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To invent and let others innovate: a framework of academic patent transfer modes

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Abstract Numerous papers on university patenting and commercialisation have mapped the patent ownership landscape at a variety of academic institutions. Despite these efforts, there is still a scarcity in empirical evidence in terms of how patented academic inventions are commercialised over time. This paper extends previous work on academic commercialisation by tracing patent ownership transfers longitudinally. We develop a conceptual framework of academic patent transfer modes that distinguishes between patents transferred through the efforts of the researchers themselves (*autonomous mode*), through university support intermediaries (*bridge mode*) or via companies (*corporate mode*). The framework makes it possible to record knowledge transfer between academic inventors and external innovators at the time of invention (*t0*), patent filing (*t1*), and any subsequent time point (*tn*). Our results indicate that a majority of the patented inventions are transferred from the inventors to outside-of-academe entities. The results show that small and medium-sized companies are the largest absorbers of academic patents. The findings have potential implications for benchmarking of universities and development of more targeted internal innovation support.

Keywords Technology transfer · Academic patenting · Innovation · University benchmarking · Patent ownership transfer

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1 Introduction

Universities are important knowledge producers including patentable and tradable inventions. However, to develop viable products and services, universities need to transfer their inventions to other organisations. Numerous studies have identified owners of academic patents at the time of patent application (Lawson 2013; Lissoni et al. 2008, 2009; Thursby et al. 2009). Yet, there is still a scarcity in empirical evidence in terms of how patented academic inventions are commercialised over time. A deeper understanding of patent transfer routes could inform innovation policy and practice. This paper addresses patent transfer between academic inventors and external innovators at the time of invention (*t0*), patent filing (*t1*), and any subsequent time point (*tn*). In adding a time component, this study extends previous work on academic commercialisation.

The routes that patented inventions take from university labs to end-users require the contribution of several entities to the development of the final product. While the importance of faculty involvement to speed product development and to succeed in commercialisation of university-originated technologies is undisputed (Edwards et al. 2003; Mansfield 1998; Thursby and Thursby 2004), research also shows that external organisations with complementary knowledge and resources are needed for downstream development of academic inventions (Leydesdorff and Etzkowitz 1998). Especially in knowledge fields of high complexity, no single organisation has the internal capabilities necessary to bring a project from idea to market (Powell et al. 1996). As university technology transfer offices (TTOs) or academic inventors lack necessary development resources, they are more or less forced to license or sell their patents to other entities (Elfenbein 2007). In the pharmaceutical sector it is common for different entities to be involved at different stages of development and commercialisation (Owen-Smith et al. 2002; Powell 1996).

Tangible traces of inter-organisational knowledge transfer can be found in the analysis of scientific publications and patents respectively (Thursby et al. 2009). Information embedded in patent documents is typically a codification of knowledge that stems from scientists' informal exchange with other scientists in universities and companies. Advantages to using patents are that they are measurable and traceable (Griliches 1990). A patent can also be seen as a first step towards commercialisation by an academic researcher. Together, these attributes of patents have given rise to a large body of research on academic patenting (Lissoni 2012) as well as policy initiatives focused on regulating, for example, ownership of academic patents.

Parallel to such initiatives, efforts to identify and categorise those organisations that absorb, patent and commercialise academic inventions have been taken (Lissoni et al. 2008; Meyer 2003). Results show that ownership of academic patents is distributed between academic inventors, universities (public and private research organisations), TTOs, and small, medium-sized and large companies (von Proff et al. 2012). In addition to analyses of the distribution of academic patent owners, investigations have been made into factors influencing the likelihood of patent transfer (Serrano 2010) and licensing (Dechenaux et al. 2008; Elfenbein 2007; Shane 2002). In attempting to understand what 'makes commercialisation of academic research happen,' researchers have explored both internal (e.g., inventors' motivations and characteristics) and external factors (e.g., patent ownership legislation and intermediary support organisations).[1]

One recent theme that has emerged from the literature on academic patenting stresses that investigations into the trading of patents or licenses generated by academic inventors but commercialised via TTOs may lead to a systematic underestimation of actual academic commercialisation (Aldridge and Audretsch 2010, 2011; Mosey and Wright 2007; Shane 2004; Thursby et al. 2009). This paper builds on the evidence presented in these studies by suggesting a framework (i.e., the ABC-framework) for analysing patent transfers that considers all patent transfer routes from the academic inventor to absorbing entities downstream. It is important to point out that patent transfer means the actual change in patent ownership from one entity to the next. Thus we do not, in this paper, include licenses or other documentation of collaboration by which knowledge and technology are commonly transferred. The formal recording of ownership information in patent data together with the transferability of patent ownership provides an opportunity to explore how, and by which entities, knowledge stemming from university research results is absorbed.

The idea behind the ABC-framework is to enable identification of all primary innovators (i.e., patent owners at filing) independent of whether the invention was conceived and patented in collaboration with an external firm, through the university TTO or via a spin-off company. By doing so, our approach stands in contrast with previous TTO-centric studies (Breznitz et al. 2008) in that we broadly cover academic research commercialisation routes. In order to capture all routes, we apply a name-matching methodology, as elaborated in Sect. 3.

However, and as is argued in this paper, there is still a scarcity in empirical evidence in terms of which individuals, companies or other organisations absorb academic inventions as the primary, secondary or any subsequent innovator. In growing seeds of academic inventions into marketable technologies, further development time and continuous matching of knowledge and competence by outside-of-academe entities are typically necessary (Dechenaux et al. 2008; Lecocq and Van Looy 2009). Therefore, the aim of this paper is to develop a framework that besides covering patent transfers broadly, also includes the possibility to longitudinally identify innovators involved in commercialisation of academic patents beyond the first incident of patent transfer (i.e., patent sale or license, Elfenbein 2007).

As discussed in greater detail in Sect. 5.0, the ABC-framework could serve as an instrument for university-to-university benchmarking and in analysing the socio-economic impact of knowledge transfer. Improved visibility of inventors and innovators involved longitudinally could guide university managers in their development of more targeted internal innovation support, including education and awareness campaigns on how to formalise industry-collaborations and manage potential transactions. Finally, a greater understanding of the extent of patent transfers can give insights into the contribution of academic knowledge to the market for science and technology (Azagra-Caro 2014; Lamoreaux and Sokoloff 1999; Serrano 2010). The study is based on empirical data from the 'Karolinska Institutet Intellectual Property database' (KIIP) which holds information collected through name-matching of academic researchers in patent databases over a 15-year time period (1995–2010) (Authors' own article to be inserted).

The paper is structured as follows. Section 2 gives an overview of previous work on mechanisms, modes and intermediaries in the context of academic technology transfer. It

[1] For an extensive list of factors synthesized from the literature see (Göktepe 2008).

also presents state-of-the-art studies on patent ownership transfer and presents the core argument. Section 3 describes the empirical setting and outlines the methodology applied. Results follow in Sect. 4 along with the development of the ABC-framework, which is applied against the empirical context. Finally, in Sect. 5, a discussion of contributions, implications and limitations is presented.

2 Literature review

2.1 Technology transfer intermediaries: inventors, TTOs and companies

Over the last four decades, topics related to academic technology transfer activities have become more noticeable on research and innovation policy agendas worldwide (Etzkowitz et al. 2000; OECD 2015). Much attention has been given to the question of how knowledge and technologies are diffused from university to industry (Bozeman 2000; Rothaermel et al. 2007).

