The Forgotten Individuals: Attitudes and skills in Academic Commercialization in Sweden

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1. Introduction

During recent decades, the university as a societal institution has been under pressure to change, in ways relevant for their commercialization activities of starting up companies and patenting. One pressure for change has been that external actors like governments increasingly expect the university to play a central and important role for economic development. Studies have been made on the impact of university research and science on economic growth (e.g. Salter and Martin, 2001), and on the different mechanisms and channels for knowledge transfer, across different industries (e.g. Cohen et al., 2002). Salter and Martin (2001) identify six major mechanisms for diffusion of university research to industry: increasing the stock of useful knowledge; educating skilled graduates; developing new scientific instrumentation/methodologies; shaping networks and stimulating social interaction; enhancing the capacity for scientific and technological problem-solving; and creating new firms. Similar lists can be found in other references. Cohen et al. (2002) show that the key channels for university research to impact industry are publications, public conferences and meetings, consulting and informal information

exchange. A second pressure for change has been the growing demands within the university to find new sources of income, beyond traditional ones of government block grants, student fees (where applicable), and competitive research grants (Powers and McDougall, 2005). Thus, topics such as the entrepreneurial university, university-industry relations and commercialization by universities and researchers have become hot topics, not only in university strategy and public policy but also in academic literature analyzing these phenomena. However, much existing literature tends to view commercialization as a strategy and activity for the university as an organization, and one that will increase the economic impact of this societal institution. As such, the literature as well as the practitioners' oriented university strategy documents and public policy initiatives often stress the necessity of building a large scale support system, such as technology transfer offices, incubators, and the like. Given this focus on the university level support structures, the individual researcher has mainly been conspicuous by his and her absence. This chapter therefore focuses on an issue, which is just emerging in the literature, namely relating the skills and attitudes of the individual researcher to the overall outcome in terms of commercialization.

The question of how and why universities are suddenly pushing to 'become entrepreneurial' has generated much literature, mainly about the American situation but increasingly with insights also about Europe and Asia. According to Clark (1997), universities started to shift from a passive to an active mode regarding commercialization in the 1990s. They are thereby becoming an institution that explores and experiments with different reactions to internal and external demands. The trend at most universities is that commercialization aspects of research are becoming an established part of their activities, and particularly in the biotech sector university business development emerges as a fundamental component of the value creation chain (Campbell, 2005). One example of this shift is that many universities began to be involved in providing support structures to facilitate such activities, especially consultancy services, patents, licensing and start-up firms which are owned by faculty and previous students. This chapter focuses upon Sweden, partly due to the national institutional context, where Sweden ranks high in terms of R&D inputs (e.g. in the European Innovation Scoreboard 2007). However, the literature about Sweden is fairly divided as to whether the Swedish innovation is

performing fairly poorly or performing fairly well, in general and in terms of specific mechanisms (see reviews and differing opinions in Ejermo and Kander, 2007; Bitard et al., 2008; and McKelvey and Ljungberg, 2008).

Indeed, there are many ways and many levels at which to explain and analyze the societal benefits of public science, as developed below in Section 2. Commercialization of research is a concept that has a meaning close to a variety of other concepts, especially academic entrepreneurship, technology transfer, externalities and knowledge spill-overs, and third stream activities. In this chapter, the idea of transfer of technology refers to the process that permits academic research results to evolve in new processes and products, which can directly influence the development and the economic growth of society. The concept of commercialization is here limited to comprise patents and start-up companies. While there are other ways of commercializing academic research, these two approaches are the ones that so far have received most attention in commercialization research and practice, and they were therefore seen as the most important to investigate. The literature review provides an analytical framework of the important variables, which is then used to generate specific research questions. The analysis therefore uses a combination of factors at the individual, research group, university level and national institutional context.

This chapter focuses only on the commercialization of university-based science and technology, based on a survey in the Swedish innovation system, as further explained in Section 3. The survey was sent to more than 1200 Swedish academics, working within six research fields of natural science and engineering, across different universities and colleges. For each field, at least one research group had received a competitive bidding, public policy research center, which had the aim of promoting technology transfer as well as high quality science. The survey examines whether and how individual researchers are involved in commercialization, defined in terms of patents and start-up companies, linking the individual to the broader selection environment. The response rate was 24 percent, with small variations between the different categories of researchers. Section 4 presents the results and analysis and Section 5 the conclusions. Section 6 draws out the implications for university strategy and for public policy.

2. Literature review

Much of the debate and research regarding commercialization has focused around patents and licensing, especially the effectiveness of specific mechanisms, and yet universities interact with society, and impact economic growth, in many other ways. Agrawal and Henderson (2002) found that only 6.6 percent of knowledge transferred between the MIT departments of electrical engineering, mechanical engineering and computer science could be allocated to patents. The rest take a variety of other channels to communicate the results, including publications, consulting, informal meetings, recruiting, joint ventures, research contacts, and personnel exchanges. Other literature argues that technology transfer from universities is best facilitated by the active involvement of university inventors, and direct academic entrepreneurship is often seen as an effective means to facilitate technology transfer (Henrekson and Rosenberg, 2001¸ Slaughter and Leslie, 1999). The effectiveness of academic entrepreneurship can however also be disputed. Academic start-ups have been found to have lower performance than non-academic ones, in terms of cash flow and revenue growth (Ensley and Hmieleski, 2005), due to limited team heterogeneity, and then in particular a limited involvement of people with business skills. This ongoing debate about the relative effectiveness of these different mechanisms for technology transfer is outside the context of our research. Instead, our main focus here is to place the individual researcher, within a broader organizational and institutional context. This chapter therefore looks at the direct commercialization, and places Sweden in relation to literature about the USA and other European countries.

To structure the literature review and the survey, we conceptualize that the individual researcher works within a specific selection environment. That environment helps (or hinders) the individual by providing information which helps the individual to define incentives, mobilize resources, and realize economic value. In other words, there is an interaction between the individuals and their environment, which enables them to identify and act upon innovative opportunities (Holmén et al., 2007). These individual researchers must act in an entrepreneurial manner to identify, act upon, and realize their ideas, also within a university context. Or, they may never do so, because of a variety of ‘blocking mechanisms’ within their specific selection environment.

Figure 1 illustrates the three main elements of the selection environment, namely the national institutional context, the university, and the research group and subject within which the individual is active.

Insert Figure 1 about here

Therefore, this literature review is structured around four topics, namely the influence of national innovation systems, the development of support structures of universities, the impact of differing research fields, and the role of individual researchers.

2.1 National Innovation Systems, including institutions and public policy

The broadest level that we identify in the selection environment is the national institutional context. The national innovation system (NIS) literature stresses the need for learning and transfer of knowledge amongst actors involved in innovation. Since this idea can also be found in other theoretical traditions, theoretical linkages can be made about the role of the national institutional context, with the attitudes and actions of individuals. Within this tradition, the national institutional structures have been studied, including aspects such as financing, IPR, institutions, regulation, and public policy. Important issues include different mechanisms to stimulate interaction, learning environments, and the effects of specific policy measures on both interaction and on growth outcomes.

