THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Exploring the black box of academia

University positioning, firm inventiveness and academic opportunities

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Abstract

This PhD thesis analyzes the role and activities of universities and academics based on three overarching themes. The first theme addresses how universities differentiate and compete. Changing conditions for universities, together with changed expectations on their role in the economy, has provided greater possibilities for specialization and differentiation among individual universities. By drawing on public administrative data, the thesis characterizes the diversity of the Swedish university system and provides an evidence-based interpretation of individual universities' "strategic position" with focus on their differential ability to attract external research funding. This provides an interpretation of whether and how Swedish universities specialize and compete. The results show that the Swedish university sector is polarized into two groups of research-oriented respectively education-dependent universities. Moreover, the ability to attract competitive external research funding is related to the universities' position. In light of the national context, the findings suggest that this polarization is not the result of strategic differentiation among Swedish universities, but rather that individual universities are largely locked in their historic positions due to path dependencies and cumulative advantages. This study contributes to the literature exploring the diversity of the European university systems.

The second theme addresses academic inventors' role in and impact on firm inventiveness. Studying firms' academic inventions sheds light on the role and impact of academic collaboration, but previous research has not analyzed the inventions resulting from university-industry collaboration. This thesis investigates the relative characteristics of firms' academic inventions - where at least one academic is involved - as well as in what ways academic inventors affect the technological importance of firms' inventions by analyzing firm patents. The findings show that firms mainly involve academics in inventions within their core technological fields. For a few dominant firms, academic patents on average have lower technological importance as compared to non-academic patents, indicating that the inventions resulting from academic collaboration relatively speaking lack direct usefulness for subsequent technological devel-

opment. The same is however not found for the majority of the investigated firms, for which the results suggest that academic patents on average have relatively more widespread impact (i.e. a wider applicability) as well as higher indirect influence on subsequent technological development. Antecedent literature claim that these results show a difference in quality between academic and non-academic patents but this thesis proposes that these results should be interpreted as indicating differences in the roles academic inventors play in firms' inventive activities.

The third theme addresses individual academics and their activities within the three roles of research, education and third mission. This theme arises from the conviction that the activities of (individual) academics are the very foundation of the university and its contribution to societal needs and economic progress. By conducting a literature review in selected journals, the thesis shows that the broader economic literature largely treats universities as a "black box" by focusing upon the outcomes of academic research, but largely ignoring the academic activities leading to these outcomes. Moreover, the thesis makes a first attempt to explore this black box, by analyzing the relation among the three academic roles at the level of individual academics. This is achieved through a survey of academics in three scientific disciplines, investigating their perception of how important their prior experiences from the three roles are for identifying and exploiting research, education and third mission opportunities. The findings show that academics perceive that all roles contribute to each other, suggesting complementarities among the roles at the level of individual academics. The study also point to that research is perceived as important for all three roles, while education is considered less relevant for the other two roles. These findings might have important implications for staffing of universities and to what extent different roles should be specialized at the level of individual academics.

Key words: Universities, academics, competition, opportunities, academic patents

Appended papers

Paper I: Ljungberg, D., Johansson, M. and M. McKelvey (2009). Polarization of the Swedish University Sector: Structural characteristics and positioning. In M. McKelvey and M. Holmén (eds.), *Learning to Compete in European Universities: From Social Institutions to Knowledge Business*, Cheltenham, UK and Northampton, US: Edward Elgar Publishing.

Paper II: Ljungberg, D. and M. McKelvey (2011). What characterizes firms' academic patents? Academic involvement in industrial inventions in Sweden. Earlier versions presented at the EMAEE conference (European Meeting on Applied Evolutionary Economics) Jena, May 2009, and the DRUID summer conference 2010, London June 2010. Submitted to an international journal.

Paper III: Ljungberg, D. (2011). Academic inventors and firm inventiveness: A quasi-experimental analysis of firms' patents. Presented at DIME final conference, Maastricht April 2011. Submitted to an international journal.

Paper IV: Holmén, M. and D. Ljungberg (2011). What do we know about what academics do? An opportunity perspective on the university literature. Earlier version presented at the DRUID Summer Conference 2009, Copenhagen, June 2009. Submitted to an international journal.

Paper V: Holmén, M. and D. Ljungberg (2011). Jack-of-all-trades or narrow specialists? Academics, opportunities and research, education and third mission experiences. Submitted to an international journal.

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DANIEL LJUNGBERG
Göteborg, May 2011

Contents

List of Tables

1 Introduction

This PhD thesis examines the role and activities of universities and academics based on three overarching themes.[1] In this thesis, universities refer to all types of higher education institutions that incorporate some degree of research in addition to education. Moreover, academics refer to the persons employed as researchers, and commonly as teachers, at universities. Thus, academics refer to all researchers at a university, ranging from assistant professors to full professors.

The starting point of the thesis is taken in the longstanding recognition of the importance of universities and academic research for technological change and economic progress. Indeed, there exists ample evidence across a range of different bodies of literature that universities and academics play a crucial role in technological and economic change (Cohen et al., 2002; Mansfield, 1991, 1998; Rosenberg and Nelson, 1994; Salter and Martin, 2001). In addition, the importance of universities and academics seems to have increased during recent decades, with the transition to a more "knowledge intensive" economy placing them in a more central role in relation to economic progress (Florida and Cohen, 1999; Lawton Smith, 2006).

A vast literature within different approaches has emerged during recent decades analyzing universities' role in and contribution to technological change and economic progress. The role and contribution of universities have commonly been analyzed either from a systematic perspective or by a focus on their outputs and external relations. From the systemic perspective scholars within the innovation systems and triple helix approach have highlighted the importance of universities for economic progress in general (e.g. Etzkowitz and Leydesdorff, 2000; Mowery and Sampat, 2005), while literature on economic geography has analyzed its role for regional growth (e.g. Varga, 2009). The literature on the output and external relations of universities has predominantly focused on their contribution to industrial innovation and industrial renewal and much attention has been rewarded to studies of university-industry interaction and academic entrepreneurship[2] (see Rothaermel et al., 2007).

Universities and academics impact and contribute to economic development by generating, disseminating and retaining knowledge, and they do this in several ways. First, many point to education as the major benefit provided by academia, in terms of training skilled graduates (including PhD graduates) that bring up-to-date scientific

[1] This PhD thesis focuses first and foremost upon economic literature. Within sociology the (individual) academic has been the subject of much research. Although to some extent studying individual academics as well as science-technology links, these sociological approaches have primarily focused on studying science in relation to a social setting, in terms of what makes science a specific entity and how scientific knowledge is created (see e.g. Pestre, 2004; Vinck, 2010). This thesis does not address universities and academics in relation to their social context, nor does it draw on sociological literature.

[2] In this thesis, academic entrepreneurship denotes the commercial activities of academics including patenting, not just their entrepreneurial efforts.

knowledge and know-how to industry and society (Florida, 1999; Salter and Martin, 2001). Second, academic research contributes to society by increasing the stock of knowledge, since research adds to the fundamental understanding of specific phenomena. Another important output of academic research is the generation of new techniques and instrumentations (de Solla Price, 1984; Rosenberg, 1992; Franzoni, 2009). Third, academics contribute to technological and economic change directly through commercializing academic research on their own and by personal interaction with their external environment, predominantly firms. Universities and academics can commercialize their research by patenting and licensing out research results or by creating new firms (Rothaermel et al., 2007). Academics can also contribute to firm innovations, by e.g. providing assistance and advice in technical problem-solving. These interactions can be informal, such as casual meetings at conferences, or formal collaborations such as consulting, contract research and joint research (Cohen et al., 2002; D'Este and Patel, 2007; Perkmann and Walsh, 2007).

This PhD thesis provides further insights into the role and importance of universities and academics, by investigating specific aspects of their activities. This is done within three themes, where the first theme studies the level of the university, while the second and third theme examines the level of the (individual) academic.[3] The first theme addresses universities as competitive and strategic actors, in terms of individual universities positioning themselves vis-à-vis other universities in regards to the offers they provide to different stakeholders, including students, firms and governments (Deiaco et al., 2009). Assuming that a university has some degree of autonomy in terms of decision-making and resource allocation, it can change its position by differentiating its offers in relation to other universities (Bonaccorsi and Daraio, 2007a).

Across national and regional settings, universities are regulated and slowly evolving institutions, and historically there has been little institutional differentiation among universities in Europe. However, an on-going transformation of the European university sectors during the last decades has provided greater possibilities, in terms of increased autonomy in decision-making, as well as increased need, due to increased competition for scarce resources such as funding and prominent researchers, for differentiation among individual universities (Bonaccorsi and Daraio, 2007a; Deiaco et al, 2009; Geuna, 1999). These changes indicate that universities can be viewed, and analyzed, as competing and strategic actors (cf. Bonaccorsi and Daraio, 2007a; Deiaco et al., 2009).

The question arises whether the transformation of the university sector has lead

[3] The themes are presented in chronological order of the studies. However, the themes are related in the following way: i) Theme 1: Universities positioning; ii) Theme 3: Academics and opportunities; and iii) Theme 2: Academic inventors and firm inventiveness. Theme 2 can be seen as a "sub-theme" of Theme 3.

to a differentiation among individual universities, i.e. whether individual universities actually compete for resources by positioning themselves in terms of their offers against other universities. Put differently, the question is whether or not the changing conditions have lead universities to innovate by strategically differentiating their offers. While there have been several case studies on individual universities (e.g. Clark, 1998) and analyses based on aggregate national statistics, studies of the position of individual universities within national university sectors (or across countries) is an emergent field (see e.g. Bonaccorsi and Daraio, 2007; Daraio et al, 2011).

This PhD thesis characterizes the diversity of the Swedish system and interprets individual universities' position. It thereby contributes to the literature exploring the diversity of the European university systems (cf. Bonaccorssi and Daraio, 2007; Daraio et al, 2011; Geuna, 1999). These studies are important from a university governance and policy perspective in light of the transformation of the European university sectors, changing the conditions in which universities operate.

The second theme addresses the role and impact of academic inventors for firm inventiveness. The focus is on investigating how the involvement of academic inventors affects firm inventiveness. During the last decades, universities and academics have increasingly been under pressure to more directly contribute to the needs of society and in particular the needs of industry (Florida and Cohen, 1999; Geuna, 2001; Salter and Martin, 2001). This has led to increased expectations and focus on academics as taking part in the creation and commercialization of technological inventions and innovations. Academics can do this for example by directly commercializing their academic research or by contributing to firms' innovative activities by engaging in informal or formal collaboration with industry. This thesis addresses academics' involvement in firms' inventive processes.

Existing research shows that i) academics are perceived as important contributors to firms' innovative performance (e.g. Cohen et al., 2002; Mansfield, 1991, 1998); ii) firms interact with academics using a wide set of different channels, such as contract research and consulting (e.g. Bekkers and Bodas-Freitas, 2008; Cohen et al., 2002; D'Este and Patel, 2007); and iii) firms gain multifaceted benefits, such as assistance in technological problem-solving, through such interaction (e.g. Bishop et al, 2011; Lee, 2000). Moreover, a few studies point to that collaboration with academics are positively related to firms' commercial success (e.g. Agrawal, 2006; Zucker and Darby, 1996; Zucker et al., 2002).

Previous research has thus focused on the relationship between universities or academics and firms, providing evidence on the perceived importance of academic collaboration for firms' innovative performance and on the association between such collaboration and commercial success. Firms, however, do not interact or collaborate with academics only for generating or accessing innovations that can be directly com-

mercialized. To a large extent firms involve academics in already on-going projects (Cohen et al., 2002; Perkmann and Walsh, 2009), where academics assist the firm in various activities such as technological problem-solving (e.g. Bishop et al., 2011; Lee, 2000). Thus, the contribution of academics to firms' innovative activities largely takes the form of firms involving academics in their (on-going) R&D activities, with academics creating and developing inventions together with or at the commission of firms. But what characterizes the inventions that firms involve academics in? And in what ways do academics, involved in firms' inventive activities, affect the inventions? These types of questions are not addressed by existing literature, but are important for our understanding of how academics contribute to technological change and firm inventiveness.

This PhD thesis investigates the characteristics of firms' academic inventions as well as in what ways academic inventors affect firm inventions. In this way, the thesis changes perspective in relation to existing literature, by focusing on the relationship between academics and firms' inventions, rather than on the relationship between universities and firms. Thus, the focus is on the outcome of university-industry collaboration, instead of the perceived importance, frequency and benefits of such collaborations. The thesis thereby contributes to the emerging literature on collaborative interaction between academics and firms (cf. Link et al., 2007; D'Este and Perkmann, 2011).

The third theme addresses individual academics and their activities within the three roles of research, education and third mission.[4] This theme arises from the conviction that the activities of (individual) academics are the very foundation of the university and its contribution to societal needs and economic progress. Universities, or departments, can to some extent guide the direction of research, education and third mission through e.g. research allocation, and academics operate in a constrained environment where their actions are to some degree shaped by issues such as regulations and availability of funding. Nonetheless, (individual) academics are to a large extent free to set and follow their own agendas.[5] Accordingly, it is individual academics that largely direct and carry out the activities at universities and it is the outcome of their activities that contributes to societal needs and economic progress. From the perspective of policy, university governance and academic research in general, it is therefore important to investigate the activities of (individual) academics in order to fully understand the role and contribution of universities.

