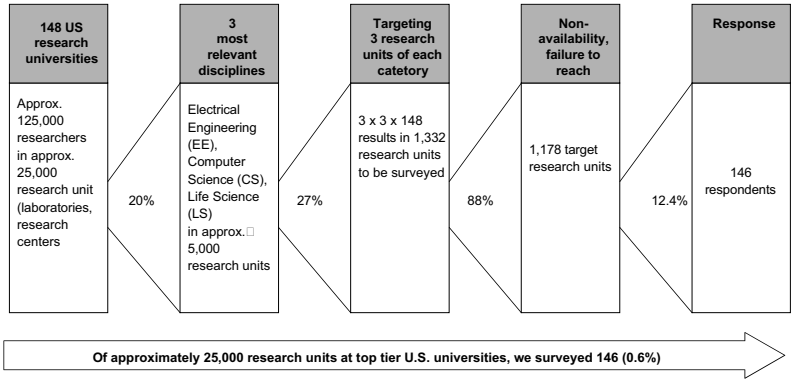
[409] See AUTM (2003), p. 4.

Exhibit 23: Sample selection process



Source: Own conception

The target group was approached via an email introducing the study and its goals, and sent an internet link to the online survey. Sending out the email to the target group, 17 emails were returned with a delivery failure message due to non-availability of the account. This reduced the number of total targets to 1,178. Also with regard to representativeness, this procedure was chosen to ensure that the sample is representative of the underlying population of research units in the U.S.

6.3. Instrument Design

6.3.1. Selection of Survey Method

Primary data can be collected by different methods, such as (1) personal interview (scheduled or intercepted), (2) telephone interview, (3) postal mailing, (4) fax, (5) email, or (6) via a website.[410] Since each of these methods has its advantages and disadvantages, the parameters of the study and research requirements determine which

[410] See Churchill and Iacobucci (2002), pp. 280-281.

methods will be favored. Important parameters of a survey are response rate, response speed, response quality, and research related costs.

Web-based surveys are increasingly used as a research means, and "the rapid development of survey on the World Wide Web (WWW) is leading some to argue that soon Internet (and, in particular, Web) surveys will replace traditional methods of survey data collection."[411] Advantages of the web-based survey are cost savings by eliminating printing and mailing, time savings for dispatch and response, and receipt of data in electronic format.[412] "For special populations that regularly use the Internet, the Web has been found to be a useful means of conducting research."[413]

With regard to potential differences in survey results depending on the survey method, Kaplowitz et al. suggest that "in a population in which each member had Web access, a Web survey application can achieve a comparable response rate to a questionnaire delivered by surface mail if the Web version is preceded by a surface mail notification."[414] Even the difference between a mail and an email plus reminder questionnaire was just above three per cent.[415]

Researchers and faculty members in the U.S. qualify as such a population, given that the Internet was essentially developed by them, a high percentage of them have email accounts, and the Internet is used on a daily basis for research activities.

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[411] Couper (2000), p. 464.

[412] See Cobanoglu, Warde and Moreo (2001). The authors tested 300 professors with different methods and found that the fastest method was fax, with an average of 4 days to respond, followed by web surveys with 6 days; the slowest method was mail surveys, with 16 days to respond; average response rate was 26 per cent for mail, 17 per cent for fax, and 44 per cent for web surveys.

[413] Kaplowitz, Hadlock and Levine (2004), p. 94, referring further to Couper, Traugott and Lamias (2001).

[414] Kaplowitz, Hadlock and Levine (2004), p. 100.

[415] See Kaplowitz, Hadlock and Levine (2004), p. 98. The authors examined 19,890 students at Michigan State University, all having an email account and free access to the internet. Response rate for a mail questionnaire was 31.5 per cent, in contrast to the email plus reminder postcard response rate which was 28.6 per cent.

In addition, negative aspects such as a potential interviewer bias, associated interview/travel costs, and interviewer availability disfavor an interview-based approach. Assessing the pros and cons of mail, fax, email, and web, the web-based approach introduced by an invitation email appeared to be the best solution, in light of low costs and quick response.

The response rate from principal investigators at university research lab, however, is not expected to be high. Kenney and Goe, for example, in a survey of 179 faculty members of Stanford and UC Berkeley, achieved an overall response rate of 13.4%.[416] They report that "this low response rate is likely attributable to the lack of free time among the faculty and the fact that this particular population is frequently subject to surveys, among other factors. The Stanford University chairman stated that his faculty received an average of one survey per week."[417] From a broader perspective, the response rate of this study appears within expectations, also in light of by Baruch's finding, who claims that response rates in academic research reports have been generally declining, and in particular top managers or representatives of an organization respond weaker than regular employees.[418]

6.3.2. Selection of Respondent

Obtaining information from an organization causes the question about which individual is best suited to provide the information. Within a research unit, the principal investigator's view about the organizational behavior might differ from the perspective of an employed research fellow. The question arises whether surveying several members of a research unit provides a more comprehensive picture. Since the number of survey targets also has to be limited, another consideration is whether one should re-

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[416] Kenney and Goe's survey consisted of a mail survey deliver directly to faculty mailboxes, followed by two follow-up letters and one e-mail query. See Kenney and Goe (2004), p. 694.

[417] Kenney and Goe (2004), p. 694.

[418] See Baruch (1999), pp. 430-431.

trieve information on a rather large number of units from one single informant, or rather on a small number of units from multiple informants.

Using just a single informant for each units carries a number of advantages: As Glick et al. pointed out, if only a single informant is contacted, there is a high likelihood that the most knowledgeable individual will provide the information.[419] In addition, Lyon et al. argue – talking about firms – that "particularly in the case of small organizations, the view of the respondent may, in fact, reflect those of the firm. Also, the use of a single informants helps to increase sample size by; (1) reducing the strain on the research budget, thereby allowing the researcher to target more firms; and (2) increasing the probability that firms will participate since only one individual in the organization is impacted."[420]

Empirical evidence supports reliability and validity of self-reported, single respondent data. According to Chandler and Hanks, self-reporting owners or chief executives of small firms found that the assessment of the owner/executives was highly correlated with the actual figures.[421]

6.3.3. Questionnaire Development

The questionnaire was presented in the form of an invitation email combined with a link to the survey website. The email was sent as a single personal message from the author of this dissertation to the respective questionnaire candidate, in order to avoid any problems with regard to mass emails, or spam.

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[419] See Glick, Huber, Miller, Doty and Sutcliffe (1990), p. 303. See also Seidler (1974) on informant bias.

[420] Lyon, Lumpkin and Dess (2000), p. 1058.

[421] See Chandler and Hanks (1993), p.

The design of the invitation email followed in essence the recommendations given by Churchill and Iacobucci:[422]

- The recipient was addressed as "Fellow Researcher" in order to highlight the academic nature of the survey, as opposed to a commercial survey.
- In order to be brief at the beginning, the email was split into a summary part upfront that is sufficient to understand the entire message, and a more detailed part at the end, to which the recipient can refer for more detailed questions.
- The brief summary message started with a three questions that should be of interest for any scientist, with the goal to raise attention. Thereafter, the scope and the purpose of the study were communicated.
- A timing indication to complete the survey (10 to 15 minutes) was given.
- For recipients not willing or able to complete the survey, an alternative solution was offered to forward the survey another member of the research team.
- As compensation for time and effort, sending the final research results was offered.
- The internet link and the login token were provided, and it was assured that all information was to be treated confidentially and anonymously.
- Personal contact details of the surveyor were provided.

It followed a more detailed second part that repeated some of the information on the brief front part, and added further information, such as detailed structure of the questionnaire, break-up of time needed per survey section, assurance that the survey can

[422] See Churchill and Iacobucci (2002), p. 348.

be done easily, and describing the alternative to forward the questionnaire to other member of the research unit.

Having clicked on the link, the respondent was guided to the survey website. The opening page on the website repeated the information regarding expected response time, purpose, and outline. For the avoidance of any doubt, the term “research unit” was defined as a comprehensive term for research laboratories, research centers, or research groups. Technical guidance on how to click answer buttons was provided, and the percentage-completed indicator at the top corner of the survey screen was explained.

The first page of the web survey asked for area of research, position of the respondent within the research unit, size of research unit, and annual research budget. On the following pages 2 to 8, question of the different constructs were presented page by page. The questionnaire concluded on page 9 with a response possibility in case of interest for the study results, and a final submission page.

With regard to page design, all pages carried the logo of the RWTH Aachen University, identifying the academic background of the survey, and an indicator showing the current completion level, which should provide the respondent with a better picture on how much time he still had to spend on the survey.

After submitting the questionnaire online, the respondents were sent an automatic email appreciating their efforts and thanking them for their time.

6.3.4. Questions and Scaling

The derivation of the survey questions was in detail presented in Chapter 4. Most of the questions were based on previously applied questionnaires by Covin and Slevin and Miller and Friesen. However, given that these questions were presented in a university context, rather than a company context, questions had to be adjusted to fit into

this environment. In addition, questions purposed by these authors were mostly presented in form of semantic differentials.

Scales in form of semantic differentials were initially developed by Osgood et al. at the University of Illinois investigating the structure of words, and were further adapted to measure attitudes.[423] Semantic differentials carry a number of advantages, such as (1) allowing for quick responses, (2) indicating not only direction, but also intensity, (3) being easily repeatable, and (4) providing standardized responses.[424] However, due to their nature of presenting differentials, they require the respondent to choose and assess between two opposing statements or descriptions, in the simplest form between polar adjectives.[425]

This approach is difficult as soon as it concerns more complex constructs as such entrepreneurial orientation and its dimensions, given that truly opposing statements are not easily formulated.[426] Therefore, this study works with modified semantic differentials, where opposing statements are tested on single, separate scales. This has the advantage that bipolar scales do not have to be developed, and similar constructs can be tested with multiple items.[427]

Direction and intensity of dimensions was measure on a seven-point Likert scale, ranging from ”strongly agree” with the statement to “strongly disagree.”[428] The neu-

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[423] See Osgood, Suci and Tannenbaum (1957)

[424] See Mindak (1961), pp. 28-29.

[425] See Garland (1990) for a more detailed analysis of semantic differentials.

[426] Miller and Friesen (1982), e.g., in their question 73 about product innovation, p. 24, use semantic differentials and differentiate between strong emphasis on true and tried products, and strong emphasis on technological leadership and innovation. However, there is an argument that a company can be both focusing on tried products, and being a technological leader.

[427] For example, the first two questions of the “risk taking” construct in this study investigate the commitment to risky projects, and the carefulness of allocation resource into uncertain projects. These questions are not fully opposed to each another, given that one can be careful with resources, but nevertheless commit to risky projects, well knowing about the risk and adjusting for it. On the other hand, these constructs control for each other in a way that one would expect opposing directions.

[428] This scale was first proposed and named after Likert (1932).

tral position is a “neither agree nor disagree” in the middle of the scale. In addition, in order to offer respondents an alternative if they do not want to answer a question, or do not have an opinion on a question, they could choose for a “not applicable (n/a)” answer. This would eliminate statistical noise from the results, given that unintended answers do not contaminate results.

With regard to duration of answering the survey, the time requirement has to be balanced in a sense that it allows for the maximum of questions being asked, but at the same time being short enough so that a high number of target respondents actually participates, and the survey is representative. It was therefore assessed that the duration of answering the survey should not exceed 15 minutes, because respondents would most likely not be willing to spend more time on an internet survey request. Therefore, questions about the constructs were limited to an average of seven questions per construct, with slight variances if required. In total, the survey contained 54 questions, of which 4 questions were control questions about the characteristics of the research unit. An average of 15 seconds per question seemed plausible. The time limit of 15 minutes was verified during the pretests.

6.3.5. Pretest

The survey pretest consisted of three stages. Firstly, a member of the Stanford University statistical support team and a researcher at the Stanford Management Science department were asked to comment on the survey with regard to its structure, scales, terminology, clarity, and purpose.[429] These comments were implemented in the survey.

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[429] The author would like to thank Leandro Saita of Stanford Graduate School of Business, for his comments during the Stanford University Social Science Statistical Support Group sessions, and Andrew Nelson of the Stanford University Management Science and Engineering Department for his helpful comments.

In a second step, the questionnaire was pretested by surveying researchers from the Stanford University radiation biology research laboratory, a highly regarded research lab with experienced researchers who are subject to surveys on a regular basis.[430]

As a third step, fellow researchers of RWTH Aachen department for business administration for engineers and natural scientists were given the opportunity to comment on the questionnaire.[431]

In summary, the three-staged pretest resulted in the clarification of the terminology, enhancing the preciseness of questions, and minor modifications to questions. All participants answered the questions within the given timeframe of 15 minutes.

6.3.6. Timing of Survey Dissemination

The initial invitation email including a description of and the link to the survey was sent out on November 24, 2004. This was the week before the Thanksgiving weekend, a major holiday in the U.S. It was expected that (1) either researchers would have time during the holidays to focus on non-work related issues and answer the survey, or (2) researchers would be away from their research unit and would not immediately respond to the email.