The American case has been widely used as a rationale to change national institutional context in other countries. One specific policy measure has been extensively commented upon, because it created an institutional change in the American system, namely Bayh-Dole. In general, it is seen as a key shift, but there have been debates about the impacts of the Bayh-Dole act and its effects on university-industry interactions in terms patenting and licensing. The Bayh-Dole Act was passed in 1980 and made it possible for universities to patent federally funded research. Concurrently, the number of patents taken out by American universities and their licensing activities, started to grow and continued to grow sharply during the 1980s and 1990s. While the cause is often attributed to the Bayh-Dole, Mowery et al. (2001) found little evidence for this. Rather, they argue that changes were already under way prior to 1980, and that the sharp rise in

patenting can also be attributed to the rise of the biomedical industry (where patents are a common form of IPR) and to the increased federal funding for this area. In addition, the patenting activities of universities were also stimulated in the USA by successful precedence (especially Stanford University and UCSF with the rDNA patent), by court rulings and by a broader shift in federal institutional framework that made it easier to patent research results in the biomedical field.

Without being the only reason for the increase of patents, most researchers agree that Bayh-Dole nevertheless likely hastened the entry into patenting and licensing by additional universities. According to Thursby and Thursby (2002), it increased the propensity and willingness to patent by administrators and faculty in particular. However, they argue that the institutional change did not necessarily lead to more research being commercialized. Rather than increasing the overall amount and distribution of commercially realizable research, the result was that more research results were patented, which lead to a lower average quality per patent. This argument is supported by the empirical data which shows that only a very small share of all patents filed by universities make up the lion's share of all their revenues from patenting (Nelsen, 2004). Arguably, this would imply that instead of generating new income streams, many universities have either been spending money in technology transfer offices without substantial returns, or they may in some cases be dependent upon a low number of high performing patents.

In Sweden, the national institutional context is different. One reason is that the individual researchers own the property rights of their research results, in what Europeans call the professor privilege. Hence, in contrast to the U.S. the university does not own the IPR. The individual researcher can, however, choose to assign the rights to the university, in return for partial benefits. Henrekson and Rosenberg (2001) argue that Sweden has a general lack of favourable institutions and pertinent incentive structures that promote the emergence of an entrepreneurial culture. This, they argue is the major explanation for the modest role of academic entrepreneurship in Sweden. A number of other institutional problems that have been argued to influence the lack of academic entrepreneurship in Sweden are: underdeveloped private equity markets, heavy taxation of entrepreneurial income, and restrictive labour laws (see e.g. Goldfarb et al., 2003; Goldfarb et al., 2001).

Hence, the literature about the national innovation system in Sweden mainly stresses the negative sides of the national institutions.

The American case – and the need for economic growth – has stimulated much debate in Sweden, with the idea of following the American institutional model. Other European countries – notably Denmark in the Scandinavian context – have already done so. The different lines of argumentation in this debate go essentially as follows. On the one hand, removing the professor privilege clause should improve patenting and licensing, as it would increase universities' incentives to be involved in the processes. On the other hand, observers have pointed out that universities have neither the structures nor experience needed for handling this. As a response to this, the important public policy actor VINNOVA has implemented a program to try to improve organizational capabilities for support structures.[1]

Patenting and starting up companies are the direct and easily observable ways to identify how and when universities impact economic growth. These can also be seen as ways in which individual researchers act less like scientists, and more like businessmen, in terms of owning IPR and even running businesses.

However, this literature also suggests that the specific orientation and organization of the national innovation system will have a broader impact on how, and whether, universities and businesses are able to interact (Lundvall, 1992; Nelson, 1992). More recent work on these lines suggests that the more conducive that the national environment and institutional structures are to collaboration, the greater will be the impact of university research on industry. Similarly, spill-overs and externalities are measured through certain proxies of collaboration and of indirect impacts through co-location. These proxies include the amount of co-publishing of university and industry researchers, references made to university research in articles published by industry researchers, and the number of citations to university research in patents. Measuring patent citations in one scientific field, Spencer (2001) found differences in citation rates between Japan and the US, such that American patents tended to cite papers more often. She attributes these national differences to US policy makers' intention throughout the postwar period to increase commercial relevance of university research. Also using patent

citations, Narin et al. (1997) found that university research has become more salient in patents over time, possibly indicating effects of public policy stimulations to interactions. The results were, however, to some extent offset by changes in US patent reference policies.

In summary, the specific Swedish innovation system provides the individual with IPR, rather than the university, and the implications are that the university has little incentive or expected return to promote commercialization. Moreover, the implications of other research about Sweden suggest that we should observe a low level of commercialization, due to the lack of incentives and lack of entrepreneurial culture. Finally, the broader effects of the national innovation systems and of localized spill-overs are usually measured at the aggregate level, and they are quite difficult to capture at the level of the individual researcher. However, they do suggest that the actors need a positive attitude towards collaboration and technology transfer, before they engage in commercialization activities.

2.2 *University support structures*

The next relevant level in the selection environment is the university, and then in particular its support structures and the typical ways in which the universities interact with society.

This topic is clearly related to the previous one, because different institutional contexts appear to provide universities and colleges with different incentives, legal rights, and rationale to be active in building specific support structures. The question here becomes how and why the universities tend to end up with different structures and mechanisms for technology transfer. Etzkowitz (2003) argues that one important difference between Europe and the U.S. is that the entrepreneurial university emerged “bottom up” in the U.S. in contrast to Europe, where the involvement in commercialization by academia is a recent “top down” process. Establishing university policies that promote the commercialization of research has been the mainstream Swedish efforts to assist academic entrepreneurship or other ways of technology transfer (Henrekson and Rosenberg, 2001). Swedish universities are said to be confronting several problems in the building up of such structures and policies. One view is that the

Swedish government has invested lavishly in university research and enacted a set of policies to facilitate knowledge transfer, but it has failed to create a good incentive system for universities and academics to pursue the commercialization of ideas originating in academia (Goldfarb et al., 2003). Jacob et al. (2003) suggest that a considerable amount of tension still exists between those who see research as a public good and those who focus on the need to integrate university based knowledge production with the rest of the economy: Hence, how increased commercialization and the new role of university inside the society should be harmonized with existing traditions in teaching and educations is still a frequent issue. A clear example of this is that in 2003, the OECD reported that knowledge of patent policies at the university level was not well disseminated among faculty and researchers at public research organizations in Europe.