There is wide consensus that knowledge and technologies are transferred from university researchers to the outside world through multiple mechanisms such as publishing, contract research, research partnerships, patenting, licensing, consulting, and founding of spin-off companies (Bercovitz and Feldman 2006; Grimpe and Fier 2010; Link et al. 2007). It has also been shown that transfer mechanisms are complementary to each other (Bekkers and Bodas Freitas 2008; Perkmann et al. 2013).

As pointed out in the introduction, academic inventors face challenges in commercialising research results on their own. Intermediaries such as TTOs and established companies are typically required to move the patented invention through further development towards market launch (Owen-Smith and Powell 2001). Consequently, it is not unlikely for university-originated technologies to be transferred between multiple entities along the value-chain (Bercovitz and Feldman 2007). Numerous studies have explored the role of academic inventors, university TTOs and companies in technology transfer (Comacchio et al. 2012; Hoye and Pries 2009; Markman et al. 2008a, b; Perkmann et al. 2013).

It is clear that academic researchers play a key part in recognising potentially patentable research results (D'Este and Perkmann 2011). Whether or not a researcher chooses to patent and commercialise his/her invention depends on a variety of factors: institutional (Aldridge and Audretsch 2010), organisational (Bercovitz et al. 2001) and personal (Owen-Smith and Powell 2001). Cunningham et al. (2014) show that academic researchers experience a number of barriers related to commercialisation of their research results. These include tension between entrepreneurial and academic goals as well as insufficient valuation, sales and market capacity of TTOs. For example, researchers with a negative experience of their TTO have a lower inclination to patent and commercialise (Owen-Smith and Powell 2001).

Other studies show that university scientists may be motivated to patent and pursue commercialisation if they perceive that it can enhance their reputation and progress their research (Baldini et al. 2007; D'Este and Perkmann 2011; Göktepe-Hulten and Mahagaonkar 2010). This notion is supported by results indicating that the quality of scientific work, measured by citations, as well as the amount of resources obtained, is higher for star scientists who publish in collaboration with new biotechnology firms than for their peers without company collaborations (Zucker and Darby 1996). Moreover, Aldridge and

Audretsch (2011) find that scientists with higher levels of social capital, measured through industry linkages, are significantly more likely to become an entrepreneur.

According to Owen-Smith and Powell (2001), motivations to patent vary between scientists in due to differences in the nature of technologies and markets. They claim that, while physical scientists perceive patents mainly as a way gain access to complementary resources, life science researchers view their inventions as tangible tradable goods. Therefore, the mission of life scientists becomes finding the best partner to develop and market their technology. Others may be influenced to engage in commercialisation by their peers (Bercovitz and Feldman 2008) or by their university's commitment to support technology transfer activities (Baldini et al. 2007).

Even though personal drive, motivation and peer influence are important in triggering patenting, complementary knowledge, experience and resources found at the internal TTO or through external companies are typically necessary to continue commercialisation (Elfenbein 2007). Today, most universities offer patenting and commercialisation services through their internal TTO, where members of the faculty can turn for advice.

In the endeavour to build entrepreneurial universities internationally, the increased importance of TTOs as "boundary spanning" organisations between academic scientists and firms (Huyghe et al. 2013; Markman et al. 2008a, b) has rendered extensive scholarly interest. For example, the role of TTOs as regional growth engines (Etzkowitz and Goktepe-Hulten 2010) and as brokers has been investigated. Studies have also focused on their strategy (Nicol 2008) and performance and productivity (Chapple et al. 2005; Hülsbeck et al. 2013; Siegel et al. 2007; Siegel et al. 2003a, b). Examples of factors found to impact productivity are faculty reward systems, TTO-staffing and compensation for the TTO (Siegel et al. 2003a, b).

While the overall objectives of TTOs are to facilitate commercialisation of academic inventions and to manage university IPR (Siegel et al. 2007), these intermediaries have been recognised to operate according to different organisational models and governance structures (Schoen et al. 2014; Siegel et al. 2003a, b). One consequence of this is the way in which a TTO approaches patent ownership distribution between different parties. Meyer (2003) suggests three technology transfer modes which describe the role that the TTO takes with regards to patent ownership and patent transfer. In the 'Direct mode,' the patent is directly transferred from the academic inventor to a third party, for example a firm. In the 'Mediated mode,' the TTO is involved in transferring a university-owned patent to a third party. In the 'Intermediary mode,' the TTO is involved in transferring the patent to a third party without the TTO taking ownership.

Recent research indicates that TTOs still seem to struggle with adopting an identity and gaining legitimacy in its role as intermediary between university and industry (O'Kane et al. 2015). These results confirm previous findings that show that more experienced academic researchers rely on their own social network of venture capitalists, business angels, and patent consultants to commercialise, rather than turning to the TTO (Mosey and Wright 2007). For example, even in countries where universities own their researchers' patents, it has been observed that academic inventors bypass university TTOs to commercialise on their own (Bercovitz and Feldman 2008; Kenney and Patton 2009).

Besides TTOs, other intermediaries such as private companies translate academic inventions through research collaboration. Small-sized companies act as brokers that absorb university-generated inventions and transfer them downstream to larger companies after further development (Stuart et al. 2007), giving rise to a market for university science (Azagra-Caro 2014).

However, successful technology transfer often requires close and continuous interactions between the inventor and the absorbing company. Thus, companies tend to enter into informal and formal research collaborations with academic researchers and engage them in contract research. Craig Boardman and Ponomariov (2009) found that informal forms of interactions often precede formal relationships. Benefits on the company side include the possibility to select and absorb new technologies at an early stage. The tacit knowledge associated with an invention often requires that the academic inventor is involved in a commercialisation process after the transfer of the technology rights. For example, Agrawal (2006) shows involvement of academic inventors in the development of the transferred technology in two thirds of a sample of MIT-owned licenses. In another study it was shown that 40 % of the technologies needed faculty co-operation to be successfully commercialised (Thursby and Thursby 2004). Especially the earlier stages of development were shown to profit from faculty involvement. Also, Zucker and Darby (1996) found that new biotechnology firms with ties to star scientists had more products in development and on the market, as well as a higher employment growth, compared with those without such connections.

2.2 Patent ownership distribution among intermediaries

The synergies revealed between traditional academic activities and industry interaction (Craig Boardman and Ponomariov 2009) imply that intermediaries play a significant role in the transfer of university-originated knowledge and technology. Therefore it is not surprising that private companies, universities via their TTOs, individual inventors and other organisations, such as government and public research organisations, have been shown to be recurring owners of academic patents (Lissoni et al. 2008, 2009; Thursby et al. 2009).

Two main models for regulating university patent ownership can be distinguished in different countries. The 'university ownership model' (e.g., Bayh-Dole Act) is when the university retains ownership of IPR generated by their researchers and the 'inventor ownership model' (e.g., Teacher's exemption or Professor's privilege) is when the individual inventor retains the ownership of the IPR. Depending on legislation and internal university policies, academic patents may be applied for inside or outside the university (Fini et al. 2010).

The largest academic patent owners in many European countries are private companies, holding approximately 60–80 % of the patents (Lissoni et al. 2008, 2009). In the US, the corresponding figure for corporate academic patent ownership is about one fourth of the patents (Thursby et al. 2009). University ownership is about 70 % in the US and less than 10 % in Europe, except in the UK ($\sim$22 %) (Lissoni et al. 2009). The academic patent ownership of individual inventors varies between about three to just above 5 % for France, UK and the US, while some European countries have considerably higher levels of individual ownership, from about eight up to 20 %. France stands out compared with other countries with an extensive governmental ownership share of 25 %. As a conclusion, the broad picture shows that private companies are the main owners of academic patents in Europe, while universities take that role in the US. Variations in patent ownership distribution at a country level, as pointed out above, can be explained mainly by factors such as differences in legislations, industry dynamics, and university policies both nationally and locally (Della Malva et al. 2013; Giuri et al. 2013; Goldfarb and Henrekson 2003; Kenney and Patton 2011; Lissoni et al. 2013).