A first reminder was sent on December 5, 2004, referring to the initial email and including again the link to the online survey. A second and final reminder was sent on December 14, 2004. It was planned that there were at least two weekends in-between each mailing, so that target persons had time to respond to the survey.

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[430] The author is grateful for the participation of Denise Chan, Nadja Dornhöfer, Rachel Freiberg, Ester Hammond, and Fiona Kaper, all researchers at Amato Giaccia's Laboratory for Radiation Biology at Stanford University, in testing and commenting on the survey.

[431] The author would like to thank Andreas Kessell and Stephan Hungeling of RWTH Aachen University for their useful comments.

6.3.7. Responses

In total, 172 target individuals responded, which results in a response rate of 14.6 per cent. In addition, 8 individuals responded that they did not find the time to fill in the survey, or had other issues hindering them to participate. 40 participants reacted on the initial email invitation, another 95 responded to the first reminder, bringing the preliminary total to 135 responses, and another 37 targets answered on the final reminder.

Of these 172 respondents, 26 questionnaires were eliminated from the relevant set because the information provided was materially incomplete and could not be used for further analysis, or because the answers were obviously provided in a misleading way (e.g. all questions being answered with the first available answer, which indicate false answers).

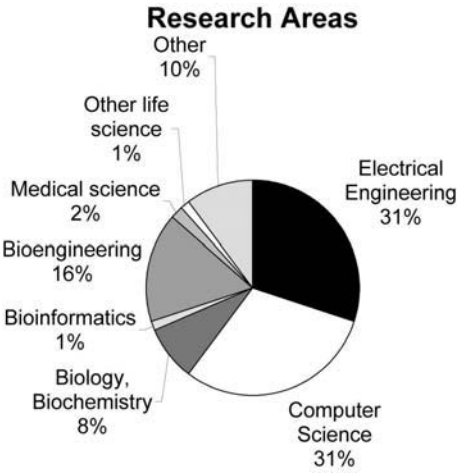
146 eligible questionnaires out of a universe of 1,178 potential respondents equal a response rate of 12.4 per cent, which is in line with comparable surveys amongst academics.[432]

From a descriptive analysis perspective, the respondents have the following characteristics: With regard to area of research, or research discipline, 44 of the 146 respondents (31 per cent) do research in the field of electrical engineering; equally, 44 respondents (31 per cent) come from computer science; from the field of bioengineering, 24 researchers responded (16 per cent); 12 biologists and biochemists (8 per cent) answered the questions; and from medical science, bioinformatics, and other life sciences, 3, 2, and 2 researchers responded, respectively. Another 15 responses (10 per cent) came from other areas, mostly from chemical engineering. The respondents' distribution is relatively evenly split between the fields of electrical en-

[432] See Kenney and Goe (2004), who report a response rate of 13.4 per cent in their study.

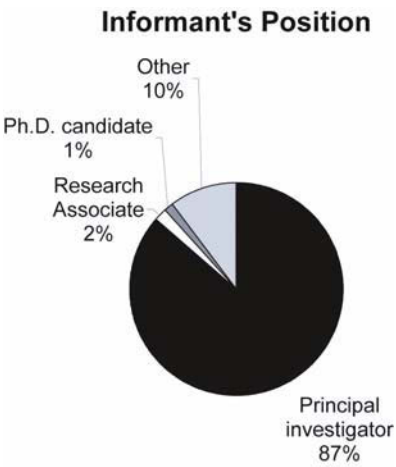
gineering, computer science, and life science in general. Exhibit 24 describes the distribution by research area.

Exhibit 24: Sample distribution by research area



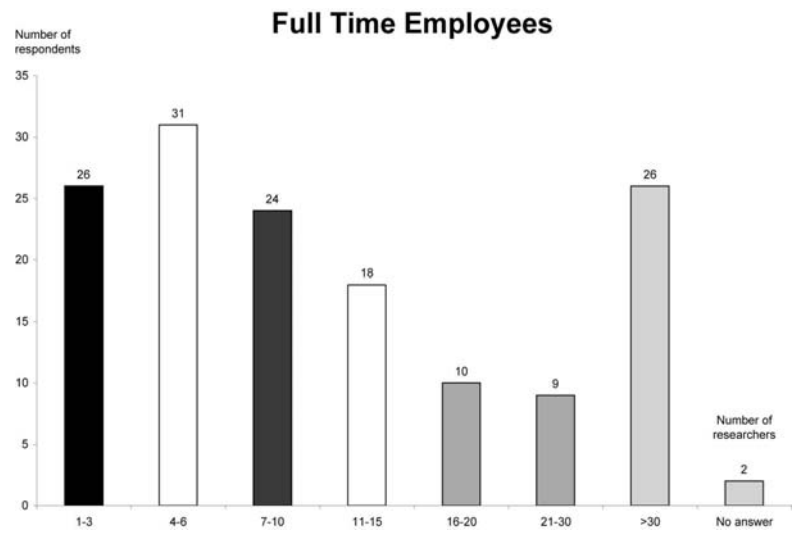
With regard to academic position with the research unit, 126 respondents (87 per cent) are principal investigators, and 5 are research associates or Ph.D. candidates (3 per cent). In addition, 10 per cent of the responses (15 in numbers) are provided by other functions in the research organization, mostly employees of the technology transfer or licensing office, or other general public relation staff. As intended, the major contributing group to the survey should be principal investigators because of their broad and general perception of the observation object. It is not believed that the contribution of 10 per cent of other respondents has a disturbing impact on the data quality. Exhibit 25 shows the sample's distribution by research position.

Exhibit 25: Sample distribution by informant's position



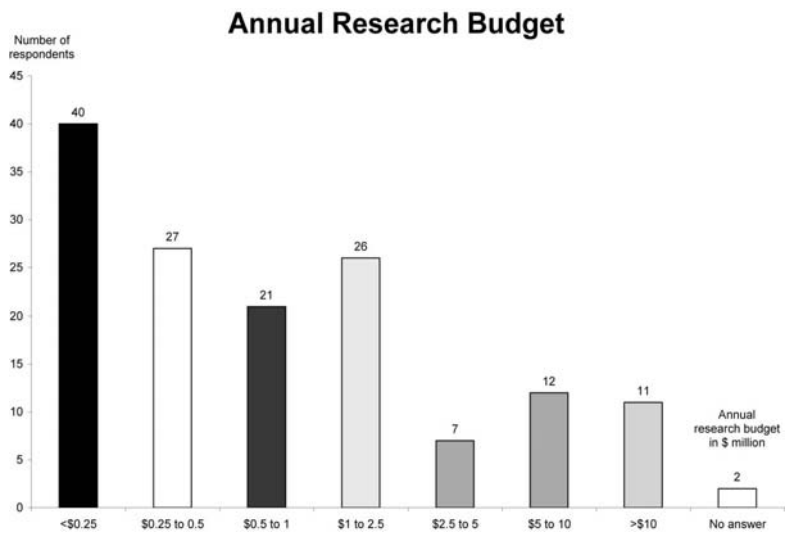
As to the number of full time employees per observed research unit, or size of research unit, 26 research units (18 per cent) employed between 1 and 3 full time researchers; 31 research units (21 per cent) had between 4 and 6 full time employees; 24 research units (16 per cent) reported between 7 and 10 full time researchers; 18 units (12 per cent) reported a number of employees between 11 and 15; 10 units (or 7 per cent) had between 16 and 20 employees; between 21 and 30 full time researcher were employed by 9 research units (6 per cent); and 26 research units had more than 30 researcher full time employed (18 per cent); 2 respondents did not provide an answer. Exhibit 26 depicts the distribution of the sizes of the responding research units. It is fair to say that the major part of research units operates with 10 or less full time researcher, comparable to small sized companies.

Exhibit 26: Sample distribution by number of full time research employees



With regard to annual research budget, Exhibit 27 shows this distribution across the 146 respondents. 40 research units (28 per cent) operate with a budget of less than $250,000; 27 research units (18 per cent) have annual research expensed between $250,000 and $500,000. Another 21 research units indicate a research budget between $500,000 and $1 million. This means that the majority of responding research unit has a research budget of less than $1 million. Another 26 units (18 per cent) budget their research expenses with $1 million to $2.5 million. In summary, nearly three quarters of research unit operate with less than $2.5 million per year. Additional 30 units (21 per cent) indicate that they have a budget available that is greater than $2.5 million.

Exhibit 27: Sample distribution by annual research budget



In summary, the data sample appears to be relatively evenly split across disciplines, number of research staff, and size of research budget. Mostly principal investigators provided answers to the questionnaire.

6.4. Data Analysis

Data analysis included the following procedure: Firstly, the sample had to be assessed with regard to the representativeness of the data versus the underlying population. Secondly, given that there might be differences between those target respondents that participated in the survey, and those who decided to decline, the so-called non-response bias was assessed. Thirdly, due to the fact that there were different potential individuals to answer the questionnaire (principal investigators, post-docs, Ph.D. students), the sample will be tested on informant bias.

Once the data sample has been analyzed on these three items, the measurement model will be assessed with regard to reliability and validity of the constructs. This will be followed by a significance test of the model.

Finally, the structural model will be assessed using the partial least squares (PLS) approach, which includes a test of the path relationships between latent variables, and explanatory power and predictive validity of the construct will be estimated.

6.4.1. Representativeness

Given that a survey of the entire universe of research units at leading U.S. research universities is neither technically feasible nor practically desirable due to costs and resource constraints, the sample's representativeness had to be assessed before further conclusions were drawn. Representativeness is an important quality indicator of any sample, and is defined as the degree to which a sample mirrors the traits and characteristics, and combinations of both, of a certain population.[433]

Response rates and trait comparisons of sample and population are means to assess the representativeness of a sample. As indicated in the previous section, the response rate of 12.4 per cent is satisfactorily within expectations and in line with comparable studies. It does not provide any indication about non-representativeness of the sample.

A comparison of known traits of the population with regard to entrepreneurial orientation is difficult, given that there is no such data available about this specific characteristic. The only information available both for the population and the sample is the breakdown by research discipline, i.e. it is known that a third of the targeted research units is in electrical engineering, a third in computer science, and a third in life science. No information was available about the number of full time employees in these research units, nor about their annual research budgets.

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[433] Bortz and Döring (2002), p. 400.

Hence, conclusions about the representativeness of the sample can only be drawn on the basis of the discipline distribution. As it can be concluded from the descriptive analysis of the previous section, the sample shows a distribution of 31 per cent in electrical engineering, 31 per cent in computer science, 28 per cent in life science, and a remaining 10 per cent in other science, primarily in chemical engineering, which should be included in the life science figure, amounting to 38 per cent. This distribution does not differ greatly from the distribution of the entire population.

In summary, it can be said that the distribution by research discipline of the sample is similar to the distribution of the population. Due to lack of information about the characteristics of number of full time employees and annual research budget, no definitive conclusions can be drawn on the basis of these two traits. However, both these distributions appear intuitive and do not raise any concerns because of a potential concentration or bias. Therefore, there is no indication that the sample is not representative of its underlying population, and, hence, that it serves well as a basis for the further statistical analysis.

6.4.2. Non-response Bias

A common problem in conjunction with mail surveys and web surveys is the problem of non-response bias. As Armstrong and Overton commented in their article on estimating non-response bias: "If persons who respond differ substantially from those who do not, the results do not directly allow one to say how the entire sample would have responded – certainly an important step before the sample is generalized to the population."[434]

As previously described, the survey instrument is introduced to the potential respondent by means of an email, which indicates in the subject line the purpose of the survey, i.e. entrepreneurial orientation in academia. Consequently, it is expected that

[434] Armstrong and Overton (1977), p. 396.

those individuals with a natural interest in entrepreneurial activity are more inclined to open and read the email, and subsequently answer the questionnaire, than individuals who have an aversion versus entrepreneurial activity, or are not knowledgeable about the concept of entrepreneurship and therefore feel uncomfortable to answer questions about the subject.

There are a number of ways to test whether non-response bias exists in a survey: Firstly, collected data can be compared with already existent data for a total population. This method can be applied when data has already been retrieved a number of times in similar surveys, so that historical comparables are available. In the present study, this is not the case, given that data in this original format was collected for the first time.

As a second alternative, the researcher can relate to subjective estimates of non-response bias, as it is described in the above paragraph. Based on a researcher's impression, one can qualitatively adjust research findings, however, hard facts or any quantitative measure do not support these adjustments.

Extrapolation is a third alternative to assess a potential non-response bias. The extrapolation method is based on the assumption that individuals who respond late in the process act more similar to non-respondent. In other words, there is a significant difference in the response pattern between earlier respondents and late respondents.

A two-sided t-Test was used to determine whether the means of the answers of the 73 early responders differ significantly from the means of the answers of the 73 late responders. If this were the case, one could have made an argument that both groups, early and late responders, do not belong to the same underlying population. All 54 items were tested as to whether there is a significant difference of the means between the two samples. The two-sided t-test was conducted using an α of 5% and 71 degrees of freedom. It resulted that the two samples did not showed any significant difference

of means on any of the items, which means that the non-response bias in the entire sample is low.