Moreover, the typical ways in which a specific university interacts with society, may be related to overall indicators of the quality of science on-going. For example, using citations of university research in patent application, studies have found highly cited American academic papers to be selectively cited by American patents (Hicks et al. 2000; Narin et al. 1997). Although patent data is influenced by reference policies set within national institutions, these indications have been confirmed in surveys. Mansfield (1995) showed that the research perceived as most important to industrial technology managers was often directly related to the quality of the university's faculty in the relevant department, and to the size of its R&D expenditures in relevant fields. However, while high quality of science seems to make the university more attractive as a collaborative partner for universities, this does not imply that marginal universities do not interact with industry. Mansfield (1995), in his survey, also found that the relationship between faculty rating and contribution to industrial innovation was so weak in several industries that it seems likely that many modestly-ranked departments play as big role in this regard as some of the highest-ranked departments. Similar results are found in D'Este and Patel (2007) for the UK case.

Partly because so many other countries wish to imitate the overall American phenomenon, there has been an increasing in interest in how specific universities handle

patenting and licensing. Consequently, much literature has come to focus on the role of university Technology Transfer Offices (TTOs), as well as incubators and science parks.

Systematic data has become available for the American context, and increasingly for international actors through professional associations. The Association of University Technology Managers (AUTM) documents the commercialization of university research in the USA. In 2004, AUTM reported that 567 new commercial products were introduced to the marketplace based on licensed technologies from 137 universities and 462 new companies based on an academic discovery were formed in 2004 with an increase up by 23.5 percent with respect to the year 2003 (AUTM, 2004). One academic review of best practices in U.S: universities' TTOs found that the existence of written policies relating to technology transfer practices provides a benefit to learning (Allan, 2001). Di Gregorio and Shane (2003) reached a similar conclusion when studying spin-off rates from US universities, and they also found that university policies of making investments in start-ups and maintaining a low inventor's share of royalties increase new firm formation.

Similar results have been found in the European context. In a survey to TTOs at 57 UK universities, Lockett et al. (2003) found that the more successful universities now have clearer strategies towards the spinning out of companies, and also use "surrogate" entrepreneurs in this process. In addition, the more successful universities were found to possess a greater expertise and networks, and equity ownership was more widely distributed among the members of the spin-out company. Hence, the result of this line of research stresses that the presence of support structures at a university, such as TTOs and incubators, can increase the chances of successful commercialization and thereby the output of inventions (Powers and McDougall, 2005).

In summary, the national institutional context has been argued to differ in ways which impact how universities actually build up their support structure. The US model is very much focused on creating incentives for universities to commercialize their research output, allowing them to experiment the best ways to do that. In contrast, the Swedish model is very much an attempt by the government to directly create mechanisms to facilitate commercialization. The implication of this research would suggest that Swedish university faculty members have limited incentives for commercializing their research and consequently also ought to have less positive attitudes towards commercialization.

Moreover, research in USA and Europe suggests that there are very similar, practical mechanisms like partial ownership, which seem to promote commitment and ultimate success. The implications are that the main support structures that individual researchers are likely to use are technology transfer offices and incubators (including various support and consultancy services associated with them). However, attending to the individual researcher level, and not only the university level, these mechanisms need to be complemented with courses in relevant areas like entrepreneurship and IPR, as these are clearly mechanisms that may promote positive attitudes and the learning of relevant commercialization skills.

2.3 Research groups and Individual researchers

The third relevant level is that of the research groups, set in relation to the activities of the individual researchers.

Many different characteristics could be analyzed, as relevant to commercialization, but the two main topics are quality and orientation of research. One important characteristic, long found in the debates, is the quality of the new knowledge. Quality of science is a difficult concept, but the indicators of scientific quality are usually quantified as publications, usually published within specific subsets of journals. This reflects a judgment about the output of individual researchers and research groups. At the overall level of the relation to university-industry interactions, most studies report a positive relationship between quality and industrial interactions. Di Gregorio and Shane (2003), for example, found that intellectual eminence (in terms of the overall academic rating score of graduate schools published in Gourman Reports) was related to the number of spin-offs from universities. Work by Zucker and Darby (1996) and Zucker et al. (1998) indicated that star scientists with relevant intellectual capital are more likely to start firms and move into commercial involvement than are marginal scientists, within the specific research area of biotechnology, and later in other areas. These star scientists should remain involved in commercialization, and not just transfer the knowledge to other companies, if companies are to grow quickly.

An issue related to quality and industrial interaction is the research area within which the individual and research group work, and existing literature shows a

relationship between specific fields of research orientation and industry interaction. The research orientation is usually measured through groupings of scientific fields or to the extent that research is applied or basic in nature. These two approaches are partly overlapping. The results indicate only small differences in the extent of interaction, but the types of interaction vary depending on whether the university is more science-based or more applied in its approach. Using share of industry funding as a proxy for commercially oriented research, Di Gregorio and Shane (2002) found that higher shares did not increase the rate of spin-offs at least. The findings of Meyer-Krahmer and Schmoch (1998), though, suggests that there are differences in the preferred types of relationships where more applied research seems to call for more contract research. In their analysis of German universities, Meyer-Krahmer and Schmoch (1998) show that university departments within science-based fields, as defined by scientific citations within patents, focus on more basic research whereas university departments in less science-based field tend to focus more on the solution of technical problems.

A topic that has received much less attention in relation to the commercialization of research is the attitudes and the commercialization skills of the individual researchers. It has even been argued that the academic inventors constitute a black box in theories on commercialization (Göktepe and Edquist, 2006), which needs to be better understood. As noted above, some literature about national institutions and university support structures do, however, make explicit predications about whether individual researchers should have incentives to engage in commercialization.

While the mentioned studies of “star scientists” (Zucker and Darby, 1996; Zucker et al. 1998) indicate that the single researcher should be seen as a fundamental actor in initiating and enhancing the technology transfer process, there is still limited evidence for this idea on a more general level. This view is hardly surprising as the researchers’ intellectual work constitutes the starting point for any resulting finding that may have the potential to be commercialized. Rather, it appears strange that some studies do not explicitly pay attention to the researchers’ role in this process, apart from being seen as a detached source of transferable knowledge, something which is strongly questioned in more elaborate theories dealing with knowledge and learning. Based on the widely accepted notion that an important part of knowledge is tacit (Polanyi, 1961) and that

knowledge cannot be expressed in its completeness in natural languages, it can thus not be converted to information and moved without the loss of this important tacit part. Hence, knowledge is to some extent contextualized in individuals and therefore has a certain "stickiness" (Szulanski, 2000). The individual researcher's knowledge is however not isolated from the direct context in which he or she performs research activities, but is at least partly a result of the social interaction with colleagues. Considering both social and individual types of knowledge (see e.g. Spender, 1996), it is clear that the research group's values, norms and ways of interacting influences the individual researchers knowledge that can be commercialized. The impact of the research group on university-industry interactions in general is often described in terms of quality and orientation of research on-going. Certain scientific and technical fields are more likely engage in certain types of interaction with industry. More recent work is also beginning to stress the importance of individuals, because knowledge is contextualized within the individual.

