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BEYOND BEAN COUNTING:

USING PATENT INFORMATION TO INVESTIGATE INVENTIVE PRODUCTIVITY IN ACADEMIA

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BEYOND BEAN COUNTING:
Using patent information to investigate inventive productivity in academia
THESIS FOR DOCTORAL DEGREE (Ph.D.)

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For my grandparents

‘Not everything that can be counted counts.
Not everything that counts can be counted.’

Albert Einstein

ABSTRACT

Contemporary universities have multiple missions: to provide education, to conduct research and to contribute to innovation and growth through so-called third stream activities. Examples of the last include both commercial undertakings, such as patenting, licensing, and new business creation, and non-commercial accomplishments, such as social outreach. Since many policymakers and other stakeholders have sought to further promote third stream activities, there is an ongoing debate about how to appropriately measure and evaluate such activities. Rather than the issue of individuals' or organisations' scientific productivity, the promotion of third stream activities highlights, among other things, how to assess *inventive productivity*, which is broadly understood here as the inventive output of individual academics, research groups or organizational units during a specific period of time. In countries like the UK and the Netherlands, where research evaluation frameworks have been introduced that include assessment of third stream activities, inventive productivity has typically been linked to the number of patent applications that have been filed or granted in a given year. However, various studies have questioned if the use of such volume-based measures appropriately represents qualitative and process-related aspects of invention and patenting processes. Building on this previous research, the present thesis asks how measurement of inventive productivity in academia can be undertaken. This overarching question is addressed in four papers, which are positioned at the intersection of research streams covering academic commercialisation, research evaluation and the use of patent-based measures in innovation studies. Data on academic inventors and patents from a single faculty medical research university are used to explore different methods for measuring inventive productivity and their consequences. Three papers elaborate on the use of available patent information for measurement of inventive productivity. Specifically, inventive productivity is operationalized based on an alternative definition of patent counts (Paper I), measures of patent survival (Paper II) and routes for patent transfer (Paper III). The findings suggest that existing patent information, when analysed longitudinally, can be used to construct more representative measures of inventive productivity compared with single-period patent counts. Paper IV extends the discussion on measurement of inventive productivity by problematizing whether volume-based patent measures capture behavioural differences among academic inventors in patenting processes. Through the tracing of inventors' experiences at the process level using interviews, behavioural similarities and differences between individual academic inventors of varying inventive productivity emerge. These findings suggest that established categorisations of academic inventors as occasional and serial inventors, based on e.g. single-period patent counts, can obscure meaningful differences in individuals' behaviours. In summary, the realization of a more tailored and targeted innovation support and assessment system would benefit from further methodological and organizational development. To move beyond bean counting based on single-period patent counts, this thesis proposes that policymakers and other stakeholders further develop volume-based measures using existing patent information and also complement such data with process-related information concerning inventor behaviours and views.

Key words: *inventive productivity, academic inventors, research evaluation, third stream measures, university, patent counts, patent survival, patent transfer, patent process, inventor behaviour*

LIST OF SCIENTIFIC PAPERS

I. Dahlborg*, C., **Lewensohn*, D**., & Sundberg, C.J. (2013). Investigating inventive productivity at Sweden's largest medical university. *International Journal of Technology Transfer and Commercialisation 12*(1-3), 102-120

II. **Lewensohn**, **D**., Dahlborg, C., Kowalski, J., & Lundin, P. (2015). Applying patent survival analysis in the academic context. *Research Evaluation*, *24*(2), 197-212

III. Dahlborg, C., **Lewensohn, D**., Danell, R., & Sundberg, C.J. (2016) To invent and let others innovate: a framework of academic patent transfer modes. *The Journal of Technology Transfer*, 1-26

IV. **Lewensohn**, **D**., Sjögren, E., & Sundberg, C.J., Does productive mean active? - Tracing patent processes of occasional and serial academic inventors, Submitted.

*equal contributions

CONTENTS

LIST OF ABBREVIATIONS

ASTP	Association of European Science & Technology Transfer Professionals
AUTM	Association University Technology Managers
EPO	European Patent Office
HEI	Higher Education Institutions
IP	Intellectual Property
KIIP	Karolinska Institutet Intellectual Property
PCT	Patent Cooperation Treaty
ProTon	European Knowledge Transfer Association
TTO	Technology Transfer Office

1 INTRODUCTION

On May 25th 2012, a patent application was submitted to the United States Patent and Trademark Office. Unknown to the world at the time, inventor Emmanuelle Charpentier[1] - then research leader for the Laboratory for Molecular Infection Medicine Sweden at Umeå University - would not only transform her own career, but also revolutionize biomedical research (Abbott, 2016). Together with Jennifer Doudna, she had discovered a method for how to edit the human genome or, simply put: a remarkable 'gene scissors.' Since then, the interest for the invention has grown explosively, both within and outside the scientific community. While the story of Emmanuelle Charpentier is unique in itself, it illustrates the impact that basic biomedical research can have on science, business and society at large.

Patenting and commercialisation of academic research results have become increasingly important goals for universities to pursue according to university decision-makers, individual researchers and policymakers globally. As illustrated by the following quote (European Commission, 2008), the policy ambition of the European Union is clear:

> 'support the development of knowledge transfer capacity and skills in public research organisations, as well as measures to raise the awareness and skills of students – in particular in the area of science and technology – regarding intellectual property, knowledge transfer and entrepreneurship'

One consequence of this policy orientation is that higher education and research institutions (HEI) are required to develop and take on various additional roles besides their traditional missions of education and research. Individual academic scientists are expected to engage with society through so-called third stream activities, which refer to 'all activities concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academia' (Molas-Gallart & Castro-Martínez, 2007). Examples of third stream activities include both commercial undertakings such as patenting, licensing and new business creation, and non-commercial accomplishments, such as social outreach. In parallel, there is increased pressure on HEIs from policymakers, funding agencies and wider society to demonstrate that publically funded organizations achieve their multiple missions (Guthrie et al., 2013). To allow for such assessments necessitates the evaluation of different aspects of academic work, see e.g., Etzkowitz (2016). One long-standing concern has been the evaluation of scientific productivity. Another concern, which is the focal interest of the present thesis, is the evaluation of third stream activities, specifically those related to academic commercialization. The assessment of individuals' and organizations' *inventive productivity*, broadly understood here as the inventive output of individual academics,

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[1] Emmanuelle Charpentier and Jennifer Doudna have been credited for the discovery of the gene-editing technology known as CRISPR–Cas9. Together with Martin Jinek, Krzysztof Chylinski, James Harrison Doudna Cate, Wendell Lim and Lei Qi, they are inventors listed in the patent application filed on May 25th 2012.

research groups or organizational units during a specific period of time, require insight into activities related to patenting, licensing and new business creation. This thesis investigates how measurement of inventive productivity in academia can be undertaken. Before discussing previous research and research design, it is worthwhile to reflect upon two major developments that have a bearing on the subject of this thesis: 1) a general societal transformation towards increased monitoring of and accountability for public sector performance and 2) an expanded strategic orientation of many HEIs, where measurement and management of academic inventions is increasingly becoming a point of contention.

1.1 PUTTING EVALUATION OF ACADEMIC WORK IN THE SPOTLIGHT

The ambition to measure the broader aspects of academic scientists' contributions, beyond the public communication of research findings through academic outlets such as journals, resonates well with international trends of increased accountability in the public sector at large (Broadbent & Guthrie, 1992). The last three decades has seen the introduction of new scientific measurement-inspired governance models and managerial practices that intend to promote efficiency, effectiveness, cost savings and streamlining throughout public organisations (Hood, 1995). The rise of evidence-based health care is one example within the public sector that has received considerable policy and scholarly interest (Timmermans & Berg, 2003). Another area affected by this general trend is higher education and research. To ensure the efficient and effective use of tax payers' money, universities are made increasingly accountable for their day-to-day operations (Huisman & Currie, 2004).

Many traditional assessment methods have a *summative* function, typically rooted in quantitative and volume-based measures, such as absolute numbers or counts of scientific publications or citations (van Raan, 2005). Notwithstanding the intended purposes of such assessment methods to provide a basis for management control and resource allocation, they have been subject to criticism for their bureaucratic nature (Rafols et al., 2016). Some countries have tried to expand their focus beyond quantitative measures to meet increased calls for *formative* research evaluation frameworks, which emphasize learning and feedback for improvement (Guthrie, et al., 2013). For example, the UK's Research Excellence Framework (Rosenberg, 2015) has more recently attracted a lot of scholarly and policy attention for attempts to include a broader range of academic research outputs and impacts, beyond the publication in particular academic journals (Martin, 2011; Penfield et al., 2014). Given the variation of agendas and goals among university stakeholders, evaluation frameworks may likely benefit from a combination of summative and formative assessment (Guthrie, et al., 2013; Molas-Gallart, 2012).

In parallel to the developments in the research evaluation arena, there have been legislative, financial and other policy interventions aimed at supporting university technology transfer (Kochenkova et al., 2016). One public policy measure which has been observed in many European countries is the formal shift from inventor-centred models of intellectual property ownership to university-ownership models (Baldini, 2006; Geuna & Rossi, 2011). The establishment of technology transfer offices and other intermediaries (Markman et al., 2008) is another example of efforts taken to facilitate value extraction from academic research results through patenting, licensing and spin-off establishments. While knowledge transfer between universities and society is by no means a new phenomenon (Martin, 2012a), it is increasingly regarded as crucial for a university's ability to generate innovation and economic growth (Etzkowitz & Klofsten, 2005). Previous works associate this trend with 'an expanded strategic scope of universities' (Sandström et al., 2016) or with 'the emergence of entrepreneurial universities' (Etzkowitz et al., 2000; Phan & Siegel, 2006).

Against the backdrop of these two major developments - to foster knowledge transfer and to account for wider aspects of academic work - various countries have introduced and refined existing research evaluation frameworks, see, e.g., national examples in the report by Guthrie et al. (2013). Countries like the UK and the Netherlands are among those that now formally include both publication-based measures and third stream measures, such as numbers of patent applications, licenses or university spin-offs, in their national research evaluation schemes (Rosenberg, 2015; Standard Evaluation Protocol, 2014).

However, echoing the critique of summative publication-based measures (van Raan, 2005), third stream measures have also been criticized for their limited capacity to account for the value and quality of academic knowledge transfer (Grimaldi et al., 2011). As suggested by Penfield et al. (2014), it cannot be assumed that funding of excellent research automatically leads to valuable inventions, innovation and socio-economic growth. In addition, the use of summative measures may lead to unwanted steering effects (see section 2.2 for a further discussion).

Another concern with the development and use of quantitative third stream measures is the limited availability of suitable data. For instance, in Sweden, there is no formal requirement or incentive for technology transfer organizations or universities to report inventions. Nor is there a common standard for voluntary disclosure. Consequently, it is difficult to obtain comprehensive patent statistics (Jacobsson et al., 2013). In the US, there have been more systematic efforts to gather this kind of information, particularly through the nationwide organization AUTM (Association for University Technology Managers). However, as the underlying statistics are based on TTO-reported data with varying coverage and response rates, there is a risk that US academic patenting and commercialization effort are underestimated[2] (Aldridge & Audretsch, 2011).

Given these challenges, the present thesis asks *how measurement of inventive productivity can be undertaken*. The thesis addresses this overarching question in four papers (Table 1). The first three papers elaborate on the use of available patent information for quantitative measurement of inventive productivity, using the case of a single faculty medical research

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[2] AUTM surveys a selection of all US universities and has response rates of between 56 and 65% (email correspondence with Chrys Gwellen, AUTM, January 2017).

university. The findings suggest, in contrast to scholars who have argued for a general reorientation away from assessment of patent-based knowledge transfer (Bölling & Eriksson, 2016; Siegel & Wright, 2015) that existing patent-related information can be used to construct more sophisticated and meaningful representations of inventive productivity. The fourth paper then extends the discussion on measurement of inventive productivity by problematizing whether volume-based patent measures capture behavioural differences between academic inventors in patent processes. Based on findings of behavioural differences between individual academic inventors, it is further argued that the measurement of inventive productivity using simple patent counts – and the resultant categorization of individuals as serial and occasional inventors - obscures such differences. This highlights the need for further methodological and organizational development, notably the inclusion of non-patent related information, in order to allow for more tailored and targeted assessment and support initiatives.

This thesis makes two main contributions: one methodological, the other conceptual. Methodologically, it provides analysts and others with more detailed evidence advantages to apply fine-grained longitudinal patent data in the measurement of inventive productivity. In particular, it demonstrates that data on patent survival and patent transfer can complement assessments based on less sophisticated volume-based measurements, notably of single-period patent counts (e.g., number of patent applications filed annually). In addition, it validates the need to use name-matching methodology in the identification of inventors, so that each academic inventor is recognized, independent of knowledge transfer mode. Conceptually, this thesis contributes to the emerging research that emphasizes the importance of micro-level qualitative, contextual and within-organizational analysis (Bercovitz & Feldman, 2008; Criscuolo et al., 2015; Gittelman, 2008b; Tanimura, 2015). In particular, it provides insights into the behavioural dynamics of academic inventors as they engage in patent processes.