6.4.3. Informant Bias

Section 6.3.2. already discussed the issues of selecting the most suited responded within an organization to answer the questions of the survey. Related to this is the issue of informant bias. Informant bias describes the relationship between the informant and the information he provides relative to the actual event. A bias implies that the informant reports information differently to how a more neutral observer would report them.[435] This bias can be significant if a survey is conducted across of group of individuals who belong only to one corporate function or one hierarchy level.

A researcher has to balance as to whether a bias stemming from interviewing a broad group of different informants with different perspectives on an organization is more helpful for the study than relying on selected individuals that have the most complete overview of an organization. For this study, it was concluded that the principal investigator's view about the organizational behavior provides the most comprehensive perspective. A single informant in an organization creates the highest consistency across all data points. Therefore, the assessment of a potential informant bias was made on a qualitative basis, which is supported by empirical evidence showing reliability and validity of self-reported, single respondent data.[436]

6.4.4. Validation of Constructs

The following sections will present an analysis of the validity and reliability of the measurement model. Based on the assumption that the data sample is sufficiently un-

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[435] See Kumar, Stern and Anderson (1993), p. 1634.

[436] See Chandler and Hanks (1993), p.

biased with regard to non-response and informant bias, the model needs to be tested with regard to indicator and construct validity and reliability.

Useful distinctions of the notion of construct validity are the perspectives of trait and nomological validity.[437] "Trait validity is investigated by considering a construct and its measures in a theoretical vacuum. … Efforts to investigate a measure's reliability, convergent validity, and discriminant validity are primarily trait validity investigations."[438] Trait validity provides, however, only necessary, but not sufficient information for accepting construct validity.

Nomological validity "is based on the explicit investigation of constructs and measures in terms of formal hypotheses derived from theory. Nomological validation is primarily 'external' and entails investigating both the theoretical relationship between different constructs and the empirical relationship between measures of those different constructs."[439]

The following sections will first define and present the notions of construct validity and reliability, as well as content, discriminant, and nomological validity, before the application of the theory and the results of the study will be presented.

Construct Validity

Bagozzi and Philips define construct validity as "the extent to which an observation measures the concept it is intended to measure."[440] According to Peter, "the term 'construct validity' generally is used to refer to the vertical correspondence between a construct which is at an unobservable, conceptual level and a purported measure of it which is at an operational level. In an ideal sense, the term means that a measure as-

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[437] See Campbell (1960), p. 546.
[438] Peter (1981), p. 135.
[439] Peter (1981), p. 135.
[440] Bagozzi and Phillips (1982), p. 468.

sesses the magnitude and direction of (1) all of the characteristics and (2) only the characteristics of the construct is purported to assess."[441]

In other terms, construct validity "refers to the degree to which instruments truly measure the constructs which are intended to measure. If the measures used in a discipline have not been demonstrated to have a high degree of validity, that discipline is not a science."[442] According to Kerlinger, validity is "epitomized by the question: Are we measuring what we think we are measuring?"[443] This refers to the extent to which an instrument actually measures what it alleges to measure.[444]

The measurement model of the present study consists of seven constructs, which all consist of reflective indicators. The following Table 17 details the initial set-up of the constructs.

Table 17: Measurement Model Initial Constructs

Construct	*Indicator*	*Label*
AUTONOMY	Individual research freedom	AUTO1
	Resource allocation responsibility	AUTO2
	Research focus adjustment	AUTO3
	Individual grant application	AUTO4
	Personal accountability	AUTO5
	Relative perceived autonomy	AUTO6
INNOVATIVENESS	Emphasis on established methods	INNO1
	Emphasis on technological leadership	INNO2
	Differentiation in research	INNO3
	Radical new methods	INNO4
	Past success	INNO5
	Willingness to adjust	INNO6
	Incorporation of external methods	INNO7
	General innovativeness	INNO8
PROACTIVENESS	Anticipation of research trends	PRO1
	Relevance of research fields	PRO2
	Anticipation of future needs	PRO3
	Alignment of research efforts	PRO4
	Responsiveness	PRO5

[441] See Peter (1981), p. 134.
[442] See Peter (1979), p. 6.
[443] Kerlinger (1973), p. 457.
[444] Carmines and Zeller (1979), p. 12.

	Leadership	PRO6
	Discussion and feedback	PRO7
	Dissemination	PRO8
COMPETITIVENESS	Competition measurement	COMP1
	Competition observation	COMP2
	Ambition	COMP3
	Communication	COMP4
	Industry interaction	COMP5
	Transfer obligation	COMP6
RISK TAKING	Commitment of resources	RISK1
	Prudent resource allocation	RISK2
	Encouragement after failure	RISK3
	Acceptance of failure	RISK4
	Acknowledgement of failure	RISK5
	Risk-friendliness	RISK6
	Eagerness for new methods	RISK7
INTERDISCIPLINARITY	Interdisciplinary exchange	INTER1
	Receipt of ideas	INTER2
	Incorporation of ideas	INTER3
	Incentives	INTER4
	Informal meeting	INTER5
	Participation in interdisciplinary projects	INTER6
	Observation of interdisciplinary projects	INTER7
	Degree of interdisciplinary knowledge	INTER8
PERFORMANCE SATISFACTION	Research results	PERF1
	Publications	PERF2
	Patents	PERF3
	Company spin-offs and start-ups	PERF4
	Presentations at conferences	PERF5
	Industry meetings	PERF6
	Entrepreneurial activity	PERF7

The fact that all indicators have been deliberately designed in a reflective format has a number of advantages. For example, an identification process to distinguish between reflective and formative indicators is not required. This could be achieved via confirmatory tetrad test as developed by Bollen and Ting.[445] The fact that the present model consists of reflective indicators only circumvents this requirement.

In addition to the theoretical and qualitative analysis which leads to the assessment of an indicator being reflective, this quality is supported by the correlation of any indica-

[445] See Bollen and Ting (2000).

tor with the construct it measures. The correlation matrix in Section 6.4.5 displays the correlations of indicators, and provides a first indication of the degree of correlation of the indicators amongst each other, and within their respective constructs.

Construct Reliability

At the same time, reliability of constructs and indicators has to be tested. According to Peter, "Reliability can be defined broadly as the degree to which measures are free from error and therefore yield consistent results."[446]

Construct reliability refers to the measurement variance of a construct, regardless of the degree of validity. However, reliability is a precondition for validity, but not vice versa. The demonstration of construct validity and reliability serves as a basis for any further tests regarding validity of the structural model. Using the PLS method, validity and reliability of the measurement model can be assessed by testing content validity of a measure, indicator and construct reliability, discriminant validity, and finally nomological validity.

Reflective indicators are considered reliable if they share more variance with their respective construct that with error variance, which is shown by a standardized loading greater than 0.707.[447] According to Holland, "a rule of thumb employed by many researchers is to accept items with loadings of 0.7 or more, which implies that there is more shared variance between the construct and its measure than error variance. Since loadings are correlations, this implies that more than 50 per cent of the variance in the observed variable (i.e., the square of the loading) is due to the construct.

In practice, it is common to find that at least several measurement items in an estimated model have loadings below the 0.7 threshold, particular when new items or newly developed scales are employed. A low loading might be the result of: (1) a

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[446] See Peter (1979), p. 6.

[447] See Carmines and Zeller (1979), p. 27.

poorly worded item, (2) an inappropriate item, or (3) an improper transfer of an item from one context to another. The first problem leads to low reliability, the second to poor content (and construct) validity, and the last to non-generalizability of the item across contexts and/or settings."[448] Indicators with loadings of less than 0.7 should therefore be eliminated.

Under PLS, three measures of construct reliability are provided: (1) Cronbach's alpha, (2) composite reliability, and (3) average variance extracted (AVE).

It can be generally said that there are two categories of reliability coefficients, those based on longitudinal data, and those based on cross-sectional data. The most commonly used reliability coefficient is coefficient alpha, an estimator of internal consistency. It was developed by Cronbach as a generalized measure of the internal consistency of multi-item scales, and is therefore called Cronbach's alpha.[449]

Cronbach's alpha is formulated as:

$$\alpha = \left(\frac{K}{K-1}\right) - \left(1 - \sum_{k=1}^{K} \frac{\sigma_k^2}{\sigma_s^2}\right)$$

where α is Cronbach's α, K is the number of items in the scale, σ^2_k is the variance of item k, and σ^2_s is the variance of the scale. Following Nunnally's recommendation, an alpha of greater that 0.7 is regarded as an acceptable level of construct reliability.[450]

Another measure to assess construct reliability is the composite reliability measure, which differs from Cronbach's alpha to the extent that it is not based on the assumption of equally weighted indicators. Composite reliability measure is therefore a close appromation of construct reliability, whereas Cronbach's alpha is rather viewed as the

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[448] Hulland (1999), p. 198.
[449] Cronbach (1951).
[450] See Nunnally (1978).

lower bound estimate of construct reliability.[451] Composite reliability measure is formulated:

$$\rho_c = \frac{\left(\sum_{k=1}^{K} \lambda_k\right)^2}{\left(\sum_{k=1}^{K} \lambda_k\right)^2 + \sum_{k=1}^{K} Var(\varepsilon_k)}$$

where ρ_c is the composite reliability, K is the number of indicators in a construct, λ_k is the component loading to indicator k of a construct and $Var(\varepsilon_k)$ is the error variance defined by $Var(\varepsilon_k) = 1 - \lambda_k^2$.

Average variance extracted (AVE) is the third measure of construct reliability. It attempts to measure the amount of variance that a latent variable component captures from its indicators relative to the amount due to measurement error.[452] AVE measures the amount of true variance explained by a construct relative to total observed variance, as opposed to Cronbach's alpha and composite reliability, which measure the relationship between individual indicators.

AVE is formulated as follows:

$$AVE = \frac{\sum_{k=1}^{K} \lambda_k^2}{\sum_{k=1}^{K} \lambda_k^2 + \sum_{k=1}^{K} Var(\varepsilon_k)}$$

where AVE is average variance extracted, K is the number of indicators in a construct, λ_k is the component loading to indicator k of a construct, and $Var(\varepsilon_k)$ is the error variance defined by $Var(\varepsilon_k) = 1 - \lambda_k^2$. It is required that AVE is greater than 0.5, which means that more than 50% of the variance of a construct comes from its indicators.

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[451] See Chin (1998), p. 320.

[452] See Chin (1998), p. 321.

Content Validity

Content validity is based on "the extent to which a measurement reflects the specific intended domain of content."[453] Says Rungtusanatham: "I sincerely believe that assessments of reliability and construct validity are virtually meaningless unless we have ensured, with some degree of confidence, the content validity of measurement instruments..."[454] Or, to follow Kerlinger: "Is the substance…of this [measurement instrument] representative of the content or universe of content of the [construct] being measured?"[455]

Content validity can be ensured by, firstly, specifying the domain of the construct, and secondly, by designing items that capture the domain as specified.[456] Quantitative methods to measure content validity are (i) the content validity ratio (CVR) approach, and (ii) Cohen's κ. The CVR approach following Lawshe works with a panel of subject-matter-experts (SMEs) which are asked to indicate whether or not a measurement item in a set of other measurement items is essential to the operationalization of the construct. The SME input is then used to compute the CVR. Cohen's κ asks SMEs to rank measurement items, and determines agreement or disagreement between experts, thereby signaling whether the construct is of practical interest or not.[457]

Given the scope of this study, involvement of expert panels to assess content validity was limited to comments from the pretest panel in a format different to that suggested by the CVR or the Cohen's κ approach. Content validation therefore consisted in a more qualitative rather than quantitative approach, however, this approach seemed justified.

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[453] See Carmines and Zeller (1979). p. 20.
[454] Rungtusanatham (1998), p. 11.
[455] Kerlinger (1973), p. 458.
[456] See Churchill (1979), p. 67.
[457] See Cohen (1960), p. 37.

Discriminant Validity

Following the definition of Bagozzi and Phillips, "discriminant validity is the degree to which measures of distinct concepts differ. This means that measures of different concepts should share little common variance (in a relative sense) and that too high a covariation casts doubt on the uniqueness of the measures and/or concepts."[458] In a PLS context, "one criterion for adequate discriminant validity is that a construct should share more variance with its measure than it shares with other constructs in a given model."[459]

Indeed, discriminant validity is relevant both at an indicator and at a construct level. At an indicator level, each indicator should only measure the construct it is intended to measure, and no other construct. At a construct level, it implies that every reflective construct differs significantly from all other constructs. Hulland refers to a measure developed by Fornell and Larcker, which uses average variance extracted (AVE), which should be greater than the variance shared between the construct and other constructs in the model.[460] This method will be considered in the analysis of the entrepreneurial orientation-technology transfer performance model.