Studies of individual academics and their activities have, however, not been a high priority within broader economic literature. Rather, the existing literature has to

[4] Third mission is the activities aimed at interacting or communicating with society at large, beyond the borders of the university and scientific community (cf. Molas-Gallart et al., 2002).

[5] This stylized argument is based on i) the ideal of academic freedom; and ii) the notion of universities as loosely coupled systems (cf. Bonaccorssi and Daraio, 2007a).

a large extent been preoccupied with studying measurable outcomes of academic research, such as patents and spin-offs, and the relation between academics and firms. While existing literature in this way can be characterized as largely treating universities, or academics as a group, as a "black box" (cf. Rothaermel et al., 2007), nonetheless the literature touches upon issues related to academics' activities. To extract these insights from existing literature in order to provide a comprehensive picture of what is known about academic activities, this thesis reviews the existing broader economic literature addressing universities and academics.

Within this third theme, the thesis also contributes empirically to the understanding of academics' activities, by investigating the relation among research, education and third mission. This line of inquiry is related to on-going debates on whether i) research and education are compatible activities (e.g. Clark, 1997; Smeby, 1998; Hattie and Marsh, 1996); and ii) there exists a trade-off between traditional academic research and third mission activities (Larsen, 2011). While existing evidence suggests that experiences in any of the roles can contribute to new research, education and third mission activities, these relations have not been systematically analyzed. This PhD thesis investigates academics' perception of how important their prior experiences from the three roles are for identifying and exploiting research, education and third mission opportunities.

As a final remark, this PhD thesis analyzes universities and academics with a particular focus on their activities in industry- and engineering-related areas. Theme 2 analyzes firms' academic inventions, while the empirical study in Theme 3 is conducted within three engineering-related disciplines. In this way this thesis does not address academics and their activities within areas related to humanities or social sciences. Moreover, the empirical studies in this PhD thesis analyze Swedish universities and academics.

This cover paper is structured as follows. In order to be able to discuss the studies and findings of this PhD thesis in relation to its research context, Section 2 provides an overview of the research setting in terms of the Swedish university system. Section 3 provides an overview of the existing literature on universities and academics, in accordance with the three themes. This overview derives the overarching research questions addressed in the appended papers. Section 4 presents an outline of the research designs and methods used in the studies making up the thesis. Section 5 briefly summarizes the five appended papers, while Section 6 provides a discussion of the contributions and key findings as well as implications and further research.

2 Research setting

This section provides an overview of the Swedish university sector. First, changes in and the current state of Swedish public policy are outlined, focusing on the major changes taking place in the 1990s. Second, an overview of the Swedish university sector is presented.

2.1 Swedish public policy

Starting during World War II, Sweden established its first "proper" science policy, followed by a growth of academic research. It was centralized and state controlled, starting by developing a research funding structure, in terms of establishing state funded research councils. The main resource allocation was provided through direct funding to academic faculties, and the focus was on long-term (indirect) benefits from public research (Benner, 2001; Jacob and Orsenigo, 2007).

The Swedish system, as many other European countries, largely followed the Humboldtian tradition, in terms of building up a university system where research and education are to go hand in hand. While several other European countries, such as Germany, in time moved away from this system by developing public research institutes, Sweden has stuck to a system where research and education are (largely) kept within the universities. The consequences of this strategy is that the Swedish system still today has relatively few research institutes and that universities lie at the heart of the public research sector (Granberg and Jacobsson, 2006; Jacob and Orsenigo, 2007).

The end of the 1960s and the beginning of the 1970s witnessed the beginning of a new period in Swedish science policy. This included a change from a relatively autonomous public research sector towards policy steering public research towards the demands and needs of different sectors in the society. This lead to a focus on interaction and collaboration among universities and other sectors, facilitated and steered through the establishment of different public agencies[6] and accompanied by a significant increase in research funding (Benner, 2001; Elzinga, 1980; Jacob and Orsenigo, 2007).

Before the 1960s, the Swedish academic system consisted of a handful of universities[7] , as well as a few universities specialized in technological and medical subjects[8]. In addition, there was also a private organization specialized in business and economics (Stockholm School of Economics). During the 1960s and 1970s, regional filials of these existing universities were founded, and during the 1980s and 1990s,

[6] This meant a decrease in the importance of the research councils.

[7] Lund University, Uppsala University, University of Gothenburg and Stockholm University.

[8] Karolinska Institutet., Royal Institute of Technology and Chalmers University of Technology.

many of these organizations expanded and became independent universities. These filials were placed in the next tier of cities such as Linköping and Umeå, mainly for reasons related to regional politics. The main task of these universities was to attract and educate more students, in order to provide the regional industry with workers (Sörlin and Törnqvist, 2000).

Large changes in the Swedish science policy took place in the 1990s. The underlying mechanisms behind these changes include a recession, accompanied by a new belief in universities as important drivers of economic growth. Jacob and Orsenigo (2007) identify two major trends in Swedish science policy during the last two decades: the ambition of policy to make universities and academic research means for economic progress in (weaker) regions, and as a source of "renewal" in the transition to a knowledge economy. Also, they argue that contemporary Swedish policy has three broad objectives: i) to promote the development of an entrepreneurial culture in higher education and research; ii) to support a greater degree of interaction between universities and society, primarily industry; and iii) to increase the pace of commercialization of academic knowledge. These developments are in line with changes in the US, Europe and Asia.

One important set of reforms that took place during this period are those that changed the balance between fixed and competitive funding. These were often related to reimbursement for education and research respectively. These changes included a reorganization of the research funding system in terms of increased reliance on competitive funding as well as the creation of infrastructure to commercialize research results (Benner, 2001; Jacob and Orsenigo, 2007). One major change of the research funding system was redistribution from block funding to more competitive funding through councils and foundations. This more competitive environment and restructuring of public authorities were also facilitated by the introduction of new public research foundations. These were based on the so-called "wage earners' funds", which originally intended to create reserves to purchase companies and thereby increase public ownership. In the end, however, the government invested this money into "new" areas of research to move Sweden into the knowledge society. These research foundations were intended to stimulate strategic research and to enhance co-operation and interaction with industry (Schilling, 2005). This entailed a decrease of the direct and fixed research funding, leading to that the majority of fixed income comes from education and not research (Benner, 2001; Jacob and Orsenigo, 2007; Sörlin and Törnqvist, 2000).

Following these large changes in research policy during the 1990s, new universities were founded. These were explicitly designed to stimulate regional economic growth and teaching, as well as to become new research centers (Schilling, 2005; Sörlin and Törnqvist, 2000). These regional universities were placed in smaller towns,

often further from metropolitan areas. Thus, one consequence of these changes was that Sweden by the end of the 1990s had several more institutions conducting research and postgraduate education.

At the same time focus had been put more on the individual researcher, societal relevance of academic research and on university-industry interaction. Related to this, in 1998 (Benner 2001) the Swedish universities were stipulated to undertake a third mission in addition to the two missions of research and education. The third mission meant that the universities were to interact with society. In addition, by recognizing the importance of universities for innovations and economic progress, Swedish policy and debates during this period increasingly adopted the concept of "innovation systems", culminating in the foundation of a government agency responsible for the Swedish innovation system (VINNOVA) in 2001 (f see Eklund, 2007).

During this time there were also reforms intended to increase the autonomy of universities, in terms of shifting some decision-making authority from the government to the universities and their leadership (Askling et al., 1999; Benner, 2001). Professors were no longer appointed by the government but instead by the universities themselves. Moreover, reforms in the 1990s increased the universities' autonomy to hire and promote at all levels (Benner, 2001; Jacob and Orsenigo, 2007). Unlike many southern European countries, Swedish university professors (and all other employees) are not national civil servants, but they are instead employees of the organization. The 1990 reforms also shifted the science policy system from the previous, more German-inspired one of resources concentrated around 'chair professors' to a more American-inspired one of tenure as related to promotion. In addition, two previously state-controlled universities were changed into private foundations.[9]

Since 1997, all universities are given fixed research funding from the government. This was not the case before, meaning that from this year more universities received fixed research funding, although initially rather limited amounts (e.g. Benner, 2001; Sörlin and Törnqvist, 2000). Although these reforms led to more universities conducting research, the overall Swedish public research funding was not enlarged, but rather spread out more thinly amongst more actors.

Similar to the general trend in Europe (e.g. Vincent-Lancrin, 2006), there has been a decrease in the relative share of government funding during the last few decades in Sweden (Heyman and Lundberg, 2002; Hällsten and Sandström, 2002). This fact, together with the mentioned policy changes, indicates that universities in Sweden, as in Europe overall, during the last decades have had an increasing reliance on external research funding, implying a more competitive environment regarding research funding.[10] This has given rise to some public debates, such as the difficulties

[9] Chalmers University of Technology and Jönköping University.

[10] Direct fixed funding for research, including funding for graduate education stood for 45 per cent of

of conducting high-quality research in this "boot-strapped" environment and the need for "critical mass" and the necessary size of research groups in order to be able to conduct "good research" (Benner and Sörlin, 2008). At the same time, the cohort of young people entering higher education has increased dramatically in the last three decades, but neither employees nor fixed funds for education have increased at the same rate (Benner, 2001; Jacob and Orsenigo, 2007; Sörlin and Törnqvist, 2000).

A few additional specificities of the Swedish policy and university system are worth pointing out here. First of all, higher education is free for students, meaning that there are no tuition fees. Instead all funding for education is fixed income, based on the number of students as well as the number of passed degrees (HSV, 2010).[11] Second, Sweden has the so-called teacher's exemption or professor's privilege, meaning that any intellectual property rights of academic inventions are granted to the inventor and not to the university where he or she works.[12] Third, the Swedish university system is still centralized in terms of resource allocation, in the sense that the government allocates fixed funding based on past allocations and the number of students (HSV, 2010).

The transformation of the Swedish, as well as overall European, university system is still on-going. The resource allocation system was recently changed in Sweden, with a share of general research funding now being allocated according to performance[13] (HSV, 2010). At the same time there has been a trend towards both public and local evaluations, with e.g. several of the larger universities recently conducting performance evaluations, mainly within research.[14] Moreover, starting from 2011, Swedish universities start to take out tuition fees for students from outside the European Economic Area (EEA) or Switzerland, which most likely will mean a substantial decrease of income for many universities.

2.2 The Swedish university sector

As pointed out in the previous subsection, the Swedish system consists mainly of universities, with very few research institutes (Granberg and Jacobsson, 2006; Jacob

all funding in 2009 (HSV, 2010). The remaining 55 per cent of the funding came from external sources, such as industry and public and private research foundations. Approximately 4 per cent of the funding comes from industry.

[11] Similarly, fixed income for research is allocated mainly according to past allocations. Since of 2009, however, 10 per cent of the funding is allocated according to performance.

[12] The teacher's exemption has been debated and voices have been made to follow countries such as Denmark and Germany in abolishing it. On the other hand has Italy recently introduced the teacher's exemption.

[13] Based on amount of external funding as well as number of publications and citations.

[14] University of Gothenburg, Lund University and Uppsala University have recently conducted such evaluations.

and Orsenigo, 2007). Currently the university sector includes more than 50 higher education institutions, of which 35 are state controlled. This thesis focuses on the universities performing research, which during the time period studied, included 30 universities.[15] Moreover, while research and education is co-located in the universities in Sweden, there is in practice a separation between undergraduate education and research in the sense that most university teachers do not conduct research (e.g. Goldfarb and Henrekson, 2003).

It should be noted that in an international perspective Sweden does not have any large universities, but rather a mix of smaller and medium-sized ones.[16] At the same time, there are few top universities in the Swedish system.[17]

The expenditure of the Swedish higher education system was in 2009 around 1,6 per cent of the GDP. Research accounts for approximately half of these expenses, or about SEK 30 billion (HSV, 2010). While the Swedish expenditure on academic research is among the highest in the world, in relation to GDP[18] , it should be noted that industry stands for the lion share of all R&D performed in Sweden. In 2007, universities accounted for approximately 20 per cent of all R&D expenditures, while industry stood for roughly 75 per cent.[19] One possible explanation of this comparatively high share of industrial R&D is that Sweden has, in relation to the size of the country, quite many multinational research intensive companies (McKelvey et al., 2008). Most of the industrial R&D is concentrated within a few large firms (e.g. Goldfarb and Henrekson, 2003).

[15] These are the thus the universities that, after the reform in 1997, are granted fixed research funding. For an overview of these universities, see Paper I.

[16] The largest university in Sweden is Lund University, with around 24 000 students.

[17] For 2010, there was one Swedish university (Karolinska Institutet) among the top 50 in the Times Higher Education world university ranking as well as in the Academic Ranking of World Universities, and two respectively three among the top 100.

[18] This is to a large extent due to the lack of research institutes in Sweden. Taking that into account the Swedish expenditures are relatively modest as compared to other OECD countries (Granberg and Jacobsson, 2006).

[19] http://www.scb.se/Pages/TableAndChart_207858.aspx

3 Previous research and problem formulation

This section presents the three themes including their empirical and theoretical background. This overview provides the basis and background for the overarching research questions addressed in the thesis.