While these studies provide empirical evidence on the variation in ownership distribution at a country level, ownership is only assessed at one point in time (e.g., at the time of patent filing). As patents may be transferred, analysing ownership solely at patent filing excludes changes that may occur over time.

2.3 Capturing patent ownership transfers broadly and longitudinally

As emphasised in the study by Fini et al. (2010), a large body of work on academic research commercialisation has mainly analysed invention disclosures, patents, licenses and spin-offs typically assigned to or initiated via a university TTO. Given the emerging evidence that a sole focus on patented inventions assigned to university TTOs may lead to a systematic underestimation of actual academic commercialisation (Aldridge and Audretsch 2010, 2011; Mosey and Wright 2007; Shane 2004; Thursby et al. 2009), it is logical that researchers have attempted to trace all patented inventions created by university scientists and not only those owned, managed and documented by a TTO (Fini et al. 2010). The latter has been realised through the application of name-matching methodologies (Bercovitz and Feldman 2008; Lissoni et al. 2008; Meyer 2003). Such non-TTO-centric approaches have enabled a broader analysis of the extent and ownership of patented academic inventions (Breznitz et al. 2008).

We argue that there, despite these efforts, is still a scarcity in empirical evidence in terms of how patented academic inventions are commercialised over time. In particular, we lack research on subsequent commercialisation. While the role of university-originated discoveries in drug development is undisputed (Edwards et al. 2003; Kneller 2010), less is known about which individuals, companies or other organisations absorb academic inventions as the primary, secondary or any subsequent innovator. There are several reasons why a longitudinal analysis of how patents change hands from the inventor to downstream players can bring new insights.

First, translation of academic inventions into innovation, especially in the area of life sciences, may occur 10–15 years after patent filing. By the same token, knowledge that "ends up" in a patent application tends to develop informally over time (Bercovitz and Feldman 2007). Analogous to the innovation process that involves the birth of a patent, technology development and marketing, Gartner and Shane (1995) claim that, 'the nature of entrepreneurship involves a sequence of events over time,-[*sic*] e.g., the formation of a business, its survival or death, the entry into self-employment, etc.' To identify parties involved in commercialising academic inventions, it is therefore essential to trace the destiny of patent applications beyond the initial filing.

Second, as pointed out in a number of previous studies, academic inventions are often commercialised through outside-of-academe parties (Chesbrough 2003; Mowery et al. 1996). In particular, the literature on strategic alliances has explored the phenomenon of university-industry interaction in the life sciences sector (Bercovitz and Feldman 2007; Stuart et al. 2007). As highlighted by Stuart et al. (2007), collaboration in this sector is characterised by tripartite alliance chains: longer term relationships between universities, biotechnology firms and established pharmaceutical companies. Thus in the context of commercialisation of patented academic life science inventions, a consideration of temporal dynamics can help untangle parties involved in the different, and at times overlapping, stages of knowledge transfer.

Third, a longitudinal analysis can provide information about any differences in rates and proportions of patent transfers between patent owners (Serrano 2010). For example, Serrano (2010) finds that small and private inventors are more active sellers of patents than government agencies and large inventors. He also demonstrates that 13.5 % of the granted patents in the investigated sample are traded at least once over the course of their lifetime.

However, the proportion of patents traded in different fields varies: 12.9 % for 'computers and communications' and 16 % for 'drugs and medical.' These sectorial differences in patent trade possibly reflect the patenting patterns found in the studies by Mansfield (1998) and Levin et al. (1987). Arguably, only a retrospective analysis could shed further light on this topic.

Fourth, in academic research assessment, where the ultimate objective is to realise long-term economic and societal gains, patent transfers could be used as indicators of knowledge diffusion (Serrano 2010; Sterzi 2013). As shown by Sterzi (2013), patents transferred to a company from a university or other public research organisation showed a higher quality premium than those that were not transferred, which points to the possibility that companies single out patents of interest. Srivastava and Wang (2014) argue that firms' involvement in patent trade could enhance their intellectual property management capabilities. Similarly, evidence on universities' extent of trade of academic patents by different intermediaries could potentially be used by university managers on how to organise their innovation support functions.

While there are studies in the academic context that have considered patent transfers longitudinally, they have applied invention disclosures or patents (and licenses from such patents) originally assigned to the TTO as units of analyses (Dechenaux et al. 2008; Elfenbein 2007; Shane 2002). The study by Dechenaux et al. (2008) is restricted to those inventions that were disclosed to the TTO between 1980 and 1996. As discussed above, such an approach is limiting and would only make sense in cases where university TTOs 'are in control' of the flows of patented inventions that emanate from their university. Therefore, investigations of the trade of patents or licenses generated by academic inventors but commercialised via the TTO risk underestimating the overall commercial activity.

The scholarly recognition that TTO-data is limited in terms of providing a complete picture of academic commercialisation modes has spurred recent studies to expand their analyses to identify all inventors and categorise all owners of academic patents (Lissoni et al. 2008). However, despite this deviation from TTO-centric studies, these papers appear to be limited in identifying patent owners at or close to patent filing. Thus, there is a gap in terms of how to broadly and longitudinally identify innovators involved in commercialisation of academic patents beyond the first incident of patent sale or licensing (Elfenbein 2007).

To fill this gap, we propose a framework to guide empirical studies in tracing patented inventions from the academic inventor to the market. Such a framework considers patent transfers longitudinally and enables identification of those individuals or organisations that absorb, patent and commercialise academic inventions. In particular, it facilitates gauging the extent of possible changes over time and enables an exploration of the possible heterogeneity in commercialisation routes.

3 Methodology

3.1 Empirical setting: a Swedish medical research university

While the literature shows compelling evidence that patents represent one of many possible ways to transfer knowledge from the research community to the broader society (Siegel and Wright 2015, British Academy of Management), results indicate that the likelihood for scientists to be involved in patent-based entrepreneurship is higher in the field of biosciences compared with in engineering and social sciences (Fini et al. 2010). Since our study draws on data from a biomedical research university, we argue that focusing on patented inventions (patents) is a useful approach in analysing knowledge transfer.

Sweden is one of few exceptions in Europe in that university researchers have the right to their patented inventions stemming from publicly funded research (i.e., the teacher's exemption). Thus, a Swedish university inventor can choose to turn to, for example, the university TTO, a venture capitalist or a company for commercialisation assistance. Due to its inventor ownership regime, Sweden has been identified as an interesting case for studying academic patenting (Jacobsson et al. 2013; Ljungberg et al. 2013).

Karolinska Institutet (KI) is one of Europe's largest medical universities and employs approximately 30 % of all researchers at Swedish academic medical faculties (Statistics Sweden). Being a single discipline faculty, KI produces about 40 % of all Swedish academic medical research (Karolinska Institutet) and has strong ties to the research hospital, the Karolinska University Hospital. Many of the researchers have a clinical background as physicians, dentists or nurses. In the mid-1990s, a formal support structure for innovation was established, including a university TTO, Karolinska Innovations AB (KIAB) (Karolinska Institutet). KIAB would, according to the typology suggested by Schoen et al. (2014), be categorised as an independent, non-exclusive, discipline specialised and forward integrated TTO. The organisational model of the Karolinska Innovation system has previously been described by Baraldi and Waluszewski (2011).