Both these contributions underscore the need for a diverse repertoire of policy initiatives that consider the heterogeneity of academic inventors. Specifically, this thesis argues that a more sophisticated use of patent information, when combined with a greater understanding of patent processes and inventor behaviour, can further inform policymakers and analysts in their efforts to design evaluation frameworks for third stream activities.

Table 1 Outlines aims, rationale and major contributions

Paper	Aim	Rationale	Contribution
I	To explore different ways to account for inventive productivity and investigate the inventive productivity of Karolinska Institutet.	It is of interest to understand how representative patent count-based measures are for evaluation of academic inventors.	Stresses the importance to relate patents to inventions to avoid under-or overestimating scientists invention related work.
II	To apply patent survival analysis and to analyse the influence of patent, assignee and inventor characteristics on patent lifespan	It is valuable to consider temporal dynamics of patent-count based measures and to better understand what variables affect patent lifespan.	Demonstrates how patent survival analysis across their lifespan is a more qualitative representation of inventive productivity compared to single period patent counts.
III	To analyse how patented academic inventions are transferred to downstream entities, by tracing patent owners longitudinally.	It is important to understand how academic patents are transferred from academia to society over time.	Emphasizes the use of longitudinal patent data. Specifically, it shows how patented inventions are transferred from academic inventors mainly to small and medium sized companies.
IV	To investigate academic inventors and their reported behaviour in patent initiation and subsequent patent management	The on-going discussions on how to support academic commercialization and patenting warrants more details insights into inventors' behaviour in such processes.	Elaborates on the conceptual understanding of inventive productivity by showing how differences in volume-based measures of patent output obscure potentially meaningful differences in academic inventors' behaviour in patent processes.

1.2 THESIS OUTLINE

This thesis consists of five main chapters. Chapter 1, 'Introduction' provides a brief overview of the thesis including the research question posed. It also positions the thesis in the context of evaluation of academic work. Chapter 2, 'Previous research,' summarizes the research streams covered in the thesis and presents the thesis rationale and argument. Chapter 3, 'Methodology,' is dedicated to research design, data collection and analysis as well as a reflection on the methodological considerations made. Chapter 4, 'Results,' outlines and discusses the main findings of the four empirical studies. Finally, Chapter 5, 'Discussion,' elaborates on the theoretical contributions and policy implications of this thesis.

2 PREVIOUS RESEARCH

This thesis is positioned within a broad and interdisciplinary field concerned with academic patenting and commercialisation. This field is characterized by its problem-driven interest in science and innovation policy-related issues (Martin, 2012b)[3]. Several reviews have proposed different ways to demarcate the literature (Gerbin & Drnovsek, 2016; Sandström, et al. 2016; Siegel & Wright, 2015; Perkmann et al., 2013; Rothaermel et al., 2007). A principal discussion centres on the role of universities in society as suppliers of both public and proprietary knowledge (Murray & Stern, 2007). In particular, the literature has grappled with the issue of the circumstances for knowledge transfer. Here, three topics concern the mechanisms of knowledge transfer (Perkmann, et al., 2013), including (1), the role of TTOs and other intermediary organisations (Debackere & Veugelers, 2005; Siegel & Wright 2015), (2), the factors (e.g., organizational or individual) influencing propensities or frequencies of patenting, licensing or other means of knowledge transfer (Azoulay et al., 2007), and (3), the practical expressions of tensions and trade-offs between academics' different missions (Baldini et al., 2007; Braunerhjelm, 2007; Murray, 2010). Yet, because of the combination of a problem-oriented approach, and the intersection between various academic interests within this broad and interdisciplinary field, a more issue-specific positioning is made below. The present thesis draws from three major streams of research (Figure 1). The first, on *academic commercialisation,* ranges from description of patenting trends at universities to assessment of the value of academic patents. The second and third research streams concern *research evaluation* and *patent-based measures,* respectively, in particular as they discuss the use (and potential misuse) of volume-based patent information. This chapter reviews contributions from these research streams and presents the thesis argument.

[3] Morlacchi and Martin (2009) explain the fragmented nature of the field of science and innovation policy studies in the following quote: 'Rather than being theory-driven or paradigm-driven, it is primarily a problem-oriented field that focuses on practical issues to do with specific policies for science, technology and innovation, taking account of the central role of firms in the evolution of technology and innovation. As such, much of it is empirically oriented and motivated; where there is theorising, this is mostly inductive, reflecting on what the empirical record appears to show. This differentiates it from social science disciplines where theory comes first and the empirical work is largely to test the theory. Drawing on a wide range of disciplines, it is generally viewed as an intrinsically interdisciplinary research area.'

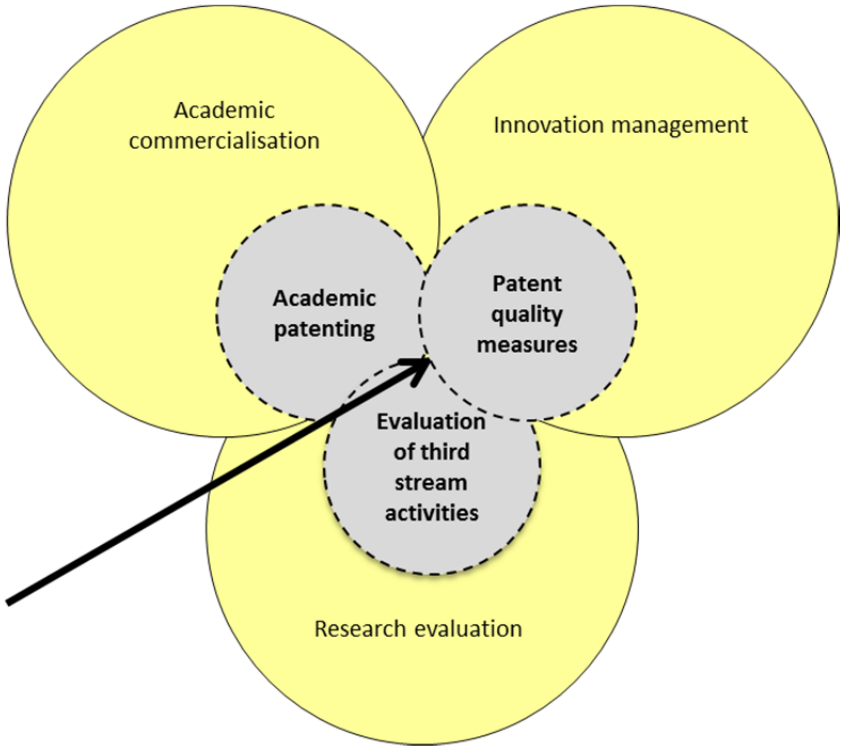

Figure 1 The present thesis draws from multiple research streams

2.1 ACADEMIC COMMERCIALISATION

One issue that has been thoroughly investigated concerns the impact of the Bayh-Dole Act or similar legislation on patenting (Geuna & Rossi, 2011; Henderson et al., 1998; Mowery & Ziedonis, 2002; Sampat et al., 2003). A core finding of these studies is that the change in intellectual property (IP) ownership legislation cannot solely explain the increase in university patenting. Rather, it is argued that funding, university autonomy and local practices are more important for patenting than a change in IP ownership legislation (Henderson, et al., 1998; Lissoni et al., 2013; Weckowska et al., 2015).

Another topic centres on the role of technology transfer organisations (Debackere & Veugelers, 2005; Muscio, 2010). In particular, factors explaining the productivity of technology transfer offices (TTOs), such as their organizational structure and the skills of the TTO staff, have been the subject of several studies (Jones-Evans et al., 1999; Siegel et al., 2003). Recent discussions point to an overall knowledge gap in academia when it comes to commercialisation of research results and therefore, suggest competence-building for university staff and TTO managers (Kochenkova, et al., 2016). This knowledge gap could possibly explain why researchers choose to commercialise their research through other channels than the TTO (Aldridge & Audretsch, 2011; Fini et al., 2010; Markman, et al., 2008).

A third area within this research stream concerns the measurement of academic patenting, commercialisation and entrepreneurship (Grimaldi, et al., 2011). While research efforts have been dedicated to identifying academic inventors and associated patent data (Lissoni et al., 2008), there has been less discussion on if and how this data could be applied in evaluation of these inventors' contributions. Specifically, there is a lack of research that problematizes the use of patent data in academic evaluation contexts.

2.2 RESEARCH EVALUATION – A HERCULEAN TASK?

In the wake of the knowledge economy, rankings have increasingly become important instruments for universities to attract new students and researchers through the communication of excellence in education and research (Hazelkorn, 2015; Marginson, 2014). The proliferation of rankings among business schools is one example of this trend (Wedlin, 2011). While benchmarking of academic research excellence through data on scientific productivity is recognized internationally (see, e.g., the Shanghai ranking), rankings of universities' third stream activities, such as their inventive productivity, are less developed. The University Multirank (Etzkowitz, 2016) and the recently launched ranking of 'The World's Most Innovative Universities' (Tobias Gajilan & Rafferty, 2016)[4] are exceptions. In competition for a top placement in academic rankings, governmental and non-governmental stakeholders worldwide have introduced various measures to evaluate the work performed by higher education institutions (see, e.g., Guthrie, Krapel, Lichten and Wooding 2016). However, as discussed below, there are several challenges with underlying ranking measures (van Raan, 2005).

Traditionally, evaluation frameworks have relied heavily on bibliometrics, such as publications and publication citations, to measure scientific productivity or academic impact. However, the use of publications has raised concerns regarding their capacity to capture the breadth of the different activities underlying the three main university missions: education, research and university-society interaction. For instance, it is suggested that the heavy reliance on scientific publications in university rankings, resource allocation and career development contributes to misalignment between universities' different objectives (Benner & Sörlin, 2015; Sanberg et al., 2014).

Another challenge is that different groups, such as faculty members and university managers, may have different views of how to shape academic work to respond to policy changes (Lockett et al., 2015). As reiterated in the research evaluation literature, the introduction of evaluation measures in academia risks steering research activities in undesirable directions; the problem of proxies becomes end goals (Langford et al. 2006, Molas-Gallart and Castro-Martiez 2007). It has been argued that the use of standardized evaluation criteria related to publication fails to appropriately consider the differing circumstances and needs of countries,

[4] There are several established non-university specific regional and international rankings for innovation. Examples include the Global Innovation Index (https://www.globalinnovationindex.org/), the European Innovation Scoreboard and the Bloomberg Innovation Index (https://www.bloomberg.com/news/articles/2017-01-17/sweden-gains-south-korea-reigns-as-world-s-most-innovative-economies).

notably those still undergoing rapid socio-economic change (Rafols, et al., 2016). Another example is that the increased importance of knowledge outputs, such as co-authorships in university research assessment exercises, causes researchers to focus their efforts on the core university undertakings of education and research (Glänzel, 2001; Leydesdorff & Sun, 2009; Persson et al., 2004). A possible consequence of this incentivisation is a drift away from third stream activities (Leydesdorff & Meyer, 2010; Markman et al., 2004).

In attempts to broaden the scope of evaluation to account for various forms of university-society interaction, stakeholders have applied a myriad of measures relating to inputs, activities, outputs, outcomes and impact (Penfield, et al., 2014). One of the areas, which has attracted a lot of attention, concerns the evaluation of faculty members' involvement in academic commercialisation (e.g., patenting and founding spin-offs) and engagement (e.g., consulting, research collaborating) (Perkmann et al., 2015). As testified by various reports and studies, there is no shortage of suggested third stream measures (Guthrie, et al., 2016; Meyer et al., 2014; Meyer & Tang, 2007). Examples include number of patents, licenses and spin-offs[5]. However, in analogy with the criticism directed towards publication-based measures (van Raan, 2005), third stream measures have been criticized for being overly crude representations of invention and patenting processes (Criscuolo, et al., 2015). Further, such measures have been accused of overlooking the broader effects of increased university commercialization (Colyvas et al., 2012) and failing to align with the activities of technology transfer offices (Bubela & Caulfield, 2010).

One methodological concern that scholars highlight is the reliance on technology transfer office data, which only captures collaboration and commercialisation that takes place through university TTOs (Phan & Siegel, 2006). As researchers have been observed to bypass their TTOs independent of IP legislation (Audretsch et al., 2006; Fini, et al., 2010; Markman, et al., 2008), TTO-based evaluations do not provide a complete picture of all invention- and innovation-related activities that university researchers engage in (Perkmann, et al., 2015). The absence of a harmonised European strategy for the development and management of third stream measures has paved the way for various data-gathering initiatives. For instance, the knowledge transfer surveys by the Association of European Science & Technology Transfer Professionals (ASTP) and the European Knowledge Transfer Association (ProTon) are based on annual surveys among selected academic institutions with varying degrees of robustness and comparability (Geuna & Rossi, 2011; Molas-Gallart & Castro-Martínez, 2007). While there have been more systematic efforts to gather technology transfer data in the

[5] Numbers of jobs created, recruitment of graduates or spin-off performance have been suggested as representative *impact* (rather than output) measures, Bölling & Eriksson (2016).