3.1 University postioning

Recent decades has seen a transformation of the university sector, which has meant a restructuring of research funding, on the one hand, and a change in policy perception of the role of universities, on the other. University sectors across the world, not the least in European countries, has faced decreasing government funding for research accompanied with an increased reliance and focus on competitive external funding mechanisms (Geuna, 2001; Vincent-Lancrin, 2006). Moreover, higher education has expanded from elite to mass-education and globalization has led to that universities to compete for students and prominent academics not only at the national arena but worldwide. In many countries, there has also been a tendency to establish more universities to meet the increasing demand on education and to contribute to regional development. At the same time, universities have increasingly been under pressure to more directly contribute to the needs of society in general and to the needs of industry in particular. This is in part due to a new policy perspective on the role of universities and in part due to changes in firms' R&D strategies (Geuna, 1999, 2001; Lawton Smith, 2006; Salter and Martin, 2001; Slaughter and Leslie, 1997). Moreover, deregulations of the academic systems across Europe have led to an increased autonomy of universities. This change in regulation has entailed many European countries changing their governance from state control to "self-regulation", where the individual universities and their leadership take on a more active role in terms of decision-making and responsibilities in regards to staff hiring and resource allocations. Governments in these countries have at the same time taken a more supervising, rather than controlling, role (e.g. Askling et al, 1999; Henkel and Little, 1999; Kogan et al., 2000). All of this have lead to a change in the nature of the pressures on universities, in the sense that they operate in an increasingly deregulated, resource constrained and "competitive" sector.[20]

[20] Does this mean that we can see universities as "competing"? Universities do not operate on "regular" markets (Bok, 2003) and they do not necessarily behave like firms since they are not coherent in terms of internal resources and routines to achieve common goals (Engwall, 2007). At the same time universities do not have the same ultimate goals as normally associated with competition since they compete over aspects such as prestige and talent rather than profits (e.g. Cowan et al., 2009; Florida and Cohen, 1999). However, there is no doubt about the fact that universities do operate in an environment with (increasingly) scarce resources, in the form of e.g. funding, top students and prominent researchers.

Historically there has been little institutional differentiation among universities in Europe. However, while universities are still regulated and slowly evolving institutions, the changed conditions provide greater possibilities for specialization and differentiation[21] among universities (cf. Clark, 1998; Bonaccorsi and Daraio, 2007a). Greater possibilities come from the increased autonomy of universities. There is seemingly also an increased need for specialization in that universities increasingly, due to the reasons pointed out earlier, have to compete for their resources. This implies that universities increasingly need to satisfy stakeholders in order to be funded.[22]

In a way, universities increasingly resemble firms. Even if there are still large differences between a university and a firm, this means that today universities can be seen as knowledge-based service providers. Their services include the transfer of new or proven knowledge directly to students or society (Deiaco et al., 2009). These stakeholders are the targets (i.e. paying or non-paying "customers") that universities need to satisfy through their services in order to gain access to scarce resources.[23]

Individual universities can thus be viewed as competing for resources by positioning themselves against other universities, in terms of how they mix the services they provide stakeholders. From a policy perspective it is important to study universities as actors that, at least to some extent, strategically react to changes in their environment and try to position themselves in relation to other universities.

While there have been several essays addressing diversity in higher education (e.g. Kogan, 1997; Teichler, 2006), case studies on individual universities (e.g. Clark, 1998) and analyses based on aggregate national statistics, studies of the position of individual universities within national university sectors (or across countries) is an emergent field (see e.g. Bonaccorsi and Daraio, 2007; Daraio et al, 2011). The basic idea in this literature on economics of universities is to analyze the transformation of the university sectors in Europe and its affect on university behavior (Geuna,, 1999, 2001) and emergent strategic positioning and differentiation (e.g. Bonaccorsi and Daraio, 2007; Daraio et al., 2011). This is achieved by analyzing administrative data on individual universities in a set of European countries.

This literature conceptualizes universities as actors with multiple inputs, such as personnel and funding, and multiple outputs, such as scientific publications and educated students (Bonaccorsi and Daraio, 2007a). From this, it is possible to an-

[21] Huisman (2004) proposes a distinction between diversity, being a descriptive and static notion, and differentiation, which rather is a change in diversity. While a substantial part of the studies referred to in this section, as well as the study conducted in this thesis, in this sense are about diversity, this thesis will use the notions interchangeably.

[22] This is visible not the least in the increased focus on international university rankings (e.g. Saisana et al., 2011), and the introduction of research evaluations in some countries, such as in the UK (e.g. Geuna and Martin, 2003).

[23] For example, to attract top students universities might have to provide certain types of courses with good reputation.

alyze if and how universities specialize by studying how individual universities position themselves in terms of their inputs and outputs. This positioning can be seen as strategic profiles of individual universities. In this conceptualization, strategy is an emergent, rather than deliberate, property of changes over time (cf. Mintzberg, 1979). Following Bonaccorsi and Daraio (2007a), it is possible to analyze if and how the population within a national university sector specializes.

Geuna (1999) found a polarization of the European university sector.[24] On the one hand, there are the pre-WW II (research) universities, which generally are large organizations with high research productivity and research orientation. These universities attract the majority of the research resources and should be in a strong position for the future to acquire competitively allocated research funding from external actors, such as governments and firms. On the other hand, there are the post-WW II (education) universities, which are mostly small in size and low in research productivity and orientation. These smaller and less research oriented universities should be in a much weaker position to acquire research funding in a competitive setting, which means they should be more dependent on industry funding. This points to that there are (increasingly) large differences in the conditions for conducting research and attracting funds among European universities. Also, it suggests that structural differences, in terms of differences in inputs and outputs, should matter for the ability to attract competitive research funding.

Bonaccorsi and Daraio (2007b) have focused on investigating the strategic positioning of universities in six European countries in regards to research as well as undergraduate education.[25] Their results show that in the UK and Switzerland research oriented universities are also the most research productive in terms of scientific publications, while in Italy[26], Spain and Portugal there is no real differentiation in terms of research orientation, i.e. most universities in these countries also has a large undergraduate education. They also found that some research oriented universities in these countries, especially those in technological fields, were better at attracting private sources of funding. Studying changes in the offering profile in relation to undergraduate education, the authors found that about ten per cent of their sampled universities changed their profiles, by proactively enlarging their teaching offers (from specialists to generalists etc.). Moreover they found that approximately 15 per cent had a large growth in student enrollment during the studied year, thus showing an ability to compete for students. However, they found that there was hardly any overlap between those universities showing high research orientation and

[24] The study concerned 379 universities in Belgium, Denmark, France, Germany, Greece, Italy, Ireland, the Netherlands, Portugal, Spain and the UK, (see Geuna, 1999, pp. 63-83).

[25] Italy, Spain, Switzerland, Norway, Portugal and the UK.

[26] While Bonaccorsi and Daraio (2007b, 2009) found that Italy is not differentiated in this way, Rossi (2009) pointed to some although less clear-cut diversity.

those being highly dynamic in terms of education. In concluding their study, Bonaccorsi and Dario (2007b) argue that their results point to the existence of emergent strategic differentiation in these countries.

The authors continued this investigation in more recent studies, including more countries but with less detailed analysis. In this way, they found that while there exists some differentiation within Europe this is a rather marginal phenomenon with only around 20 per cent of the studied universities being either education or research oriented. At the same time, their investigation showed differences between countries, with only the UK, Switzerland and the Netherlands showing diversity in terms of research while larger education oriented universities were only present in Italy and Spain (Bonaccorsi and Daraio, 2009). Moreover, the countries showing differentiation in terms of research also are the ones that perform better (in terms of international publications). Similarly, Daraio et al. (2011) found that only a few European countries show a clear differentiation in regards to universities' research output and competitive funding, and that for most countries there are no correlation between research and funding.

In addition to these studies, there are some investigations of more specific issues related to this topic of "economics of universities". Gulbrandsen and Slipersater (2007) explored the commercial and entrepreneurial activities of universities in the UK, Switzerland and Norway, pointing to the difficulties in measuring these activities due to lack of relevant (administrative) data. Lepori et al. (2007) investigated the higher education funding in several European countries and provided some evidence on changes in this funding during a ten year period. Among other things, they pointed to that UK is the only country in their sample where the government is no longer the main funder. In other European countries some evidence were found that universities have increased their income from grants and contract, suggesting some degree of freedom in seeking funding. Moreover, Lepori (2010) investigated the subject mix of universities in six European countries, finding that a stylized classification accounted for most differences between these universities. First, they found two types of specialist universities, technical universities and universities specialized in humanities and social sciences. Furthermore, the majority of universities in all studied countries consisted of the older large generalists.

In addition to these cross-country studies, there have been some investigations of specific national contexts (see e.g. a number of studied included in Bonaccorsi and Daraio, 2007; Bolli and Somogyi, 2011; Rossi, 2009). Indeed, one reason why Europe as a whole is interesting is that the on-going transformation is occurring across many diverse national institutional contexts, where the national university systems differ in relation to e.g. the degree of autonomy (e.g. Kyvik, 2004). Therefore studies of the economics of universities need to take the national context into proper

account (Bonaccorsi and Daraio, 2007a), meaning that studies of specific countries are important additions to cross-country analysis.

One particular national context that has not been studied by the aforementioned scholars is Sweden. Sweden is similar to the rest of Europe in terms of the direction of policy reforms, providing greater possibilities for specialization and differentiation for individual universities. At the same time, the Swedish university system and policy have some (unique) features, which make it an interesting context for these types of studies (see Section 2). The aim of this theme is to characterize the diversity of the Swedish university sector and to propose an interpretation of the position of individual universities. The following research questions are addressed:

- *What does the Swedish university sector look like in terms of diversity among individual universities? Do Swedish universities differentiate in terms of research?*

Moreover, while several of the previously reported studies have investigated different sources of funding, no previous study has analyzed the relation between university characteristics and the ability to attract external competitive funding.[27] The question is whether there is diversity among universities in the ability to attract external research funding and whether this ability is related to the position of universities. The increased focus and reliance on competitive external funding makes it important to investigate which types of universities are able to successfully compete for such funding, both from the perspective of university governance and public policy. In addition, the ability to attract competitive external research funding can be seen as a performance measure of universities. A university's relative share of an external source of funding is analogous to its market share, and it thereby signals its ability to compete for this funding. In this sense the (relative) ability to attract external research funding can be seen as a metric, by which stakeholders can evaluate the performance of universities (cf. Deiaco et al., 2009). The research question is as follows:

- *Which types of universities, in terms of their position in the Swedish university sector, are able to successfully compete for external research funding?*

3.2 Academic inventors and firm inventiveness

Universities have during the last decades increasingly been under pressure to contribute more directly to the needs of society and in particular the needs of industry (Geuna, 2001; Salter and Martin, 2001). This change has come about from an increased recognition of the role of knowledge in economic progress, putting universities in a more central and accountable position in relation to economic activities

[27] One, more recent, exception is a study by Rossi (2009), who analyzes the Italian system.

(Florida and Cohen, 1999; Lawton Smith, 2006). In this way, governments and policymakers expect universities and academics to commercialize academic research and aid industry. At the same time the reliance and focus on competitive external research funding has increased (Geuna, 2001; Vincent-Lancrin, 2006), accompanied by increased reliance on and importance of R&D collaboration in industry (e.g. Howells, 1990; Lawton Smith, 2006).[28]

All of this has led to that universities increasingly have had to interact with society (the so-called "third mission"), not the least with industry. The third mission of universities is in this regard an increasingly important set of activities, beyond research and education. The emphasis has been on universities and academics contributing more directly to technological change and economic progress, through their relation and interaction with the external environment, predominantly with industry (Etzkowitz, 2003; Florida and Cohen, 1999; Lawton Smith, 2006).

Accordingly, a vast literature has emerged, studying universities and academics commercializing research and contributing directly to the need of industry. In this thesis, I broadly categorize these studies into two conceptually distinct but empirically overlapping areas: academic entrepreneurship and university-industry interaction. The original use of the notion of academic entrepreneurship was restricted to refer to academics setting up business firms to commercialize research results (Franzoni and Lissoni, 2008). In this thesis, I broaden the notion to refer to when universities and academics, by themselves, directly commercialize academic research, which entails not only firm creation but also patenting and licensing.

The literature on academic entrepreneurship, as defined in this thesis, has mainly been preoccupied with studying issues related to academic spin-offs, technology transfer offices (TTOs) and university patenting and licensing.[29] Studies have been conducted on the determinants of academic spin-offs, in terms of e.g. university policy and firm characteristics, and the degree of firm creation at different universities (e.g. Landry et al., 2006: Lockett et al., 2003; Link and Scott, 2005; Nicolaou

[28] These changes have been characterized in different ways. For instance, some have argued for a change in the "social contract" between universities and the state, from a "science push" model of knowledge and innovation production to a model where academics and universities are more accountable and have to directly address the needs of society (Martin and Etzkowitz, 2000). Similarly, Gibbons et al. (1994) argue that the recent decades have witnessed a change in knowledge production towards a new mode (Mode 2) where knowledge creations is increasingly influenced by the needs of society and conducted by multi-disciplinary research. Related, Etzkowitz and Leydesdorff (2000) argue that universities have increasingly taking on a third mission of contributing to societal need in addition to research and education. This has meant that knowledge increasingly is produced through the interactions among universities, governments and industry (the "Triple helix"). However, universities have always, to some extent, contributed directly to societal needs and interacted with industry, which contradicts the validity of these characterizations (e.g. Martin and Etzkowitz, 2000).