3.2 Data

3.2.1 The KIIP database

University-owned patents are relatively straightforward to track in patent databases by searching for the university name in the assignee field. However, finding non-university-owned patents is challenging, since the owner could be either a person or an organisation. For that reason, statistics on European academic patents are scarce (Geuna and Nesta 2006). In Sweden, due to the inventor ownership model, this challenge applies to most academic patent searches. Since Swedish universities do not normally track patents filed by researchers, there is no systematic or aggregated knowledge of inventive productivity at Swedish universities. Researcher name-matching, rather than university name-matching, makes it possible to better compare academic patenting across universities and countries (Balconi et al. 2004; Iversen et al. 2007; Lissoni et al. 2006, 2008; Meyer 2003; Thursby et al. 2009).

For the purpose of this study, all patents filed by researchers at KI over the time period 1995–2010, were collected using a name-matching methodology, resulting in the Karolinska Institutet Intellectual Property (KIIP) database (Authors' own article to be inserted). The construction of KIIP started in 2011 and contains information on 7110 KI-researchers, including name, position, department and research group affiliation. Both junior and senior researchers were included. Additionally, KIIP covers most jurisdictions (countries) in the world as well as information on patent owners.[2]

To build KIIP, data from four main sources were combined: (1) lists of KI-researchers from the university personnel registry, (2) patent data from Innography®, (3) patent data

[2] Previous studies has shown joint patent ownership to be relatively rare (Hicks and Hegde 2005; Lawson 2013), for which reason it is not analysed in the present study.

from Thomson Innovation®, and (4) manually collected assignee[3] information. The construction of the database included the following five main steps: (1) sampling, (2) search and retrieval of patent records, (3) validation of inventors, (4) normalisation and categorisation of assignees, and (5) adding INPADOC[4] patent families and legal status information.

3.3 Data analysis

3.3.1 Normalisation and categorisation of patent owners

It is not unusual that patent databases lack information and contain various spelling mistakes. To normalise the data, the dataset was manually cleaned from spelling mistakes. To prevent overestimation of the number of patent ownership transfers, company name-changes were eliminated and companies (e.g., *AstraZeneca Ltd.* and *AstraZeneca Inc.*) within the same Group (*AstraZeneca*) were clustered (Fischer and Henkel 2012). If a patent changed owner through a merger or acquisition, this was considered a transfer of patent ownership.

Prior to 2012, there was no requirement to include patent owners in US patent applications.[5] For this and other reasons (e.g., human errors), the dataset contained patent documents with empty 'ownership'[6] fields, some of which were likely meant to denote the inventor (Thursby et al. 2009). Due to this uncertainty embedded in public patent data, empty cells were referred to as 'unassigned,' abbreviated 'UA.'

Previous research has shown consensus in categorisation of original owners of academic patents into the following groups: i.e., individuals, companies, research organisations and universities usually through their TTOs (Balconi et al. 2004; Fabrizio and Di Minin 2008; Lissoni et al. 2009; Thursby et al. 2009). As in these studies, patent owners were categorised into eight groups outlined in Table 1. In this paper, only two companies fulfilled the criterion for 'large enterprise' and were, for data management purposes, included in the SME-category. The category 'TTO' refers to the TTO associated with the studied university (Table 1).

3.4 Ownership transfer in multiple steps

As elaborated on above, this paper considers patent ownership longitudinally and the data constitutes information on patent owners at *t0*, *t1* and *t2* (see Fig. 1). While the original and current owner are assigned at *t1* (time of patent application) and *t2* (time of data download in 2011) respectively, *t0* (time of invention) represents the time point when the invention is in the hands of the inventor/s. Based on the inventor ownership legislation in Sweden (see 3.1), the inventor was assumed to equal the owner at the time of invention (*t0*). Additional ownership transfers could have occurred during the time period between *t1* and *t2*, but they were not investigated here. The time point *tn*, where *n* represents any year between the

[3] The assignee or applicant refers to the owner of the patent.

[4] An invention is defined as an extended INPADOC patent family, which means that all patent records, directly or indirectly linked via a priority document, belong to same patent family (European Patent Office).

[5] Inventors are considered owners on a US patent application by default until a separate assignment is done. Before 2012 there was no requirement for the owners to be included in the patent application (USPTO 2011).

[6] Also called 'assignee' field or 'applicant' field.

Table 1 Categorisation of patent owners

Categories of patent owners	Explanation
SME	Small and medium-sized enterprise <250 employees
LE	Large-sized enterprise 250–499 employees
MNC	Multinational corporation ≥500 employees
RO	Research organisation or university
IND	Individual, usually refers to the inventor
TTO	Technology transfer office associated with the focal university
OTHER	E.g., governmental org., research foundation, patent advisory firm
UA	Unassigned, information lacking in public patent data

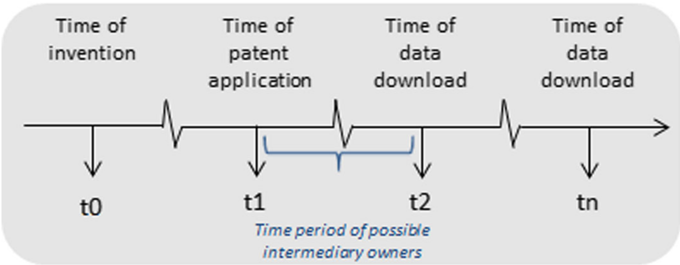

Fig. 1 Method for analysing patent ownership changes over time. Ownership information at the events *t0*, *t1*, *t2* and *tn* provide the empirical foundation of the analysis

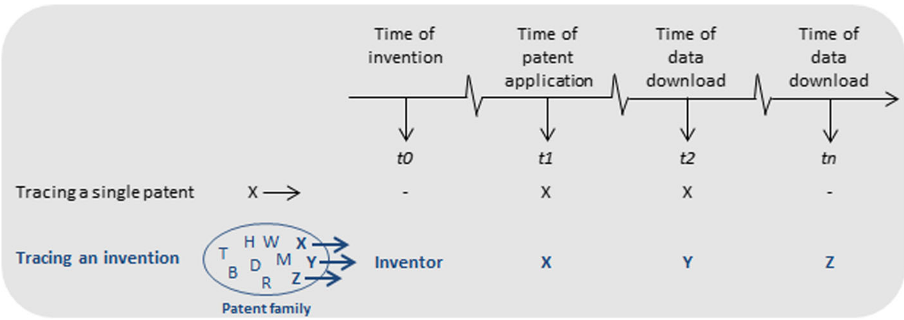

Fig. 2 Comparison of methods to capture patent ownership changes longitudinally, by tracing a single patent versus tracing a patent family member

filing of the first patent application and 20 years thereafter, provides the possibility to continuously track ownership status changes over the course of the patent life cycle.

Since patents in the sample were filed at different time points between 1995 and 2010, the time period between *t1* and *t2* may vary between 1.5 and 15 years after the priority date.[7] Since an inventor can wait before filing a patent, the time between *t0* and *t1* may also fluctuate. This time lag is unknown, but could be investigated through inventor interviews.

[7] Priority date equals the filing date of the first patent application for a specific patent family (European patent office).