US through AUTM, the underlying statistics also rely on survey methods with inherent reliability issues[6].

Another methodological limitation of third stream measures is the traditionally strong emphasis on count-based measures, such as number of patent applications filed annually (Ernst & Omland, 2011; Fisch et al., 2015). As pointed out previously, patent counts have several inherent limitations (Basberg, 1987; Griliches, 1990; Narin & Breitzman, 1995). For instance, they do not shed light on the technological or commercial value of patents (Ernst & Omland, 2011). Nor do they reveal much about the underlying processes of invention, patenting and commercialisation (Gittelman, 2008b). Indeed, recent research points to a lack of studies that observe what occurs inside an organisation *before* a patent application has been filed (Tanimura, 2015). In one of the few studies that takes this perspective, the conclusion is drawn that the sole use of patent count-based measures can be misleading of an organisation's broader 'innovative capability' (Criscuolo, et al., 2015). The authors argue that managerial decisions preceding patent filing ought to be considered to avoid significant selection sample bias, which has been highlighted by Gittelman (2008b) previously.

Count-based measures have also been criticized for their inability to demonstrate socio-economic impact (Colyvas & Powell, 2009; Grimaldi, et al., 2011). For example, in the field of medicine, the translation from basic research to implementation in health care implementation typically occurs non-linearly over the course of a decade or two (Molas-Gallart et al., 2016). Thus, to capture socio-economic impact, measures need to support long-term evaluation cycles. While there appears to be agreement in the research evaluation literature that socio-economic impact is distinguished from research output, recent work suggests that activities carrying *potential* economic impact could be used as evaluation indicators (Perkmann, et al., 2015). According to Perkmann et al. (2015), consulting and licensing are examples of output or activities that are accompanied by both direct and indirect traceable economic value. They explain that these activities and academics' expertise are examples of how university-originated knowledge 'is made liquid' through the fees and funding that come with such assignments and transactions. However, there are other recent claims that suggest a skewed evaluation focus on activities rather than their impact, due to measurement difficulties (Bölling & Eriksson, 2016).

Despite the criticism of third stream measures outlined above, there are few methodological suggestions on how to improve and complement count-based approaches. Rather, studies propose a general reorientation away from assessment of patent-based knowledge transfer towards evaluation that considers other forms of university-society interaction, including social outreach and student start-ups (Bölling & Eriksson, 2016; Siegel & Wright 2015).

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[6] With a response rate of between 56 and 60%, almost 40% of the surveyed universities are not evaluated. Further, only those universities that have a staff member who is also a member of AUTM are targeted in the annual surveys (email correspondence with Chrys Gwellem at AUTM, January 2017).

While this thesis recognizes that an overly strong focus on patent-based outputs risks favouring universities with proportionally more patenting in national benchmarking (Rossi & Rosli, 2013), it is still argued that existing patent information can be used to construct more meaningful measures of inventive productivity. In other words, patent data can provide more nuanced representations of inventive productivity. As such, it is motivated to explore the thus-far relatively neglected topics of patent quality and patent process in the academic evaluation context.

2.3 REPRESENTATIONS OF PATENT INFORMATION: COUNT, QUALITY AND PROCESS

The value or quality of patents is a highly debated topic in research and business communities, in particular among intellectual property stakeholders (e.g., patent and trademark offices) (Chien, 2017). Previous work argues that patent value could be compartmentalised into value based on 'renewal value' and 'strategic value' (Gambardella et al., 2008). Renewal value, elaborated on below, is equated to the monetary value that a patent applicant pays to maintain a patent over time (Pakes & Schankerman, 1984). The strategic value of a patent is less defined and benefits from being interpreted against contextually-derived parameters (e.g., type of sector) (Gittelman, 2008a). Operationalisations of patent information are rooted in a long research tradition at the intersection of research in economics, management and science policy (Griliches, 1990; Schmookler, 1966; Trajtenberg, 1990). In particular, patent counts and patent citations have been used as measures of 'innovation performance' of organisations, industry sectors and countries (Danguy et al., 2014; Ernst, 2001; Fisch, et al., 2015; Trajtenberg, 1990). The following quote from Griliches (1990) illustrates the embrace of patent data in the study of invention and innovation:

> 'In this desert of data, patent statistics loom up as a mirage of wonderful plenitude and objectivity. They are available, they are by definition related to inventiveness, and they are based on what appears to be an objective and only slowly changing standard.'

While the quote above points to the attraction of patent information, it is widely recognized that the pieces of information contained in a patent ought to be 'handled with care,' as testified by ongoing discussions on the relationship between inventions, patented inventions and innovation (Basberg, 1987; Gittelman, 2008b; Pavitt, 1985). Recent work shows that patent information can only help explain a small part of the value differences between patents (Gambardella, et al., 2008; Gittelman, 2008a). Therefore, the use of patent counts risks under- or overestimating inventive productivity (Narin & Breitzman, 1995). One fundamental question has to do with how these counts are constructed. As the same patent portfolio can be counted based on its patent applications, granted patents or patent families (i.e., inventions), and also in reference to jurisdictions and dates, it is vital to clarify the methodology used (Dernis et al., 2001). In Figure 2, an attempt is made to illustrate how the same root invention may generate multiple records as patent prosecution proceeds. Different treatment of patent counts may have a significant impact in terms of benchmarking and evaluation of patent portfolios (Ernst & Omland, 2011).

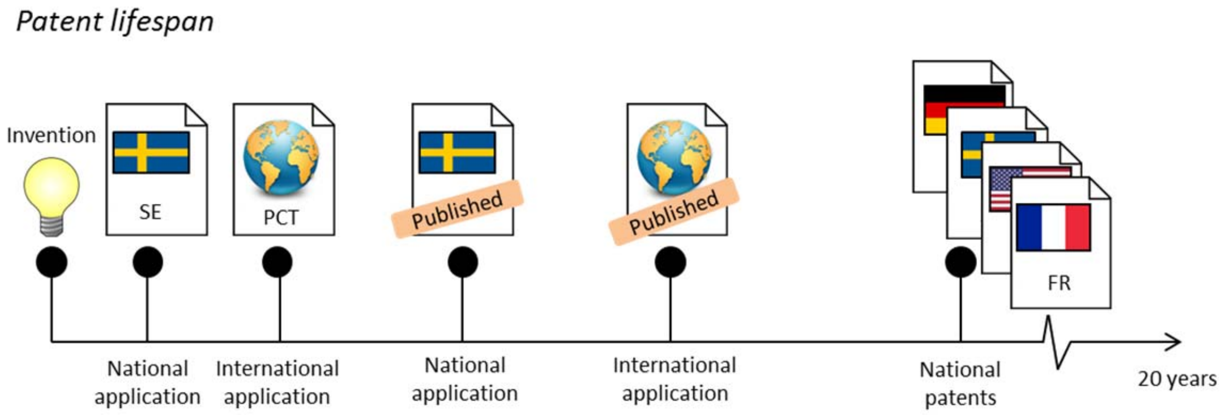

Figure 2 From one root invention to multiple national patents. A national application is filed and followed by the filing of an international patent application; a PCT (patent cooperation treaty) application. Both the national and international patent applications are officially published 18 months after their respective filing. The PCT application then enters 'the national phase', i.e. patents can be obtained in designated countries. This procedure 'patent prosecution' gives rise to multiple patent records.

Patent citations have specifically been used to study knowledge flows among and between researchers, universities and corporations (Van Looy et al., 2007). In comparison to patent counts, it has been inferred that patent citations better reflect the quality of an invention or technology, based on the assumption that the extent of citations a patent has received from another patent gives an indication of value (Hagedoorn & Cloodt, 2003). However, recent evidence indicates that citations do not capture knowledge flows equally. As shown in the study by Roach and Cohen (2013), citations are more suited as measures of knowledge flows originating in scientific publications compared with knowledge transferred in less open ways, such as through contracts or consulting. Further, the authors claim that 'Citations similarly do not reflect the contribution of public research to firms' basic research, perhaps because the outputs of basic research are less likely to be patented relative to those of applied research and development.' In addition, since a majority of citations are added to patent applications by patent examiners and not by inventors or applicants during its prosecution, scholars question if patent citations reflect inventor knowledge (Alcacer & Gittelman, 2006; Alcácer et al., 2009). Furthermore, it cannot be assumed that analysts are able to understand the content and importance of each cited reference (Michel & Bettels, 2001). The recent insights provided by Roach and Cohen (2013) suggest that patent citations, albeit widely applied in the economics, management, and policy literatures, need to be critically assessed before applied in academic evaluation schemes.

Besides patent citations, there are other information components of a patent that have been used to estimate patent quality. Examples include data on assignees (e.g., patent owners) and renewals (here referred to as patents' legal status or patent survival) (Figure 3). Patterns of renewals have been suggested to reveal a patent's quality based on observations showing that greater value can be attributed to long-lived patents compared with short-lived patents (Guellec & van Pottelsberghe de la Potterie, 2000, 2002; Lanjouw et al., 1998; Pakes & Schankerman, 1984). A possible explanation for such evidence has to do with the underlying assumption that assignees choose to maintain (i.e., pay fees for) only those patents they consider strategically important and therefore implicitly of higher quality (Schankerman &

Pakes, 1986). To maintain a granted patent, European assignees have to pay renewal fees annually, while the US renewal fee requires payment at 3.5 years, 7.5 years and 11.5 years post-grant. Since it is the responsibility of the patent assignee to pay these fees, changes of patent assignees can be traced and used to research patent transfer[7]. For instance, if an academic patent is sold to a corporation, the assignee changes from the name of the inventor or the university TTO to the name of the company. In comparison to citations, which to a large extent depend on subjective assessment of external patent examiners (Azagra-Caro et al., 2011), data on assignees and the legal status of patents are generated according to a standardized process, highly interlinked with the formal requirements of the patent and trademark offices to which the patent application has been submitted.

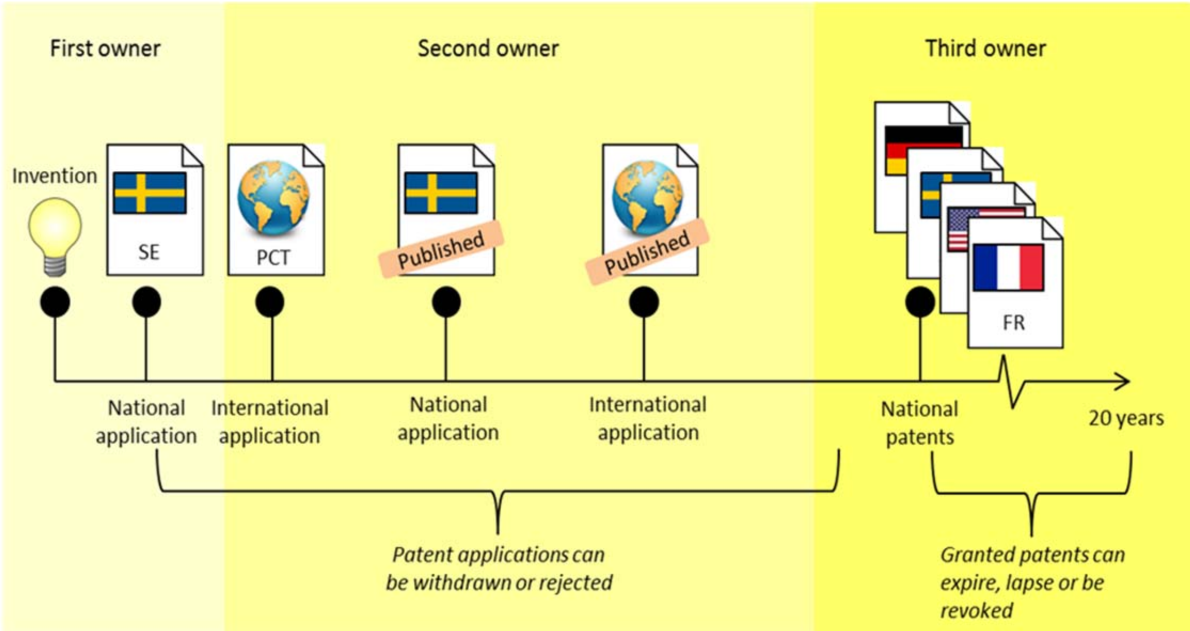

Figure 3 Legal status and ownership changes may occur across the patent lifespan. In previous studies, information about such changes has been applied to estimate patent quality.