Nomological Validity

According to Peter, "nomological (lawlike) validity is based on the explicit investigation of constructs and measures in terms of formal hypotheses derived from theory. Nomological validation is primarily 'external' and entails investigating both the theoretical relationship between different constructs and the empirical relationship between measures of those different constructs."[461] In other terms, nomological validity

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[458] Bagozzi and Phillips (1982), p. 469.
[459] Hulland (1999), p. 199.
[460] See Hulland (1999), p. 200.
[461] Peter (1981), p. 135.

refers to the extent to which a theoretically derived construct is confirmed using empirical research methods.[462]

6.4.5. Evaluation of Test Results

Based on the different aspects of validation laid out in the previous section, the study will execute the following procedure to analyze and evaluate the entrepreneurial orientation-technology transfer performance construct: Based on the underlying theory as described in Chapter 3 and 4, a model that is valid from a content perspective has been derived. As a next step, indicator reliabilities are determined using the PLS Graph software. After elimination of those indicators with loading lower than 0.7, construct reliability is determined via PLS Graph, providing coefficients of Cronbach's alpha, composite reliability and average variance extracted. Thereafter, discriminant validity for both items and constructs were analyzed, before the determination of nomological validity concludes the investigation. Table 18 summarizes the procedure.

Table 18: Procedure of Evaluating Test Results

Procedure Step	**Comment**
1. Determine content validity	Derived from theory as described in Chapter 3 and 4
2. Determine indicator reliability	Item loading greater than 0.7
3. Determine construct reliability	Three coefficients: Cronbach's alpha greater 0.7 Composite reliability greater 0.7 Average variance extracted greater 0.5
4. Determine item discriminant validity	Item loads higher with respective construct than with any other construct (covariance matrix)
5. Determine construct discriminant validity	Square roots of AVE should be larger than correlations
6. Determine nomological validity	Derived from theory as described in Chapter 3 and 4

Source: own conception

[462] See Bagozzi (1981b), p. 327.

Autonomy Construct

The autonomy construct consists of 6 reflective indicators, of which three indicators ("resource allocation responsibility", "personal accountability", and "relative perceived autonomy") obtained loadings of less than 0.7, resulting in removal of those indicators. After removing these items and re-estimating the construct, the remaining 3 indicators ("individual research freedom", "research focus adjustment", and "individual grant application") continued to show loadings greater than 0.7.[463]

Construct reliability of the autonomy construct was relatively strong, with a Cronbach's alpha as a lower boundary of 0.762. They estimated composite reliability in the high 80s is also a strong figure, which is supported by the average variance extracted.

Table 19: Reliability Coefficients of the "Autonomy" Construct

AUTONOMY		
Item reliability		
Indicator	*Label*	*Loading*
Individual research freedom	AUTO1	0.902
Resource allocation responsibility	AUTO2	removed
Research focus adjustment	AUTO3	0.823
Individual grant application	AUTO4	0.785
Personal accountability	AUTO5	removed
Relative perceived autonomy	AUTO6	removed
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.762
Composite reliability		0.876
AVE		0.703

[463] See Table 19.

In summary, the autonomy construct presents itself from a statistical point of view as sufficiently well defined with three reliable items, and a comfortable degree of reliability at the level of the construct.

Innovativeness Construct

The innovativeness construct consisted originally of 8 reflective items, of which 2 items ("emphasis on established methods", "willingness to adjust") were removed due to too low item loadings. The remaining 6 items displayed loading greater than 0.7, and therefore can be considered reliable.[464]

Table 20: Reliability Coefficients of the "Innovativeness" Construct

INNOVATIVENESS		
Item reliability		
Indicator	*Label*	*Loading*
Emphasis on established methods	INNO1	removed
Emphasis on technological leadership	INNO2	0.769
Differentiation in research	INNO3	0.800
Radical new methods	INNO4	0.747
Past success	INNO5	0.808
Willingness to adjust	INNO6	removed
Incorporation of external methods	INNO7	0.727
General innovativeness	INNO8	0.891
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.869
Composite reliability		0.855
AVE		0.627

[464] See Table 20.

From a construct reliability perspective, both Cronbach's alpha and composite reliability show value in the mid-80s, with Cronbach's alpha actually being the higher of the two values, despite the fact that it usually is regarded as the lower boundary of any construct reliability estimation. Nevertheless, these values show a comfortable degree of reliability, which is supported by an average variance extracted above 0.6.

The innovativeness construct looks strongly equipped with only 2 items being removed, and a high degree of construct reliability. It will be interesting to study the impact of innovativeness on technology transfer performance, because one would expect a relatively strong link between this dimension and the endogenous variable.

Proactiveness Construct

The proactiveness construct encompassed originally 8 items, of which 2 ("anticipation of research trends", and "relevance of research fields") were removed due to too low item loadings. The remaining items showed loadings greater than 0.7. Theoretically, reflective constructs could be estimated on a stand-alone basis, given that the indicators are a reflection of the construct. Changes in factor loadings, however, occur once exogenous and endogenous variables are combined to the total construct. At that stage, items loadings are recalculated, and minor changes in item loading can occur.

This has been the case in item loading PRO8 ("dissemination"). Upon the stand-alone estimation of the proactiveness construct, the item showed a loading above 0.7, and therefore was not removed from the construct. However, upon estimation of the total model, the loading fell slightly to now 0.67. Given that this value is still relatively close to the required threshold of 0.7, no major impact – neither negative nor positive – on the construct was expected, and the item was kept as part of the construct.[465]

[465] See Table 21.

Table 21: Reliability Coefficients of the “Proactiveness” Construct

PROACTIVENESS		
Item reliability		
Indicator	*Label*	*Loading*
Anticipation of research trends	PRO1	removed
Relevance of research fields	PRO2	removed
Anticipation of future needs	PRO3	0.778
Alignment of research efforts	PRO4	0.762
Responsiveness	PRO5	0.750
Leadership	PRO6	0.732
Discussion and feedback	PRO7	0.767
Dissemination	PRO8	0.670
Construct reliability		
Test criterion		*Value*
Cronbach’s alpha		0.847
Composite reliability		0.881
AVE		0.554

With regard to construct reliability, both Cronbach’s alpha and composite reliability demonstrate relatively high values in the mid to high 80s; the AVE value of 0.55 is at the lower end of the desired range, but nevertheless about the minimum required of 0.5.

Competitiveness Construct

The next construct – competitiveness – includes six reflective items, of which three (“competition measurement”, “competition observation”, and “communication”) showed loadings greater than 0.7, whilst the remaining three (“ambition”, “industry interaction”, and “transfer obligation”) showed loadings lower than 0.7 and had to be

removed.[466]

With regard to construct reliability, again, the construct shows relatively solid figures, with a lower boundary Cronbach's alpha of more than 70 per cent, a composite reliability of more than 85 per cent, and an average variance extracted of more than 66 per cent.

In its entirety, the competitiveness construct appears robust with three solid item loadings, indicating strong item reliability, and comfortable construct reliability stemming from Cronbach's alpha, construct reliability and AVE.

Table 22: Reliability Coefficients of the "Competitiveness" Construct

COMPETITIVENESS		
Item reliability		
Indicator	*Label*	*Loading*
Competition measurement	COMP1	0.874
Competition observation	COMP2	0.743
Ambition	COMP3	removed
Communication	COMP4	0.822
Industry interaction	COMP5	removed
Transfer obligation	COMP6	removed
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.721
Composite reliability		0.855
AVE		0.664

[466] See Table 22.

Risk Taking Construct

Despite the fact that 4 out of 7 reflective indicators had to be removed in the risk taking construct ("commitment of resources", "prudent resource allocation", "encouragement after failure", and "eagerness for new methods were removed"), the remaining three indicators ("acceptance of failure", "acknowledgement of failure", "risk-friendliness") showed strong item loadings of more than 0.7, and lead to strong construct reliability.[467]

Cronbach's alpha is comfortably above 75 per cent, and composite reliability of 0.876 indicates sufficiently strong construct reliability. An AVE of 0.703 supports the indication of strong construct reliability.

Table 23: Reliability Coefficients of the "Risk Taking" Construct

RISK TAKING		
Item reliability		
Indicator	*Label*	*Loading*
Commitment of resources	RISK1	removed
Prudent resource allocation	RISK2	removed
Encouragement after failure	RISK3	removed
Acceptance of failure	RISK4	0.752
Acknowledgement of failure	RISK5	0.749
Risk-friendliness	RISK6	0.889
Eagerness for new methods	RISK7	removed
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.762
Composite reliability		0.876
AVE		0.703

[467] See Table 23.

Interdisciplinarity Construct

The last of the exogenous latent variables, interdisciplinarity, was initially designed with 8 reflective indicators. Of those 8, only 2 ("incentive", and "observation of disciplinary projects") had to be removed due to low item loadings. The remaining 6 items showed loadings greater than 0.7, thereby indicating sufficiently high item reliability.[468]

With respect to construct reliability, composite reliability showed a strong value of more than 90 per cent, and Cronbach's alpha signaled a lower boundary of 87.6 per cent. AVE is at 0.632.

Table 24: Reliability Coefficients of the "Interdisciplinarity" Construct

INTERDISCIPLINARITY		
Item reliability		
Indicator	*Label*	*Loading*
Interdisciplinary exchange	INTER1	0.735
Receipt of ideas	INTER2	0.831
Incorporation of ideas	INTER3	0.786
Incentives	INTER4	removed
Informal meeting	INTER5	0.824
Participation in interdisciplinary projects	INTER6	0.808
Observation of interdisciplinary projects	INTER7	removed
Degree of interdisciplinary knowledge	INTER8	0.784
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.876
Composite reliability		0.912
AVE		0.632

[468] See Table 24.

Performance Satisfaction Construct

Similar to the exogenous latent variables, the endogenous latent variable has to be tested on item and construct reliability. The construct of performance satisfaction was designed with 7 reflective indicators, of which 3 ("research results", "publications", and "presentations") were removed.

Table 25: Reliability Coefficients of the "Performance Satisfaction" Construct

PERFORMANCE SATISFACTION		
Item reliability		
Indicator	*Label*	*Loading*
Research results	PERF1	removed
Publications	PERF2	removed
Patents	PERF3	0.700
Company spin-offs and start-ups	PERF4	0.859
Presentations at conferences	PERF5	removed
Industry meetings	PERF6	0.864
Entrepreneurial activity	PERF7	0.899
Construct reliability		
Test criterion		*Value*
Cronbach's alpha		0.867
Composite reliability		0.901
AVE		0.696

Of the remaining 4 items, 3 were beyond the 0.7-threshold ("company spin-offs and start-ups", "industry meetings", and "entrepreneurial activity"). One item ("patents") just touched the 0.7-mark.[469] In fact, this value hit the 0.7 upon connecting the exogenous and endogenous variables and re-running the model, thereby readjusting the item

[469] See Table 25.

loadings. Therefore, the 0.700 value was viewed of being acceptable and the item was not removed from the model.

With regard to construct reliability, both Cronbach's alpha and composite reliability signal very comfortable values in the high 80s and 90s. AVE is also relatively high with a figure close to 70 per cent. In summary, the performance satisfaction construct carries all characteristics of item and construct reliability.

6.4.6. Discriminant Validity

Item discriminant validity is assessed using a comparative matrix approach. The matrix displays correlations between all reflective indicators and the latent variables. Ideally, an indicator achieves the greatest loading (and the highest correlation) with the construct it is supposed to measure, not with any other construct.

Table 26 contains the matrix of correlations between reflective indicators and latent variables. The highest correlation in each row has been bolded. It shows that in deed indicators show consistently highest correlation within their respective construct. This means that item discriminant validity high. With regard to construct discriminant validity, this is also assessed via a comparative method, comparing square roots of average variance extracted (AVE) with the respective inter-construct correlation.

Table 27 displays correlations of the various latent variables with each other in a correlation matrix. Below, respective average variances extracted (AVEs) of the constructs are shown, plus their respective square roots. None of the correlations is greater than the square root of a construct's average variance extracted, which leads to the conclusion that all constructs are satisfactorily construct discriminant.