In the dataset, there are 4176 unique patent records corresponding to 703 inventions. To include the maximum of possible events that could be reflected in the data, the *first published* patent document in a patent family was selected to represent the original owner at *t1* and the *last published* patent document, in the same patent family, was selected to represent the current owner at *t2*. In most cases this approach resulted in two different patent records for each invention. In Fig. 2, the methodology used to capture ownership changes longitudinally by tracing a selected patent family representative is outlined. This method is compared with tracing of ownership changes by single patents (Serrano 2010; Sterzi 2013). In cases where an invention only included one patent record, that record was used to represent both events. This gave a sample of a variety of jurisdictions and a maximum time period of possible ownership change. Patent Cooperation Treaty[8] applications were not chosen as representatives, as they are only 'alive' for 30 months, which limits the window of ownership change to less than 3 years.

4 Results

In this section, results of patent ownership distribution and patent ownership transfer of patented inventions at Karolinska Institutet are presented. The case serves as a basis to exemplify the methodology suggested in this article.

4.1 Patent ownership distribution

The ownership distributions of the 703 patented inventions at Karolinska Institutet at *t1* (original owner) and *t2* (current owner) are shown in Table 2. The largest owner category at *t1* is SMEs (51 %) followed by individuals (17 %) and the TTO (12 %). Ownership is distributed between 131 SMEs, 32 MNCs and 22 research organisations at *t1* and 149 SMEs, 34 MNCs and 18 research organisations at *t2*. The overall trend in the sample is that patent ownership is transferred from TTO ownership and individual ownership at *t1* to SME ownership at *t2* (see Table 2). At *t2*, the TTO owns 6 % of all patents generated at Karolinska Institutet. Thus, half of the original holding was transferred between *t1* and *t2*.

4.2 Patent ownership transfer

Based on the categorisation of owners (Table 1), 49 patent ownership transfer routes are identified. A transfer route is defined as the pathway along which ownership is transferred from the academic inventor (*t0*) via the original owner (*t1*) to the last known owner (*t2*). It is important to point out that in some cases ownership may remain with the inventor, which means that there is no change of owner along the transfer route. In Fig. 3, the proportions of patents transferred from academia to downstream entities are visualised in three steps.

In this paper, patent ownership transfer denotes all possible transfers between and within all categories. First, transfers are traced between different owner categories (e.g., from SME to MNC). Then, transfers are analysed within the same category (e.g., from one SME to a different SME).

[8] The Patent Cooperation Treaty is an international treaty between more than 140 countries. It enables seeking patent protection for an invention simultaneously in a large number of countries by filing a single 'international' patent application (WIPO 2012).

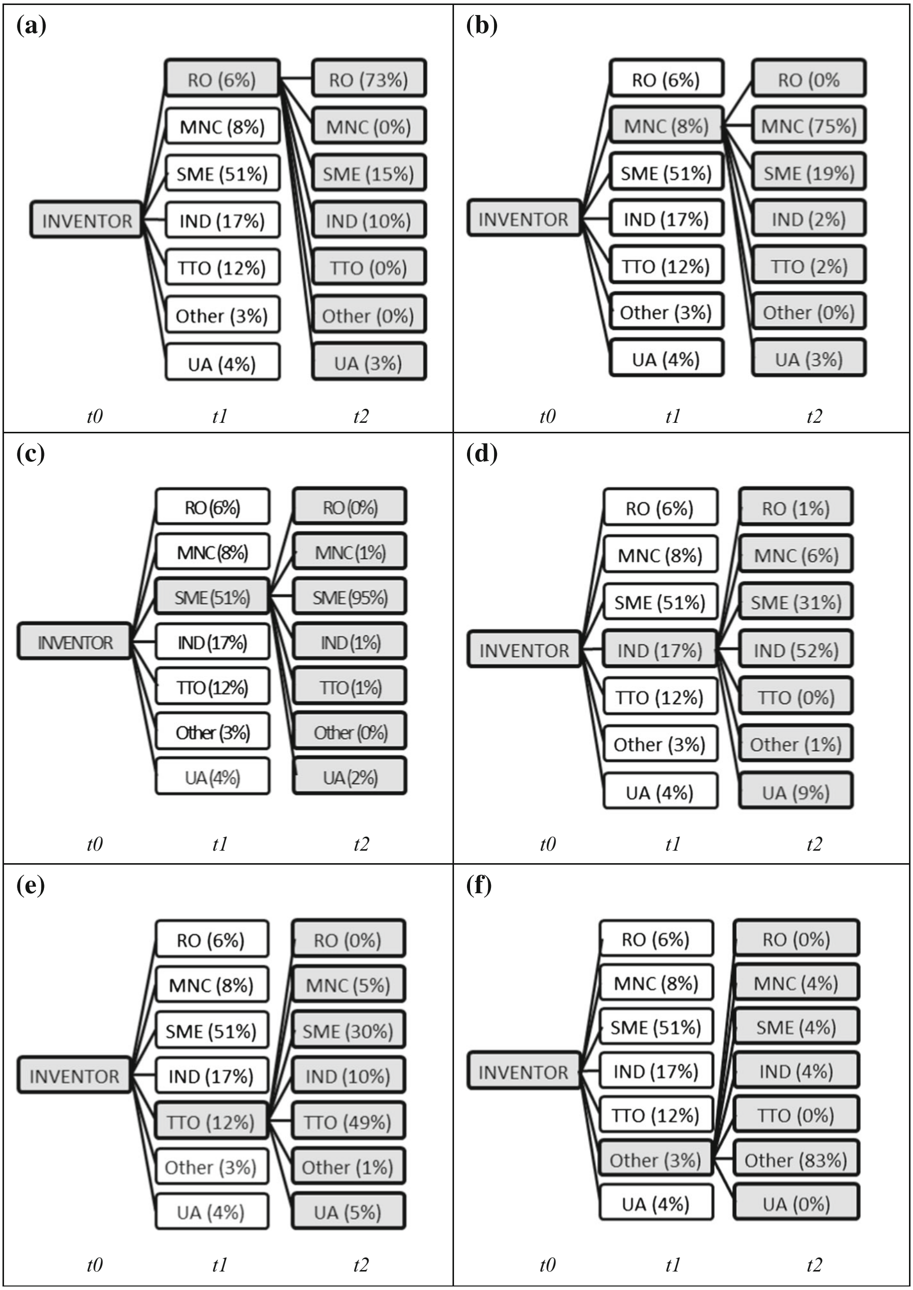

Fig. 3 Transfer of patent ownership between owner categories (**a**–**f**) at three time points: *t0* (inventor), *t1* (original owner) and *t2* (current owner). **a** RO as intermediary, **b** MNC as intermediary, **c** SME as intermediary, **d** individual as intermediary, **e** TTO as intermediary, **f** other org. as intermediary

Table 2 Distribution of inventions in number and share at Karolinska Institutet over the time period of 1995–2010

1995–2010	Original owner (*t1*)		Current owner (*t2*)	
	No of inventions	Share of inventions (%)	No of inventions	Share of inventions
SME	356	51	430	61
IND	116	17	80	11
MNC	59	8	67	10
TTO	82	12	43	6
RO	40	6	31	4
Unassigned	27	4	30	4
Other	23	3	22	3
Total	703	100	703	100

In the first transfer step, from *t0* to *t1*, 17 % of the patents stay with the inventor and the rest are transferred to other entities. At *t2*, 11 % still remain in the hands of inventors meaning that the rest has been transferred to other entities. Results also show that 27 % of all patents are transferred twice, first between *t0* and *t1* and again between *t1* and *t2*. This number includes transfers both between and within owner categories.

Figure 3a shows all transfer routes with a research organisation as intermediary, at *t1*. A large majority (73 %) of the inventions transferred between *t1* and *t2* remains in the hands of research organisations. The other major recipients are SMEs (15 %) and individuals (10 %).