Unlike studies in the corporate context that investigate patent transfer (Serrano, 2010) and patent survival (Maurseth, 2005; Svensson, 2013; van Zeebroeck, 2011), there is a scarcity of similar work in the academic context. In particular, how patents are traded between different entities across the patent lifespan has not been traced systematically (for one exception, see Drivas, Economidou, Karamanis and Zank 2016). This thesis stresses the importance of

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[7] It is important to note that assignee data stemming from patent databases of patent offices may vary in quality. Local rules, procedures and organisation of patent offices could explain quality heterogeneity. For example, transfers of European patent applications are only recorded in the European Patent Register 'at the request of an interested party, upon production of documents providing evidence of such transfer' (see Article 71, Rule 22.1 of the EPC (European Patent Convention). In the US, before the year 2012, named inventors were considered owners of a US patent (or the application for the patent). This was changed after Sep 16 2016 so that 'the original applicant is presumed to be the initial owner of an application for an original patent' (see https://www.uspto.gov/web/offices/pac/mpep/s301.html).

extending measures of inventive productivity in time. Thus, analyses of patent survival (**Paper II**) and patent transfer (**Paper III**) fill a gap.

At the same time, the present thesis argues that these approaches are limited in that they rely on underlying assumptions about how patenting is initiated and subsequently managed (Criscuolo, et al., 2015; Tanimura, 2015). As emphasised by Aaboen and Holgersson (2016), aggregate analysis of academic patents and larger inventor populations appear to assume that inventions are selected, patented and subsequently commercialised in a linear systematic fashion. However, emerging work has begun problematizing this notion and has started to explore the heterogeneous landscape of patent processes. By shifting the focus from a quantitative to a qualitative interpretation of these processes, attention has been directed towards inventor behaviour and motivation in academic patenting and commercialisation activities (Fogelberg & Lundqvist, 2012; Jain et al., 2009; Llopis & Azagra-Caro, 2015). Insights from these studies point to the importance of considering faculty heterogeneity beyond the number of patents generated. Similarly, it can be worthwhile to consider heterogeneities in invention and patent management. For instance, recent theory development at the firm level suggests that to understand value creation from patents, investigations of how managerial capabilities (i.e., patent information and patent protection management) influence firm performance are necessary (Ernst et al., 2016).

In contrast to investigations in the corporate setting and at a national level that have begun to explore questions of strategic and organizational nature concerning patenting (Al-Aali & Teece, 2013; Beukel, 2013; Candelin-Palmqvist et al., 2012; Harhoff & Wagner, 2009; Somaya, 2012), there has been much less focus on these issues in the academic setting (Aaboen & Holgersson, 2016). Therefore, this thesis argues that a deeper understanding of invention-related work requires a consideration of both the quantitative and the qualitative aspects of inventive productivity. In particular, it stresses that within-organizational studies at the process level ought to be conducted and used in addition to summative measures, such as patent counts, survival and transfers, for a more complete understanding. In doing so, this thesis attempts to respond to calls for more versatile methods to measure inventive productivity, including longitudinal studies and case-level analysis that originates in primary data (Aaboen & Holgersson, 2016; Candelin-Palmqvist, et al., 2012; Gittelman, 2008b; Tanimura, 2015).

3 METHODOLOGY

This thesis comprises four studies (**Papers I-IV**), of which three are based on quantitative patent information (**Papers I-III**) and one is based on academic inventors' accounts of their involvement and behaviour in patent processes (**Paper IV**). Together, these studies investigate inventive productivity in relation to three dimensions: count, quality and process. The present thesis applies a mixed method approach and uses descriptive, statistical and interview-based methods (Table 2). This chapter outlines the methodological choices in research design, data collection and analysis. It also includes a description of the KIIP (Karolinska Institutet Intellectual Property) project, of which the studies conducted here are a part[8]. In addition, an overview of the different methods of data collection and analysis is included. Methodological considerations end this chapter.

Table 2 Overview of methodology applied in the four papers of the thesis

Paper	Method	Sample	Data source	Analysis	Dimension
I	Quantitative	703 inventions	KIIP database	Descriptive	Count
II	Quantitative, longitudinal	500 patent applications	KIIP database	Statistical	Quality
III	Quantitative, longitudinal	703 inventions	KIIP database	Descriptive	Quality
IV	Qualitative, semi-structured interviews	20 academic inventors	KIIP database, interviews	Iterative content analysis	Process

3.1 RESEARCH DESIGN

3.1.1 The case of Karolinska Institutet

The explicit topic of this thesis is the evaluation of individuals' and organisations' inventive productivity. This requires a study design which allows for a detailed investigation into the research, invention and patent landscape that academic inventors navigate. For this reason, a single faculty medical research university was selected as a site of study (Yin, 1994). Karolinska Institutet (KI) is internationally recognized for its research[9] and also known for awarding the Nobel Prize in Medicine or Physiology through the Nobel Assembly. With one of the largest publically-funded university research budgets in Sweden, it conducts 40% of all academic medical research in the country. The geographical proximity and traditionally close professional ties to the Karolinska University Hospital makes KI a fruitful setting to pursue

8 For more information about the KIIP project, see www.kiip.se

9 In the latest Shanghai ranking, Karolinska Institutet ranked no. 12 out of the top 200 medical research (see Academic Ranking of World Universities, http://www.shanghairanking.com/ARWU2016.html).

projects in the nexus of clinical research and basic science. One example of the strong connection between the university and the university hospital are employees with double-affiliation, e.g., physician-scientists (Ley & Rosenberg, 2005). Since medical research universities have been shown to account for a majority of invention disclosures generated in the academic context (Mowery & Ziedonis, 2002), KI offers an interesting context to study life science inventions and inventors. Besides its critical mass in the life sciences, another reason for the choice of KI has to do with the Swedish policy context in terms of the university intellectual property rights (IPR) legislation[10]. Regulated in Swedish law since 1949, academic scientists own the intellectual property rights to any patentable invention stemming from their research, i.e., ‘inventor-ownership regime.’ Unless otherwise contractually agreed upon, this rule, also referred to as the teachers’ exception, applies to Swedish university scientists at all levels ranging from PhD candidates to professors[11]. It means that each individual scientist can choose if, how and with whom he/she wishes to initiate patenting and commercialisation. The absence of formal requirements to disclose potential inventions opens up the avenue for ‘self-organisation’ and plurality of patenting and commercialisation processes. Therefore, from a research perspective, the case of KI provides insights into a world ‘untouched’ by policy interventions with regards to ownership regimes (compared with Bayh-Dole-like legislation). The possible advantages of an inventor-ownership regime has been argued in recent studies (Kenney & Patton, 2011).

3.2 DATA COLLECTION

3.2.1 The Karolinska Institutet Intellectual Property Research Project

This thesis builds on longitudinal patent data generated in the Karolinska Institutet Intellectual Property (KIIP) project. Conducted at the department for Learning, Informatics, Management and Ethics (LIME), the KIIP project aimed to study outputs, processes and outcomes of invention-related activities originating in the academic setting of KI. Through a methodology that combines semi-automated name-matching and manual work, developed by Charlotta Dahlborg and Danielle Lewensohn between 2011 and 2013, all university inventors, employed 1995-2010, have been identified. Besides information on inventors (e.g., academic position, department, research group etc.), the KIIP project has generated data on patents, technologies and companies (e.g., patent frequency, patent ownership and transfers,

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[10] Italian universities and some other universities globally (e.g., University of Waterloo, Canada) are subject to similar legislation, which means that academics own intellectual property rights to their patented inventions.

[11] For research on legal aspects of the teachers’ exception (also referred to as the professors’ privilege), see, e.g., Wolk (2003).

spin-offs, geographical distribution of owners, patent legal status information, collaborations and networks etc.).

3.2.2 Identification of academic inventors

Despite the last two decades' heavy digitalisation of patent information at most patent and trademark offices around the world, the need to clean, normalise and organise the data for research and evaluation purposes remains. Patent data management is particularly challenging when it comes to academic inventions, since there is no comprehensive ready-made source of academic inventors. One of the most difficult aspects is identifying those researchers within a faculty who are named as inventors on patent applications. Efforts to gather data on academic inventors and associated patents vary. While academic inventors in the US and most other countries are obliged to disclose their inventions to the university, research shows that TTOs are often bypassed by scientists (Aldridge & Audretsch, 2011; Fini, et al., 2010). Instead of disclosing inventions to the university, researchers patent through industry collaboration or on their own. Thus, any identification of those inventors who have utilized the services of a university TTO will most likely represent an underestimation of the actual number of academic inventors. As pointed out above in section 2.2, in countries where data collection on academic inventors relies on surveys, there is an inherent risk of underestimated invention disclosure and associated patents. To avoid survey reliability issues due to for example low response rates, researchers and other organisations have developed alternative methods to identify academic inventors (Figure 4).

One such method is to generate inventor data from public or private patent databases. This can be done by searching for the name of a specific university or the academic titles (e.g., Prof). The latter approach has been utilized in particular to collect data on German academics (Dornbusch et al. 2013). It is also possible to match faculty name lists with public patent databases (Thursby et al. 2009, Lissoni et al. 2008, 2009). A third approach is to match scientific author information with inventor data. Additionally, as shown in the work by Ejermo (2011), one way to identify academic inventors is through matching of citizen ID number (i.e., Swedish 'personnummer') with patent data (i.e., EPO address data) and university employee register (Integrated Database for Labor Market Research).

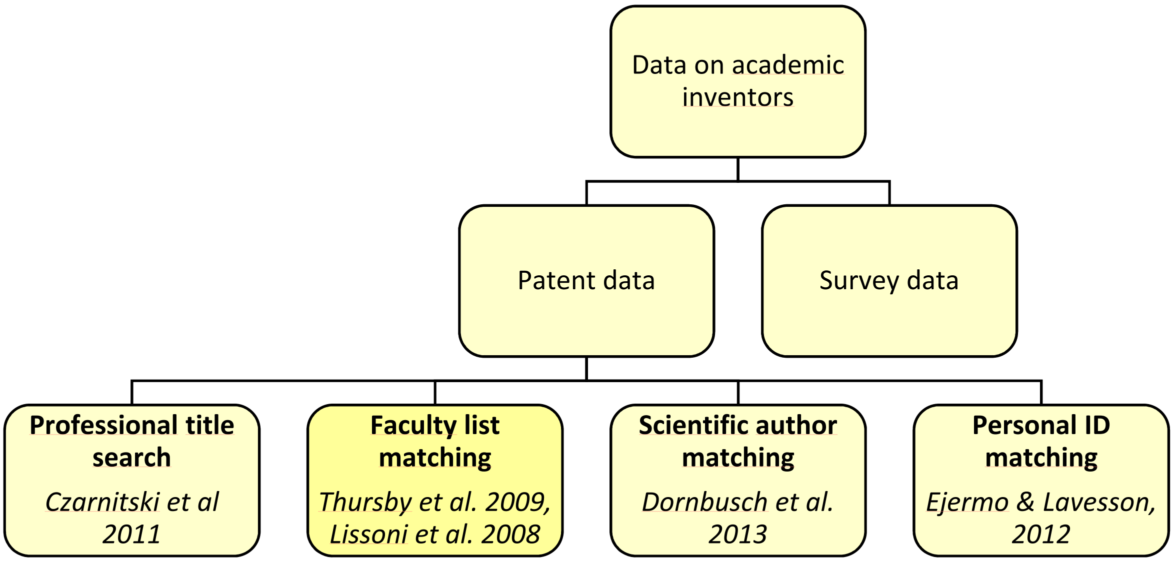

Figure 4 Academic inventors have been identified through survey or patent data. In the present thesis, 'faculty list matching' was applied.

As pointed out by Dornbusch et al. (2013), there are limitations with all of these approaches. Depending on the dataset, there are different validation methods available, including comparing retrieved results with inventor surveys or lists of university names (Dornbusch et al. 2013). However, since this thesis concerns a Swedish university, where a majority of academic patents are owned by companies and not the university (Dahlborg et al. 2016), the latter approach was not deemed useful. Rather, manual validation had to be carried out as explained in section 3.2.5 below.

3.2.3 The Karolinska Institutet Intellectual Property database

In order to study academic invention and inventors at Karolinska Institutet, a novel database, the KIIP database, was constructed. There have been previous efforts to identify Swedish academic inventors and their patents through the work of Lissoni et al. (2008) and Ejermo and Lavesson (2012). However, the part of the KEINS database that covers Swedish inventors does not contain any data after 2004. Another drawback is that it excludes information on PhD students. The data collected by Ejermo and Lavesson covers the time period 2001-2007. In addition, as pointed out by Ejermo (2012), there were some difficulties in identifying inventors, particularly from Uppsala University and Karolinska Institutet. The reason for that was that some of them had written the address of their university in the patent application, rather than their own home address. Since Ejermo's method depended on inventor address information, this had implications for the final sample. Additionally, neither of the above-referenced databases contains multijurisdictional patent data.

As this thesis included longitudinal analysis (specifically in **Paper II** and **Paper III**), it was of interest to cover as long a time period as possible with a maximum of twenty years (max patent lifespan). In addition, it was deemed interesting to cover the year when the university technology transfer office was first established, namely 1995. Therefore, at the time of the initiation of the KIIP project (2011), it was decided to identify all KI inventors between 1995 and 2010. As pointed out in **Paper I** (page 112), publication of patent applications occurs 18 months after patent filing. Therefore, only those patent applications filed between January 1st 1995 and November 9th 2009 were included in the dataset.