[29] For an extensive review of university entrepreneurship, including what I here label as academic entrepreneurship, see Rothaermel et al. (2007).

and Birley, 2003; Wright et al., 2004). Others have instead studied characteristics and factors explaining the productivity of university technology transfer offices in regards to facilitating licensing of university patents (e.g. Carlsson and Fridh, 2002; Feldman et al., 2002; Klofsten and Jones-Evans, 2000; Markman et al., 2005; Siegel et al., 2003). Many studies have also been conducted directly on university patenting and licensing, investigating factors related to the propensity to patent and the ability to license out university patents to industry (e.g. Carayol, 2007; Elfenbein, 2007; Jensen and Thursby, 2001; Jensen et al., 2003; Stephan et al., 2007). Another stream of literature has focused on comparing university patents with firm patents, generally concluding that university patents have higher quality or value, measured as number of forward patent citations, compared to firm patents (e.g. Bacchiocchi and Montobbio, 2009; Henderson et al., 1998; Sampat et al., 2003; Sapsalis et al., 2006).[30]

The literature on university-industry interaction studies academics contributing to industrial needs and economic growth through their direct interaction with firms. These interactions include a diverse set of activities such as collaborative research, consulting, contract research and industry training (Cohen et al., 2002; D'Este and Patel, 2007; Perkmann and Walsh, 2007; Schartinger et al., 2002). This thesis distinguishes between studies analyzing the perspective of universities and academics and studies focusing on the firm perspective.

Starting with the university perspective, studies have been made on issues such as academics' attitude towards and motivations for interacting with industry. In this regard, findings point to that a majority of academics engage in interaction to further their own research, by e.g. gaining access to additional research funding, and only a minority for commercializing research or for personal income (Baldini et al., 2007; D'Este and Perkmann, 2011; Lee, 2000). Related to this, studies also point to that academics benefit from industry collaboration by e.g. gaining ideas for further research, testing applications or securing funding (Abreu et al., 2009; D'Este and Perkmann, 2011; Lee, 2000; Meyer-Krahmer and Schmoch, 1998; Perkmann and Walsh, 2009). Another focus has been on the extent and perceived importance of different types of interaction. These studies point to that academics interact with industry using a wide set of channels (Bekkers and Bodas Freitas, 2008; D'Este and Patel, 2007) and that collaborative forms of interaction, such as contract research and consulting, are far more common than academic entrepreneurship activities, such as firm creation and patenting (Agrawal and Henderson, 2002; D'Este and Perkmann,

[30] Note that university patents refer to patented inventions owned by a university. The notion academic patent instead refers to patents with at least one inventor affiliated to a university, regardless of the owner of the patent. This distinction is important since in many European countries, not the least in Sweden, the bulk of academic patents are owned by firms rather than by universities. The opposite is true in for instance the USA (e.g. Geuna and Nesta, 2006; Lissoni et al., 2008).

2011; Klofsten and Jones-Evans, 2000). Moreover, studies have been conducted on the influence of different, organizational and individual, characteristics on the propensity for interaction (e.g. D'Este and Patel, 2007; Link et al., 2007; Perkmann et al., 2011; Ponomariov, 2008; Schartinger et al., 2001, 2002). These studies for example point to the rather self-evident situation that previous experience in commercialization and interaction increases the propensity to interact (e.g. D'Este and Patel, 2007). Other authors have investigated the impact of industry interaction, as well as academic entrepreneurship, on academics' productivity and research agendas (for a recent review, see Larsen, 2011). While the evidence to some extent is inconclusive, several studies point to that engagement in industry interaction and academic entrepreneurship has no or even a positive effect on academic productivity in terms of publishing (e.g. Blumenthal et al., 1996; Gulbrandsen and Smeby, 2005; van Looy et al., 2004).

From the firm perspective, the literature has focused on the perceived overall importance of universities for firm innovations, the extent and importance of different channels of interactions and different types of benefits gained from collaborating with academics and universities. These studies point to a positive impact of university interaction on the innovative performance of firms (e.g. Cohen et al, 2002; George et al., 2002; Lööf and Broström, 2008; Mansfield, 1991, 1998). Others have looked at relative importance of universities, showing that universities are generally an important source for innovations in firms but to a lesser extent than for instance consumers and suppliers (Cohen et al., 2002; Klevorick et al., 1995). Another stream of literature has studied the importance of different mechanisms of interaction, providing evidence that firms consider university patents and licenses as less important than publications, informal contacts and collaborative forms of interaction (e.g. Bekkers and Bodas-Freitas, 2008; Schartinger et al., 2002). Others have studied the perceived importance of different types of benefits that firms gain from interacting with academics and universities. These studies show assistance in technological problem-solving and gaining access to new research and ideas for product development as highly important benefits (Bishop et al., 2011; Lee, 2000; Schartinger et al., 2001).

In addition, some authors have focused on the relation between academic inventors and commercial success of firm innovations. For instance, Agrawal (2006) showed that engaging the academic inventor in the commercialization process of licensed university patents increases the likelihood and extent of commercial success. Similarly, Zucker and Darby (1996) found that collaboration between firms and so-called star scientists is related to the success of the firm.

To conclude, the literature dealing with the impact of academics and universities on firms' innovative activities has thus focused on the relation between firms and

academics (or universities), providing empirical evidence mainly on the perceived importance of different channels of interaction and different types of benefits. Moreover, the authors that have analyzed the outcomes of university-industry collaboration have studied the association between academic collaboration and commercial success by focusing on either “star scientists" (Zucker and Darby 1996) or on the collaborative development of university generated inventions (Agrawal, 2006).

Firms, however, do not interact or collaborate with academics only for generating or accessing commercializable innovations. At the same time have university-generated inventions and innovations been shown to be only moderately frequent and important for firms (e.g. Perkmann and Walsh, 2007). Firms to a large extent rather involve academics in already on-going projects (Cohen et al., 2002; Perkmann and Walsh, 2009), where academics assist the firm in various activities such as technological problem-solving and product development (e.g. Bishop et al., 2011; Lee, 2000). Thus, the contribution of academics to firms' innovative activities largely takes the form of firms involving academics in their (on-going) R&D activities, with academics creating and developing inventions together with or at the commission of firms. Therefore, studying firm inventions with academics as inventors would shed further light on the role and impact of academics in industrial innovations.

There are, however, no existing studies analyzing the inventions that result from collaboration between firms and academics. Put differently, previous research has not studied the relation between academics and the inventions[31] that firms involve them in. The aim of this PhD thesis is to investigate two related issues, namely: i) what characterizes firm inventions involving academic inventors; and ii) in what ways academics affect the inventions that firms' involve them in. A specific focus is put on the (technological) importance of firms' academic inventions[32] as compared to their non-academic inventions, in order to reveal the role and impact of academics on firms' inventive activities. Accordingly, the following two overarching research questions are posed:

- *What characterizes firms' academic inventions in comparison to firms' non-academic inventions?*
- *In what ways do academic inventors affect firm inventions?*

[31] Invention refers to the creation of something new, and can largely be seen as the result of combinations of new or existing knowledge sets or technologies (e.g. Fleming, 2001; Nelson and Winter, 1982). It stands in contrast to innovation, which rather denotes an invention that has been ”put in use”.

[32] An academic invention here denotes an invention having at least one inventor affiliated to a university.

3.3 Academics and opportunities

Universities are loosely coupled systems, in the sense that they consist of rather autonomous subunits that follow their own objectives (Bonaccorsi and Daraio, 2007a). These units can consist of various constellations, including individuals, research groups, and departments but can also consist of cross-cutting networks or constellations of academics. Universities, or at a lower level departments, can to some extent guide the overall direction of research and education through resource allocation, but (groups of) individual academics can to a large extent create and follow their own agendas. Ultimately, it is the individual academics that direct and carry out the activities at universities and it is the outcome of their activities that contributes to societal needs and economic progress. Put differently, academics are the engine that keeps universities running. This suggests that to fully understand the role and importance of universities, we need to investigate the activities through which (individual) academics create and disseminate knowledge: we need to open up the university to investigate what goes on inside. The question that arises is what do (individual) academics do, beyond the general characterization of academics as conducting research, teaching and supervising students, and engaging in third mission activities? What do we know, in terms of existing literature, about what they do?

This PhD thesis does not address the more "mundane", albeit non-trivial and important, day-to-day activities of academics. Rather, the focus is upon the activities through which academics create new outcomes within the three roles of research, education and third mission. In this sense, this theme centers on the "novelties" that academics create across their three roles, which may be beneficial for different stakeholders or users (see Section 3.1). That is, these novelties (opportunities) are to become new or improved offers, which include, but are not limited to, new scientific publications, new research instruments, and new courses or lectures, provided to various stakeholders in the form of students, firms, government or the scientific community.[33]

For the purposes of this theme as well as for further investigations of academics' activities, this PhD thesis proposes the opportunity concept as a fruitful avenue for conceptualizing academics' activities. Opportunity is a multifaceted concept, present not the least in the literature on entrepreneurship (see Short et al., 2010). An opportunity can be defined as consisting of ideas, beliefs and activities that enable the creation of some outcome having some degree of novelty for the agent (cf. Venkataraman, 1997). This entails ideas regarding in what ways value can be created for others and the means of delivering and leveraging from this created value (cf. Holmén et al., 2008; Hsieh et al., 2007). Consequently, opportunities can be used to characterize

[33] This PhD thesis denotes the novel activities as innovative activities, which can be seen as opportunities that academics identify and act upon, while the novel outcomes can be seen as "innovations".

all sorts of activities leading to novel outcomes. Opportunities for an academic may entail novelties for research, education and third mission.

Opportunities can be characterized as consisting of two distinct, though not sequentially determined sets of activities: i) identification, which refers to the subjective and cognitive identification of opportunities[34] ; and ii) exploitation, which consists of an actor's activities aimed at developing and realizing the opportunity. This PhD thesis thus conceptualizes academics' activities as processes of opportunity identification and exploitation.

The interest of this PhD thesis lies first and foremost in what the economic literature has to say about academics and their activities, not the least since it is this literature that can be expected to inform policy. While studies of individual academics and their activities have not been a high priority within broader economic literature, it to some extent provides insights into academic activities.[35] However, there are no systematic reviews that attempt to extract these insights from existing literature in order to provide a comprehensive picture of what is known about academic activities. This leads to the following overarching research question:

- *What do we know, in terms of existing literature, about academics' (innovative) activities from an opportunity perspective?*

Academics can be involved in three main types of activities - research, education and third mission - and one important issue is to what extent these roles contribute to each other. While anecdotal evidence suggests that experiences in any of these can contribute to the others, the relation between on the one hand research and education and on the other hand research and third mission has been the topic of debates and several studies. In regards to the relation between research and education, studies have found no association between research productivity and teaching quality (Hattie and Marsh, 1996; Marsh and Hattie, 2002). At the same time point anecdotal evidence and several case studies to compatibility between the two, with especially research providing important input to education (e.g. Neumann, 1992; Clark, 1997; Smeby, 1998). This indicates that the precise nature of the research and education relation has not been established.

In regards to the relation between research and third mission, there is an on-going debate on whether there exists a trade-off between traditional academic research and

[34] This is equivalent to identifying a problem-solution pair, where a problem is found and identified to be valuable because its expected solution will create value or reduce cost for someone in some manner (Hsieh et al., 2007). While only a few identified problems are related to opportunities, the discovery or creation of a problem worth investigating is a focusing device for what academics choose to work on.

[35] Some more narrowly focused strands of literature, such as the economics of higher education, has focused on some academic activities.

third mission activities. Fears has been expressed that working together with industry or engaging in commercialization activities take time away from research and might turn academics away from "basic" research to more applied investigations (see Larsen, 2011). Recently there have been several studies conducted on these issues, mainly investigating the relation between academic productivity or impact and industry engagement or commercial activities such as patenting and setting up firms. Although the results are somewhat mixed, most studies seem to point to that there is a positive relationship, meaning that those academics who patent or interact with industry also are those that publish the most (e.g. Azoulay et al., 2007; Buenstorf, 2009; Calderini et al., 2007; Gulbrandsen and Smeby, 2005; Stephan et al., 2007).

Beyond these types of studies, there are, however, currently no systematic studies that investigate the relationship among the three roles of research, education and third mission. To shed further light upon this issue, one crucial aspect is to what extent academics draw on their prior experiences in the three roles when engaging in research, education, and third mission activities that lead to new outcomes. In line with the conceptualization of academics' activities as processes of opportunity identification and exploitation, this thesis aims to investigate the importance of academics' prior experiences within the three academic roles for identifying and exploiting research, education and third mission opportunities. Thus, the thesis addresses the following overarching research question:

- *How important do academics perceive their prior experiences within the three academic roles to be for identifying and exploiting research, education and third mission opportunities?*

4 Research design and methods

This section provides an overview of the research design and methods used in the five appended papers. Table 1 summarizes the research design and methodological choices for each paper.

4.1 Paper I

The objective of Paper I was to characterize the diversity of the Swedish university sector and to analyze whether structural differences between universities are related to the ability to attract external research funding. Thus, the unit of analysis was the university. In relation to the objective, and in light of the existence of comprehensive public data on the Swedish university sector, a descriptive analysis relying on secondary data was deemed appropriate. A descriptive analysis was preferred, since universities in Sweden are quite few, providing limited possibilities to make sound statistical analysis.