Figure 3b shows all transfer routes where an MNC is the primary innovator. It can be observed that 8 % of all inventions are transferred from the inventor (*t0*) to MNCs (*t1*). At *t2,* as many as 75 % of these inventions are still owned by MNCs. A deeper analysis of the ownership transfer rate between two different MNCs (e.g., AstraZeneca to Pfizer) shows a transfer of 11 % between *t1* and *t2,* see Fig. 4 below. The second largest group of recipients at *t2* is SMEs (19 %).

In Fig. 3c, SMEs account for about half of all inventions derived from the academic inventors. In 95 % of the cases, these inventions stay with an SME at *t2* during the timespan of our study. However, in 10 % of the cases, there is an ownership transfer between two different SMEs, see Fig. 5 below. Few inventions, 3 % in total, are transferred to MNCs, the TTO or individuals at *t2*.

Figure 3d shows all transfer routes where the inventor is the intermediary absorber of the patents (17 %). The results show that about half of the 17 % of the inventions at *t1* remain with the individual inventor at *t2*. This proportion is likely even higher considering that 4 and 9 % of the inventions belong to the ownership category 'unassigned'. The most common recipient of inventions at *t2*, apart from individuals, is SME (31 %).

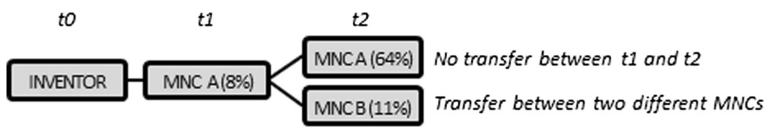

Fig. 4 Patent ownership transfer between two different MNCs between *t1* and *t2*

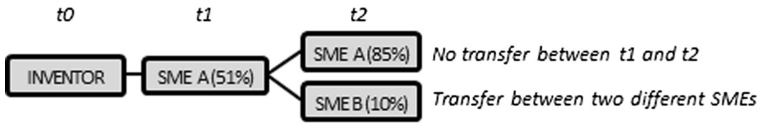

Fig. 5 Patent ownership transfer between two different SMEs between *t1* and *t2*

Figure 4e shows all inventions where for which the TTO takes initial ownership. About half of the inventions originally owned by the TTO (12 % at *t1*) are transferred to another entity at *t2*. The major recipient of inventions from the TTO is the SME category (30 %). The TTO seems to return ownership of 10 % of the inventions to their inventors.

Figure 3f shows all transfer routes that go via the category 'other' at *t1*. Most of these inventions (83 %) stay within this category and the rest are evenly distributed to the ownership categories MNC, SME and individual at *t2*.

As shown in Table 3 below, 49 patent ownership transfer routes are identified. By calculating the relative share of each transfer route it is possible to see which transfer routes that are used most and least. Results show a multitude of transfer routes used. Only eleven transfer routes have no patents transferred through them. This information will be used in the next section to develop a framework of technology transfer modes.

4.3 Developing the ABC-framework of academic patent transfer modes

As illustrated in Fig. 6, we develop a framework, the ABC-framework that can be used to analyse knowledge transfer from academia to the outside world. By investigating patent ownership transfers at multiple time points (*t0*, *t1*, *t2* and *tn*), this paper stands in contrast to previous studies that have considered ownership at a single time point, commonly at the time of patent filing (Lissoni et al. 2008; Thursby et al. 2009). Following the categorisation of patent owners used in Sect. 3.3.1, all 49 ownership transfer routes outlined in Table 3 were bundled into three main modes of technology transfer. These modes reflect the 'commercialising choice' that academic inventors are assumed to make every time they patent an invention through the internal university TTO (i.e., bridge mode), a firm (i.e., corporate mode) or on their own (i.e., autonomous mode) (Audretsch et al. 2006). Each mode is elaborated further below. It is important to clarify that the same academic inventor could choose different routes of patent transfer for different inventions. Thus, in attempting to commercialise inventions, the inventor may turn to the TTO in relation to one invention and found a spin-off company in relation to the next. As explained in the literature review in Sect. 2, these choices could depend on prior commercialisation experience, the existence of a social network or the nature of the invention per se. The *ABC-framework* is illustrated in Fig. 6 below and definitions of the three modes of technology transfer follow.

The first group of transfer routes constitutes inventions that are transferred via the individual, i.e., the academic inventor equals the original patent owner. Commercialisation is driven by the personal effort and initiative of the inventor (Hoye et al. 2006; Siegel et al. 2003a, b; Thursby et al. 2001). This group of transfer routes is referred to as the *autonomous mode (A-mode)* of technology transfer.

The second group of transfer routes concerns patents for which the university TTO or an external research organisation takes initial patent ownership and serves as a bridge between university and industry (Markman et al. 2008a, b, Muscio 2010). The similarity between these intermediary actors is that part of their mission is to support academic researchers in

Table 3 Overview of the number and share of inventions transferred through each transfer route

	Transfer routes	Inventions			Transfer routes	Inventions	
	Inventor-IND	No	%		Inventor-TTO	No	%
1	INV-IND-IND	60	8.5	29	INV-TTO-IND	8	1.1
2	INV-IND-SME	36	5.1	30	INV-TTO-SME	25	3.6
3	INV-IND-MNC	7	1.0	31	INV-TTO-MNC	4	0.6
4	INV-IND-RO	1	0.1	32	INV-TTO-RO	0	0.0
5	INV-IND-TTO	0	0.0	33	INV-TTO-TTO	40	5.7
6	INV-IND-Other	1	0.1	34	INV-TTO-Other	1	0.1
7	INV-IND-UA	11	1.6	35	INV-TTO-UA	4	0.6
	Inventor-SME				Inventor-Other		
8	INV-SME-IND	4	0.6	36	INV-Other-IND	1	0.1
9	INV-SME-SME	338	48.1	37	INV-Other-SME	1	0.1
10	INV-SME-MNC	5	0.7	38	INV-Other-MNC	1	0.1
11	INV-SME-RO	0	0.0	39	INV-Other-RO	1	0.1
12	INV-SME-TTO	2	0.3	40	INV-Other-TTO	0	0.0
13	INV-SME-Other	1	0.1	41	INV-Other-Other	19	2.7
14	INV-SME-UA	6	0.9	42	INV-Other-UA	0	0.0
	Inventor-MNC				Inventor-UA		
15	INV-MNC-IND	1	0.1	43	INV-UA-IND	2	0.3
16	INV-MNC-SME	11	1.6	44	INV-UA-SME	13	1.9
17	INV-MNC-MNC	44	6.3	45	INV-UA-MNC	6	0.9
18	INV-MNC-RO	0	0.0	46	INV-UA-RO	0	0.0
19	INV-MNC-TTO	1	0.1	47	INV-UA-TTO	0	0.0
20	INV-MNC-Other	0	0.0	48	INV-UA-Other	0	0.0
21	INV-MNC-UA	2	0.3	49	INV-UA-UA	6	0.9
	Inventor-RO						
22	INV-RO-IND	4	0.6		Sum	703	100
23	INV-RO-SME	6	0.9				
24	INV-RO-MNC	0	0.0				
25	INV-RO-RO	29	4.1				
26	INV-RO-TTO	0	0.0				
27	INV-RO-Other	0	0.0				
28	INV-RO-UA	1	0.1				

their commercialisation endeavours. Hence, patents transferred via the TTO or research organisations are included in the *bridge mode (B-mode)* of technology transfer in the framework.

The third group of transfer routes implies a direct transfer from the inventor to a company, i.e., an SME or an MNC. Direct transfer to a company indicates prior industry interaction, such as research collaboration or contract research (Cohen et al. 2002; Perkmann et al. 2013). Henceforth, this group of transfer routes is called the *corporate mode (C-mode)* of technology transfer.