While the systematic process in constructing the KIIP database is explained in **Paper I**, it is considered worthwhile to describe some of the main steps and include additional details of importance for the appended papers. Also, methodological considerations relevant for this thesis are outlined below. The main steps in the construction of the KIIP database are outlined in Figure 5.

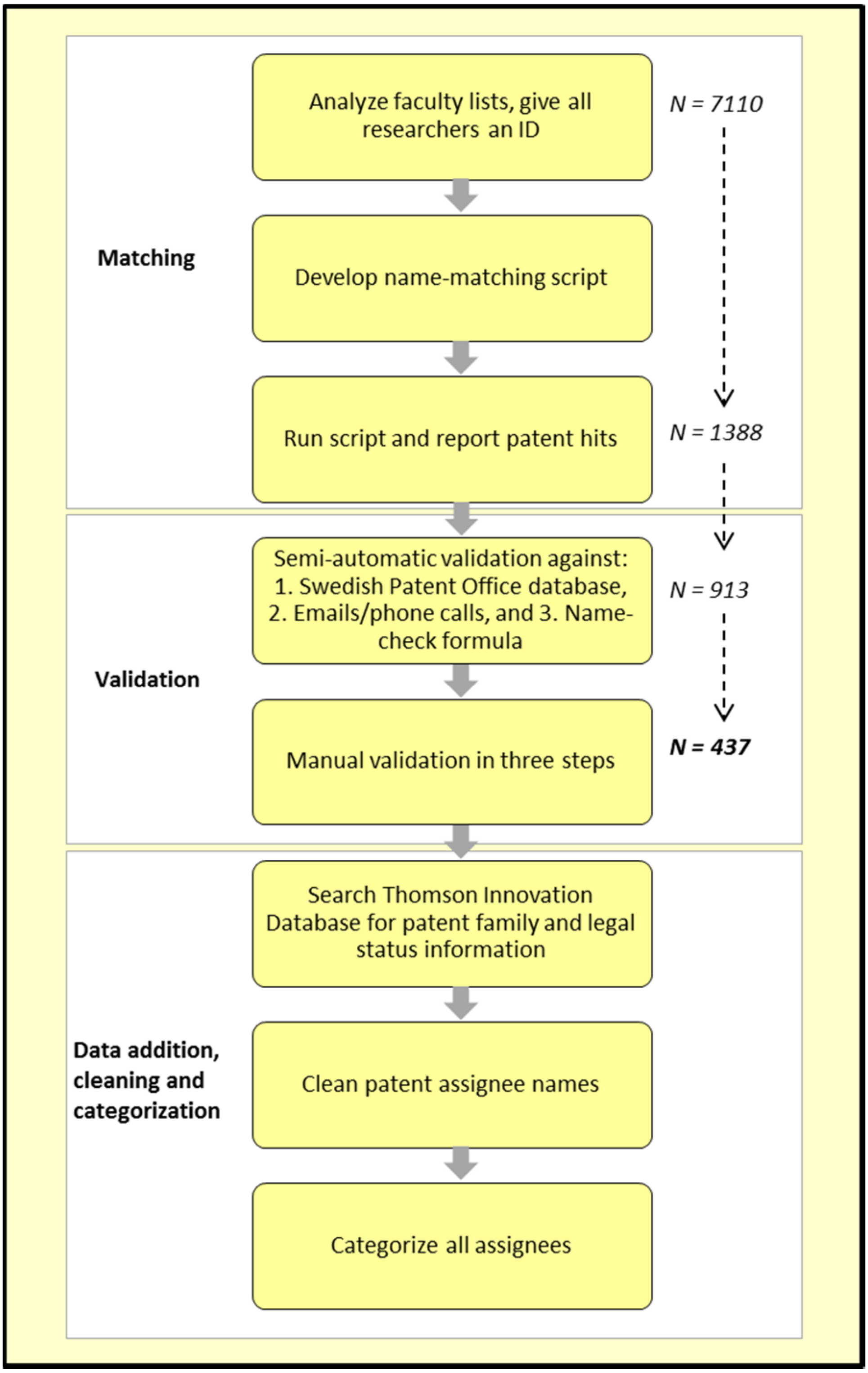

Figure 5 The main steps involved in developing the KIIP database: matching (1), validation (2) and data addition, cleaning and categorization (3)

3.2.4 Name-matching

The initial criteria applied to identify KI inventors were (1) that they were employed at any time between 1995 and 2010, and (2) that they had generated at least one invention (i.e., being named as inventor on at least one patent application). The first step was to go through university employee lists, made accessible for research purposes. In contrast to the work by Lissoni et al. (2008), there were no restrictions in terms of title or career stage in construction of KIIP. That meant that only administrative staff was excluded from the list. Each researcher was given a 'Researcher ID.' In total 7110 researchers were identified.

The next main task was to develop scripts that could search for inventors and identify patents automatically. For the purpose of the KIIP research project, we were able to access the private database Innography©, which allowed for searches in multiple jurisdictions (e.g., US, EP, JP, SE, KR). The initial script would search for a researcher's name in the 'inventor' field in the Innography© database. The script used in the search for inventors would also take the time of employment into account. Thus, the date in the 'priority date' field in the Innography© database had to fall between the start and leave dates of a particular researcher. Note that only those researchers whose start and leave dates fell anytime between 1st Jan 1995 and 31st Dec 2010 were investigated in this thesis. A hypothetical example of an inventor who ultimately would be considered a match could have been employed at KI between 1997 and 2003 and filed a patent application in the year 2002.

In terms of researchers' names, the search script considered middle names and the unique Swedish characters å, ä and ö, which are common in Swedish names and surnames. As discussed in **Paper** I, there was a need to 'replace' these letters with how they are written in official patent documents (see **Paper** I, page 108, Table 4). Once an inventor match was made, the script would report the number of patents the inventor had generated. The automated search generated 1,388 inventors who were each given an 'Inventor ID.'

3.2.5 Validation

The 1,388 identified inventors were split into two groups. The first group contained 131 inventors with 150 patent hits or more. The other group contained 1,257 inventors. A majority of the inventors in the first group could be excluded as KI inventors after checks against the Swedish Patent Office database. However, a few of them had to be validated through direct contacts via email or phone calls. To identify false positives in the second group, a 'name check formula' was applied (described in **Paper I,** pages 108-109). This step left 1,032 inventors who had not yet been validated. We were able to contact about a third of these via email to confirm whether they fulfilled our criteria to be identified as KI inventors.

The last main step in developing the KIIP database was to manually validate the remaining 913 inventors through desktop research or direct contact by email or phone. It was necessary to do so due to the existence of 1) name misspellings and 2) common Swedish and Asian names. As pointed out in **Paper I** (page 109), there were examples of identified KI inventors who shared their name with other inventors. To clarify whether the sample of 913 inventors had any false positives, a validation procedure was developed (Figure 6). A first step was to check the inventor's patent application for assignee, IPC class, title, abstract and claims. For example, if data on claims, IPC classes and assignees clearly indicated that the inventor was active in a field completely unrelated to life sciences, the inventor was considered a non-KI inventor. If this approach was deemed not sufficient in determining actual KI inventors, a second step involved searching the background of co-inventors in scientific and other sources. A third approach was to consult patent documents to find inventors' nationality and address information. In many cases, all three steps were necessary to exclude false positives. The manual validation was documented in the KIIP database (in Microsoft Access) by marking which researcher performed the validation and whether the inventor was deemed a true or false positive (**Paper I**, page 110, Table 6). Since we retrieved patents in multiple jurisdictions, we developed an automated approach to validate all patent family members at once. This method was only applicable if a patent family contained a SE, US, EP or WO record. The manual validation gave a total of 437 academic KI inventors with associated patent data. Important to note is that the 437 inventors corresponded to 6,010 patent records. However, the occurrence of co-inventorship meant that the sample contained 4,176 unique patent records.

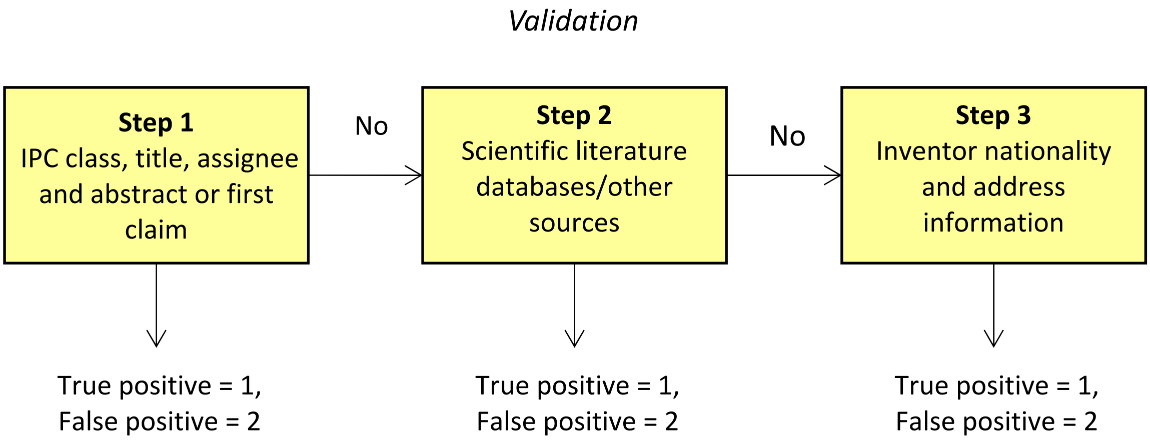

Figure 6 The three-step procedure used to validate inventor names in the development of the KIIP database

3.2.6 Data addition, cleaning and categorisation

Since the patent data retrieved from Innography© did not contain any details on patent families or patent legal status, we searched the Thomson Innovation® database. The search was done by applying publication numbers and generated a link between the 4,176 previously retrieved patent records and 703 patent families. In this thesis, the definition of patent family corresponds to the concept of 'an INPADOC patent family' (see **Paper I**, page 106). Additionally, legal status information used in the analysis in **Paper II** was also generated in this step. Legal status data can be used to assess to what point in the patent lifespan a patent application or a granted patent has progressed. According to WIPO[12] such data are used to determine whether:

- examination of a patent application is still pending;
- the application has been withdrawn or was rejected;
- a patent has been granted and is still valid; or
- a granted patent has expired, lapsed or been revoked.

Information on patent owners was retrieved from each patent record through the assignee field in patent records. As pointed out earlier in this thesis, an effect of the teachers' exception is that the owner of a university-originated patent may be a company, the university TTO, another organisation or the inventor him-/herself. Much like in the case of inventor names, patent assignee names had to be controlled for spelling mistakes. For the purpose of **Paper III**, in which patent ownership transfer was investigated, it was particularly important to ensure that corporate names were cleaned. As exemplified in the **Paper III** (Section 3.3.1) companies such as AstraZeneca Ltd. and AstraZeneca Inc. were clustered into the same group (AstraZeneca). In addition to normalising and correcting assignee names from spelling mistakes, we searched for and analysed company-related information such as type, size and age. As a result, we were able to categorise all assignees as outlined in **Paper III**, page 11, Table 1. In this thesis, joint patent ownership is not investigated in detail, based on two arguments. First, joint patent ownership constitutes a very small fraction as compared with single ownership (Hicks & Hegde, 2005). Second, companies tend to avoid co-owning patents with others, due to difficulties in managing shared IP (Hagedoorn, 2003). In this context, it is worthwhile noting that joint inventorship does not equal joint ownership. Given the collaborative nature of academic research, joint invention is most likely more common than joint ownership. For a discussion on joint patents, see Kim and Song (2007).

3.2.7 Interviews

To further probe the matter of how to understand and measure academic invention, **Paper IV** differs methodologically from the three previous papers. Given the relatively less studied issue of inventor behaviour in patent processes, the focus in **Paper IV** was to get a better understanding of how such processes are initiated and subsequently managed. As shown in **Paper III**, a majority of the academic patented inventions (71%) were transferred to companies. The TTO was much less frequently involved in patent processes, as indicated by the longitudinal tracing of patent transfers. Based on these insights and following the reasoning of Göktepe (2008), who claims that 'inventors cannot be isolated from the environments in which they are living and working' it was considered suitable to interview a selection of academic inventors about their involvement in the patent processes.

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[12] See http://www.wipo.int/patentscope/en/programs/legal_status/.

Inventors were selected from the KIIP database with a consideration of their previous invention experience (i.e., number of inventions), academic position, and gender. An effort was made to cover as many of the 22 research departments as possible. In Table 3, the distribution of researchers and inventors is outlined. Similar to previously observed inventor distributions in both corporate and academic settings (Narin & Breitzman, 1995; Wallmark, 1997), the distribution of inventors in terms of number of inventions generated was skewed (see **Paper IV**, Appendix 1). Moreover, approximately half of all inventions were generated by 35 inventors. The greater part of the faculty had made one or two patented inventions during the investigated time period. In line with Göktepe (2008), this latter group was referred to as occasional inventors and defined as having less than three patents (representing one invention). Inventors with three or more patents were labelled serial inventors. Among the final selected sample of 20 inventors, eleven ended up in the 'occasional' category and nine were defined as serial inventors.