The implications are that their actions in regards to patents and start-up companies will be conditioned by their attitude and competencies towards commercialization, as well as by the broader selection environment. Because the likely intensity and mechanisms for university-industry interaction can differ greatly by quality of science and research field, the implication is that the research design should focus on a population of individual researchers which are relatively homogeneous. Within that group, one can then investigate diversity. Moreover, we should expect that the more positive attitudes and more competencies in commercialization that the individual holds, the more likely they will be engaged in commercialization.

2.4 Research Questions

Figure 1 placed the individual researcher in relation to three elements of their selection environment, namely national institutions, their university support structure, and their research group. This literature review has gone through these variables in terms of their main findings, and drawn out the implications for what can be expected in the Swedish case. This is a new line of research, previously neglected in the literature, where this paper explicitly relates the individual researchers' actions and attitudes, to their interpretation of the broader selection environment. In particular, the contribution of this

paper will therefore be to link the attitudes and skills of individual researchers to the commercialization of research findings.

Based on our analytical perspective, and the implications from existing literature, this chapter will therefore address the following three research questions:

- RQ1: How to characterize the commercialization activities of Swedish researchers, individually and at an aggregate level?
    - To what extent do they patent and start academic spin-off companies?
- RQ2: What are the researchers' attitudes and skills concerning commercialization and their university?
    - What are the researchers' attitudes towards patenting? Towards starting up new companies? Towards their own skills in commercialization?
- RQ3: What are the relationships between commercialization activities and the attitudes and skills of the researchers?

3. Research Design

The research design has been based on our aims both to obtain systematic quantitative data about Sweden and to further develop concepts and theories relevant for understanding the process of commercialization of research results. In terms of developing concepts and theories, the main contribution is our shift to examining and explaining how and why individual researchers' attitudes and skills are related to the level of universities as organizations.

In order to answer the research questions specified above, we have carried out a survey of individual researchers in Sweden. The survey does not target all academic researchers in the country. Instead we have focused on six specific research areas in engineering and natural sciences, to decrease variance across the sample. All the fields are ones in which basic research is performed but where the results lead to specific technological solutions as well. These six chosen research areas have at least one Swedish university which set up a research center (won through competitive bids) with the specific aims to promote university-industry interaction, commercialization, and more

generally, economic growth. We then examined all universities and university colleges in Sweden with a research center or department in that subject.

3.1 Methodology: Survey

The methodology consists of a web-based survey. The survey was designed after a thorough review of literature, and the aim was to elicit data that would increase our understanding of Swedish academic researchers' involvement in the commercialization of university research. Commercialization was defined as consisting of two activities, the generation of start-up firms, and the generation of patents that are licensed or sold out. In addition, the survey results should help us identify differences between researchers who have commercialized their findings and those researchers who have not been involved in such activities, as related to the three elements in the selection environment. Survey questions therefore asked questions about whether individuals were positive or negative towards different commercialization activities; about how the individuals perceived their attitudes as compared to their research group as a whole; about their knowledge and possible use of the university support structure; and about communication with industry and broader institutions. These questions were included, because they represented possible explanations for differences between commercializers and non-commercializers that we identified in the literature review above.

The survey was sent to a little more than 1200 researchers employed at Swedish universities and university colleges, representing a number of personnel categories which can be assumed to engage at least to some extent in research. Six research areas of engineering and natural science were chosen, namely: Fluid Mechanics, Inorganic Chemistry, Wood Technology, Computer Science, Biotechnology and Automatic Control. We chose them because these are all areas where at least one of the universities hosts a national competence center. VINNOVA, the Swedish Agency for Innovation Systems, set up these VINNEX Centers, with the explicit aims 'to become an academic, multidisciplinary Centre of Excellence by actively involving a number of companies in joint research' and 'to promote the implementation of new technology and to strengthen the technical competence in Swedish industry'. All other universities or university colleges with centers and departments in the same research area were then identified and

included in the sample. Hence, while only one of these universities have a specific VINN Excellence Centers in any given area, the research field per se has been identified as one of interest to companies and to Swedish industry.

Taking these VINNEX centers and the other major departments at center resulted in a total population from different universities (in capitals below). Note that each university may have more than one relevant center or department. This then resulted in a survey sent to 50 departments in the six research areas, distributed according to the following list. For a complete list of departments included, see Appendix A.

1) Fluid Mechanics (5 departments at 4 different universities)
2) Inorganic Chemistry (6 departments at 5 different universities)
3) Wood Technology (7 departments at 6 different universities)
4) Computer Science (10 departments at 7 different universities)
5) Automatic Control (11 departments at 6 different universities)
6) Biotechnology (11 departments at 6 different universities)

Before sending out the survey, we initially contacted the head of departments (or research leaders) for approval to conduct it. The survey was performed using a web-based questionnaire, with the initial query and reminders sent out during a period of three months. The data in the database was analyzed using SPSS software.

3.2 Reliability

The population is quite large, to be inclusive of these six research areas, and hence the total population was composed of 1219 academic researchers. The response rate was 24.2 percent, leaving us with usable responses from 295 researchers. The response rate is thus relatively low as compared to surveys on other topics conducted in Sweden, but about the same rate as surveys on university-industry relations conducted in other countries. Still, some reservations should be made for the comparably low response rate, which most certainly was influenced by the large number of questions in the web-based questionnaire. We therefore analyzed for representativeness of the sample, as compared to the total population receiving the questionnaire.

To avoid bias of over- and under- representation of specific research areas, we also checked the response rate by research area (e.g. aggregated for all universities within a specific area).

Insert Table 1 about here

Table 1 thus presents the population, sample and response rates per research area. On the whole, response rates were quite similar, although inorganic chemistry was slightly below the average and automatic control slightly above. Based on the limited variation in terms of response rates from the different research areas, we concluded that the sample was not biased towards any one research area, and decided to use the whole sample.

To avoid bias introduced by the over- and under-representation of specific types of personnel categories, we checked this in the response rate for the population and sample, as shown in Figure 2.

Insert Figure 2 about here

As seen in Figure 2, the sample is reasonably representative of the different types of jobs found in the population as a whole. The groups which are slightly over-represented are PhD students, Post Docs and Associate Professors whereas the groups slightly under-represented are Professors and research assistants. Nevertheless, the differences are small enough to allow us to regard the sample as representative for the whole population.

Obviously, the researchers in the sample, as well as the total population of researchers receiving the survey, work within only six specific science and engineering fields. Hence, care should be taken not to generalize from these fields to all other areas. Generalizations may most likely be possible towards engineering fields, while it is more questionable whether the findings presented here are valid also for science fields of a less applied nature, such as e.g. the more fundamental areas of physics.