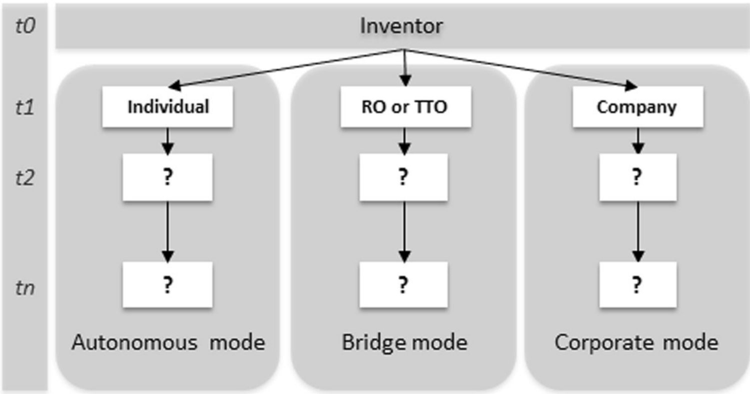

Fig. 6 The ABC-framework of academic patent transfer modes

4.4 The ABC-framework exemplified

The *ABC-framework* is exemplified by the case of Karolinska Institutet. Altogether, transfer patterns of 624 inventions (i.e., patent families) are investigated. Table 4 shows the distribution of patents transferred through each mode. The least used transfer routes are indicated with an asterisk in Table 4. They add up to 1 % in the *autonomous mode*, 4 % in the *bridge mode* and 3 % in the *corporate mode*.

The framework of technology transfer modes is illustrated in Fig. 7. It demonstrates the predominant transfer routes in each mode (those without an asterisk in Table 4), indicating the proportion of patents transferred from inventors to downstream entities.

4.4.1 The autonomous, bridge and corporate modes of patent transfer

The inventor takes initial ownership of the patent in the *autonomous* mode. As shown in Fig. 7, 17 % of all patents are transferred by individual inventors, which can be explained by previous studies addressing the importance of networks of academic scientists and industry professionals (Aldridge and Audretsch 2011; Colyvas et al. 2002; Thursby and Thursby 2002). Additionally, 'entrepreneurial experience' and 'inclination toward commercialisation' are two inventor characteristics that have been shown to be of significant importance in commercialisation of academic research (Marion et al. 2012). Our finding is in line with prior work which has found that researchers bypass their TTO (Audretsch et al. 2006; Fini et al. 2010; Markman et al. 2008a, b). For example, in a study of 54 US universities, Markman et al. (2008a, b) observed that 42 % of the professors bypassed the TTO. Additionally, the existence of the teacher's exemption in Sweden, which both encourages and places a responsibility on academic researchers to commercialise, could explain the 17 % patent transfer observed. The predominant absorbers of patents from the inventor (*t1*) are SMEs (*t2*). The SME in an individual case could either be a new spin-off company or an established company. However, if the inventor has previously founded a spin-off company, it is likely that future research in the same technological area would be directly assigned to that company at *t1*. Thus, such transfer would be categorised into the *corporate mode*.

Table 4 Clustering of patent transfer routes into the autonomous, bridge, and corporate modes

	No. of inventions	Share of transfer route	Share of the transfer mode
Autonomous mode			
Inventor-IND-IND	60	10 %	17 %
Inventor-IND-SME	36	6 %	
Inventor-IND-MNC*	7	1 %	
Inventor-IND-RO*	1	0 %	
Bridge mode			
Inventor-TTO-TTO	40	6 %	19 %
Inventor-TTO-SME	25	4 %	
Inventor-TTO-MNC*	4	1 %	
Inventor-TTO-IND*	8	1 %	
Inventor-RO-RO	29	5 %	
Inventor-RO-SME*	6	1 %	
Inventor-RO-IND*	4	1 %	
Corporate mode			
Inventor-SME-SME	338	54 %	64 %
Inventor-SME-MNC*	5	1 %	
Inventor-SME-IND*	4	1 %	
Inventor-SME-TTO*	2	0 %	
Inventor-MNC-MNC	44	7 %	
Inventor-MNC-SME*	9	1 %	
Inventor-MNC-IND*	1	0 %	
Inventor-MNC-TTO*	1	0 %	
	624	100 %	100 %

* Least used transfer routes

The *bridge mode* includes patents where the TTO or a research organisation is involved in facilitating the transfer process by taking initial ownership of inventions. About 19 % of all inventions are transferred through this mode, see Fig. 7. The relatively low ownership share of the TTO in this sample could be explained by the Swedish university IPR ownership legislations. It implies that Swedish university TTOs have to 'compete' for academic inventors with ambitions to commercialise their research results on an open market. This can be compared with findings in the US context, with a long history of university ownership, where TTOs have been shown to hold 70 % of academic patents (Audretsch et al. 2006; Thursby et al. 2009).

Almost two thirds (see Fig. 7) of all transfer routes are included in the *corporate mode,* which indicates previous university-industry collaboration. Comparing the proportions of patents that are transferred via the three transfer modes, the majority are transferred to the business sector. These results are in line with previous studies which show that between 50 and 80 % of European academic patents are owned by companies (Lissoni et al. 2008). Previous studies have identified that a greater part of company-owned academic patents are often owned by a few MNC (Lissoni et al. 2008; Meyer 2003). Interestingly, results from this study show a different pattern at Karolinska Institutet, namely that while 71 % of all academic patents (see current owner in Table 2) are company-owned, SMEs make up

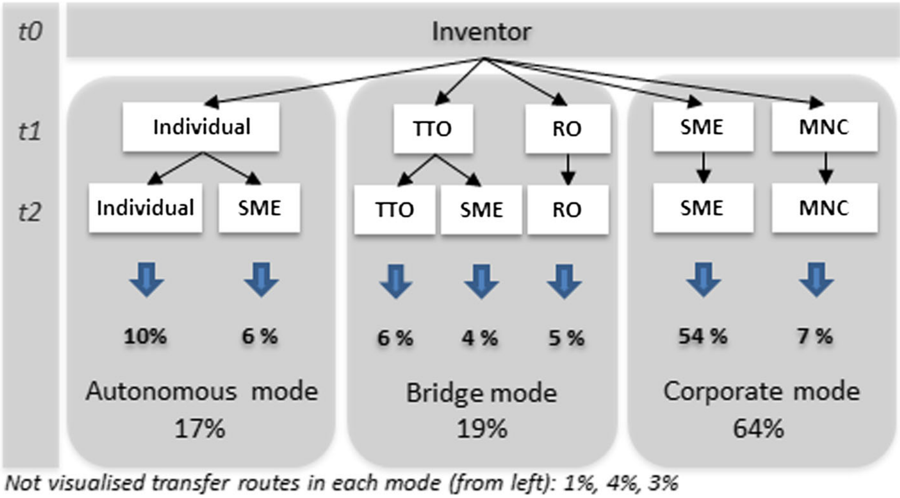

Fig. 7 The ABC-framework of academic patent transfer modes illustrating the proportion of patents transferred from inventors at Karolinska Institutet to downstream entities

61 % of all academic patents. The difference in ownership between SMEs (61 %) and MNCs (10 %) could be explained by the inclination of smaller firms to take on early-stage university technologies (Laursen and Salter 2004; Thursby et al. 2001).