The data, with the exception of publications, was drawn from a public Swedish national database on universities (the NU-database[36]). The database is run by the Swedish National Agency for Higher Education and is comprised of data that the agency collects on a yearly basis directly from all Swedish universities as well as from other sources. From this database, data was collected on finances, number of students and researchers. Publications were gathered from the Science Citation Index (SCI) and the Social Science Citation Index (SSCI). Using this data, a set of metrics was constructed, such as "research orientation" and "research intensity". The metrics used are based on and in line with the metrics used by other studies (e.g. Bonaccorsi and Daraio, 2007b, 2008; Geuna, 1999; Jongbloed et al., 2005). For all types of data, this paper uses the averages over the period 2001-2005, except for publications that use the average for 2001-2004. The reason is lack of data subsequent to 2004. Moreover, the average over the period is used as in particular the amount of grants and funding can vary considerably from year to year.

4.2 Paper II and III

The overarching objective of Paper II was to investigate the relative characteristics of firms' academic inventions, while for Paper III it was to analyze the effect of academic inventors on the technological impact of firms' inventions. Analyzing patents was deemed as appropriate for these objectives, since patents provide rich and readily available data on inventions. Moreover, patents are useful for analyzing

[36] http://www.hsv.se/statistik/statistikomhogskolan

the technological importance of inventions since patent citations provide traceable links between inventions (e.g. Jaffe and Trajtenberg, 2002).

It has been argued that patents with academic inventors that are owned by industry result from academic consulting in firms (Thursby et al., 2009). In this way, these types of patents can be seen as representing inventions that results from firms involving academics in their inventive activities, rather than inventions originating at universities. Thus, it is possible to contribute to the emerging literature on collaborative interaction between academics and firms (e.g. Link et al., 2007) by studying these types of patents.

Patents have rarely been used to investigate these issues in earlier research, since these types of patents are not easily identified. This PhD thesis sampled Swedish academic patents from the KEINS database. This is a comprehensive database on European academic patent applications, containing European Patent Office (EPO) patents that have been matched with data on academic inventors. The database was constructed by identifying academic patents by matching patent inventors with academic scientists of all ranks (from assistant to full professor) (for a detailed account of the database and its construction, see Lissoni et al., 2006).

Paper II and III are based on the same original sample of academic and non-academic patents. The sample was constructed by drawing all patent applications in the KEINS database having Swedish academic inventors and firm assignees with priority years 1985-2000.[37] PATSTAT was used to collect all non-academic patent applications assigned to the firms identified as owners of the sampled academic patents. Only non-academic patent applications having at least one Swedish based inventor were included in the resulting sample.

The OECD citations database was used to retrieve all additional patent data, such as priority years and the number of patent citations (see Webb et al., 2005). This database was issued by European Patent Office (EPO) together with the OECD, and contains detailed patent data covering all EPO applications, as well as all patents filed for under the "Patent Cooperation Treaty" (PCT), between 1978 and 2010.

In Paper II, the analysis was conducted using different econometric estimations. In this way, this paper statistically analyzed associations between academic inventors and a set of patent characteristics. Paper III, instead employed a quasi-experimental research design to analyze the effect of a treatment (academic inventor) on a sampled population (firms' patented inventions) in terms of a set of specific outcomes (technological importance). This was done by statistically creating a control group consisting of non-academic patents that are identical or highly similar to a corre-

[37] Patent applications were included regardless of whether they had been granted or not, since the focus is on academic inventions overall and not only on the ones regarded by patent examiners as patentable.

sponding academic patent on a number of important patent characteristics.[38] After matching, the observed average difference between the groups (average treatment effect) can be attributed to the presence of academic inventors since the potential effect of other characteristics on the outcome has been accounted for. This makes it possible to draw inferences about the casual effect of academic inventors on the technological importance of firm patents, rather than investigating associations between variables as in Paper II. More importantly, however, such a design accounts for any additional variable that may confound the analyzed relation between treatment and outcome (cf. Shadish et al., 2002).[39]

4.3 Paper IV

The purpose of Paper IV was to analyze existing literature dealing with universities and academics, to shed light on what is known about academics' innovative activities. Articles were collected by performing key word searches in a selected set of journals. The journals were chosen from the broader economic literature dealing with topics related to i) studies of universities and academics as intrinsic parts of the economy; ii) having high impact factors; and iii) having highly cited articles as revealed by our search of the ISI database. The search was limited to include literature published from 1995 onward.[40] We read the abstract of all collected articles to assess their relevance. Only empirical articles primarily studying universities or academics were included in the final sample. Thus, we did not include purely conceptual articles. All in all, 201 articles were analyzed.

First, to analyze the papers, a random subsample of the collected articles was read closely to provide a deeper understanding of the literature at hand. Second, a content analysis was conducted, where all collected articles were coded according to a set of dimensions and categories, using a coding schedule made up of four dimensions in a newly developed opportunity framework.[41] The categories were coded according to a coding manual with related rules, by reading method sections and abstracts of all articles. A pilot test was conducted, followed by revision of the manual and coding rules.

[38] The paper uses the matching estimators developed by Abadie et al. (2004) and Abadie and Imbens (2006).

[39] The quasi-experimental design used in the paper allows for inferring causality, but I cannot distinguish whether it is the academics that affect the importance of patents or if they are involved in specific types of inventions that are related to some level of importance. Moreover, the matching is only done on observable patent characteristics, meaning that there might be unobserved confounding variables.

[40] To be included in the analysis, the article must have appeared in a peer-reviewed journal by January 31, 2009.

[41] The opportunity framework consist of four dimensions: i) opportunity identification; ii) opportunity exploitation; iii) sources of opportunities; and iv) targets.

A quantitative approach was employed, but in a "qualitative" manner, meaning that the coding was not automated and the coder had to make qualitative judgments from case to case with the support of the developed coding rules. The reason is that in this context an automated coding process would not be possible from a data analysis perspective; one cannot simply search for a term corresponding to a coding category in the article database and count the number of times it appears, since any term used in a specific article could be referring to previous research, rather than being part of the study at hand. Likewise, some terms might be part of more than one dimension and category.

4.4 Paper V

The purpose of Paper V was to investigate the relationship among the three academic roles, in terms of how important academics perceive their experiences from prior research, education or third mission activities to be for identifying and exploiting opportunities in the three roles. Data was collected using a telephone interview survey to follow up answers and correct misunderstandings. Since the purpose was to measure the relevance for how research, education and third mission opportunities draw on the academics prior experiences in each of the three roles rather than testing theory, a descriptive survey was conducted (Forza, 2002).

The main part of the survey was developed to capture the respondents' perceptions regarding the importance of prior experiences in each role for identifying and exploiting research, education and third mission opportunities. Respondents were asked to consider their activities within the three roles during the last five years, as restricting the time period eases respondents' recollection. Respondents were asked to assess the relevance, best representing his or her situation, of each of the academic roles for research, education and third mission opportunities respectively. This lead to nine survey items, designed as forced choice with each item capturing one relation quantitatively. A ten-point scale was used where "Not relevant" equates 1-2, "Some Relevance" 3-4, "Relevant" 5-6, "Very Relevant" 7-8 and "Highly Relevant" 9-10.[42]

To measure the differences in the relevance of the three academic roles for opportunity identification and exploitation in research, education and third mission, the survey operationalized opportunity identification in terms of finding valuable problems (Pounds, 1969; Landry, 1995; Nickerson and Zenger, 2004: Hsieh et al., 2007).[43] Respondents were asked whether the nine relations were more important,

[42] Ranging from e.g. 1 – "Results and insights from my own previous research activities are irrelevant when planning or changing the content and set-up of my teaching activities" to 10- "Results and insights from my own previous research activities are crucial when planning or changing the content and set-up of my teaching activities"

[43] "Problem" was defined as "something that one can see a solution to and that are 'packaged' in some

of the same importance or less important for finding or formulating new problems than for carrying out a project or exploit an opportunity. The answers were given the value 1, 0, and -1 respectively.

The sample frame was constructed by collecting names and contact information from university websites because there are no official records or lists of academics and university employees in Sweden. This entailed identification of departments, divisions and research groups related to the chosen academic fields. Three sample frames were constructed, one for each of the chosen academic fields. Qualitative judgments were required because there is not any standardized list for classifying departments and other academic organizational units according to disciplines or sub-fields in Sweden, and there are plenty of organizational units comprising several different sub-fields. To control for these judgments, we asked respondents open-ended questions about the nature of their research, and used a snowballing approach to evaluate whether the population had been correctly identified.

A probabilistic sampling was employed by randomly drawing a sample of academics from the sample frames. We first approached the sampled academics by e-mail, presenting our study. After this, contact was taken over telephone. All in all, 50 interviews were conducted out of 53 contacted academics.[44] All non-respondents stated lack of time as the reason for not participating. Academics with lack of or minor experience in any of the three roles are excluded from the analysis of corresponding relations. However, in the sample this only affects the relations related to third mission.

4.5 Reliability and validity

Reliability refers to the consistency of measurement of a concept, and is the agreement in results measuring a concept using maximally similar methods (Campbell and Fiske, 1959). The studies conducted in this PhD thesis are overall characterized by high reliability. The papers in the first two themes (Paper I-III) are based on readily available and quantitative data and the measurements employed are commonly used indicators. The studies in the third theme (Paper IV-V) to some extent rely on qualitative judgments, but were conducted using well-specified constructs.

Construct (or measurement) validity refers to the extent to which the employed constructs measure the intended concepts (Shadish et al., 2002). While the studies conducted in this PhD thesis overall employ common indicators and constructs, some comments are warranted. For the studies in the second theme (Paper II-III),

manner, e.g. in the form of a scientific article, a workshop or a student course".

[44] The sampled academics are representative of the constructed sample frames, in terms of position and disciplines.

patents were analyzed as indicators of inventions. A patent contains a well-specified technical problem and its proposed solution and can in this way be seen as a self-evident indicator of an invention (e.g. Jaffe and Trajtenberg, 2002). However, not all inventions are patented, and there are especially differences between sectors in the propensity to patent inventions. This naturally limits the validity of the indicator.

Paper II and III specifically focused on analyzing the (technological) importance of patents. The studies employed a set of different indicators to capture this importance, primarily based on forward patent citations. The rationale for this is that patents are commonly assumed to provide a paper trail of knowledge flow between inventions that can be traced and analyzed by studying patent citations (e.g. Marco, 2007; Thursby et al., 2009), and that the extent of this knowledge flow indicates the importance of the patent for subsequent technological development (e.g. Jaffe and Trajtenberg, 2002). While patent citations are commonly used for this purpose, there have been concerns whether or not patent citations actually indicate that the inventors consciously drew on the cited inventions, especially for patents applied at the European Patent Office (EPO) (e.g. Alcácer and Gittelman, 2006; Criscuolo and Verspagen, 2008).[45] However, the interest of these studies was the link between inventions regardless of whether or not the inventors were aware of this link, and therefore the assumption was made that citations do indicate knowledge connections between patents, albeit possibly being a somewhat noisy indicator. There is empirical evidence indicating that this is a reasonable assumption; Duguet and MacGarvie (2005) for instance find a positive association between EPO patent citations and actual technology flow.

For the study in Paper V, the construct validity was ensured by thoroughly testing the survey items. During the pre-test, open discussions were included in every interview, as well as up-front definitions and we followed up with more definitions and examples when needed. This led us to rephrase some of the survey items. Most importantly, however, was that the pre-test indicated that the respondents were unable to clearly distinguish third mission from the other two roles. Therefore we provided the respondents with a list of third mission activities up-front in the interviews and clarifications were provided when asked for during the interviews. During the interviews, construct validity was also ensured by holding open conversations throughout the interviews. This allowed for "correcting" respondents' misunderstandings of the questions, as well as gaining qualitative insights.

External validity refers to the degree to which results can be generalized. In this PhD thesis, the external validity is mainly affected by the Swedish setting in which all studies are conducted, as well as by the focus on engineering-related disciplines. For

[45] This is due to that a significant share of citations found in EPO patents is actually listed by the patent examiners.

Paper I, generalizability is not a major concern, since the objective of the study was to characterize the Swedish setting. Nonetheless, the results of the study are in line with findings from other national settings (see Section 6.2), which indicates some degree of generalizability as long as one takes the specificities of the Swedish setting under consideration (see Section 2). For Paper II and III, there are no a priori reasons to believe that the Swedish setting greatly affects the external validity. However, the dominance of a few multinational corporations in Sweden overall and in the present patent sample must be taken into consideration (see Section 6.3), suggesting that the findings may differ for other countries. Moreover, all inventions are not patented and the propensity to patent differs across industries. Paper V studied Swedish academics in three engineering-related disciplines, which limits the external validity in the sense that the results are not necessarily generalizable to other disciplines, such as those in humanities and social sciences.

A final remark relates to the fact that the studies included in this PhD thesis are stand-alone, in the sense that the papers investigate different phenomena. In this sense, there is no triangulation of the results between papers (cf. Jick, 1979). The exception is the studies conducted in the second theme, where similar issues are investigated, albeit with different focus, using different but complementary indicators and methods.

Table 1: Summary of research designs and methodological choices

	Paper I	Paper II	Paper III	Paper IV	Paper V
Research objective	Characterize the diversity of the Swedish university system, in terms of structural characteristics. Analyze which types of universities, in terms of structural characteristics, are able to successfully compete for external research funding	Analyze the (relative) characteristics of firms' academic patents	Analyze in what ways academic inventors affect the technological importance of firm patents	Analyze what is known, in terms of existing literature, about academics' activities from an opportunity perspective	Investigate the perceived importance of academics' prior experiences in the three roles for identifying and exploiting research, education and third mission opportunities
Unit of analysis	University	Patent characteristics	Technological importance as indicated by patent citation indicators	Relationship between the three academic roles	
Research design	Quantitative: Descriptive	Quantitative: Econometrics	Quantitative: Quasi-experimental	Quantitative and qualitative: Content analysis	Quantitative and qualitative: Survey
Data sources	NU database Publication data from SCI/SSCI	KEINS database on academic patents Extract from PATSTAT OECD citation database 2006	KEINS database on academic patents Extract from PATSTAT OECD citation database 2010	201 articles	Descriptive telephone interviews with 50 Swedish academics.