4. Empirical Results and Analysis

This section consists of three parts. The first sub-section answers the questions about how to characterize the commercialization of Swedish researchers. The second sub-section concentrates on the attitudes and skills of the individual researcher. The final sub-section addresses relationships between commercialization activities and the skills and attitudes of the individual researcher.

4.1 Commercialization Activities

This sub-section addresses the first research question, namely how to characterize the commercialization activities of Swedish researchers, individually and at an aggregate level?

Taking into account all valid responses, a total of 23 researchers (8.6 percent) have tried to commercialize university research by creating and developing academic spin-offs. To this should be added that another 18 researchers (6.7 percent) state that they have in a spin-off started by someone else. Furthermore, 40 out of the researchers (14.4 percent) had obtained patents. Out of these, 16 of the researchers (5.8 percent) had also managed to sell the patent or license it out. As a number of researchers had used both ways to commercialize, a total of 52 researchers (19.3 percent) had been engaged in patenting and/or the start-up of a spin-off company. If we only consider the start-up of firms and the patents that have so far been commercialized through sales or licensing, this figure drops to 11.5 percent. Comparing the data from the different research fields, we note that the commercialization frequency in certain fields appear to be much higher than in others (see Figure 3). In the areas “Computer Science” and “Fluid Mechanics”, as many as approximately 15 percent of the researchers have commercialized some of their research findings, while the corresponding number for “Wood Technology” researchers is 4 percent.

Hence, this sub-section has shown that a little more than 10 percent of the researchers in the sample had directly commercialized their results, either through licensing out or selling patents they had generated, or by starting up a company based on their research findings. Extending the view of commercialization to include also patents that so far have not been sold or licensed out, almost 20 percent of the researchers had been involved in commercialization. While there is only limited data available on the

patenting of academic researchers, we can see that this is relatively well in line with the frequencies presented by Lissoni et al. (2007), which reveal a great variation between different fields of research, but smaller differences between researchers in different countries.

Insert Figure 3 about here.

4.2 Attitudes and Skills, in relation to their University

This sub-section addresses the second research question, namely what the researchers' attitudes and skills are concerning commercialization and how they perceive that commercialization is regarded by their university?

The results indicate that the respondents clearly have a positive opinion towards commercialization. Researchers were asked to respond on a 7-point Likert scale, about their personal opinion and about their perception of the predominant view in their research group. As shown in Figure 4a, they tend to give positive scores to commercialization of research results in general, with more respondents being 'very positive' than they perceive their research groups to be. A reasonable interpretation of the latter is that commercialization is not discussed that much and that some researchers may feel that they are more positive to this than they think is seen as positive by their peers.

Figures 4b and 4c show similar results towards, respectively, patenting and founding a company. From these results we can first of all conclude that more respondents are negative towards patenting than towards founding a company. Note also that a neutral attitude is more common towards these specific mechanisms, as opposed to commercialization in general, both for respondent's personal opinion and for the research group. This suggests that researchers are more positive to other mechanisms of technology transfer, which go beyond the narrow definition of commercialization used here.

Insert Figures 4 a, b and c about here

Researchers were also asked if they had considered commercializing their research. Here the respondents were given several alternatives and could also provide answers besides these. The results of this are seen in Table 2.

Insert Table 2 about here

Based on the above, it is clear that many of the researchers have the ambition to sooner or later commercialize their research findings. Which may also actually become reality, given that a large number of the respondents are PhD students who in most cases have limited possibilities to combine studies with commercialization activities However, we also see that as many as 21 percent of them do not find that there is time for commercialization activities, and almost 14 percent state that they do not know how they should commercialize it. Looking only at patents, the two most important reasons for not patenting are lack of personal time and resources for doing so, and a preference for publishing instead of patenting, underlining the results regarding attitudes above. The lack of commercialization knowledge and skills becomes even more striking if we look at the researchers' answers to the explicit question whether they actually feel that they have the necessary skills and knowledge to start their own spin-off company. A clear majority (69 percent) then answered that they believe that they at present do not have sufficient skills to do so. Lockett et al. (2005) argue that knowledge gaps can occur at different levels of analysis, and that we need studies that address the lack of knowledge at different levels of analysis. The results of this study clearly reveal one such knowledge gap, in terms of missing entrepreneurial and business skills.

What can also be seen from the statistics is that formal training in business and entrepreneurship, as well as work experience from outside the university, appear to reduce this problem. There is a significant difference (chi-square test) between individuals who have undertaken formal training and those who have not in terms of their perceived commercialization skills (see Table 3). However, formal training is of course only one way to improve individual skills in a practice-oriented discipline such as business and entrepreneurship. Another factor that definitely can make a difference for the perceived ability to start a company is work experience outside the university.

Comparing researchers with work experience from private firms with the ones who do not have such experience, a significant difference in their perceived ability is seen (see Table 4).

Insert Tables 3 and 4 about there

Based on the above, we would argue that a substantial part of the researchers may actually refrain from commercializing their research due to their own perceived inability to do so, even if they in many cases have some research results that they consider to have a potential commercial value. It is in this context that the university support structure services are launched, of course, as a way to enable individual researchers to get around the problems of lack of skills and experience with commercialization. Instead of acquiring the skills needed themselves, researchers can to some extent rely on their university support structure for commercialization. This includes services such as technology transfer offices, access to patent attorneys, rent subsidies in incubators, consultancies for business plans and setting up companies, and the like. They help the individual researcher overcome blocking mechanisms within their national institutional context, something which appears logical given the researchers' responses. However, this is based on the possibility to separate the knowledge from the researcher who have created it, and also that the specific piece of knowledge is of an explicit nature.

But do the individual researchers know that commercialization is part of the university strategy or that services are provided? Our results suggest that this awareness is limited. Despite the public debate in Sweden, our results indicate that universities may not have signaled their focus on commercialization internally well enough – or that the individual researchers were not listening, if they have signaled it. In as many as 35 percent of the cases, the researchers were actually unaware of any commercialization focus in the university's strategy. Hence, despite the need for Swedish universities to increase the commercialization and the substantial efforts they put into this, the message does not seem to get through to all researchers. Moreover, many researchers did not feel that they receive support and encouragement from the university to patent or found an academic spin-off in order to develop their results commercially. This problem was also

identified by Siegel et al. (2003), who found that the universities' outspoken strategies and goals in terms of research commercialization were not reflected in e.g. performance evaluations and reward structures. An important question here is thus to what extent it is actually beneficial for the single researcher's career development to spend substantial time on commercialization, as evaluations still have a very strong focus on research and teaching performance.