Table 26: Correlation Matrix of Reflective Indicators and Latent Variables

	AUTO	*INNO*	*PRO*	*COMP*	*RISK*	*INTER*	*PERF*
AUTO1	**0.902**	0.132	0.202	0.190	0.068	0.059	0.181
AUTO3	**0.671**	0.137	0.177	0.199	0.022	0.133	0.149
AUTO4	**0.371**	-0.085	0.024	0.184	0.193	0.049	0.049
INNO2	-0.011	**0.497**	0.455	0.166	0.173	0.112	0.273
INNO3	0.137	**0.800**	0.550	0.376	0.223	0.267	0.272
INNO4	0.073	**0.554**	0.323	0.101	0.190	0.180	0.199
INNO5	-0.013	**0.808**	0.611	0.459	0.073	0.146	0.303
INNO7	0.006	**0.404**	0.212	0.144	-0.043	0.019	0.211
INNO8	0.142	**0.508**	0.350	0.282	0.122	0.079	0.213
PRO3	-0.057	0.096	**0.271**	0.006	0.059	-0.001	0.143
PRO4	-0.114	0.051	**0.184**	-0.038	-0.014	0.025	0.135
PRO5	0.070	0.265	**0.437**	0.084	0.037	0.020	0.236
PRO6	0.015	0.630	**0.732**	0.467	0.201	0.163	0.355
PRO7	0.135	0.521	**0.561**	0.366	0.138	0.103	0.195
PRO8	0.118	0.648	**0.670**	0.720	0.096	0.191	0.231
COMP1	0.090	0.434	0.462	**0.874**	0.048	0.172	0.162
COMP2	0.261	0.361	0.377	**0.743**	-0.014	0.230	0.096
COMP4	0.194	0.329	0.308	**0.468**	0.071	0.130	0.139
RISK4	-0.050	0.063	0.066	-0.071	**0.895**	0.074	0.005
RISK5	-0.011	0.054	0.034	0.046	**0.475**	0.025	-0.068
RISK6	0.019	0.146	0.152	0.136	**0.601**	0.177	0.060
INTER1	0.037	0.200	0.226	0.250	0.081	**0.842**	0.209
INTER2	0.121	0.191	0.156	0.138	0.209	**0.900**	0.229
INTER3	-0.048	0.200	0.215	0.184	0.144	**0.457**	0.204
INTER5	0.060	0.125	0.148	0.152	0.056	**0.896**	0.274
INTER6	0.107	0.122	0.098	0.088	-0.042	**0.730**	0.178
INTER8	0.043	0.145	0.160	0.147	0.108	**0.872**	0.287
PERF3	0.009	0.157	0.140	0.042	0.025	-0.042	**0.184**
PERF4	0.111	0.142	0.181	0.076	0.026	0.017	**0.259**
PERF6	0.088	0.009	0.077	0.062	0.003	0.080	**0.397**
PERF7	0.077	0.115	0.199	0.060	0.028	0.157	**0.392**

Table 27: Construct Discriminant Validity Comparison of AVE and Construct Correlation

	AUTO	INNO	PRO	COMP	RISK	INTER	PERF
AUTO	1.000						
INNO	0.129	1.000					
PRO	0.189	0.727	1.000				
COMP	0.209	0.517	0.557	1.000			
RISK	0.079	0.443	0.390	0.174	1.000		
INTER	0.168	0.424	0.454	0.425	0.459	1.000	
PERF	0.215	0.389	0.438	0.178	0.452	0.421	1.000
AVE	0.703	0.627	0.554	0.664	0.639	0.632	0.696
SQR(AVE)	**0.838**	**0.792**	**0.744**	**0.815**	**0.799**	**0.795**	**0.834**

At the same time, high construct discriminant validity supports the hypothesis that the various constructs are uncorrelated with each other (Hypothesis 7). Similar to Lumpkin and Dess' approach, entrepreneurial orientation dimensions do not have to be equally pronounced in order to have an impact on entrepreneurial activity.[470]

6.4.7. Significance of Constructs

PLS Graph provides path coefficients for the various paths between the exogenous and endogenous latent variables of the model indicating the weight and relative importance of the exogenous variable. However, significance of the path coefficient is not provided, which means that potentially a path coefficient signals a relative strong impact on a construct, however, this coefficient not necessarily has to be significant.

In order to judge significance of path coefficient, these have to be retrieved separately. Whilst in traditional regression analysis standard errors and t-values are analytically determined, PLS requires the use of re-sampling techniques such as bootstrapping or jackknifing. Using a bootstrap technique, the following significance levels for various alpha levels can be determined:

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[470] See Lumpkin and Dess (1996), p. 149.

Table 28: Summary of tested hypotheses, path coefficients and significance levels

Hypotheses	Relationship	Path coefficient	Significance	alpha level
H 1	AUTO → PERF	0.137	1.7259	10%
H 2	INNO → PERF	0.068	0.5613	none
H 3	PRO → PERF	0.265	2.3666	5%
H 4	COMP → PERF	-0.164	1.9524	10%
H 5	RISK → PERF	0.241	2.5341	5%
H 6	INTER → PERF	0.207	1.9434	10%
H 7	INDEPENDENCE	NA	NA	discriminant

Based on these results, it shows that 5 out of 6 path coefficients show significant values of 10% or better.

6.4.8. Explanatory Power of the Model

Based on the partial least square estimation, the structural model was estimated with regard to its explanatory power. Inner weightings of the model were estimated using path weightings on the basis of a sample size of 146 research units being investigated.

The explanatory power of the model can be represented by the coefficient of determination R^2, which encompasses the proportion of the total variation of y (about its mean $\bar{y}$) that is explained by the fitted model. R^2 is determined as

$$R^2 = 1 - \frac{\sum_{n=1}^{N} (y_n - \hat{y}_n)^2}{\sum_{n=1}^{N} (y_n - \bar{y}_n)^2}$$

on the basis of PLS calculating case values for all latent variables. y_n is the construct score of the endogenous variables estimated with the n^{th} set of its indicators, $\bar{y}$ is the arithmetic mean of all construct scores y_n, and $\hat{y}_n$ is the construct score calculated on the basis of the case values of the n^{th} exogenous variable.

An R^2 of 1 would reflect 100 per cent explanation of the variance of the endogenous variable by the variance of the exogenous variable. In contrast, and R^2 of 0 reflects no explanation of the variance of the endogenous variable by the exogenous variable. An R^2 of minus 1 would demonstrate a negative correlation and explanation of the endogenous variable.

For our sample of 146 research units, PLS estimated an R^2 value of 33.9 per cent for performance satisfaction, reflecting a satisfying result for the entrepreneurial orientation construct. More than a third of the variance of the performance satisfaction construct can be explained by the variance in the dimensions of entrepreneurial orientation, which represents a solid model fit.

6.4.9. Predictive Power of the Model

Whilst R^2 indicates the explanatory power of the model, its ability to predict results is equally of importance. One means to measure the predictive power of the model is a coefficient developed by Stone and Geisser. Stone and Geisser's Q^2 is derived from the idea that "the prediction of observables or potential observables is of much greater relevance than the estimation of what are often artificial construct parameters."[471]

PLS calculates the Stone and Geisser coefficient using various blindfolding procedures. For this purpose, parts of the data are omitted, the remaining part is used to estimate the model, and subsequently the omitted data is estimated on the basis of the established parameters. This procedure is repeated until every data point has been omitted and estimated.[472]

The Q^2 coefficient is determined on the basis of the following formula:

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[471] Geisser 1975, p. 320.

[472] See Chin (1998)

$$Q^2 = 1 - \frac{\sum_{d=1}^{D} E_d}{\sum_{d=1}^{D} O_d}$$

where E_d is the sum of squares of prediction errors, O_d is the sum or squares of errors using the mean for prediction and D is the omissions distance.[473]

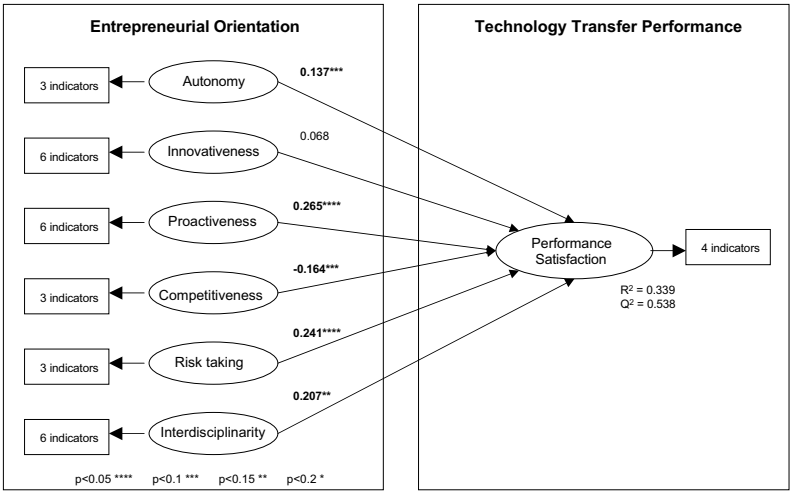
For our sample of 146 research units, PLS estimated a value of 53.84 per cent for the Stone-Geisser-coefficient Q^2 of the endogenous variable of "performance satisfaction". Predictive relevance is assigned when the Q^2 value is positive, whilst a negative value hints to less predictive relevance. Given that both endogenous variables show positive values around the 54 per cent mark, relatively strong predictive relevance can be confirmed.

6.5. Summary

This chapter presented the data collection process and analyzed the data. It turns out that from a data analysis perspective, the underlying PLS model shows all required characteristics of being valid and reliable from an item and construct perspective.

[473] Omission distance is 101.

Exhibit 28: Structural Model including path coefficients



Source: Own conception

As presented in Exhibit 28, path coefficients from proactiveness and from risk taking to performance satisfaction are significant at a 5 per cent significance level. Path coefficients from the constructs of autonomy and competitiveness to the performance satisfaction construct are significant at a 10 per cent significance level, and the path coefficient between interdisciplinarity and performance satisfaction shows a 15 per cent significance level. Overall, 5 out of 6 path coefficients are meaningfully significant. Only between the innovativeness construct and the performance satisfaction construct, no significant relationship could be determined.

By order of magnitude, path coefficients between proactiveness and performance satisfaction (0.265) and risk taking and performance satisfaction (0.241) show the strongest values, followed by the relationships between interdisciplinarity and performance satisfaction (0.207), and autonomy and performance satisfaction (0.137).

The relationship between competitiveness and performance satisfaction carries a negative path coefficient of –0.164.

The R^2 value, i.e. the explanatory power of the model, shows that 33.9 per cent of the variance of the endogenous variable can be explained by the variance of exogenous model. In other terms, more than a third of the variance of technology transfer performance satisfaction can be explained by the variance of entrepreneurial orientation.

With regard to the predictive power of the model, the Stone-Geisser coefficient Q^2 of 53.8 per cent indicates a high degree of predictive power of the model.

The following chapter will provide an interpretation of the results extracted from the model.

7. Results and Discussion

Knowledge and innovation are the most valuable resources in the twenty-first century. The success of a modern economy depends to a large degree on how and how quickly the transfer of knowledge and innovation into new products and technologies is managed.[474]

It is alarming, though, that new business creation in technology-based industries in Germany has declined over the last couple of years. Whilst during the end of the 1990s in particular computer-service and software-related companies were main drivers of new business creation in Germany, these activities fell strongly after the turn of the millennium. Today, the decline of technology-based business creation is even accelerating. This is the more concerning because new technology-based companies tend to develop into major employment providers and wealth generators in future year. In times of drastic job cuts at established companies caused by the need to further enhance competitiveness, productivity and efficiency, it is crucial that new, young companies provide alternative employment opportunities and growth potential in high-tech industries.[475]

In particular in comparison to the U.S., the lack of young, growing companies is one of the main problems of new employment generation in Germany. Also in the U.S., big firms, such as e.g. General Motors, IBM, Motorola, and J.P. Morgan Chase, have cut the number of employees over the recent years, similar to job reductions at major German companies. Nevertheless, the U.S. economy was in a position to reallocate jobs from established industries into new, young industries in technology and services. High-tech start-up companies are the biggest generator of new jobs in the U.S.[476]

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[474] See BMBF (2001), p. 1.
[475] See Niefert, Metzger, Heger and Licht (2006), p. 1.
[476] See Remington (2005), p. 17.

The ability of the developers of new ideas – often research faculty at top research universities – to switch into an entrepreneurial role and start a business venture to harvest the economic benefits of an invention is much more common in the U.S. than it is in Germany. However, these activities also differ from institution to institution in the U.S. In other terms, not every research universities in the U.S. "produces" regularly new companies, licenses and products.

The purpose of this concluding chapter is to present an interpretation and discussion of the results of the study on entrepreneurial orientation in academia, to detail potential implications for research units, and to put them into perspective for future researchers in this field.

The presentation of the results and the discussion will refer to the research questions formulated in the opening chapter of this dissertation, i.e. to what extent is entrepreneurial orientation at the level of the research unit important for start-up creation and technology transfer. On the basis of the entrepreneurial orientation construct, we will discuss how the different dimensions of entrepreneurial orientation impact technology transfer success, and how organizations can modify these dimensions in order to enhance their technology transfer performance.

7.1. Interpretation of Results

The theory of entrepreneurial orientation tries to provide one possible approach as to why some U.S. universities create more technology transfer than others. Some universities, such as Stanford, University of California, MIT, Columbia, have proven in the past and continue to show that they can frequently produce academic-based start-up companies and thereby add to the wealth of their community and their university. Other universities of a similarly high academic reputation have not necessarily demonstrated that they are in a position to create successful university start-up companies and technology transfer.