5 Summary of appended papers

This section presents an overview of the appended papers.

5.1 Paper I

Title: Polarization of the Swedish University Sector: Structural characteristics and positioning

This paper characterizes the diversity of the Swedish university sector by studying structural characteristics of Swedish universities, and relating these characteristics to the propensity to attract competitive external research funding. This is done to investigate i) whether the Swedish university sector is clearly differentiated in terms of research; and ii) structural differences between universities regarding the ability to attract competitive funding.

The focus is on structural characteristics related to research. For external research funding, only funding for which universities and research groups have to compete is included. This excludes general university funds (i.e. block funding and similar) and by definition internal funds. In the analysis, different types of external funding are compared to income generated from undergraduate (including Masters) education. Thereby it is possible to differentiate universities that access resources through research from those that access resources through education. To make a more detailed analysis, external research funding is broken down into eight categories, including industry funding. The empirical analysis is descriptive and is based on public administrative data on Swedish universities.

The findings show a clear and consistent differentiation of the Swedish university sector, which is polarized into two clearly separated groups. The first group is labeled as the "Larger research and teaching intensive" universities, and consists of the largest, most research oriented and research productive universities. These universities also educate the most students in absolute, but not in relative, terms. The second group is labeled as the "Smaller education dependent" universities, and these are smaller, regional and have lower research productivity. These universities are also more oriented towards education than research.

The "Larger research and teaching intensive" universities are "high-performing" in terms of attracting external research funding related to income from education, while the "Smaller education dependent" universities are "low-performing", having high financial dependence on education. This points to that the investigated (structural) characteristics are related to the ability to attract external research funding, and thus that position of individual universities is related to the ability to compete for research funding.

5.2 Paper II

Title: What characterizes firms' academic patents? Academic involvement in industrial inventions in Sweden

Paper II analyzes the characteristics of firms' academic inventions, by comparing firms' academic and non-academic patents. Particular focus is put on the relative "importance", in terms of differences in patent importance between firms' academic and non-academic patents. This is done by analyzing indicators for i) technological impact, in terms of forward patent citations; ii) novelty and/or inventive step of patents; as well as iii) application status. Moreover, the paper examines differences in the frequency and importance of academic patents in relation to firms' overall patent portfolio by utilizing the concept of "technological profiles". The empirical analysis in this paper is based on a database of Swedish academic patents.

The results show that firms' academic patents largely differ from non-academic patents, both in terms of general patent characteristics, such as scientific links and project scope, and in terms of patent importance. Moreover, academic involvement mainly takes place in inventions highly related to firms' technology base ("Core technological fields"). In marginal technological fields, academic patents are associated with higher probability of novelty and higher technological impact as compared to non-academic patents. In contrast, academic patents in core technological fields are associated with lower technological impact and lower probability of being granted. From the results, it is suggested that firms involve academics for problem-solving activities in their core technological fields.

5.3 Paper III

Title: Academic inventors and firm inventiveness: A quasi-experimental analysis of firms' patents

Paper III studies the impact and role of academic inventors on firm inventiveness, by analyzing the average effect of involving academics as inventors on the technological importance of firms' patents. Drawing on a database of Swedish academic patents, a quasi-experimental design is employed by matching firms' academic and non-academic patents on a set of patent characteristics. Technological importance is measured using three types of indicators: i) technological impact, as indicated by the number of patent citations received; ii) generality of the impact in terms of the extent to which citing patents are spread across technological fields; and iii) persistence of the technological knowledge, measuring the extent to which patents' knowledge is spread and retained in subsequent patents in the patent citation network.

For a few dominant firms, the findings point to a negative effect of academic inventors on the technological impact. Results moreover show that for a majority of the sampled firms, there is a positive effect of academic inventors on the generality and persistence of firms' patents. The paper interprets these results to indicate that academics on average take one of two broad roles when collaborating on firm inventions. For a few firms, having a dominant position in terms of patenting and academic collaborations, academics act as problem-solvers leading to either incremental or highly firm-specific inventions with relatively low technological impact. For the majority of firms, however, academics are involved to assist in technology development, with the resulting inventions having more widespread impact and providing a basis for subsequent advances to larger extent, as compared to the firms' average non-academic invention.

5.4 Paper IV

Title: What do we know about what academics do? An opportunity perspective on the university literature

This paper analyzes what is known about academics' (innovative) activities. Literature on universities and academics is reviewed by applying an opportunity-based framework on articles in selected journals within broader economic literature.

A main part of the literature focuses on narrowly selected outcomes, including patenting and firm creation, and the determinants and characteristics of university-industry interaction and academic entrepreneurship. Surprisingly little seems to be known about the activities of academics that lead to these and other outcomes. Specifically, the literature analyzes university output as if it produces for product markets, rather than analyzing the role and nature of academics as specialized service providers across a range of activities. The paper argues that this is a serious shortcoming from a policy perspective, because it hampers our understanding of universities and academics.

5.5 Paper V

Title: Jack-of-all-trades or narrow specialists? Academics, opportunities and research, education and third mission experiences

Academics perform the three roles of research, education and societal interaction (third mission). While some evidence suggests that experiences in any of these can contribute to new opportunities for each of the roles, these relations have not been systematically analyzed. This paper investigates academics' perception of how important their prior experiences from the three roles are for formulating and develop-

ing new research, education and third mission opportunities. Drawing on structured telephones with 50 Swedish academics, the paper shows that academics perceive that all roles contribute to each other, suggesting complementarities among the roles on the level of individual academics. The strongest relations for research and education were self-referential, i.e. from research to research and education to education. However, for third mission opportunities, research was the strongest contributor. The weakest relations were from education to research and from education to third mission. Self-referential relations were more important in terms of identifying opportunities than for opportunity exploitation. Third mission was more important for opportunity identification for all of the three types of opportunities, while education was not perceived to contribute much to opportunity identification for any of the roles. Importantly, our findings suggest that research on average contributes to both identification and exploitation of opportunity for the three roles.

6 Discussion

This section discusses the PhD thesis' key findings and main contributions. For a summary of the findings and contributions provided by each appended paper, see Table 2. First, the overarching perspective of the thesis is discussed, followed by discussions of each of the three themes. The section concludes with putting forward the implications of the thesis, as well as discussing potential future research.

6.1 The overarching perspective of the thesis

This PhD thesis has analyzed the role and activities of universities and academics based on three overarching themes. In order to discuss and conclude the thesis, it is fruitful to make an analogy to the firm (or at the level of the individual academic – the entrepreneur). The underlying reason for such an analogy is simply to adopt and adapt concepts that may facilitate the present discussion as well as future research on these subjects.[46]

More specifically, the overarching topic addressed in this PhD thesis can be seen as the "innovating" activities of universities and academics. Innovation in this context is a slightly different concept compared to the traditional firm-centered definition of innovation. Here, innovation refers to new outcomes (or activities) from the perspective of the innovating actor with the intended, assumed or claimed ability to be beneficial for some stakeholder.[47] (However, there does not need to be direct market transaction.) Furthermore, innovating refers to different issues depending on the unit and the level of analysis. At the level of the university, innovating refers to individual universities positioning themselves vis-à-vis other universities. Assuming that a university has some degree of autonomy in terms of decision-making and resource allocation, it can e.g. change its business to create a new niche relative to other universities (see Section 3.1).[48] In this sense, universities' "innovating activities" are ways by which universities try to diversify their offers in order to satisfy different stakeholders and thereby gain access to scarce resources. This is closely related to Clark's characterization of the entrepreneurial university:

> "An entrepreneurial university, on its own, actively seeks to innovate how it goes about its business. It seeks to work out a substantial shift in

[46] Thus, this PhD thesis does not claim that universities are analogous to firms.

[47] This is in line with the definition provided in the Oslo manual: "The minimum requirement for an innovation is that the product, process, marketing method or organizational method must be *new (or significantly improved) to the firm*." (OECD, 2005 p. 46).

[48] Thus, at the level of the universities innovations can be seen in relation to the university's "business model" or its offers (e.g. setting up new programs in new and "hot" topics).

> organizational character as to arrive at a more promising posture for the future." (1998, p. 4)

At the level of the (individual) academic, innovating refers to the activities leading to new outcomes, from the perspective of the academic, within the three roles of research, education and third mission. This includes, but are not limited to i) incrementally improving and developing already existing activities or outcomes, such as developing the curriculum for a course; ii) creating more "radical" novelties, such as setting up and running an entirely new course or setting up and conducting a new research project leading to new scientific publications; or iii) creating or taking part in the creation of technological inventions or innovations.

From this perspective, this PhD thesis can be seen as addressing i) strategies at the highest level of analysis, in terms of characterizing the diversity of the Swedish university sector and proposing an interpretation of the position of individual universities (Theme 1); ii) the inner processes of academia, i.e. the "innovating" processes of individual academics. This was done by performing a literature review in regards to academics' innovating activities as well investigating the relation among the three academic roles, both from an opportunity perspective (Theme 3); and iii) specific "business models" of academics, in terms of investigating what characterizes firm inventions involving academic inventors, and in what ways academics affect the inventions that firms' involve them in.

Thus, in different ways, this thesis has adopted and adapted innovation-related concepts to study universities and academia. Why is this important? Over the years leading up to this PhD thesis, my understanding of the activities and behavior of universities and academia has been influenced by economics of innovation and the broader economic literature. In a way, this understanding can be problematic as there are differences between firms and universities on the one hand, and business-men or entrepreneurs and academics on the other hand. That being said, I am certain that most would agree with me that academics do perceive that they compete as well as collaborate with colleagues. This competition and collaboration is not only taking place across the boundaries of their home university but academics also interact with colleagues in their local environment, competing to increase or maintain their share of internal resources or collaborating to access larger external (interdisciplinary) research funding. There exist plenty of anecdotal evidence for such patterns of competition and collaboration, not only across disciplines but also between divisions and research groups. The implication from this is that in order to be and remain successful academics need to "innovate", in terms of e.g. generating new interesting research to be published and to access funding or develop and run courses that attract high-quality students.

In the face of the changing conditions for academia occurring across the world,

universities seem to become more similar to firms, although some fundamental differences remain (e.g. Deiaco et al., 2009). To some extent, this implies that the adopted innovation perspective in this thesis is becoming more central and important for analyzing universities and academics. If academia is in fact moving into a more competitive regime, there is a need for adopting and adapting concepts that can capture these changes and new conditions. Indeed, we cannot understand, analyze or even think about that for which we have no words.

There exist many potentially fruitful concepts related to innovation and business that can be adopted and adapted for this purpose, some of which have been employed in this PhD thesis. Such concepts include innovation, strategy, business model, entrepreneurship, opportunity and knowledge-based services. I do not claim to be the first to recognize the potential usefulness of these types of concepts, and there have indeed been authors that have employed notions such as strategy and entrepreneurship to analyze universities and academics. However, there do not seem to have been any rigorous attempts to evaluate and adapt these concepts in order to make them directly applicable to the setting of academia.[49] Also, I do not claim that the perspective offered in this PhD thesis is the only relevant one. The innovation-related perspective is rather complementary with for instance sociological views.

This PhD thesis has provided some early efforts to conceptualize the innovative activities of universities and academics, albeit with an empirical focus. In line with the reasoning provided in this section, I argue that this is a useful perspective for moving forward, but there is much that remains to be done.

6.2 University positioning

Research has highlighted that European countries are rather heterogeneous when it comes to the diversity of universities (e.g. Daraio et al., 2011). A few countries, most notably the UK and the Netherlands, show a clear differentiation between research oriented and education oriented universities, while many other countries, such as Italy and Spain, do not (Bonaccorsi and Daraio, 2007b, 2009). The Swedish university sector in this regard seems similar to countries such as the UK, with a clear differentiation between research-oriented and education-oriented universities. The Swedish universities, are in this way polarized into two clearly separated groups - the "Larger research and teaching intensive" respectively "Smaller education dependent" universities. First of all, there is a concentration of not just research but also education in the larger (and in most cases older) universities, in the sense that these research-oriented universities are the most research-intense as well as educate the most students in absolute terms. At the same time, the smaller regional universities

[49] An exception to this is the work on strategic differentiation by Bonaccorsi and Daraio (2007a).