Summarizing the above, the survey has shown that the researchers in question are in general neutral or positive towards commercialization. Thus, the results show the opposite of what we would expect to see, based on the literature on the national institutional context, in which it is suggested that Swedish academics would be negative to commercialization, due to low entrepreneurial focus and lack of supporting institutions. This sub-section also showed that 35 percent of the respondents did not know about their university strategy for commercialization. While the attitude does not appear to constitute a problem, lack of skills and time definitely seem to be barriers for commercialization This issue is however at least to some extent possible to handle with formal training in business and entrepreneurship, or increased possibilities to go back-and-forth between positions in academia and industry.

4.3 Relationships between Commercialization Activities and Individual Skills and Attitudes

This sub-section addresses the third research question, namely the relationships are between commercialization activities and the researchers' attitudes and skills. Moving from the attitudes of the researchers to their knowledge and skills related to commercialization, we can distinguish two important sets of knowledge skills. On the one hand researchers need to be knowledgeable in their scientific field, and on the other hand they need skills to commercialize this knowledge. As a first step we turn to their scientific knowledge, here measured as number of scientific publications, to see if there is a difference regarding this between the individuals who commercialize and the ones who do not commercialize.

The results of the test indicate that there is a significant positive correlation between a researcher's number of publications and the act of commercializing research

findings. Researchers who have commercialized their research have an average of 45.8 publications, while non-commercializing researchers on average have 15.4 publications. This seems logical, as the number of publications reflect the amount of research that is performed, and consequently also the potential for commercialization. However, a number of other factors that are positively correlated with the number of publications, such as for instance the age of the researchers, should be controlled for in order to be able to analyze this inter-relationship in a more rigorous manner. What could also be argued against this result is that some publications can take place on behalf of e.g. patenting, and thus to some extent would limit commercialization. Nevertheless, this is in line with the empirical findings of O'Shea et al. (2005), pointing to the mutually reinforcing nature of excellent researchers and entrepreneurial activities at universities. This observation therefore once again points to the importance of the ideas about star scientists (Zucker and Darby, 1996) and indicates that we should regard commercialization as a complement to research, and not as a substitute for it (Etzkowitz, 2003). With more research being performed by skilled researchers, they are also more likely to generate new knowledge that can be commercialized.

A second issue is whether gaining skills through attending courses on commercialization does not only influence the perceived commercialization skills, but also actually lead to more commercialization. We analyze attended courses on subjects related to commercialization to see if the use of these courses is correlated with the founding of an academic spin-off and/or licensing or selling of a patent. We conduct a chi-square test on two variables:

- Commercialization, whether an individual has tried to commercialize his/her research, either by licensing or selling a patent or by starting a new firm based on research findings.
- Attended courses in areas of direct relevance for research commercialization, such as e.g. Business, Entrepreneurship and Intellectual Property Rights.

Insert Table 5 about here.

Based on the results in Table 5, there appears to be a significant relationship ($p<0.01$) between the two investigated variables. Attending courses on commercialization subject is directly linked with the creation of spin-offs and the selling or licensing of patents. The causal relationship behind this correlation is of course difficult to determine. Either it is the case that researchers who have taken courses related to commercialization are more likely to actually engage in such activities, or it may be that researchers who are considering the commercialization of some research findings, or are already involved in doing so, see a need to attend courses that can provide them with improved commercialization skills.

When comparing the frequency of commercialization between the group of researchers who have working experience from private firms outside academia and the ones who do not have such experience with a chi-square test, we see a similar pattern (see Table 6). The group with working experience has a significantly higher frequency of commercialization. This underlines the results from an earlier study by Dietz and Bozeman (2005), in which they found that even modest increases in industry experience influenced patenting rate significantly.

Comparing with the results concerning researchers' perceived commercialization ability, we can note that training and working experience do not only co-vary with a perceived improvement in the ability to commercialize research, but also with actual commercialization frequencies.

5. Discussion and implications

This chapter addresses the skills and attitudes of individual researchers, in relation to the commercialization of academic research.

The results and analysis above can be summarized as follows, thereby providing the answers to our three research questions. First of all, we note that a little more than 10 percent of the respondents have actually commercialized their research, either in the form of starting a company or by generating patents that have been licensed or sold out. Taking into consideration also patents that so far have not come into commercial use, this figure rises to almost 20 percent.

What regards the researchers' attitudes towards commercialization activities, it is seen that most researchers are positive to it and that only few of them are negative. It can be noted that they are more positive towards commercialization in general than towards patenting, implying that there sometimes are conflicting interests between publishing and patenting.

While attitudes towards commercialization were in general positive or very positive, and thus ought not to constitute a major issue, the perceived lack of commercialization skills is definitely a barrier to realizing the potential economic value of academic research results. The reasons for not commercializing that were brought forward were primarily lack of time and commercialization know-how. In particular, the lack of skills needed for starting spin-off firms appear to be a significant barrier to this kind of commercialization. Very few of the researchers felt that they had the necessary skills to start up a spin-off company on their own, which may explain part of the lack of commercialization actions. Another result that underscores this is that among researchers who had actually commercialized some of their findings, there was as significant over-representation of the ones who had taken courses in commercialization-related matters or had previous experience from working in firms outside the university. What the causality behind these correlations looks like is difficult to say based on the data at hand. Either persons who are more interested in commercialization follow such courses, or people who get engaged in commercialization activities become aware of the need to improve their skills in this field. One thing that talks against the latter is that opinions about commercialization in general are positive among the researchers, and that the decision to commercialize thus ought to be more a matter of skills than attitude.

Based on the empirical observations, we fully agree with Lockett et al. (2005) that many researchers who are willing to commercialize their research are not capable of doing so, and that it is important to distinguish between the researchers who are willing to commercialize their research and the ones who are capable of doing it. However, apart from finding the ones with the appropriate skills, an even more important task is to make sure that more researchers who want to commercialize their research are given the possibility to develop also their business skills, e.g. through training programs or periods in industry. As described by O'Shea et al. (2007), entrepreneurship development

programs at different levels is for instance a fundamental part of the commercialization activities at MIT. This component is still missing at many universities, and this gap needs to be filled to enable other parts of the commercialization support system to work well. An alternative approach to deal with the problem of lacking commercial skills is that researchers more frequently should take on a more technical role in their ventures and let more business-oriented individuals lead the spin-off (Lockett et al., 2005), possibly in combination with hiring more researchers with industrial experience, as suggested by Dietz and Bozeman (2005).

Furthermore, it was found that the knowledge among researchers about the universities' strategies and ambitions for commercialization is limited. A substantial part of the respondents did not know about their existence, which points to a need for more and clearer communication from university management regarding this aspect, and to assure that these strategies are reflected in actions. Just like Siegel et al. (2003), we see that one important way of facilitating commercialization of academic research is to align the performance evaluation systems at universities with the desire to commercialize more research, e.g. by considering commercialization experience and skills in promotions and hiring. We can conclude that the strategies of many universities in their ambitions to commercialize more of the research findings put much emphasis on support structures that can facilitate commercialization initiatives once they have started, while they do not attend sufficiently to the genesis of research commercialization, which is more dependent on the attitudes and skills of individual researchers. This appears to be a particularly challenging issue in Sweden, where the professor privilege assigns the IPR of research findings to individual researchers and thus make it even more necessary that the individual researcher is both willing and able to take the first steps towards commercialization.