Table 3 The inventor population represents about 6% of the full researcher population

Research population distribution	Number of researchers	Percent of all researchers
All researchers	7110	100 %
Non-inventors	6673	94 %
Inventors	437	6 %
Occasional inventors	337	4,7 %
Serial inventors	100	1,4 %
Inventors responsible for half of patented inventions	35	0,05 %

The interviews were semi-structured, lasted between 40 and 120 minutes and were conducted between September 2015 and June 2016. To learn about the activities surrounding the filing and management of a patent application, each interviewee was asked about his/her experiences related to a specific patent case. This approach required preparation of each interview in terms of information extracted both from the KIIP database and from *espacenet* (the European Patent Office database). While the questions followed an open-ended format, all interviewees were initially asked 'how patenting became a topic in their own research processes'. The interviews were digitally recorded and afterwards transcribed.

3.3 DATA ANALYSIS

3.3.1 Longitudinal analysis of patent survival and transfer

Patents only provide legal protection as long as they are maintained. This means that patent owners are required to pay the initial and subsequent time-specified fees to keep their monopoly rights. To analyse patent survival or patent lifespan in **Paper II**, European patent (EP) applications were selected from the KIIP database and analysed using statistical methods. The main reason for the selection of EP applications as the unit of analysis was that we had access (via Thomson Reuters©) to the legal status information of EP records. The selected EP applications (N = 500) represented 57% of all patent families in the dataset (404/703). As explained in **Paper II**, patent survival was calculated using SRA (Single Renewal Approach). Following van Zeebroeck (2011), this method involved calculating the time between the birth of the patent application and the latest legal status date (here referred to as event or patent survival). The latter date means that patent protection is terminated, for example due to a lapse or withdrawal of a patent application or a patent. The longest time period covered was 18 years. Importantly, the sample contained both pending patent applications and granted patents (see **Paper II**, page 8, Figure 4).

In order to test if the theoretically-derived independent variables affected patent lifespan, a multivariable statistical treatment was conducted, divided into three major steps: Kaplan-Meier analysis (Rich et al., 2010), Cox proportional regression (Fox, 2002; Neely et al., 2013) and a sensitivity analysis of the latter. These methods were deemed suitable since the sample included data on lifespan. In particular, it was important to account for the difference in exposure time among the patent applications in the sample. The first step was to apply Kaplan-Meier analysis, as it takes such differences into account in comparing duration of survival (Figure 7). Kaplan-Meier analysis was helpful in estimating the statistical significance of the influence of the independent variables (one variable at a time) on patent lifespan. The second step was to investigate the impact of multiple variables on a moving target (time-to-event) through Cox proportional regression analysis (Cox analysis). This method generates an estimate of the hazard ratio (HR), which indicates the probability of survival for each of the examined variables. As stated in **Paper II**: 'A decreasing HR indicates higher probability of survival and vice versa.' The third step involved a sensitivity analysis, where Cox analysis was applied with (Model II) and without (Model I) the so-called 'Granted factor.' The aim of adding the factor was to explore how information on whether patent applications had been granted or not affected the results. SPSS and STATA software were used in the analyses in **Paper II**.

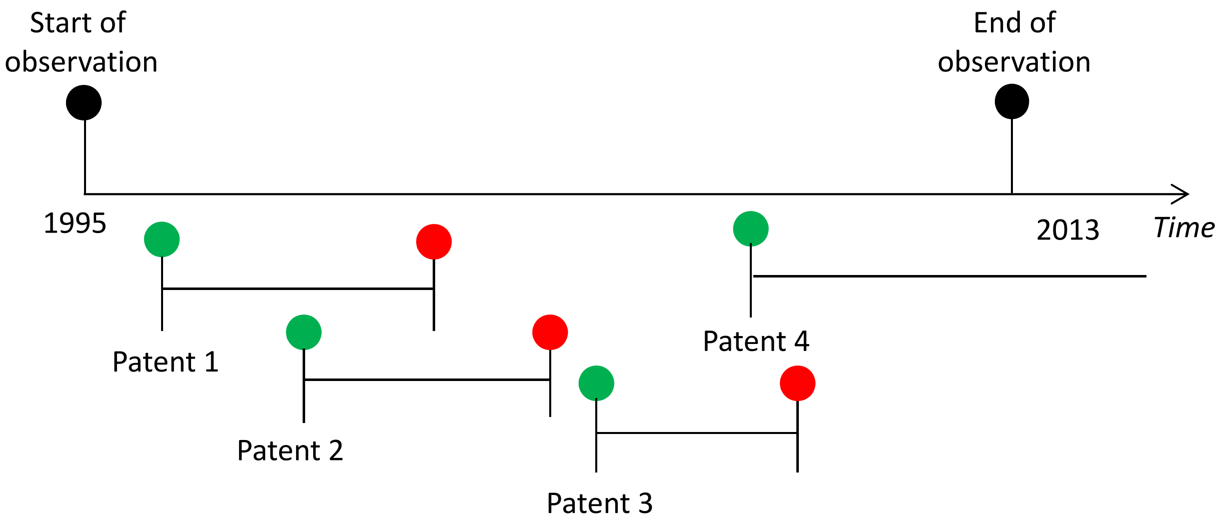

Figure 7 illustrates the 'births' (green) and 'deaths' (red) of patent applications in the sample. Note that patent applications may be born and may die at different time points during the overall observation period (1995-2013).

As in **Paper II**, patents were analysed longitudinally in **Paper III**. To trace changes in patent ownership, analysis of assignee changes within each of the 703 patent families were conducted. The patent owners analysed here were listed in Table 2 in Section 4.2 in **Paper III**. Through KIIP, there is information on patent owners at three time points; *t0, t1* and *t2.*

The two latter time points represent the owner at the filing of the patent application (anytime between 1995 and 2010) and at the time of data download (2011). As discussed in **Paper III**, the academic inventor is assumed to own the patent at the time of invention or *t0*. Since the purpose of **Paper III** was to observe patent transfers that may have occurred across a maximum time period of 15 years, the earliest and latest published patent records in each patent family were selected. The assignees in each document were analysed at the three time points (Figure 8).This was repeated for all 703 patent families. In addition, it was examined if there had been any changes within the assignee types MNCs and SMEs between *t1* and *t2*. The sample contained patent applications with priority dates ranging between 1995 and 2010. Consequently, the exposure to plausible patent transfers within the same patent family varied between 1.5 and 15 years.

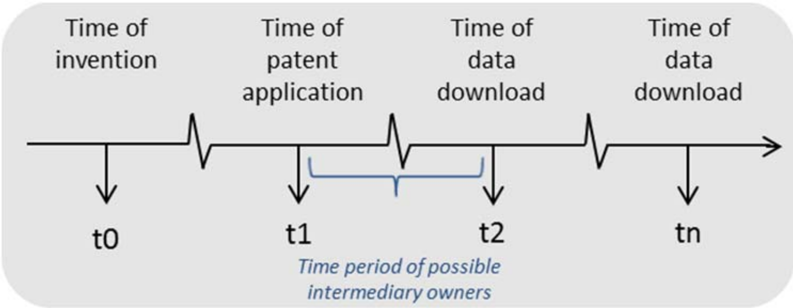

Figure 8 Method for analysing patent ownership changes over time. Ownership information at the events t0, t1and t2 provide the empirical foundation of the analysis in Paper III (Dahlborg et al., 2016).

3.3.2 Iterative content analysis of semi-structured qualitative data

The 20 interviews represented interviewees' reflections of their patent processes. All interviews were conducted using a common semi-structured interview guide (see **Paper IV**, Appendix 2). Despite these efforts to systematically structure interviewees' accounts in a comparable manner, there were some challenges with 'steering' the interviewee to discuss one invention at a time. This was most notable in interviews with serial inventors. As a consequence, one of the first steps was to map each patent process discussed and chronologically plot related activities. At the same time, each patent process discussed was coded as Patent 1, Patent 2 and Patent 3 etc. in NVivo (version 9). After this initial coding, the interviews were treated in accordance with conventional content analysis, in which codes and analysis are developed concurrently (Hsieh & Shannon, 2005). Coding was carried out in multiple steps by the first author and to increase its validity, codes suggested by the first author were iteratively discussed within the author group. The manuscript was further scrutinized by four senior researchers outside the author group at a seminar.

3.4 METHODOLOGICAL CONSIDERATIONS

The empirical focus on one single faculty university potentially limits the generalizability of the findings to other academic settings. In particular, since the investigated patents and inventors emerge and operate in a life science-oriented ecosystem, some findings must be interpreted in this context. However, since researchers in the life sciences have been shown to have a higher tendency to patent (Stephan et al., 2007) and to be more active in commercialization of research results (Owen-Smith & Powell, 2001), compared with scientists in other disciplines, the choice to investigate a medical research university was deemed appropriate. A related argument supporting the selection of this specific case is that almost half of the national government funded research budget is allocated solely to Karolinska Institutet, meaning that it represents a large part of Sweden's academic scientific productivity within life science. Furthermore, its size and scientific rank provides a basis for comparison with existing single-university case-based approaches (Bercovitz & Feldman, 2008; Göktepe, 2008; Stephan, et al., 2007; Wallmark, 1997).

To study academic invention solely through the lens of patent information has its limitations. Firstly, patenting is one of many sources of university-originated invention. By looking at patent data, only those inventions that are patented are captured (Figure 9). In the life science field in particular, it can be difficult to separate knowledge, accumulated over time and across multiple processes, into independent elements of patentable inventions (Hagedoorn, 2003). Therefore, patents do not constitute all inventions made at the university. Secondly, not all researchers are inventors. For instance, as shown in the present thesis and in other studies, less than 10% of the overall faculty members are named inventors (Dahlborg et al., 2013; Lissoni, et al., 2008). Thirdly, patents do not necessarily translate into products and services (Walsh et al., 2016). Still, the combination of being aware of the inherent limitations that patent data have and also exploring non-patent data supports the methodological choices made in this thesis. In particular, the application of a longitudinal perspective through patent survival and patent transfer analyses allows for systematic analyses that meet the shortcomings of patent count-related measures. In addition, the mix of quantitative data with semi-structured interviews increases methodological credibility and overall understanding of invention output and underlying processes.

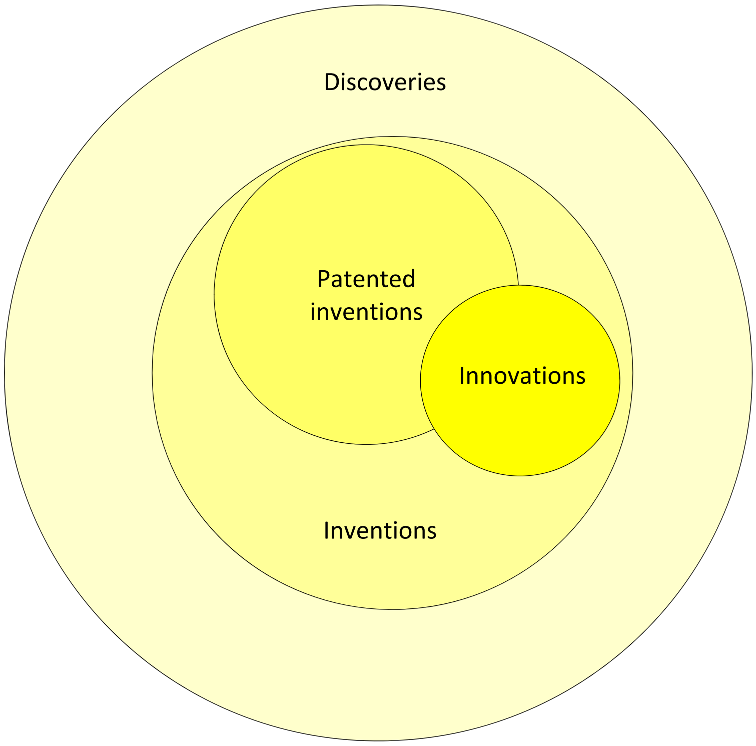

Figure 9 Adaptation from Basberg (1987). A schematic outline of the relation between discoveries, inventions, patented inventions and innovations.

4 RESULTS: MEASURING MULTIPLE DIMENSIONS OF INVENTIVE PRODUCTIVITY

This thesis demonstrates how inventive productivity can be represented against multiple dimensions, specifically count, quality and process. In this chapter, the main results in the four appended papers are discussed.

4.1 PAPER I

Paper I – *Investigating inventive productivity at Sweden's largest medical university* – is an effort to show that inventive productivity can be measured in terms of numbers of patents or inventions distributed across different organizational levels (i.e., the overall research population, departments and individual researchers). It addresses the numerical relationship between inventions and patents[13] and demonstrates that the same dataset of academic patents can generate different numerical outputs (Table 4).