Table 2: Summary of key findings and contributions

	Paper I	Paper II	Paper III	Paper IV	Paper V
Key findings	Polarization of the Swedish university sector into two distinct groups: i) "Larger research and teaching intensive" universities; ii) "Smaller education dependent" universities. Universities' position related to the ability to attract external research funding: i) "Larger research and teaching intensive" universities are "high-performing"; ii) "Smaller education dependent" universities have high financial dependence on education.	Firms' academic patents differ from non-academic patents on several patent characteristics. Academic involvement mainly takes place in inventions highly related to the technology base (core technological fields). Overall, firms' academic patents are less important than their non-academic patents. Firms' co-invented academic patents more important than non-academic patents in marginal technological fields.	Negative effect of academic inventors on the technological impact of firms' patents. i) For five dominant firms; ii) Problem-solving activities in "incremental" or highly firm-specific inventions/problems. Positive effect of academic inventors on the generality and persistence of firms' patents. i) Technology development activities leading to inventions with more widespread impact as well as providing a basis for subsequent technological development.	Literature focuses on research as a source of opportunities. Few studies on educational activities. Literature highly concentrated on a few outcomes of academic research, mainly patents/licenses, spin-offs and publications	Academics perceive that research, education and third mission opportunities to some extent at least draw on their experiences in each of the roles This suggests some degree of complementarities among the three academic roles. Education perceived as the least relevant source for research and third mission opportunities, while research was perceived as the most relevant source for research and third mission opportunities.
Contributions	Evidence based characterization and interpretation of individual universities' position in the Swedish university sector Investigates the relationship between individual universities' characteristics (position) and their ability to attract competitive external research funding.	Provides evidence on the relationship between academic inventors and firm inventions, furthering our understanding about university-industry collaboration.	Provides evidence on the impact of academics on firm inventiveness, furthering our understanding about university-industry collaboration. Introduces new research design (quasi-experimental) and new measures (of patents' "knowledge persistence") for analyzing technological importance of inventions (patents).	Systematic analysis of all studies of universities and academics found in broader economic literature. Exploring the "black box": investigating what is known from existing literature about academics' activities, rather than focusing on narrow, albeit measurable, outcomes of their activities.	Provides evidence on the relationship between the three academic roles of research, education and third mission. Exploring the "black box": investigating how important academics perceive their prior experiences within research, education and third mission are for creating new outcomes within the three roles.

rely heavily on education for income, and have not been able to differentiate in terms of research, as indicated by their lower research productivity as well as large number of, relatively "empty", research subjects.

There is also differentiation in terms of competitive funding, and it is mainly the larger research intensive universities that are able to compete for all types of external funding. The smaller regional universities rely mostly on the fixed income from education, which is the largest source of fixed income available for universities. In this way the position of individual universities in Sweden seems to be related to the ability to attract competitive research funding. Rossi (2009) showed a similar result for Italy, while Bonaccorsi and Daraio (2007b) point to an association between research intensity and ability to attract private funding.

Related to this, the smaller regional universities attract relatively little industry funding.[50] While this naturally to some extent can be explained by the smaller size (in research and overall) as well as research profiles of these universities[51], this do suggest that the researchers in these universities to a lesser extent engage in third mission activities related towards industry (cf. e.g. Bolli and Somogyi, 2011; Gulbranden and Slipersaeter, 2007). In this way, it seems like these universities, as compared to the larger universities, to a lesser extent address the need of industry. This stands in contrast to the fact that one of the explicit goals of Swedish public policy has been to stimulate economic progress at the regional level by allowing and encouraging these regional universities to address the needs of local firms (see Section 2). It also stands in contrast to the fears expressed by Geuna (1999, 2001), that smaller younger universities would, due to funding reasons, be forced to adhere to the needs of industry at the expense of fundamental research. Looking at the income streams of the Swedish universities, the findings do not suggest this to be the case for Sweden, where industry funding are concentrated at the larger research oriented universities.[52]

Having concluded that the Swedish university sector is clearly differentiated, the question is whether this is the result of emergent strategies in terms of individual universities (strategically) positioning themselves against others. Some authors have interpreted their results as evidence of existence of strategic differentiation of European universities (Bonaccorsi and Daraio, 2007b). However, in light of the Swedish

[50] Income from contract research from other, non-industrial, external organizations show a similar pattern.

[51] It is the absolute largest and most research intensive universities, together with the universities specialized in technology and medicine, that are able to attracts the most industry funding. It should, however, be pointed out that most of the smaller regional universities conduct research within technology and medicine.

[52] This is also visible by the fact that only a fraction of firm-owned academic patents have academic inventors affiliated to the smaller regional universities (Ljungberg and McKelvey, 2008).

setting (see Section 2) the polarization between "Larger research and teaching intensive" and "Smaller education dependent" universities rather suggest a lack of differentiation emerging from strategic positioning. Rather the differentiation seems to be the work of history; the older universities do what they have always done – teach the bulk of students and conduct the most research, thus being able to successfully compete for external research funding – while the smaller younger universities fall behind on research. Most of these smaller regional universities were founded with the objective to attract more of the reserve of talent into higher education, in order to provide the regional industry with workers (see Section 2.1). While all universities in Sweden were granted research funding in the 1990s, the findings of this thesis point to that these regional universities to a large extent still play the role of educator of the regional talent (although this may not necessarily benefit only the regional industry).

It should be noted that this does not necessarily mean that there are no strategic differentiation at all among Swedish universities, but rather that in the light of the Swedish setting there are no clear-cut evidence for such (proactive) behavior of universities, at least not in a very successful manner.[53] Thus, this PhD thesis argues that the position of individual universities in the Swedish university system is largely not the result of strategic differentiation but rather the result of "path dependencies" and "cumulative advantages" . While path dependencies do not stand in direct contradiction to the existence of strategic behavior of individual universities, the argument of lack of strategic differentiation should be interpreted in terms of that individual universities largely do not seem to break out of their historic positions. For instance, the fact that the smaller regional universities have not differentiated in terms of research but rather keeps to a "business model" relying mostly on education may be the result of strategic considerations. While all of the studied Swedish universities, as of 1997, are allocated fixed research funding, more than half of the existing sources of funding are competitive external funding while the fixed research funding is based mainly on size. Due to reasons of cumulative advantages, the smaller regional universities, which are for the most part quite new in the research game, might find it difficult to compete for this funding. At the same time, the largest available source of fixed funding comes from education. It is not hard to imagine that the smaller regional universities find it easier to attract more students, thereby increasing their income due to fixed funding, than to compete for the most competent researchers in an attempt to increase its research performance in order to better compete for research funding.

Sweden thus shows a lack of strategic differentiation, where universities are, will-

[53] Indeed, there are two younger universities present in the group labeled "Larger research and teaching intensive", as well as one outlier lying between the two groups. This might suggest that these three universities have (proactively) positioned themselves. However, these universities were among the first to be founded in the wave of university foundations in the 1960s and 1970s, and their position might just as well be the result not of strategic behavior but of historic objectives of the government and public policy.

ingly or unwillingly, locked in their positions. This in its turn points to potential institutional rigidities for specializing in the Swedish system. One plausible explanation of the lack of strategic differentiation is lack of strategic autonomy. While universities in many European countries, including Sweden, has gained increased autonomy during the recent decades they are still to a large extent governed by regulations. In Sweden, this is for instance related to regulations when it comes to financial freedom and selecting and hiring academic staff. The degree of autonomy can also differ between individual universities within a national context due to historical and structural reasons.

All this does not necessarily mean that the current institutional setting is not to some degree conducive for differentiation and strategic behavior. For instance, there might not currently be any (emergent) strategic differentiation because of too little time from increased autonomy and other policy changes to allow universities to change their behavior. For several reasons, universities are slow moving institutions and it might very well be that the time horizon is just too short and that the increased autonomy awarded Swedish universities in the 1990s will eventually lead to overall strategic positioning.

All national settings differ to some degree and in some ways the Swedish national setting is rather different from other European countries. Therefore the results from this thesis might not be generalizable beyond the Swedish setting. However, there was not any intention of this theme to provide generalizable results, but rather the aim was to characterize the Swedish university sector.

6.3 Academic inventors and firm inventiveness

Firms mainly interact with academics to invent within their core technological fields. These patented inventions, here called academic patents, are associated with lower importance as compared to non-academic patents within core technologies, while firms' academic patents within marginal fields are related to higher relative importance. Moreover, for the majority of the investigated firms, academic patents on average have a more widespread diverse impact (higher generality) as well as higher indirect influence on subsequent technological development (higher persistence) but with similar direct technological impact as non-academic patents. However, for a few dominant firms, academic patents on average have lower technological impact as compared to non-academic patents, indicating that the inventions resulting from academic collaboration relatively speaking lack direct usefulness for subsequent technological development. Therefore, the technological importance of firms' academic inventions seem to depend on i) the technological profile in which the patent is located; ii) which indicator is analyzed; and iii) to some extent on the firm.

The common interpretation of technological impact, as measured by a patent's forward citations, is that it indicates the value or quality of a patent. This is to some extent corroborated by empirical evidence that forward citations are related to the economic value of patents (e.g. Gambardella et al., 2008), firms' market value (Hall et al., 2005), and the social value of the underlying invention (Trajtenberg, 1990). While the results in this thesis points to that a substantial part of (some) firms' academic inventions have less direct technological impact than corresponding non-academic inventions, the importance and role of academic inventors may however not be as straightforward as captured by such direct impact of the resulting patents. First of all, forward patent citations are a "noisy" indicator, explaining only a small share of the value of the underlying inventions (Gambardella et al., 2008; Jaffe and Trajtenberg, 2002). Second, since academic patents for larger firms stand for only a small share of the overall patent portfolio, it might be that these result from inventions that are not directly comparable with firms' average inventions – in other words, it might be that firms involve academics in specific types of inventions. This thesis proposes that comparing firms' academic and non-academic patents reflects the role academics play in firms' inventive activities, rather than the "quality" of their work and the resulting inventions.

Drawing on a typology of university-industry collaborative projects provided by Perkmann and Walsh (2009) and based on the results from this theme, three stylized roles that academics play when collaborating with firms are proposed in this thesis.[54] The first role concerns academics assisting firms in improving or developing technologies ("technology development") that have commercial relevance if successfully developed. On average, the inventions resulting from such technology development would not necessarily have high direct impact on technological development, since the technology being developed probably have not (yet) found a wide direct usefulness. Rather, it would provide the basis for subsequent technological development. For the majority of firms, academic patents have a more diverse impact and a higher impact down the line of technology development: that is, these inventions, while not being on average more directly important for subsequent inventions, seem to provide the basis for later, and more diverse, development to a larger extent than average non-academic inventions.

The second role relates to academics being involved in problem-solving activities in more incremental inventions. This would entail academics assisting firms in solving specific problems related to some product or process close to market or related to the firms' own manufacturing processes (cf. Perkmann and Walsh, 2009). Problem-solving activities would lead to either very incremental or highly firm specific inventions, thus having low direct usefulness for subsequent technology development,

[54] These roles are not comprehensive or necessarily mutually exclusive.

but can nonetheless be an important contribution. For a few dominant and patent prolific firms, academic patents on average have lower direct technological impact, suggesting that these firms mainly involve academics for problem-solving activities.

The third and final role concerns academics being involved in inventive activities within firms' marginal technologies. Since the firms' internal competencies are limited in these fields, external partners are needed for building up the internal knowledge base by exploring new areas of potential commercial interest lying outside the mainstream activities of the firm. Academics are engaged for generating and testing ideas that are potentially valuable if developed and successfully commercialized in some manner. Since academics are involved due to their expertise within a field where the firm has limited internal competencies, such idea testing projects should (through technology development) result in inventions that are more important as compared to the firm's internally created inventions. Indeed, the few academic patents that are related to firms' marginal fields are associated with higher importance.

One question that arises in relation to this theme is the motivations of academics and firms for collaborating in this manner, as well as the benefits that they gain from this. First of all, why would academics engage in problem-solving activities with firms? Accessing research funding, or personal income, is one possible answer to this question. Previous research on university-industry interaction has indeed pointed out that accessing research funding is one of the major motivations of academics to interact with firms (D'Este and Perkmann, 2011; Lee, 2000; Meyer-Krahmer and Schmoch, 1998). Another motivation is demonstrated in Theme 3 (see Section 5.5 and 6.4), where academics reported industry interaction as conducive in terms of providing insight to their academic research and keeping up-to-date with the problems and needs of industry. In general, the interaction with firms provides academics with insight and inputs that can be exploited in their own research as well as education activities, regardless of the nature of the interaction (cf. e.g. Abreu et al., 2009; Balconi et al., 2004; D'Este and Perkmann, 2011; Lee, 2000; Mansfield, 1995; Meyer-Krahmer and Schmoch, 1998; Perkmann and Walsh, 2009).

When it comes to the firm perspective, the question is whether or not academics are able to satisfy the needs of industry through their collaborative activities. While this thesis cannot answer this question, it does provide some indications. First of all, for a majority of firms, academic inventions seem to provide the basis for later, and more diverse, development to a larger extent than the average non-academic inventions. In this way, these patents seem to be important beyond the direct technological impact (or "patent value"). While the firms owning these patents are highly heterogeneous, the majority of them are not very patent productive indicating that these are relatively small firms with limited in-house R&D. In this way, the academic in-

ventors probably provide an important contribution by assisting these firms in their technology development.

Second, in marginal technologies firms' academic patents are associated with higher technological impact as compared to non-academic patents. This indicates that, to the limited extent that firms' actually involve academics within these fields, academic inventors provide an important contribution to the firms' inventive activities.

The findings within this theme might to some extent be the result of the Swedish setting being dominated by a few R&D intensive and large firms. Thus, it might therefore be that that the results are only generalizable to countries with similar context. For example, it might be that the suggested role of academics as problem-solvers is less dominant in settings that are not dominated by a few large firms. However, I would argue that this does not invalidate the findings of this theme but that the relative importance of the different academic roles will differ across nations.