Our results can be put in context of the public debate, because we provide a very different focus. With the exception of a few vocal critics, our interpretation of the assumptions underlying the debates can be summarized as follows: Universities should commercialize more so that society benefits more (and previously before everyone saw the cost of TTOs, so universities generate new income streams). Often, the assumption has been that individual researchers choose not to, and are not good at,

commercialization, and that universities and government agencies should focus on building university specific support structures, especially for the handling of patents and intellectual property rights (IPR). While such structures play an important role in the process of commercializing research results, they are not always useful when the knowledge in question cannot be separated from the researchers who have created it. In accordance with O'Shea et al. (2007), we thus see a need for holistic approaches to research commercialization, looking at individuals, organizational features, culture and the external environment together to understand what can be fruitful ways forward, instead of focusing on emulating single aspects of well-known successful cases like MIT.

Our findings suggest that the impact of the university support structure may have been inflated. In contrast, other aspects of this process, and in particular the individual researchers, being the holders of contextual and tacit knowledge and the genesis of innovations, have received too little attention. This highlights the possibilities to impact commercialization activities by influencing the attitudes and actions of individual researchers, through the use of various means.

Consequently, an increased focus on preparing researchers for these activities by providing training and increasing the possibilities to combine an academic career with work in companies stand out as two possible mechanisms to ameliorate the situation. A final implication is the need for universities to communicate their ambitions and strategies to commercialize research more extensively, something which actually by itself could raise the awareness and willingness to participate in commercialization activities.

6. Acknowledgements

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Figure 1: Conceptual Model of the Selection Environment affecting Individual Researchers

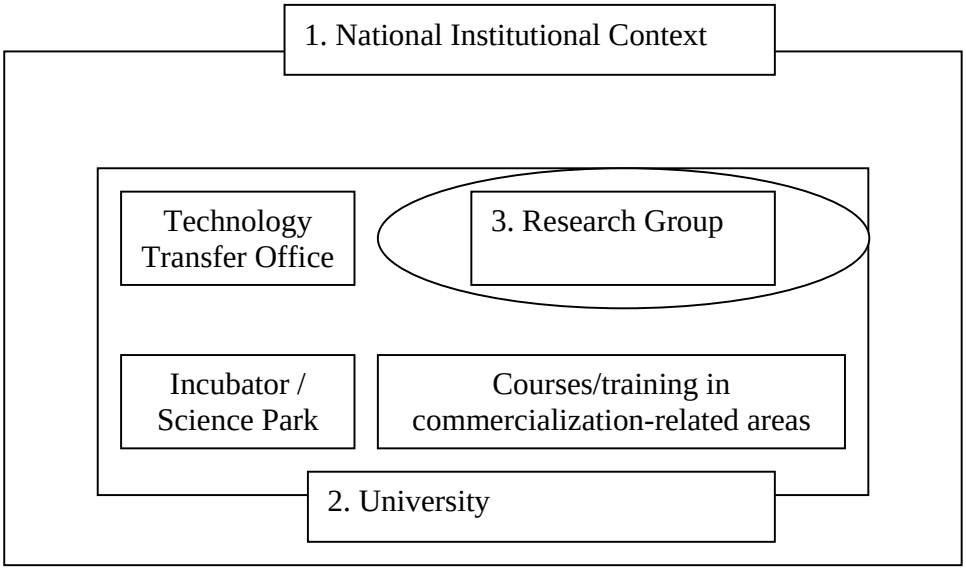

Table 1. Responses from the different research areas

	POPULATION	**SAMPLE (responses)**	**RESPONSE RATE**
Fluid Mechanics	139	31	22.3%
Wood Technology	112	29	25.9%
Biotechnology	327	80	24.5%
Computer Science	301	74	24.6%
Automatic Control	198	52	26.3%
Inorganic Chemistry	142	29	20.4%
TOTAL	**1219**	**295**	**24.2%**

Figure 2. Comparison of sample and population based on researcher categories

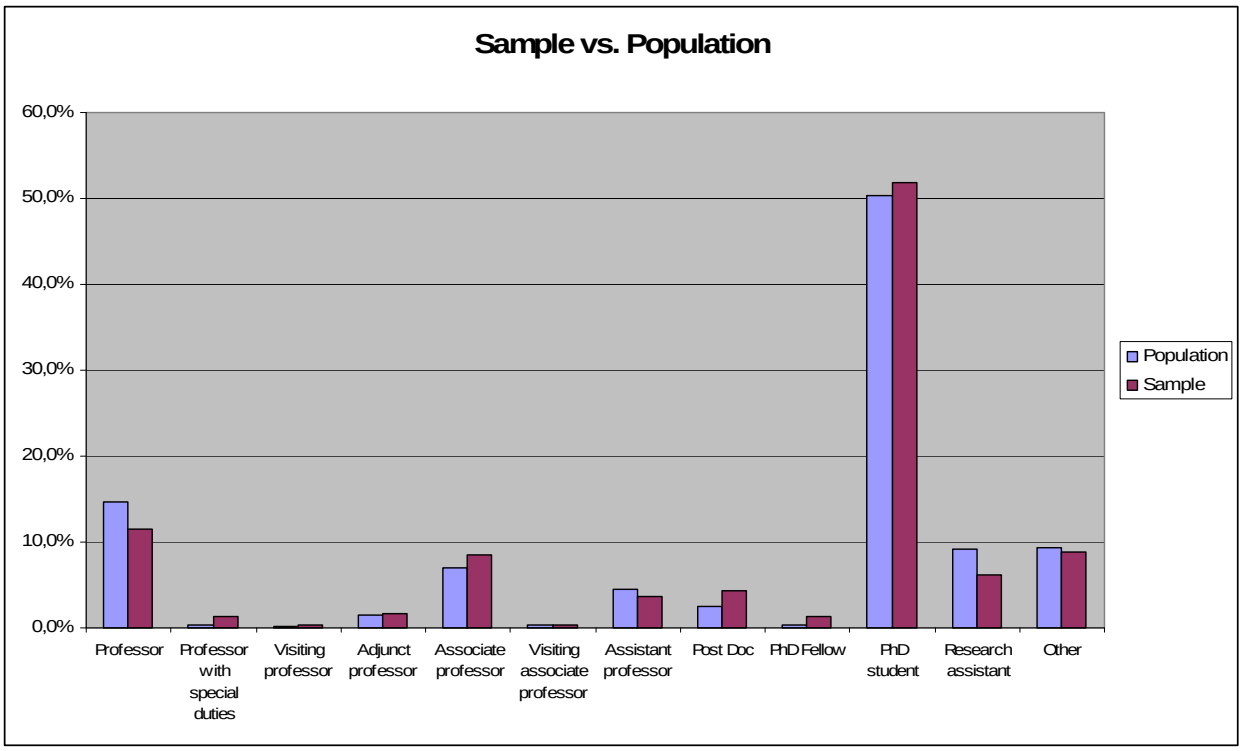

Figure 3. Commercialization frequency in different research fields.