Table 4 The same dataset can generate different numerical outputs Dahlborg et al. (2013)

No. of patent records	No. of KIIP-selected patents	No. of inventions
4,176	3,313	703

To highlight these output differences with regard to patent vs. invention counts, a count-logic, referred to as the KIIP selection, is introduced. The argument behind this approach is that selecting certain patent records in a patent family to represent one invention, rather than counting every single patent record generated from a root invention, can help mediate the risk of overestimating inventive productivity. In line with Dernis et al. (2001), **Paper I** stresses the importance of 'standardizing' the representation of a patent family to a maximum of one patent application and one granted patent per jurisdiction. The differences in counts between an invention represented by *numerous* patent records generated in communication with patent offices versus an invention represented by a *selected* number of patents and patent applications are illustrated in **Paper I**, page 111, Table 7.

Building on the relationship between inventions and patents, two alternative ways to represent inventive productivity are proposed: *faculty patenting* and *inventor productivity*. Results show that 6% of the faculty have at least one invention, which means that there is one invention produced per ten faculty members (703/7110). In terms of *inventor productivity*, our results show that the 703 identified inventions were generated by 2,276 inventors. This means that on average three inventors were involved in each invention[14]. Furthermore, the results show that inventor productivity distribution is highly skewed within the pool of

[13] "Patents" is used here to refer to both patents and patent applications.

[14] Less than 20% (437) of all 2276 inventors have a KI-affiliation, which means that 80% of the inventors are external (e.g. affiliated to another research organisation or a company).

inventors, with 50% of all inventions originating from 35 inventors (Figure 10). **Paper I** also exemplifies how different results for *inventor productivity* are obtained when the KIIP selection logic is applied (see **Paper I**, pages 114-115, Table 9, 10 and 11).

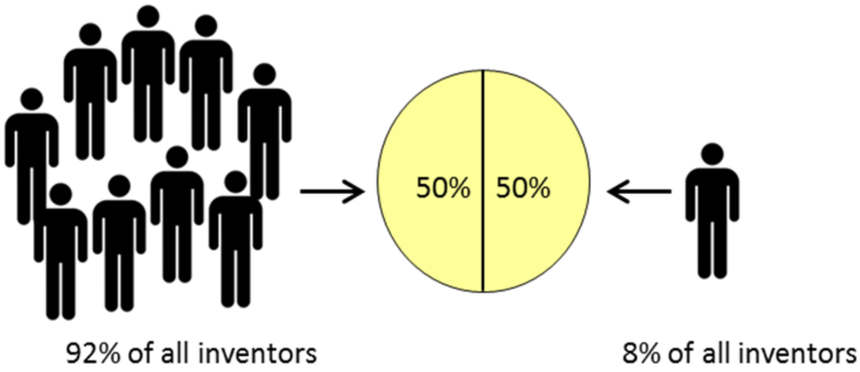

Figure 10 8% of all inventors have generated the same amount of inventions as the larger majority (92%).

4.2 PAPER II

Paper II – *Applying patent survival analysis in the academic context* – investigates the temporal dimension of inventive productivity through a study of patent application lifespan. At the time of analysis (Autumn 2013), more than one third of the sample of EP patent applications were granted. However, only 23% of these granted applications were 'alive.' Among the non-granted applications, 46% were not in force, which indicates that they were abandoned before a decision on grant was made. These results are in line with previous studies, indicating that up to 50% of all patents lapse without being renewed (Gittelman, 2008a). A possible explanation as to why more than 75% of the granted patents are not in force may be related to how owners of academic patents view the possibilities to use their patents strategically. Large portions of the investigated sample of inventions are owned by SMEs (61%), the university TTO (6%), other research organisations (4%) and individual inventors (11%). Thus, resource constraints and a plausible lack of strategic patent management skills could explain why the majority of the absorbed university patent applications are not maintained. **Paper II** also analysed how a selected number of variables influenced patent survival. The results showed that differences in patent lifespan correlated to patent, inventor, and assignee characteristics (Tables 5 and 6). The findings on patent characteristics, such as patent citations and patent family size, resonate with results in previous literature. However, the statistical analysis cannot in itself provide explanations for some less intuitive findings regarding inventor and assignee characteristics. For example, it is not clear why patent applications from solely internal university inventors would have a higher probability of survival than patent applications from a mix of inventors. Similarly, it is unclear why patents assigned to university inventors are maintained longer than patents assigned to a company. Unlike the situation in Japan, where government-related patents (e.g., academic patents) are exempted from patent fees and maintained almost the full patent life cycle (Goto & Motohashi, 2007), Swedish academic inventors are responsible to cover any patent fees.

Table 5 Results for multivariate Cox proportional hazard regression, Model I estimating patent survival. Exp(B) is the hazard ratio (HR) with the corresponding 95% confidence interval (CI). Significance at 5% level. Pseudo R-square: 0.403 Lewensohn et al. (2015)

Model I	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI	
							Lower	Upper
PATENT CHARACTERISTICS								
No. of backward citations to patents			15.37	2	.00			
0						1.00		
1-4	-0.35	0.14	6.47	1	0.01	0.70	0.54	0.92
5+	-0.85	0.23	13.10	1	0.00	0.43	0.27	0.68
No. of forward citations			19.16	2	.00			
0-4						1.00		
5-10	-.25	.16	2.42	1	.12	.78	.57	1.07
11-20	-.71	.16	19.15	1	.00	.49	.36	.68
No. of claims			7.87	3	0.05			
1-15						1.00		
16-50	.32	0.14	5.22	1	0.02	1.38	1.05	1.82
51+	.54	0.25	4.89	1	0.03	1.72	1.06	2.79
Missing	.31	0.20	2.54	1	0.11	1.37	0.93	2.02
Patent family size			38.90	2	.000			
1-5						1.00		
6-10	-.23	.18	1.56	1	.21	.80	.56	1.14
11-20	-1.11	.22	26.24	1	.00	.33	.22	.51
INVENTOR CHARACTERISTICS								
Internal university inventor proportion			6.27	2	.04			
Mix						1.00		
Only KI	.37	.15	5.89	1	.02	.69	.51	.93
ASSIGNEE CHARACTERISTICS								
No. of assignees								
0 (one)						1.00		
1 (multiple)	0.41	0.21	4.03	1	0.04	1.51	1.01	2.26
Assignees' market proximity			21.01	5	0.00			
Individual						1.00		
University spin-off	0.92	0.31	8.80	1	0.00	2.50	1.36	4.59
SME	1.26	0.31	17.02	1	0.00	3.52	1.94	6.40
MNC	1.23	0.33	13.64	1	0.00	3.43	1.78	6.60
University TTO	0.89	0.36	5.95	1	0.01	2.43	1.19	4.95
Research organisation	0.79	0.33	5.92	1	0.01	2.21	1.17	4.19

Table 6 Results for multivariate Cox proportional hazard regression, Model II estimating patent survival including factor "granted". Exp(B) is the hazard ratio (HR) with the corresponding 95% confidence interval (CI). Significance at 5% level. Pseudo R-square:0.493 Lewensohn et al. (2015)

Model II	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI	
							Lower	Upper
PATENT CHARACTERISTICS								
No. of backward citations to non-patent documents						1.00		
0	0.17	0.19	0.79	1	0.37	1.18	0.82	1.72
1-4	-0.22	0.22	0.99	1	0.32	0.80	0.52	1.24
5+			20.33	5	0.00			
No. of forward citations						1.00		
0-4	-0.42	0.16	6.46	1	0.01	0.66	0.48	0.91
5-10	-1.07	0.18	37.25	1	0.00	0.34	0.24	0.48
11-20			6.42	2	0.04			
Patent family size						1.00		
1-5	0.09	0.17	0.26	1	0.61	1.09	0.78	1.54
6-10	-0.30	0.21	1.98	1	0.16	0.74	0.49	1.13
11-20			37.26	2	0.00			
ASSIGNEE CHARACTERISTICS								
No. of assignees						1.00		
0 (one)	0.48	0.20	5.96	1	0.01	1.61	1.10	2.36
1 (multiple)			5.99	2	0.05			
Assignees' market proximity								
Individual						1.00		
University spin-off	0.67	0.29	5.23	1	0.02	1.95	1.10	3.45
SME	1.06	0.29	13.21	1	0.00	2.88	1.63	5.08
MNC	1.14	0.32	12.71	1	0.00	3.12	1.67	5.84
University TTO	0.96	0.36	7.14	1	0.01	2.62	1.29	5.32
Research organisation	0.66	0.32	4.39	1	0.04	1.94	1.04	3.60
GRANTED FACTOR								
Not granted						1.00		
Granted	-2.04	0.20	108.41	1	0.00	0.13	0.09	0.19

4.3 PAPER III

Paper III – *To invent and let others innovate: a framework of academic patent transfer modes* – investigates how patents are transferred between different parties such as individuals, companies and other organisations. Specifically, the study quantifies the proportion of patents transferred from academic inventors to downstream entities between three points in time. In applying a longitudinal approach, **Paper III** elaborates in part on the findings in **Paper II** regarding patent survival and illustrates how inventive productivity can be operationalized both over time and in relation to ownership. While the results demonstrate the use of multiple transfer routes, there appears to be a 'preference' for using the corporate mode in transferring academic inventions (Figure 11). At the time of our analysis (t2), 71% of all the patents were owned by a corporation; 61% of these patents belonged to an SME. As companies absorb a majority of the academic patents, individual inventors, the technology transfer office and research organisations lose ownership shares in academic inventions between t1 and t2. Given the challenging conditions for individual inventors and TTOs to commercialise academic inventions (elaborated on in **Paper IV**), the observed ownership distributions are not surprising.

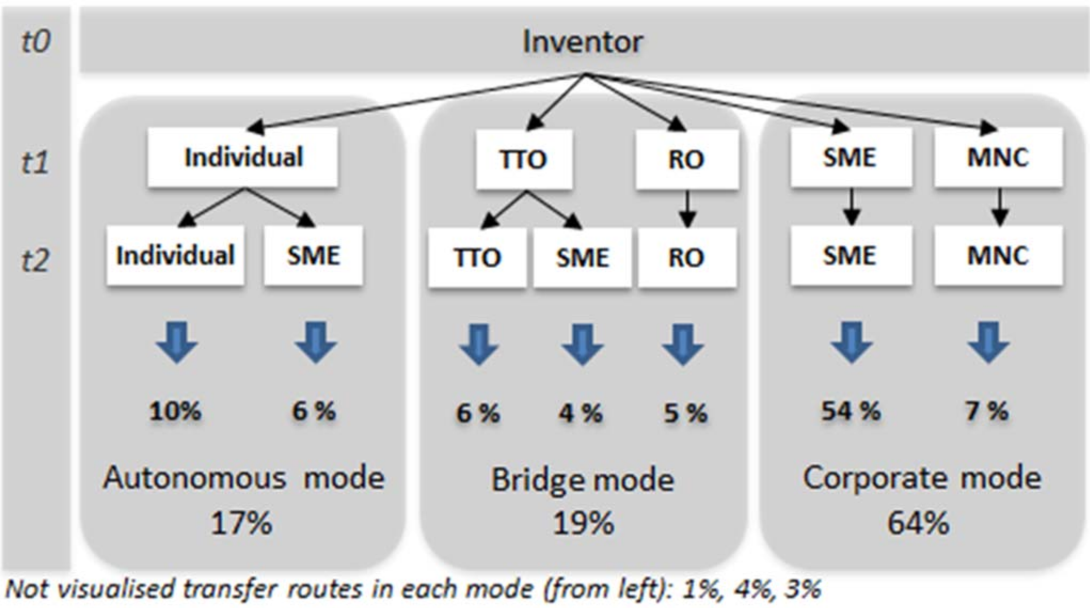

Figure 11 The ABC-framework of academic patent transfer modes illustrating the proportion of patents transferred from inventors at Karolinska Institutet to downstream entities (Dahlborg, et al., 2016).

4.4 PAPER IV

Paper IV – *Does productive mean active? Tracing patent processes of occasional and serial academic inventors* – investigates academic inventors and their reported behaviour in patent initiation and subsequent patent management using qualitative data. This study extends the quantitative approach in **Papers I-III** by focusing on the processes through which outputs such as patent applications arise. In line with the rationale presented by Criscuolo et al. (2015), **Paper IV** does not assume that patenting takes place as a linear and sequential process. Rather, the focus of the interviews was to explore how patenting is initiated and how inventors behave in patent initiation. In particular, the study addresses inventor behaviour at the intersection of activity and productivity. To contribute to the overall thesis question of how measurement of inventive productivity can be undertaken, a mix of twenty occasional and serial academic inventors was interviewed in a semi-structured manner. The interviews covered a total of 49 patent processes.