6.4 Academics and opportunities

The analysis of the broader economic literature revealed that the existing literature has largely treated academia and universities as a "black box", focusing on measurable outcomes of academic research and third mission activities. In this way, the activities going on "inside" the university have been largely overlooked in existing studies. There are, at least, two points to be made from this. First of all, while the existing focus of the literature has provided valuable insights on important topics such as university-industry interaction and academic entrepreneurship, this literature seems to suffer from diminishing returns. The reason is that a large part of the attention has been rewarded to issues such as academic spin-offs and university patenting, which are relatively marginal phenomena compared to other university activities, including firm interactions. Second, (individual) academics are the engine of the universities, as argued earlier, and it is their activities and outcomes that contribute to societal needs. A deeper understanding of academic activities is important for understanding the role, impact and "inner workings" of universities, and thus important from the perspective of university governance and public policy.

Existing literature indicates that there is no productivity trade-off between education and research (e.g. Hattie and Marsh, 1996) and no, or even a positive, relation between research productivity and engagement in third mission activities related to academic entrepreneurship and industry interaction (see Larsen, 2011). The question is then whether there exist more qualitative complementarities between the roles that do not translate into enhanced productivity. Indeed, academics perceive that their experiences in all of the three roles contribute to how they identify and exploit research,

education and third mission opportunities, which suggests complementarities among the roles on the level of individual academics. While there might exist trade-offs among the three roles due to alternative costs that was not captured in Theme III, the results of this thesis suggest that all three roles, and especially research, provide relevant inputs for each other. This is in line, and extends upon, findings of some authors that there is compatibility between research and education, with especially research providing important input to education (e.g. Neumann, 1992; Clark, 1997; Smeby, 1998).

Following in the Humboldtian tradition, it seems that research is to some extent at the heart of academic activities, in the sense that academics seem to benefit significantly from their research experiences in all three roles. This suggests that while academics might not boost their productivity being involved in research, it indicates that it does benefit their work. In this way, research and third mission seem to be closely linked on the level of the academic, which is to be expected within engineering-related disciplines where science and technology commonly co-evolve (Rosenberg and Nelson, 1994) and where academics to some extent collaborate with industry to find out where to direct their research (Balconi et al., 2004).

The relation between education and the other two roles are, however, less straightforward. Research seems to provide important inputs to education at higher levels, while it at lower levels, such as undergraduate, is perceived to contribute less. At the same time, while education is perceived to have some relevance, it is the least important role in terms of identifying and exploiting opportunities for both research and third mission. The insights gained from the actual educational activities are generally perceived as lacking substantial research potential. Given that the results indicate that education is less important for identifying than for exploiting opportunities, this might suggest that education facilitates academics' understanding of a field and thereby has indirect benefits for research that are difficult to capture and perceive.

The relations among the three roles are in this way rather complex, and there are many potentially interesting issues to address here. One particularly interesting issues is the specialization of academics, i.e. whether individual academics should be specialized in one role or if they should be "jack-of-all-trades". First of all, as stated above all roles provide relevant contributions to each other. This, together with the lack of productivity trade-offs shown by previous research, indicates that for the individual academic it might be beneficial to perform or at least dabble in all three roles. At the same time, however, the strongest relations for research and education were self-referential, i.e. from research to research and education to education. This suggests that these two roles to some extent are self-reliant, in the sense that the roles contribute most importantly to themselves. This is line with the responses provided

during the interviews, where student feedback was the most commonly perceived source of input for education while research was perceived to build mostly on the own previous research as well as benefit from interaction with colleagues. In this way, research and education might function well in silos (cf. Hattie and March, 1996), with any potential input coming from the other roles being the extra value added. Importantly, for third mission opportunity, research was the strongest contributor, while the self-referential relation was perceived as more important for identifying than exploiting opportunities. In this way, research and third mission seems to be closely linked, as might be expected, suggesting that third mission to some extent ought to be connected to research on the level of the academic.

While performing all three roles might be beneficial, it thus seems that individual academics can specialize in education or research (third mission). What does this mean for the university in terms of staffing? Since undergraduate education seems not to need active links to research, this can probably be separated in the sense that academics teaching at this level do not need to be researchers themselves. Indeed, such separation (within universities) is commonplace in the Swedish system (see Section 2). For higher levels of educations, it seems that close links with research are beneficial to some degree. However, seeing that this relation seems to not be very strong, as argued earlier, it might suffice if this link is indirect. Assuming that universities have a hard time hiring academics that are strong at both research and education, which might be the case especially for smaller universities, it might suffice to facilitate interaction and collaboration between researchers and teachers to reap at least some part of the complementarities between the two roles. Similar argument can be made regarding the relation between education and third mission. While research and third mission almost per definition are linked, as also shown in this thesis, a strong researcher is not necessarily strong at third mission activities. As pointed out in Section 6.2, it seems that the Swedish smaller regional universities interact with industry to a relatively low extent, as indicated by their low dependence on industry funding. For these universities, or at lower levels such as a departments, one way to instill a culture more open towards such third mission activities is to employ an academic that is not necessarily strong in terms of research but that has (vast) experience in e.g. industry collaborations. It has been argued that the collaborative behavior of local peers shape the individual collaboration behavior of academics (Tartari et al., 2010). Thus, by introducing such a person in the research environment may over time foster a new more open culture, to the extent that other conditions are favorable.

Overall, individual academics need not necessarily be jack-of-all-trades, but facilitating the interaction and collaboration between the different roles at the university may "spill" over some complementary benefits between the roles as well as facilitate the learning of individual academics.

The study investigated Swedish academics in three engineering-related disciplines, which limits the generalizability of the results.The three disciplines investigated in this thesis were chosen on the expectation that all three roles have some impact upon each other. However, in other disciplines, such as in humanities or social sciences, these relations will be less pronounced, especially in terms of third mission.

6.5 Implications

The polarization of the Swedish university sector was argued to largely not be the result of strategic differentiation among Swedish universities, but rather that individual universities are locked in their historic positions due to path dependencies and cumulative advantages. In terms of potential implications, the question is whether the current polarization of the Swedish university sector is desirable or whether more or less diversity would be favorable. A university system where individual universities largely are able (and motivated) to strategically differentiate – i.e. a university system consisting of Clark's "entrepreneurial universities" - would be desirable for many reasons, not the least since it would provide an increased flexibility, in terms of the ability to adapt to changing conditions and demands. Such flexibility becomes important not the least in the light of the still on-going changes facing universities, with increased demand for education, competition over funding, and expectations on universities to take on more roles and activities.

As pointed out earlier, we might not see any clear strategic differentiation due to too short time horizon, and it seems plausible that, in line with the arguments expressed by authors such as Deiaco et al. (2009) and Bonaccorsi and Daraio (2007a) that the on-going transformation of the European university sector will sooner or later "force" universities into a more competitive regime, where they will have to position themselves in relation to other universities in order to be able to compete for scarce resources. However, as pointed out earlier, there might be some institutional constraints that may hinder such a change, not the least in terms of lack of strategic autonomy.

Lack of strategic autonomy in this context can be seen as a catch-all-phrase for a variety of different issues that constrain universities, such as legal rules for selecting and hiring academic employees and lack of financial freedom. While it is beyond this PhD thesis to provide a comprehensive picture or prescribe a "cure" to any "illness" that might exist in the university system, I will here touch upon a few issues.

Clark (2003) argues that one key element for universities to be able to transform themselves into more proactive and strategic actors are a diversified funding base, beyond fixed governmental funding. Indeed, seeing that fixed funding tend to

be earmarked for specific purposes, additional external funding, while also possibly to some extent conditional, provides the "budgetary autonomy" needed for strategic efforts. It might seem like the financing of academic research is rather well functioning in the Swedish system in the sense that it is indeed the most research productive universities that are able to attract external research funding. While this might seem good and well it probably to some extent comes at the expense of the smaller regional universities in the sense that the seeming inability of these universities to attract research funding renders them with a potentially lower autonomy. The only real way to increase the research competence and productivity of the university is to hire new competent researchers, but with their limited capital, as well as relatively lower reputation, the smaller regional universities probably find it difficult to hire competent researchers in competition with the older larger universities. In this way, the current funding system seems to uphold some sort of cumulative advantage that the smaller universities are unable to break. Thus as long as the conditions remains similar, these universities can be expected to largely remain in their current position or even increase their focus on education, as argued earlier.

It might be difficult to restructure the funding regime in such a way that the smaller regional universities are able to increase their "market shares", at least without directly allocating these universities with additional less conditional funding. One potential way of facilitating additional income might however be to increase the ability of universities to generate their own income (cf. Clark, 2003). In the current Swedish system, universities are not allowed to take out student tuitions and fees nor are they able to accept endowments. While the former would be one potentially interesting income stream for universities, it is not very likely that this will be politically possible to introduce, not is it necessarily desirable. Endowments on the other hand would be a possible way to increase the income and strategic autonomy of universities. While this is very likely to still be likely to favor mostly the larger universities, it might be a way forward.

The findings on the relations among the three academic roles can have important implications for staffing of universities and to what extent different roles should be specialized on the level of the individual academic. If the proposition that undergraduate education to a large extent have less need for active links to research holds, one possibility for the future might be that we will see some smaller regional universities abandoning the highly uncertain research game and focusing only on undergraduate teaching, where they can access fixed funding. In principle, this can lead to a division of labor between universities between those conducting only undergraduate teaching and those doing higher level education as well as research. Whether such a division of labor would actually be desirable is beyond the scope of this PhD thesis, but it seems like undergraduate education suffice with more indirect links to research.

As pointed out in Section 2.2, Sweden has, in relation to its size, many R&D intensive multinational companies and the industrial R&D is to a large extent concentrated in a few such firms. In the light of the increasing globalization, there has been a tendency of such firms to relocate their headquarters to other countries and to be merged or acquired by other non-Swedish firms. While most of the firms doing this have kept large parts of their R&D within the country, it is not farfetched to speculate that in many cases much of their R&D will sooner or later also be relocated. Almost half of the Swedish firm-owned academic patents are owned by a handful of such firms, and the question then follows what would it mean for the academics and their universities if these firms relocate. First of all, it would mean that one seemingly quite important "business model" of academic inventors would disappear, i.e. assisting firms in problem-solving activities. This in its turn would mean a loss not only of a source of additional research resources but also a source of potential research opportunities (cf. Theme 3), since proximity seems to matter for whether firms perceive assistance in problem-solving as beneficial (Bishop et al., 2011). It is highly plausible that some disciplines in Sweden are in fact quite depending on a few of these large firms, in terms of research opportunities. In technology-related disciplines, such as engineering-related fields, research is commonly interrelated with industrial technology development (Rosenberg and Nelson, 1994). To the extent that academic patents are representative of university-industry collaboration overall, this might thus have quite large consequences, not only for individual academics or research groups but also for universities at large, not the least for the universities specialized in technology and medicine. Thus, if the large firms vacate the country the universities and academics need to find new sources of research opportunities or there is a risk that certain disciplines will suffer or maybe vanish from the international frontier. Another potential solution is naturally that the universities relocate together with the firms.

6.6 Future research

The present study of the Swedish sector was a static analysis, in the sense that it did not investigate whether there have been a change in the positions of individual universities over time. Many existing studies of the European sectors have likewise been static in this way although some authors have studied some specific issues over time especially the educational subject mix (e.g. Bonaccorsi and Daraio, 2007b; Lepori et al., 2010). To be able to clearly distinguish any emergent strategies of individual universities, a dynamic approach is needed, both for the specific Swedish case and for Europe overall.

Moreover, existing studies have, for the sake of simplicity, focused on rather nar-

row indicators, mostly related to research outputs, thus not including many aspects of the offers that universities provide. Existing research, also that focusing on one national context (including this thesis), has in this way provided a rather aggregated and fragmented analysis. To further the understanding of the strategic positioning of European individual universities, all the missions of universities, i.e. research, education and third mission, needs to be taken into account, using different "metrics". It is therefore important to develop and evaluate such metrics, that span all of the activities and knowledge services of universities and that are comparable across national settings (see Deiaco et al., 2009 for an overview of such metrics). These types of studies might also be benefited by supplementing quantitative analysis with more qualitative data on the strategic considerations of universities.

The studies in this PhD provided insight on the inventive collaboration between academics and firms, but there are still many issues to investigate relating to this. While I would encourage all types of efforts that shed further light on the collaboration between firms and academics, I will here suffice to provide suggestions related to patent studies. One weakness of the current studies was the lack of supplementing the patent data with more qualitative insights. One potentially fruitful way forward would be to investigate the nature of firms' academic patents in a qualitative manner or to conduct an interview study of collaborating academic and firm inventors. This would be a good complement to studies like the present one and could shed further light on for example the roles academic play when involved in firms' inventive activities.

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Note on the appended studies

Daniel Ljungberg has had an active role in all stages of the research in the five appended papers, as well as in the writing of them.

Paper I

The purpose and research design of the paper was developed together with the two co-authors. Daniel Ljungberg was responsible for the data. The analysis and writing was a collective effort.

Paper II

Daniel Ljungberg developed the initial idea leading to the paper, but the final purpose was developed together with the co-author. Moreover, Daniel Ljungberg collected and cleaned the data used in the analysis, as well as developed the research design and conducted the statistical analysis. The results were analyzed together with the co-author and the writing was a collective effort.

Paper III

Single-authored.

Paper IV and V

Purpose, research design and analysis of results were developed jointly by the two authors, and both papers were co-written. Daniel Ljungberg was responsible for collecting the data as well as for data analysis.