The reasons for this can be numerous. One could be that environmental factors of a university, i.e. closeness to a leading industry center, presence of venture capital, availability of cooperating companies, have a stimulating impact on the technology transfer process of universities.[477] Another possibility is that once successful universities in technology transfer attract more entrepreneurially-minded students and researchers, and thereby create a self-fulfilling prophecy of accelerated start-up generation. This follows the "success breeds success" theory of Frank and Cook, saying that the top universities have better access to top talent due to the fact that they offer better opportunities to these individuals.[478]

Complementing these thoughts, the approach of entrepreneurial orientation of an academic institutions being the explaining variable for success tries to approach the issue from a more internal perspective, and leaves external factors aside. As the results of the study have demonstrated, there is a generally positive relationship between the degree of entrepreneurial orientation in a research institution, and its technology transfer performance. On this basis, one can conclude that internal, organizational aspects contribute to the success variable. This again means that management of research units, taking external conditions as a given, can change and improve the results of a academic research.

7.1.1. Object of Observation and Informant

The application of economic and management theories to create a better understanding of behavior and process in higher education institutions is still at early stage, and it is often disputed whether it is suitable to use management theory in academia. Nevertheless, we have observed on various occasions that management theory delivers valuable results when applied to higher education institutions.

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[477] See Powers and McDougall (2005), p. 291.
[478] See Frank and Cook (1995), p. 36.

Similarly in the case of this study, entrepreneurial orientation as a management theory contributes to the discussion about how research institutions behave, and where university management should attach any future steering measure.

To start with, it is noteworthy that the analysis focuses on the research unit, i.e. the research lab or department, as the object of observation. Previous studies in the context of entrepreneurship in academia often times looked at the individual researcher, or the entire university organization. In the present case, behavior at the research unit level was analyzed. Given the study's results with regard to construct validity, it can be assumed that the research unit – e.g. a lab consisting of several staff members, guided and managed by a principal investigator – is a relevant part of the organization to be analyzed. Similar to identifying and isolating the Strategic Business Unit (SBU) in general management literature, future research should continue to focus on the research unit as object of observation and investigation.

Secondly, collecting data via an individual in a leadership position, i.e. the principal investigator, is a possible way of generating data that represents the behavior of the research object, given that this individual has the perspective and knowledge to provide information about the research object with some distance. This individual will also be the most logical person to implement organizational management measures based on the theory of entrepreneurial orientation. Depending on the magnitude of the various dimensions of entrepreneurship orientation, dimensions such as autonomy or risk friendliness can be managed or improved.

Most importantly, there is a generally positive relationship between the construct of entrepreneurial orientation and technology transfer performance. More than third of the variance of technology transfer performance can be explained by entrepreneurial orientation, according to the model. This means that if management of a research unit plans to increase its performance with regard to technology transfer, it can use – similar to management of a business unit – the concept of entrepreneurial orientation and

deploy tools and processes which make the organization more entrepreneurial, which should lead to enhanced technology transfer performance.

7.1.2. Impact of Entrepreneurial Orientation Dimensions

In the following, we will elaborate on the individual dimensions of the entrepreneurial orientation construct and examine what impact these dimensions have on the technology transfer performance, and how they can be managed. Further, it will be referred to the hypotheses established in Chapter 4 and discussed whether these hypotheses have to be rejected or not.

Autonomy

The autonomy construct proved to have significant influence on technology transfer performance at the 10 per cent significance level. Of the constructs indicators, three of them – "individual research freedom", "research focus adjustment", and "individual grant application" – showed relevant loading greater than 0.7 and remained in the construct for model estimation. Hypothesis 1 will not be rejected.

The ability of team members to individually determine the content of their research, and the organization's ability to provide its team members with this freedom, carried the highest loading and seems to be a of major importance to determine the extent of autonomy in a research unit.

Secondly, the ability of a research unit to adjust its research focus and redirect its efforts into more promising fields on a self-determined basis, without asking for permission from a higher authority, emerged as an important component of the construct. Lastly, the ability to apply for research grants on an individual basis and thereby generate funds for research activities demonstrated a high enough loading and contributed to the autonomy construct.

The notion of autonomy is often discussed in the context of academic institutions and performance. On the one hand, researchers demand autonomy as part of their underly-

ing research ethics and philosophy (freedom of research). On the other hand, increased autonomy seems to be beneficial for technology transfer, because researchers are in a position to determine by themselves which research areas are most promising and will deliver optimal research results. Hence, as a consequence, research unit managers should continue to allow their research unit staff members sufficient freedom to steer their research focus, and grant them sufficient autonomy in their research focus. Autonomy seems to have positive implications on technology transfer.

Innovativeness

An unexpected outcome was the relatively weak or non-relevant contribution of innovativeness to the relationship of entrepreneurial orientation and performance. Innovation is a key element in the entrepreneurship process, and one of the most broadly investigated and discussed in the entrepreneurship literature. Our sample could not confirm a significant link between innovativeness and performance satisfaction. However, the construct itself looks robust. With only 2 out of 8 indicators removed, and a Cronbach's alpha of 0.87, it shows characteristics of high reliability. The indicators removed – "strong emphasis on experimenting with established and tried ideas" and "we have adjusted the focus of our research activities" – are in fact those indicators that reflect little of a strong posture of innovation within a research unit. Indicators with the strongest loadings are "general innovativeness", "successful research results", and "strong emphasis on technological and intellectual leadership" with loadings of 0.8 or greater. Hence, the construct appears to be reliable. Nevertheless, the relationship to performance satisfaction was not significant, and Hypothesis 2 has to be rejected.

Reasons for this result might lay in the nature of the innovativeness concept in academia. Being a researcher in a lab means that innovation is part of the job description. Therefore, innovativeness as an organizational characteristic was not viewed as being relevant or special in the assessment of whether technology transfer benefits from innovativeness or not.

For managers of research units, this means that the degree of innovativeness within a research team is not the main point to be concerned about. Other dimensions have much greater impact on technology transfer success.

Proactiveness

Proactiveness contains an element of curiosity and the search for new opportunities. In fact, the proactiveness dimension emerges as most relevant part of the entrepreneurial construct as relates to its impact on performance satisfaction. The proactiveness-performance satisfaction path carries the highest coefficient value (2.65), and is significant at the 5 per cent level. The proactiveness construct had only 2 out of 8 removed and a Cronbach's alpha of 85 per cent, i.e. it signals high reliability. Indicator loadings are relatively evenly distributed across the various indicators.

There is a tendency that research units anticipate and have a forward-leaning posture, trying to be the first to discover any specific phenomena in their research field. Interestingly, indicators dealing with external factors such as responsiveness to clients' or patients' needs, and responsiveness to discoveries of researchers outside the research unit, also carry high loadings. In other terms, a research unit is not an inward-oriented organization, quite the opposite. Being responsive to the environment is an important characteristic of a research unit and enhances the proactiveness dimension, which results in positive impact on technology transfer. Therefore, Hypothesis 3 is not rejected.

The proactiveness dimension is a well-suited attachment point for the management of universities: Encouraging research units to embrace opportunities and to react and respond swiftly and pronouncedly on needs and developments can be fostered by management via incentives or measures. Simply sending researchers on a regular basis to meetings and conferences will enable them to interact with and respond to developments of their peers, which will in itself push their on research forward.

Competitiveness

The dimension of competitiveness or competitive aggressiveness, as it was originally labeled by Lumpkin and Dess, also demonstrated unexpected and interesting results. After elimination of three indicators due to too low loadings, the remaining three indicators supplied a construct that was considered reliable with a Cronbach's alpha of 0.72 and composite reliability of 0.86.

Whilst all other significant dimensions showed a positive relationship to technology transfer performance satisfaction, the path from the competitiveness construct, however, carries a negative value of 0.164. However, it would be premature to conclude that the more competitive research units behave, the less satisfied they are with their performance.

The negative direction of the competitiveness-technology transfer performance relationship can be explained by the item operationalization. In this case, the items "competition measurement", "competition observation", and "communication" relate to the openness of dialogue with other research groups, and the way how result work it measured and exchanged with third parties. It becomes clear that research units tend to have a preference to work on a stand alone basis, and do neither compare and share their work with other researchers, nor do they inform other researchers before any publication has been done. Therefore, research units might disagree about sharing information, but at the same time are satisfied with the outcome of their technology transfer.

On this basis, the results do not conflict with the underlying theory to the extent that Lumpkin and Dess postulated a positive relationship between competitiveness and performance. Due to the operationalization of the construct, the relationship signals a negative direction, however, the argument should be much more that the magnitude of the construct relates positively with the endogenous variable. Therefore, we would argue that this is special case of the construct, and more work you be spent on the operationalization of the construct, and its measurement. Hypothesis 4 should not be rejected.

On the other hand, it will be a valid discussion whether the concept of competitiveness is justified in the context of entrepreneurial orientation in academia. One could argue that similar to the constructs of autonomy, innovativeness, risk taking and proactiveness, the competitiveness construct was developed on the basis of the existing literature on competitiveness in the context of for-profit-organizations, i.e. firms. It seems that the nature of competitiveness relates a lot to free market forces, where the market often rewards an aggressive behavior because the organization differentiates itself from other market participants. This situation is different in the context of not-for-profit universities, and therefore this special dimension should be investigated more closely.

Risk taking

To what extent do researchers engage into any risks during their studies? Can a research unit behave risk-friendly or risk-adverse it their activities, risk being the risk to succeed or not succeed? Entering into research activities with the goal to generate technology transfer in form or a new technology or a new product is subject to different kinds of risk: A research unit commits time, material and financial resources to a project, and obviously has to decide which projects to pursue, thereby facing opportunities costs for all alternative projects it decides to reject. In this regard, research units face risks of not being successful and wasting resources on projects that might fail. At the same time, a project might have only a marginal impact or contribution to an existing theory or practice, thereby having a relatively high probability to succeed, as opposed to a radically new project that could have great impact, but the probability of success is relatively low. In other words, research units and principal investigators have to assess their chances of success and coordinate their research efforts accordingly.

In this study, the risk taking-performance relationship was significant and strongly pronounced with a path coefficient of 0.241 at a 5 per cent significance level. The dimension of risk taking has the second highest path coefficient following proactiveness at a similar significance level. In other words, the risk taking construct was a major

contributor to the overall entrepreneurial orientation-performance relationship. Hypothesis 5 is not rejected.

From the initial set up of the risk taking construct, four items had to be removed due to too low item loadings. Three items remained in the construct, “acceptance of failure”, “acknowledgement of failure”, and “risk-friendliness”. The construct, hence, was condensed to the components of how to deal with failure, and attitude versus risk.

Failure is an important element of risk, in particular in the context of technology transfer and start-up activity. Most new ventures fail, therefore, the way organizations deal with failure is an important precondition in order to encourage researchers to take on risks and pursue the research endeavors.

Interdisciplinarity

The discussion about interdisciplinarity in academia and its contribution to technology transfer performance has increased in importance over the last decade. Sciences are converging in particular in the segments of life science, but also across the various engineering disciplines. Bioengineering, biophysics, and biocomputation are a few examples. Nanotechnology is another area where different sciences contribute to a mutual goal.

Interdisciplinary research centers serve as a basis for enhanced technology transfer, because researchers learn about alternative solutions for their research problems from other disciplines. The interdisciplinarity construct signaled high construct reliability with a Cronbach’s alpha of 0.876. Only two of the original eight items had to be removed (“incentives” and “observation of interdisciplinary projects”). The item “Receipt of ideas from researchers of other disciplines” carries the highest loading, followed by “Opportunity to meet researchers from other disciplines informally and regularly in order to exchange ideas”. In other terms, the exchange of information and ideas across research disciplines is key. The process resembles to opportunity recognition: Researchers need to have the opportunity to encounter view and ideas from other

disciplines and project them on their own specific problems; this leads to better solutions, which will lead to higher technology transfer. Hypothesis 6 is not rejected.

Fostering the information exchange of researchers can have various forms and degrees of intensity. Starting from an informal verbal exchange of ideas between two researchers, it can continue with regular informal gathering for researchers to meet and discuss their research projects, to regular conferences and speeches where researchers present their work, to joint interdisciplinary research projects with different teams. The end of the spectrum is potentially an interdisciplinary research center staffed with researchers across various faculties, working on joint interdisciplinary projects.

From the perspective of university management, this study indicates that increased interdisciplinary research is part of greater entrepreneurial orientation, which in return results in greater technology transfer performance. Enabling a frequent and open exchange between researchers, providing opportunities for idea spotting and communication are levers university management can use in order to increase technology transfer.

Independence of Exogenous Variables

One of the basic assumptions of Lumpkin and Dess's model of Entrepreneurial Orientation was the notion that all five dimensions of autonomy, innovativeness, proactiveness, competitiveness, and risk taking might vary independently, and might not covary.[479] On this basis, every single one of the dimensions could prove to have a significant influence in the model, with all other dimensions not being relevant at all. Based on the outcome of the discriminant validity analysis, it was shown that the entrepreneurial orientation dimensions do not covary, and hence Hypothesis 7 is not rejected.

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[479] See Lumpkin and Dess (1996), p. 137.