5 Discussion and conclusion

In this study, the transfer of patented academic inventions from inventors to various entities was explored by tracing patent ownership changes over time. The empirical data was derived from the KIIP database, which holds results generated through name-matching of academic researchers and patents at Karolinska Institutet (Authors' own article to be inserted). Patent owners at three time points were identified and the extent of patent ownership changes was examined. Although this paper generates multiple findings, it contributes foremost to the literature on academic patenting and technology transfer by proposing a framework to guide empirical studies in analysing patent transfers longitudinally and broadly.

5.1 Implications of the framework at the university, market and regional level

In light of the ongoing policy debate on third mission indicators (Molas-Gallart and Castro-Martínez 2007), traditional methods of assessing university performance by scientific publications are insufficient. To better capture the impact of academic research on society, we have previously suggested that research evaluation should consider a broader part of researchers' activities, such as patenting (Authors' own article to be inserted). Following that reasoning, the ABC-framework offers opportunities for policy makers and university managers to benchmark and measure technology transfer outcomes, nationally and internationally.

As change of ownership has been shown to be an indicator of patent quality (Sterzi 2013), we stress that analysis of the extent of patent transfers longitudinally points to the ability of the university to produce research results demanded by industry. The notion that increased commitment by universities encourages faculty commercialisation endeavours (Baldini et al. 2007) implies that improved visibility of the patent owners could guide university managers in developing 'made-to-measure' innovation support. Specifically, education on how to formalise industry-collaborations and manage potential transactions is needed. Analogous to the use of publication-based citation analysis in mapping knowledge flows, the ABC-framework could also be used in resource allocation directed towards specific researcher subgroups.

At the market level, our approach maps university-industry interactions and deal-making between firms active on the market of science and technology. To expand the picture of which patented inventions have been traded and not (Serrano 2010), a combination of patents and licences could also be applied in the analysis. At the regional level, different local conditions such as knowledge base and industrial dynamics require an adaptation of innovation policies (Asheim and Coenen 2005; Tödtling and Trippl 2005). Hence, patent transfer analysis can inform such policies by providing evidence of inter-organisational ties (Owen-Smith and Powell 2004), rate of technological diffusion (Markman et al. 2005) and influence of universities on surrounding industry (Lendel 2010). While spin-off companies located in the proximity of a parent university have been shown to stimulate regional economic growth, patent transfers that are directly absorbed by foreign corporations may not necessarily contribute to the region in the same way (Steffensen et al. 2000). Further, it could be interesting to apply the ABC-framework to investigate whether patent ownership distributions in different countries or regions remain constant long-term or not.

We argue that our framework is suitable not only for university-to-university benchmarking, but also as a step in analysing socio-economic impact. In identifying the absorbers of academic inventions across time and geography, we provide guidance for further analysis of firm-specific performance indicators (e.g., growth, employment, investment) and business networks.

5.2 Implications of applying the framework in the life sciences

Our findings support existing studies on academic research commercialisation that have analysed academic patents broadly (i.e., patents stemming from the entire faculty). The application of the ABC-framework to the case of Karolinska Institutet illustrates that patented inventions are transferred through a multitude of routes (Cohen et al. 2002; Perkmann et al. 2013). Therefore, we conclude that it is not sufficient to only assess IPR flows through a university's TTO, as that could exclude a major part of the internal patenting activity (Saragossi and van Pottelsberghe de la Potterie 2003). This claim is also supported by those studies that have observed 'TTO-bypassing' by scientists subject to university ownership regimes (Audretsch et al. 2006; Markman et al. 2008a, b). A plausible consequence of not detecting 'bypassing behaviour' could lead to incorrect national technology transfer statistics. We interpret this as suggesting that knowledge on what share of academic inventions are transferred via different routes could help in supporting academic inventors in their interactions with other academic institutions and companies (Fini et al. 2010). As this paper alludes, name-matching of academic researchers could help uncover 'patent transfers' that are off the 'TTO radar' and appropriately categorise them into the *autonomous* or *corporate modes*.

In line with previous research results on patent ownership distribution in the European context (Lissoni et al. 2008; Lissoni and Montobbio 2015), our findings show that a majority of the patented inventions are absorbed by non-academic entities such as private firms. Given the time and costs involved in developing university-originated applications in the medical and life sciences sector (DiMasi 2002, Lipsky and Sharp 2001), the result that more than two thirds of all patents are transferred through the *corporate mode* clearly indicates the importance of university-industry collaboration for technology transfer. In particular, in the biopharmaceutical sector, research points to the significant role of biotech SMEs as intermediaries in the drug development process (Owen-Smith et al. 2002; Powell 1996; Stuart et al. 2007), which is confirmed by the large share (61 %) of SME ownership at *t2* in this sample. Also in other sectors, SMEs appear to play a major role in commercialising early technologies. For example, results from the EU Innovation radar project confirm the importance of SMEs in in bringing ICT technologies to market (De Prato et al. 2015).

The observation that international science-industry collaboration gradually replaces the importance of local collaboration, as inventions move along the technology life cycle Lecocq and van Looy (2009), could explain the relatively large share of national SME-ownership found. Moreover, as we analyse patented technology stemming from life science research, we conclude that any associated products will most likely not have moved sufficiently far along the product life cycle to attract the attention of international corporations. Another reason for why we do not observe a large proportion of MNCs as academic patent absorbers could be the ubiquitous use of licenses in the life sciences.

In addition, corporate ownership of academic patents could also be understood in relation to regional industrial dynamics. Drawing on the work by Meyer (2003), who found that large corporations were the most frequent owners of Finnish academic patents, it is likely that the traditionally strong Swedish biotech industry has been in a favourable position to absorb inventions stemming from the country's largest medical research university.

While the empirical findings can be interpreted to be specific to the medical and life sciences, where product development can take up to two decades, we suggest that the ABC-framework is applicable in analysing knowledge flows across institutions and sectors. Altogether, this study enhances our understanding of academic patent transfer. As stressed by (Authors' own article to be inserted), evaluation of academic research through the lens of patent information should consider a combination of patent-based measures. Therefore, it might be worthwhile adding longitudinal analyses of patent ownership transfers to the bibliometrics toolbox.

5.3 Limitations and opportunities for future research

This article provides evidence to the emerging literature on patent ownership transfers. However, there are limitations. The study is performed at one single university in a context where inventors are free to choose their own intellectual property transfer channels. Even though we argue that the results indicate similarities with other universities, independent of IPR ownership legislation, it would be interesting to widen the analysis to include other universities, nationally and internationally. Our approach biases technology transfer based on patents. To capture academics' broader involvement in technology transfer, it could be useful to expand the study to cover other knowledge flows. To really understand if there are any substantial differences in technology transfer output, it is important to account for other technology transfer mechanisms, such as licensing and collaboration.

In addition, taking into account conditions specific to a country or university (e.g., geographic localisation, university management, funding, awareness, researcher motivation) is essential to understand how to optimise internal university support infrastructure. Investigations into the background of inventors and their roles in commercialisation could provide insights that cannot be extracted from quantitative patent data analyses. For example, in order to understand why almost 10 % of the inventions remain in the hands of the inventors, more in-depth analysis of inventor behaviour is needed. This should be coupled with studies of the role of university leadership and innovation intermediaries in the management of IPR at universities.

Also, as SME ownership representation is relatively large in our sample, it would be interesting to study SME performance over time, in terms of products and revenues. In particular, the establishment and development of university spin-offs based on academic inventions opens for further research questions. Depending on the empirical context, the *bridge mode* could be widened to include other university-industry intermediaries such as technology parks, business incubators and venture capital funds (Muscio 2010). Finally, since the data was not time-weighted, it is important to remember that different patents are exposed to longer or shorter time frames to change owner.

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