The overall contribution of **Paper IV** centres on the observed heterogeneity of patent processes in terms of 1) how they are initiated and 2) how individual inventors describe their own behaviour in such processes. As explained thoroughly in Section 4.1 of **Paper IV**, patent initiation occurs in three main ways: formally, culturally or spontaneously. Interviewees exemplified how these patent initiation processes were facilitated through networking and prior experience in different research environments (e.g., other universities or in corporate R&D departments). Furthermore, **Paper IV** sheds light on how inventors describe their behaviour in terms of to what extent they take the initiative and assume responsibility for underlying patent process activities. The sampled interviewees gave their accounts of how they were either *active* or *passive* in patent processes activities such as patent drafting or paying for patents. **Paper IV** reveals that whether inventors adopt an active or passive behaviour can vary both between patent processes, and within an individual process (see **Paper IV**, page 24, Table 3). With regards to the latter finding, inventors mentioned cases where a company that initially absorbed the patented invention was no longer interested in pursuing commercialisation, which shifted the responsibility to manage (i.e., maintain) the patent from the company to the academic inventor. The presence of such 'back and forth patent transfers' could serve as an explanation for observations made in **Paper II** indicating that academic inventors 'are better' at maintaining the patents longer than corporate firms. In tracing inventors' experiences of patent processes, it appears that companies 'help' inventors pay for patents, at least for a certain portion of the patent lifetime, thereby prolonging patent survival. Altogether, **Paper IV** concludes that productivity cannot be assumed to equate active behaviour. In summary, the paper suggests a more granular classification of inventors based on behavioural characteristics within the patent process rather than established output measures (e.g. patent or invention counts) of such processes.

5 DISCUSSION

This thesis has used patent information and interview data to investigate academic inventive productivity. Informed by studies that discuss evaluation of third stream activities and the meaning of patent data, it points to the need for analysis of inventive productivity along multiple dimensions. Each of the four stand-alone papers in this thesis suggests alternative ways to evaluate inventive productivity beyond single-period patent count-based measures. Together, these papers contribute to theoretical development and provide implications for universities, governmental bodies and other third-party financiers and policymakers.

5.1 CONTRIBUTIONS TO THEORY DEVELOPMENT AND DIRECTIONS FOR FUTURE RESEARCH

This thesis makes two overarching contributions: one methodological, the other conceptual. First, it speaks to studies that problematize evaluation of third stream activities. Grimaldi et al. (2011) and other scholars have stressed the measurement gaps that exist in studies of academic commercialisation. In particular, they question the capacity of count-based measures to evaluate the quality and impact of academic commercialisation. The present thesis addresses this concern by arguing that inventive productivity can be measured along multiple dimensions. Moreover, it is demonstrated in **Papers II** and **III** that tracing patent applications longitudinally and observing patent survival and patent transfer provides different representations of inventive productivity than single-period counts. Through the results from **Paper I**, the present thesis also generates insights for how to compare different kinds of single-period counts (i.e., patent applications vs. granted patents vs. patent families) and contributes to methodological discussions in relation to over- or underestimations of inventive productivity by patent counts (Dernis, et al., 2001; Narin & Breitzman, 1995).

While patent survival and patent transfer are investigated in two separate papers herein, future research could benefit from analysing the relationship between patent lifespan and patent transfers (Serrano, 2010; Svensson, 2013). To better understand the influence of inventors and assignees on patent lifespan, a more granular analysis of decisions to commercialise and renew patents is necessary (see Svensson 2012). Building on the results in **Paper IV**, an alternative approach to capture decision-making could involve studies of ethnographic nature, in order to enable a more sociologically informed analysis (Gittelman, 2008a).

Furthermore, drawing on the methodological lessons from the KIIP project, notably regarding name-matching, it would be worthwhile to explore more recent automation and validation methods that have been developed and tested since the establishment of the KIIP database, see, e.g., Dornbusch et al. (2013). Taking an organizational level analysis, as in the KIIP project, also offers the potential for continuing the work of integrating patent data with other sources of firm and individual-level socio-demographic data (Jung & Ejermo, 2014; Väänänen, 2010).

The second contribution speaks to studies that conceptually problematize patent value and the meaning of patent information as measures of innovation. Drawing on the notion that patent information has limited capacity in explaining the value or impact of patents (Gittelman, 2008b), this thesis opens up the avenue towards a reconceptualization of inventive productivity and the circumstances that promote it.

In line with emerging studies that stress the need to more thoroughly evaluate the use and analysis of patent information in innovation and management research (Criscuolo, et al., 2015; Tanimura, 2015), this thesis emphasizes the importance of also considering invention and patent micro-processes (Gittelman, 2008b). The idea that underlying behaviour and decisions made through iterative person-to-person interactions drive the organisation of research, invention and patent processes is not reflected in summative evaluation (Molas-Gallart, et al., 2016). Here, **Paper IV** points to the relevance of further research on individual-level cognitive and motivational heterogeneities among academics (Jain, et al., 2009). Building on the analyses in both **Paper III** and **Paper IV**, which show the heterogeneity of both formal and informal relationships between individuals and organizations, there is also reason to further probe specific arenas where the distributed processes of academic invention and innovation occur. For example, as part of looking into the context in which individual academic inventors orient themselves, one possible avenue for future research is to investigate inventor-team composition (Ali & Gittelman, 2016) as well as behavioural characteristics. The role of managerial capabilities, such as patent protection and patent information management (Aaboen & Holgersson, 2016; Hall et al., 2014), could also be the focus of further investigations into the influence of individual academic inventors' direct and indirect relationships. Similarly, the specific findings regarding the limited role of TTOs in both **Paper III** and **Paper IV** suggest the need to revisit how TTO-generated data on academic inventive processes is used both in evaluation and strategic management, as TTOs are only one among several possible intermediaries that absorb and manage university inventions (Fini, et al., 2010; Grimaldi, et al., 2011; Markman, et al., 2008).

5.2 IMPLICATIONS FOR POLICY AND PRACTICE

A first message from this thesis is that any attempts to reform academic merit and innovation support systems should assess inventive productivity in relation to multiple dimensions. Indeed, to reduce the risk of over- or underestimating output of academic invention, this thesis offers a rationale for analysts on how to relate patent counts to inventions (**Paper I**), patent survival (**Paper II**), patent transfer (**Paper III**) and inventor behaviour in underlying process activities (**Paper IV**). At the same time, the results in this thesis highlight the importance of being aware of the scope conditions for using patent information to evaluate academic work. For instance, to account for the fact that far from every patent application survives the full patent life cycle (i.e., 20 years from patent filing), it is advisable to conduct retrospective assessments. As suggested here, longitudinal analysis of the survival and transfer of university-originated patent applications provides more information on the progress and absorption of patent applications over time compared with 'snapshots' based on annual numbers of patent applications (filed or granted). Drawing on the argument that categorisations of inventors based on patent or invention counts do not capture potentially relevant behavioural differences (**Paper IV**), this thesis further proposes to complement patent information with non-patent information. In particular, academic inventors' own perspectives when it comes to how (or rather if) inventive productivity is accounted for are missing today. Therefore, it would be interesting to account for academic researchers' and other stakeholders' knowledge and views of how invention-related work could be evaluated.

A second message concerns potential implications for the design and development of innovation promoting activities and support. In line with the conclusions of Göktepe (2008), the present thesis points to the importance of considering and adapting support systems to the heterogeneity of academic inventor populations. Furthermore, since results show that the TTO absorbs and transfers less than one tenth of all university-originated inventions (**Paper III**), this thesis suggests that universities focus their efforts in developing strong research and business collaboration networks. Indeed, results on inventor behaviour in patent processes (**Paper IV**) imply that one-policy-fits-all solutions for academic technology transfer are unlikely to address individuals' heterogeneous needs and organizationally desirable behaviour. Following the reasoning of Ali and Gittelman (2016) that points to the importance of boundary-spanning scientists in academic invention and commercialisation processes, combined with evidence on the influence of peers (Bercovitz & Feldman, 2008) and social networks (Aldridge & Audretsch, 2011; Lissoni, 2010), active inventors may be more valuable than serial inventors to universities. Therefore, efforts to mobilise active inventors among faculty members could be used to promote innovation inside research departments.

A third message has to do with the potential implications for the use of patent information and other innovation-related data[15] in resource allocation, collaboration and

[15] Although not investigated in this thesis, an implication of the presented studies is that the integration of innovation-related data, referred to as Innometrics, has potential to further develop third stream measures

commercialisation. At a national level, one initial step to remedy the lack of systematic and comprehensive documentation of Swedish academic inventors could be to establish a harmonized patent information infrastructure. Such an approach would enable cross-national mapping and analysis of these inventors through the application of the methods herein. In addition, it could generate insights on clusters of converging technologies and inventor collaboration networks. Furthermore, such analysis could be leveraged in patent pooling between universities or through other means of intellectual property-based transactions (Eppinger & Tinnemann, 2014). Thus, a national infrastructure for patent data could serve a dual purpose: evaluating academic work and commercialisation decision-making. The rapid technological development of big data analytics through machine learning and other approaches opens up new avenues for assessments and benchmarking of academic institutions worldwide. Finally, the present thesis is an attempt to critically reflect on how relatively unexploited patent information could be used to further the understanding of knowledge accumulation and knowledge exchange.

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that cover the span 'from the birth of an academic invention to the creation of growth in terms of new business creation and job opportunities.'

6 POPULÄRVETENSKAPLIG SAMMANFATTNING

Hur mäter man innovationsförmåga? Syftet med denna avhandling var att ta reda på just detta med utgångspunkt i offentligt tillgänglig patentinformation. Bakgrunden till avhandlingens frågeställning är den uppmärksamhet som på senare år kommit att riktas mot utvärdering av akademisk forskning. I Sverige, liksom i övriga världen, har vi kunnat bevittna ett ökat fokus på styrning och reglering av universitet. En effekt av detta är implementeringen av nya system för granskning och mätning av såväl kunskapsproduktion som nyttiggörande av kunskap. I samband med denna förändring har det tillkommit krav på olika former av samverkan mellan universitet och det omgivande samhället. Utöver att många anslagsgivare numera begär att sökanden beskriver hur deras forskningsresultat ska komma till nytta avspeglas denna strävan även i forskningspolitiska satsningar på innovation t.ex. genom stöd till etableringen av innovationskontor. Vissa länder har även valt att utvärdera innovationsförmåga genom att följa upp antalet sökta och godkända patent, licensieringar och företagsstarter. Emellertid har tidigare forskning kritiserat dylika mått för att osynliggöra väsentliga kvalitets- och processaspekter av hur akademiska uppfinningar uppstår och utvecklas.

I tre av avhandlingens fyra delarbeten undersöks hur patentinformation kan användas för att ge en mer nyanserad bild av både enskilda forskares och universitets innovationsförmåga. Ett delarbete problematiserar även hur väl befintlig patentinformation återspeglar akademiska uppfinnares beteende under processen som leder till en patenterad uppfinning. Avhandlingen kartlägger alla de patent som skapats av forskare vid Karolinska Institutet mellan åren 1995 och 2010. Å ena sidan visar resultaten att de mått som används i vissa länder idag, såsom exempelvis antalet sökta eller godkända patent, kan medföra såväl under- som överskattning av forskares innovationsförmåga. Å andra sidan pekar resultaten på att innovationsförmåga endast på ett ofullständigt sätt kan avbildas med hjälp av patentinformation. I tre av de totalt fyra studierna undersöks olika kvantitativa patentbaserade mått. Artikel I relaterar olika sätt att räkna uppfinningar i form av så kallade patentfamiljer till godkända patent respektive patentansökningar. Artikel II analyserar akademiska patents överlevnad. I Artikel III undersöks hur ägandestrukturen av akademiska patent förändras över längre tid. Sammantaget visar de tre studierna på behovet av att studera vad som händer med patenterade uppfinningar över tid. Artikel IV bygger på intervjuer med tjugo forskare om deras erfarenheter av patentering och kommersialisering. Den huvudsakliga slutsatsen av denna studie är att etablerade kvantitativa sätt att kategorisera uppfinnare som tillfällig- eller serieuppfinnare, utifrån antalet patentansökningar de står med på, inte fångar väsentliga skillnader i hur individer beter sig under innovationsprocessen. Genom att utveckla utvärderingsmetoder bortom kvantitativa utfallsmått finns möjligheten att identifiera beteenden och egenskaper som kan bidra till att förklara och stötta ökad innovationsförmåga. En övergripande slutsats i avhandlingen är att det finns ett behov av att skapa en mer nyanserad förståelse av hur uppfinnare agerar och interagerar med andra intressenter under den patenterade uppfinningens tillblivelse och vidare kommersialisering. Avhandlingen föreslår att bedömningen av forskares bidrag till samverkan och nyttiggörande bör omfatta fler dimensioner av innovationsförmåga än de som avbildas med enkla, volymbaserade mått av antalet patent. En förhoppning är att denna avhandling bidrar till att universitet, anslagsgivare och andra berörda parter utvecklar användningen av den kunskapskälla som information om patent och akademiska uppfinnare utgör.

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This thesis owes its creation to several people.

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