7.2. Implications for Research Units

The results of this study signal a number of implications for the management of organizational behavior in research organizations. As described in the opening section of this study, governments, companies, regional representative, and communities have an interest in universities and research organizations to create business opportunities, and as a consequence, create companies, jobs and wealth in the respective region. Management of universities and research laboratories are searching for guidance how to manage these organizations most effectively towards this goal, and how to set incentives in a way that they foster entrepreneurial activity.

As an overall finding, entrepreneurial orientation has a positive impact on technology transfer, i.e. the more entrepreneurial a research faculty behaves, the higher is the degree of technology transfer of that organization. This study has shown that in particular the aspects of autonomy, risk taking, and interdisciplinarity, seem to have significant influence on the technology transfer success of a university.

In other terms, university management and research leaders should enable their research organization to work in an autonomous environment, providing freedom and space with regard to idea development, and establishing research focus. It seems that the more researchers have the liberty to choose their individual research domain, the more successful the technology transfer mechanism works.

Similarly, incentives for risk taking, and acceptance of failure, foster technology transfer activities. For example, one of the major advantages of the Silicon Valley region, where both Stanford University and parts of University of California are located, is without doubt that failure to succeed with a business venture is accepted. Most of first time ideas fail, therefore an environment that encourages people to continue or start again their activities after a failure will in the long run produce more technology transfer than others.

A major driver of the technology transfer process in the U.S. was the Bayh-Dole legislation of 1980. The German government learned from experience of the Bayh-Dole Act and introduced a modern employee invention act (Arbeitnehmererfindungsgesetz, ArbNErfG) in 2002.[480] The goal of the German act is to encourage researchers to patent and commercialize their inventions more regularly. Historically, researchers and professors were the legal owners of their inventions, with the result that new inventions were infrequently reported and patented due to lack of incentives and control. Secondly, once an invention was published in a scientific journal or at a conference, the invention as such became public knowledge and was restricted from being patented. Universities did not have access to inventions, and did not have the right to commercialize them.

Under the newly introduced law, a researcher has the obligation to report any new invention to his/her university. The university can then decide if it wants to patent and commercialize the invention or not. In this case, the researcher will receive 30 per cent of the gross revenues of this patent. It is expected that the introduction of this new law will modernize the researcher-university relationship, and accelerate patent generation at higher education institutions, which should benefit in particular smaller and medium-sized companies as the main potential users of these patents.[481]

7.3. Limitations and Future Research Aspects

This dissertation was designed to survey a very broad and relatively inclusive set of research units across the top tier of U.S. universities. In fact, all 148 universities reporting to the AUTM survey were addressed in the survey, and 1,178 individual researchers were contacted, of which 146 responded. Despite this relatively positive response, the picture of entrepreneurial orientation at U.S. research units is still scattered, and the data quality depended on a single respondent as a representative of his

[480] See BMBF (2002).
[481] See BMBF (2001), p. 3.

organization. A key element of the survey was that the level of investigation was not the individual researcher, but the research unit, i.e. the research lab or the research center. This fact was important because the underlying theory of entrepreneurial orientation is an organization phenomenon, rather than an individual one.

The intent of this dissertation was also to provide empirical support to the theoretical framework of entrepreneurial orientation in the context of academic organizations. Entrepreneurial orientation has been tested mostly with for-profit organizations, and their application with not-for-profit organizations is less common. However, there are several cases where theories stemming from the field of corporate behavior were applied with non-profit organizations such as hospitals.

Future research should follow along these lines and provide more insight in behavior of academic organizations, which are highly complex due to the very specialized role each single department fulfills. There is still a lot of uncertainty about the antecedents of each single dimension. Components such as autonomy and risk taking would deserve much more focus, in order to isolate their impact on overall entrepreneurial activity.

Another interesting aspect for future research is the approach of Bhuian et al.: In the context of not-for-profit hospital, the authors found that the relationship between an orientation construct such as entrepreneurial orientation and performance is not necessarily linear or upward sloping, but rather curve linear or U-shaped.[482] In other terms, there is a possibility that entrepreneurial orientation has a positive impact on performance to a certain degree, however, it entrepreneurial orientation becomes too pronounced, it might have a negative impact on performance. This part of the entrepreneurial orientation-performance relationship deserves further attention.

This dissertation left deliberately moderating and contingent variables aside in order to reduce complexity. Introducing moderating factors such as environment, govern-

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[482] See Bhuian, Menguc and Bell (2005), p. 11.

ance structure, access to resources, etc. can add another perspective on the issue. In addition, broadening the scope of the investigation and lifting it to an international level should provide more insight about the nature of the entrepreneurial orientation construct. Similar studies could be conducted in countries such as the U.K., Germany, France, and Japan.

An extremely useful data provider for the analysis of university performance and development in the U.S. is the Association of University Technology Managers, AUTM, which provided parts of the underlying information for this study. Technology transfer management needs to satisfy highest standards and should develop best practice. An organization similar to AUTM does not exist yet in Germany. It will be in the interest of universities, government, industry, and society that technology transfer in academia will be made measurable, and best practice can be communicated. Professional training of technology transfer management is required in order to accelerate innovation and new venture creation in Germany. Therefore, an organization like AUTM for German universities would be desirable.

7.4. Summary

This study demonstrated that entrepreneurial orientation is relevant for the technology transfer process in academia. Entrepreneurship is a process, and this process can be improved at universities by means of economic organizational behavior theory. The theory of entrepreneurship orientation is a means to learn more about the technology transfer process at universities. The relationship between entrepreneurial orientation of a research unit and its technology transfer performance is positive. Entrepreneurial orientation, consisting of its dimensions autonomy, innovativeness, proactiveness, competitiveness, risk taking, and interdisciplinarity, can be managed and improved.

8. Conclusion

Governments, companies, regional representatives and communities have an interest in universities and research organizations to create business opportunities and, as a consequence, to create companies, jobs and wealth in their respective region. Academic research institutions have therefore transformed from providers of education and research to creators of technology, businesses and economic growth.

The extent to which a research organization is entrepreneurially oriented is an important indicator of its performance in the technology transfer process. Based on the theoretical framework of Lumpkin and Dess, this study has demonstrated how different magnitudes of entrepreneurial orientation have positive impact on technology transfer. For decision makers, this means that enhancing the entrepreneurial orientation of a research unit may foster the technology transfer process and create products, businesses and jobs.

As an overall finding, entrepreneurial orientation in general has a positive impact on technology transfer, i.e. the more entrepreneurially a research faculty behaves, the higher is the degree of technology transfer success of that organization. In particular the aspects proactiveness, risk taking, interdisciplinarity, and autonomy have significant influence on the technology transfer performance at universities. Similar to studies on entrepreneurial orientation on companies, decision makers have to think about how to implement the entrepreneurial orientation construct as a management tool.

Management of universities and research laboratories knows about the expectations that the society sets in academia, and they search for guidance how to manage their organizations most effectively towards this goal and how to set incentives that will foster entrepreneurial activity. Interestingly, results from corporate literature show that the notion of autonomy needs to be connected with a sufficient guidance by managers since too much decentralization might lack efficiency. Furthermore, the effect of autonomous groups should be monitored, and if results are not as expected, freedom

of action must be restrained. In the context of academia, this study implies a more consequent focus on freedom. The strong effect of autonomy and risk-taking suggests that the more researchers have the freedom to choose their individual research domain, the more successful the technology transfer mechanism works. Further research could stress on this suggested difference.

Similarly, strong influences of risk-taking and innovativeness may imply the need to establish incentives for risk-taking and to develop an acceptance for failure in order to foster technology transfer activities. Most of first time ideas fail, therefore only those environments that encourage people to continue or start again new activities after a failure will produce more technology transfers than others.

The intent of this study was also to provide empirical support to the theoretical framework of entrepreneurial orientation in the context of academic organizations. Entrepreneurial orientation has been tested mostly with for-profit organizations, and their application with non-profit organizations is less common. However, there are several cases where theories stemming from the field of corporate behavior were applied with non-profit organizations such as hospitals. Future research could follow these lines and provide more insight in behavior of academic organizations, which are highly complex due to their highly specialized role. In addition, broadening the scope of the investigation and lifting it to an international level should provide more insight about the nature of the entrepreneurial orientation construct. Similar studies could be conducted in countries such as the UK, Germany, France, and Japan.

There is still a lot of uncertainty about the antecedents of the entrepreneurial orientation dimensions. Components such as autonomy and risk-taking would deserve much more focus, in order to isolate their impact on overall entrepreneurial activity. Lastly, this study left deliberately moderating and contingent variables aside in order to reduce complexity. Introducing moderating factors such as environment, governance structure, access to resources, etc. can add another perspective on the issue.

Appendices

A. Survey Instrument

A.1. Invitation Email

From: jan.boehm@win.rwth-aachen.de

Subject: Online Survey on Entrepreneurial Orientation in Academia

Date: November 24, 2004 3:05:58 PM GMT+00:00

To: jan.boehm@win.rwth-aachen.de

Dear Fellow Researcher,

- Why do some universities create more start-up companies than others?
- Does technology transfer depend on the organization of work in research labs?
- Does interdisciplinary research foster the creation of new companies?

In a survey of universities in the U.S., we want to investigate these and other related questions. The survey focuses on entrepreneurial orientation of research organizations, and is conducted out of Palo Alto, California, as part of a Ph.D. dissertation at RWTH Aachen University in Germany.

Here a brief summary of our request (please find more details at the bottom of this message):

- We kindly ask for 10-15 minutes of your time to respond to this survey
- If you personally do not have time to respond, please forward this email to a member of your research team; any member of your team (PIs or co-PIs, research associates, Postdocs, Ph.D. candidates, or students) will be equipped to respond
- To compensate for time and effort, we would be pleased to provide you with the results of the survey and recommendations for researchers; please indicate your interest at the end of the survey
- The following link will lead you to the online survey opening page:

http://www.rwth-aachen.de/gruenderkolleg/marketing/survey//index.php?sid=6

- Your login token is: **f2196z**

All information you provide will be treated confidentially and processed anonymously.

Thank you very much for your cooperation.

Best regards

Jan Boehm
Ph.D. Candidate
RWTH Aachen University
Contact Phone in Palo Alto: (650) 498 9623
Email: jan.boehm@rwth-aachen.de
Homepage: http://www.win.rwth-aachen.de

If you have a little more time, we are pleased to provide more details about this survey:

We are conducting a survey among U.S. universities as part of a dissertation project. The dissertation deals with the subject of "Entrepreneurial orientation at U.S. universities". Based on this survey, our goal is to identify the specificity of key dimensions of entrepreneurial orientation, such as autonomy, competitiveness, or risk taking, and relate them to entrepreneurial performance, such as starting a company or filing patents.

This dissertation is supervised by Professor Dr. Malte Brettel, Professor of Business Administration for Engineers and Scientists at the RWTH University in Aachen, Germany.

The above link and login will guide you to an online survey consisting of 8 parts:

- Part 1 will ask 4 basic questions about your research unit (research lab, department, or center) - Estimated time required for answering: 1-2 minutes
- Parts 2-8 will ask questions about the entrepreneurial orientation in your research unit - Estimated time required for answering: 9-13 minutes

In total, answering this survey should take ca. 10-15 minutes of your time. All questions of Parts 2-8 can be answered with one click on a 7-point-scale, which will enable you to work quickly through the survey. All information provided in this survey will be treated confidentially and will be processed anonymously. We will not publish any rankings or relative performance analysis. In case you do not know the answer to a question, or you are unsure about an answer, you can leave the question unanswered ("N/A", "not applicable").

If the recipient of this message personally does not have time to respond, we kindly ask to forward this email to any other member of the research team (PIs or co-PIs, research associates, Post-docs, Ph.D. candidates, students); the questions in the survey are formulated in a way so that any member of the research team will be in a position to answer them. Receiving a response from any team member is more important to us than the fact which member of the research team has answered the questions.

As an incentive to participate in the survey, and to compensate for time and effort, we are happy to send to you - upon request - the results of the survey which will include recommendations for researchers how to achieve better entrepreneurial results.

If you have any questions regarding this survey, please contact jan.boehm@rwth-aachen.de.

We appreciate very much your cooperation, time and effort.

Best regards

Jan Boehm

Ph.D. candidate at the

Chair of Business Administration for Engineers and Scientists

RWTH Aachen University, Germany

Contact Phone in the Palo Alto: (650) 498 9623

Email: jan.boehm@rwth-aachen.de

Homepage: http://www.win.rwth-aachen.de

A.2. First Reminder Email

From: jan.boehm@win.rwth-aachen.de

Subject: Online Survey on Entrepreneurial Orientation in Academia

Date: December 6, 2004 10:38:22 AM GMT+00:00

To: jan.boehm@win.rwth-aachen.de

Dear Jan,

Shortly before Thanksgiving, I emailed you and asked for your participation in a survey regarding entrepreneurial activities in academic research. Even though I know that you probably have a tight schedule, I would really appreciate if you reconsidered participating in this survey. It is part of my Ph.D. thesis, and therefore really important to me.

You will find the online questionnaire under the following link:

http://www.rwth-aachen.de/gruenderkolleg/marketing/survey//index.php?sid=6

Your login token is: f2196b

All details will be explained on the website. I truly appreciate your support and the time spent.

If you have any questions regarding the survey, please feel free to contact me anytime.

With the best wishes for the holiday season,

Yours sincerely,

Jan

Jan Boehm

Ph.D. Candidate

RWTH Aachen University

My current contact details:

Phone number in Palo Alto, California: (650) 498-9623

Email: jan.boehm@rwth-aachen.de

Homepage: http://www.win.rwth-aachen.de

A.3. Second Reminder Email

From: jan.boehm@win.rwth-aachen.de

Subject: Online Survey on Entrepreneurial Orientation in Academia

Date: Tue, 14 Dec 2004 20:41:58 +0100 (MET)

To: jan.boehm@win.rwth-aachen.de

Dear Jan,

Shortly before Thanksgiving, I emailed you and asked for your participation in a survey regarding entrepreneurial activities in academic research. I have received a number of responses since, however, to make this survey successful and meaningful, I just need a few more.

Therefore, I decided to send out another reminder, hoping that I will not cause any inconvenience to you. I would really appreciate if you reconsidered participating in this survey. It is part of my Ph.D. thesis, and therefore truly important to me.

You will find the online questionnaire under the following link:

http://www.rwth-aachen.de/gruenderkolleg/marketing/survey//index.php?sid=6

Your login token is: f2196b

All details will be explained on the website. I really appreciate your support and the time spent.

If you have any questions regarding the survey, please feel free to contact me anytime.

With the best wishes for the Holiday Season,

Yours sincerely,

Jan

Jan Boehm

Ph.D. Candidate

RWTH Aachen University

My current contact details:

Phone number in Palo Alto, California: (650) 498-9623

Email: jan.boehm@rwth-aachen.de

Homepage: http://www.win.rwth-aachen.de

B. Survey

Online Survey
Entrepreneurial Orientation in Academia

Welcome!

Thank you very much for participating in this survey. It will take 10-15 minutes to respond to the questions.

The survey asks about organizational behavior of research units (i.e. laboratories, centers, or research groups). Part 1 asks general questions about your research unit. Parts 2-8 ask more specific questions about behavior.

If you do not know the answer to a question, please leave it unanswered and continue. By default, the questions are marked "N/A" ("not applicable").

The bar in the top right corner indicates the percentage of the survey already completed.

At the end of the survey, please continue to the last page and submit your data. All information will be treated confidentially, and all analysis will be conducted on an anonymous basis.

If you are interested in receiving the result of this study, please provide us with your contact email address at the end of the survey.

[Next >>]

Entrepreneurial Orientation in Academia

1. Information about Research Unit

Research unit means the research laboratory, the research center, or the research group you are working in.

1.1.: What is the area of research of your research unit?

Please tick only one of the following:

- ☐ Electrical Engineering (or other engineering fields, expect for bioengineering)
- ☐ Computer Science (or other computer research fields)
- ☐ Biology, Biochemistry
- ☐ Bioinformatics
- ☐ Bioengineering
- ☐ Medical science
- ☐ Other life science research areas
- ☐ Other: _____

1.2.: What is your position within your research unit?

Please tick only one of the following:

- ☐ Principal Investigator
- ☐ Research Associate/Fellow
- ☐ Postdoctoral Fellow
- ☐ Ph.D. Candidate
- ☐ Graduate Student
- ☐ Undergraduate Student
- ☐ Other: _____

1.3.: How many full time employees do research in your research unit?

Please tick only one of the following:

1-3	4-6	7-10	11-15	16-20	21-30	>30
☐	☐	☐	☐	☐	☐	☐

1.4.: What is the size of the annual research budget of your research unit?

Please tick only one of the following:

less than $250,000	$250 to 500,000	$500,000 to 1 million	$1 to 2.5 million	$2.5 to 5 million	$5 to 10 million	more than $10 million
☐	☐	☐	☐	☐	☐	☐

2. Autonomy

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
...our team members have great freedom to individually determine the content their research	☐	☐	☐	☐	☐	☐	☐
...we are self-responsible for the allocation of research funds	☐	☐	☐	☐	☐	☐	☐
...our team members can individu-ally change and adjust the focus or our research, if required	☐	☐	☐	☐	☐	☐	☐
...team members have the oppor-tunity to apply for research grants	☐	☐	☐	☐	☐	☐	☐
...we drive our projects forward with personal effort and account-ability, and lead them to success	☐	☐	☐	☐	☐	☐	☐
...we enjoy are provided programs supporting particularly innovative and interdisciplinary research (incentives)	☐	☐	☐	☐	☐	☐	☐
...we enjoy a relatively high degree of flexibility and autonomy com-pared to other research units	☐	☐	☐	☐	☐	☐	☐

3. Innovativeness

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
...we have a strong emphasis on experimenting with established methods and tried ideas	☐	☐	☐	☐	☐	☐	☐
...we have a strong emphasis on technological and intellectual leadership, and innovation	☐	☐	☐	☐	☐	☐	☐
...we are motivated to pursue new avenues in research, away from the beaten path	☐	☐	☐	☐	☐	☐	☐
...we have a tendency to try radi-cally new methods and experi-ments	☐	☐	☐	☐	☐	☐	☐

…we have achieved a number of successful new research results over the last 5 years	☐	☐	☐	☐	☐	☐	☐
…we have changed and adjusted the focus of our research activity significantly over the last 5 years	☐	☐	☐	☐	☐	☐	☐
…we incorporate new external methods and ideas into our own research projects	☐	☐	☐	☐	☐	☐	☐
…we consider ourselves as being relatively innovative	☐	☐	☐	☐	☐	☐	☐

4. Proactiveness

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
…we try to anticipate new research trends	☐	☐	☐	☐	☐	☐	☐
…we aim to be active in the most relevant research fields	☐	☐	☐	☐	☐	☐	☐
…we try to anticipate future needs of human/patients/users/clients	☐	☐	☐	☐	☐	☐	☐
…we align our research efforts according to these needs	☐	☐	☐	☐	☐	☐	☐
…we respond to new discoveries outside our research unit, and make them part of our own re-search	☐	☐	☐	☐	☐	☐	☐
…we are a leader in our research field	☐	☐	☐	☐	☐	☐	☐
…we present and discuss our re-search results rapidly and ask for feedback	☐	☐	☐	☐	☐	☐	☐
…we disseminate our knowledge to other researchers outside our research unit	☐	☐	☐	☐	☐	☐	☐

5. Competitiveness

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
…we measure our research quality and results against other research units	☐	☐	☐	☐	☐	☐	☐

…we observe research activities of other research units and try to position our activities relative to them	☐	☐	☐	☐	☐	☐	☐
…we aim for becoming one of the highest quality research units	☐	☐	☐	☐	☐	☐	☐
…we share our results with other research units	☐	☐	☐	☐	☐	☐	☐
…we have an interest in supplying our research result to companies in order to facilitate rapid development or marketable products and technologies	☐	☐	☐	☐	☐	☐	☐
…we see it as an obligation to transfer our knowledge to the industry in order to create new products and technologies	☐	☐	☐	☐	☐	☐	☐

6. Risk-taking

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Disagree	Strongly disagree
…we commit a large part of our resources to projects where the outcome might be groundbreaking, however, the probability of success is low	☐	☐	☐	☐	☐	☐	☐
…we are careful allocation resources on uncertain research projects	☐	☐	☐	☐	☐	☐	☐
…we are encouraged to continue difficult research projects, even if we just experienced a failure in this project	☐	☐	☐	☐	☐	☐	☐
…failure to succeed accepted	☐	☐	☐	☐	☐	☐	☐
…we openly admit failure, and are ready to stop research projects if failure becomes evident	☐	☐	☐	☐	☐	☐	☐
…we have a generally risk-friendly approach towards research and committing research resources	☐	☐	☐	☐	☐	☐	☐
…we are eager to exploit new research opportunities and methods	☐	☐	☐	☐	☐	☐	☐

7. Interdisciplinarity

In our research unit,...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
...we are interested in having an interdisciplinary exchange of ideas with other researchers	☐	☐	☐	☐	☐	☐	☐
...we receive a lot of ideas from researchers in other disciplines	☐	☐	☐	☐	☐	☐	☐
...we try to incorporate these ideas into our own research	☐	☐	☐	☐	☐	☐	☐
...we have the opportunity to meet researchers from other universities informally and regularly in order to exchange ideas	☐	☐	☐	☐	☐	☐	☐
...we have had a number of successful interdisciplinary projects over the course of the last 5 years	☐	☐	☐	☐	☐	☐	☐
...we observe that there are interdisciplinary research projects at our university	☐	☐	☐	☐	☐	☐	☐
...we are relatively well informed about the research of our researchers in other disciplines of our university	☐	☐	☐	☐	☐	☐	☐

8. Performance Satisfaction

In our research unit, we are relatively satisfied...

Please tick the appropriate response for each item:

	Strongly agree	Agree	Some-what agree	Neither agree nor disagree	Some-what disagree	Disagree	Strongly disagree
...with the quality and quantity of our research results compared to other research units	☐	☐	☐	☐	☐	☐	☐
...with quality and quantity of our publications compared to other research units	☐	☐	☐	☐	☐	☐	☐
...with quality and quantity of our patents compared to other research units	☐	☐	☐	☐	☐	☐	☐
...with the degree of involvement of our research in company spin-off activity	☐	☐	☐	☐	☐	☐	☐
...with quality and quantity of our presentations at conferences	☐	☐	☐	☐	☐	☐	☐
...with quality and quantity of our meetings with industry representatives or entrepreneurs	☐	☐	☐	☐	☐	☐	☐
...with the entrepreneurial activity of our research unit	☐	☐	☐	☐	☐	☐	☐

9. Survey results

I would like to receive the results of this study. Please send them to the following email address: _____

L

C. U.S. Research Universities

Arizona State University
Auburn University
Baylor University
Boston University
Bowling Green University
Brandeis University
Brown University
Brigham Young University
California Institute of Technology
Carnegie Mellon University
Case Western Reserve University
Clemson University
Colorado State University
Columbia University
Cornell University
Creighton University
Dartmouth University
Duke University
East Carolina University
Emory University
Florida Atlantic University
Florida International University
Florida State University
George Mason University
Georgetown University
Georgia Institute of Technology
Harvard University
Indiana University
Iowa State University
Johns Hopkins University
Kansas State University
Kent University
Louisiana State University
Marquette University
Massachusetts Institute of Technology
Michigan Institute of Technology
Michigan State University
Mississippi State University
Montana State University
New Jersey Institute of Technology
New Mexico State University
New York University
North Carolina State University
North Dakota State University
Northeastern University
Northwestern University
Notre Dame University
Ohio State University
Ohio University
Oklahoma State University
Oregon State University
Pennsylvania State University
Portland State University
Rice University
Rockefeller University
Rutgers University
Southern Methodist University
Stanford University
SUNY Albany
SUNY Binghamton
SUNY Buffalo
SUNY Stony Brook
Temple University
Texas A&M
Texas Institute of Technology
Tufts University
Tulane University
University of Akron
University of Alabama at Birmingham
University of Arizona
University of Arkansas
University of California at Berkeley
University of California at Davis
University of California at Irvine
University of California at Los Angeles

University of California at Riverside
University of California at San Diego
University of California at San Francisco
University of California at Santa Barbara
University of California at Santa Cruz
University of Central Florida
University of Chicago
University of Cincinnati
University of Colorado Boulder
University of Connecticut
University of Dayton
University of Delaware
University of Florida
University of Georgia
University of Hawaii
University of Houston
University of Illinois at Chicago
University of Illinois at Urbana-Champagne
University of Iowa
University of Kansas
University of Kentucky
University of Louisville
University of Maine
University of Maryland
University of Massachusetts
University of Miami
University of Michigan
University of Minnesota
University of Mississippi
University of Missouri
University of Montana
University of Nebraska
University of Nevada at Las Vegas
University of Nevada at Reno
University of New Hampshire
University of New Mexico
University of New Orleans
University of North Carolina at Chapel Hill
University of North Carolina at Charlotte
University of North Texas
University of Northern Iowa
University of Oklahoma
University of Oregon
University of Pennsylvania
University of Pittsburg
University of Rhode Island
University of Rochester
University of South Alabama
University of South Carolina
University of South Dakota
University of South Florida
University of Southern California
University of Tennessee
University of Texas at Arlington
University of Texas at Austin
University of Toledo
University of Utah
University of Vermont
University of Virginia
University of Washington
University of Wisconsin Madison
University of Wisconsin Milwaukee
Utah State University
Vanderbilt University
Virginia Commonwealth University
Virginia Institute of Technology
Wake Forest University
Washington State University
Washington University
Wayne State University
Western Kentucky University
Wright State University
Yale University

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