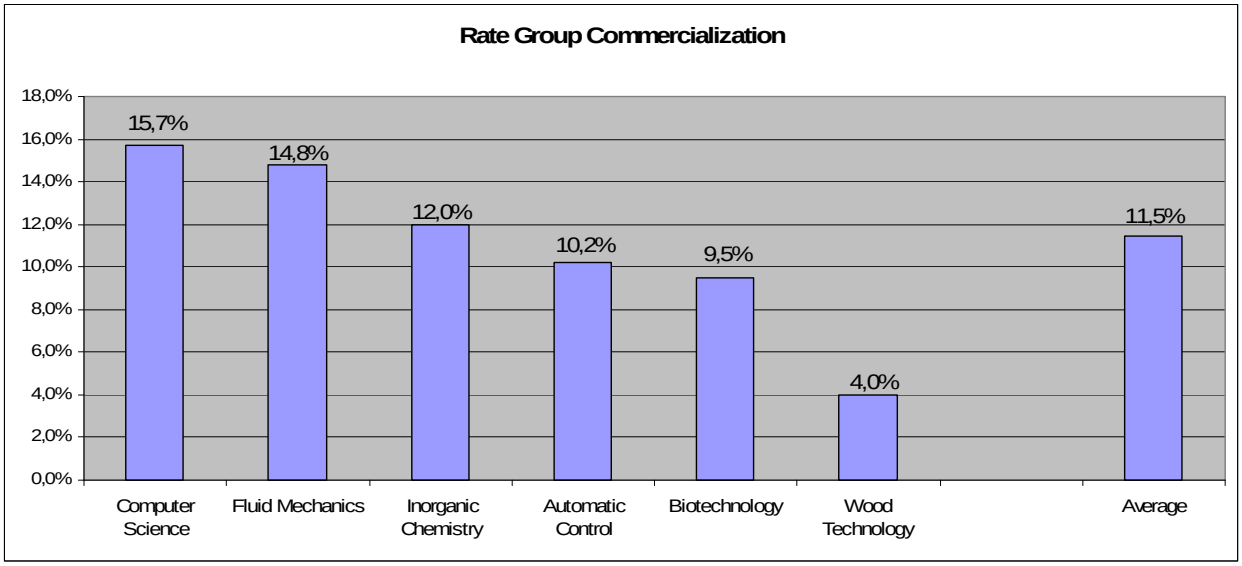

Figure 4a. Attitude towards commercialization, for individual and research group

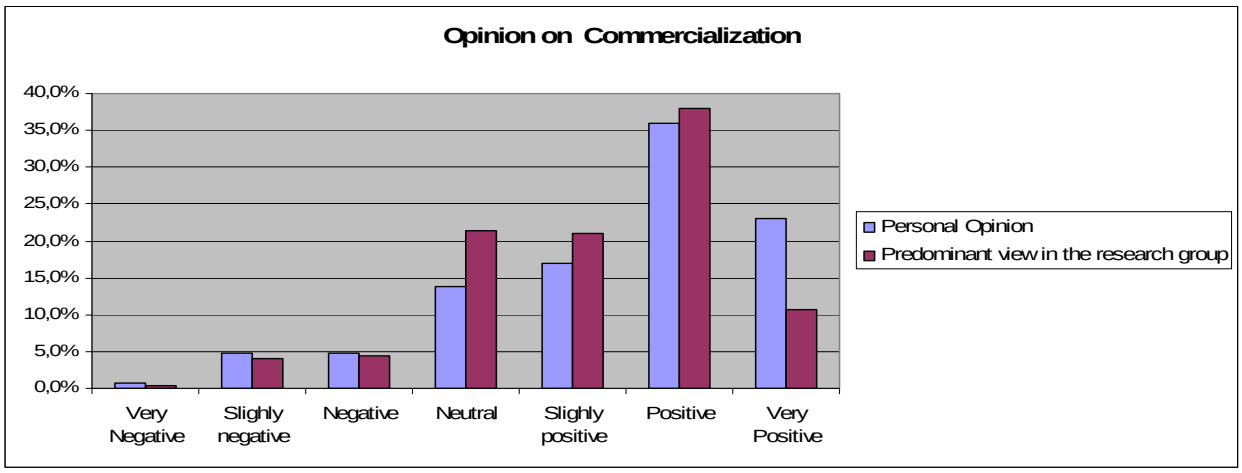

Figure 4b. Attitude towards patenting, for individual and research group

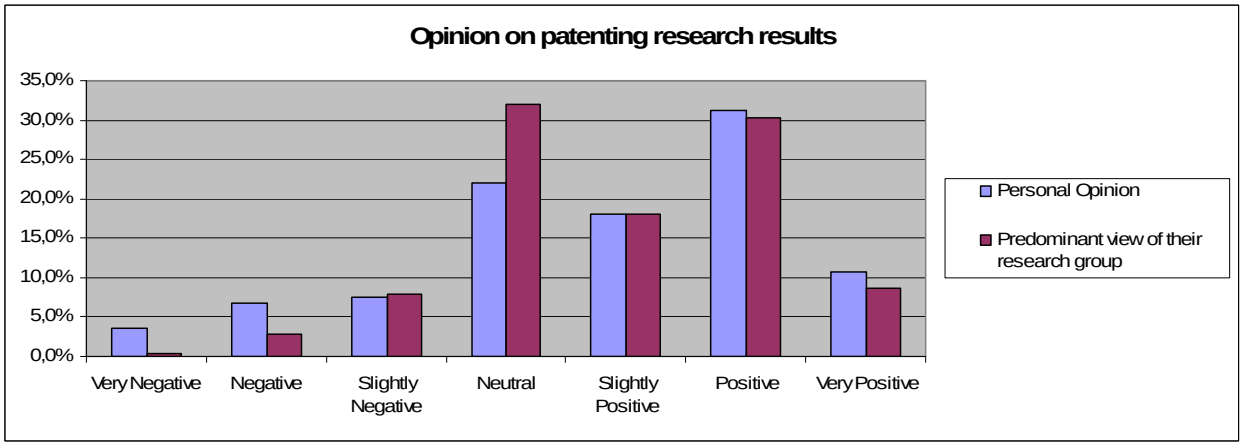

Figure 4c. Attitude towards founding a company, for individual and research group

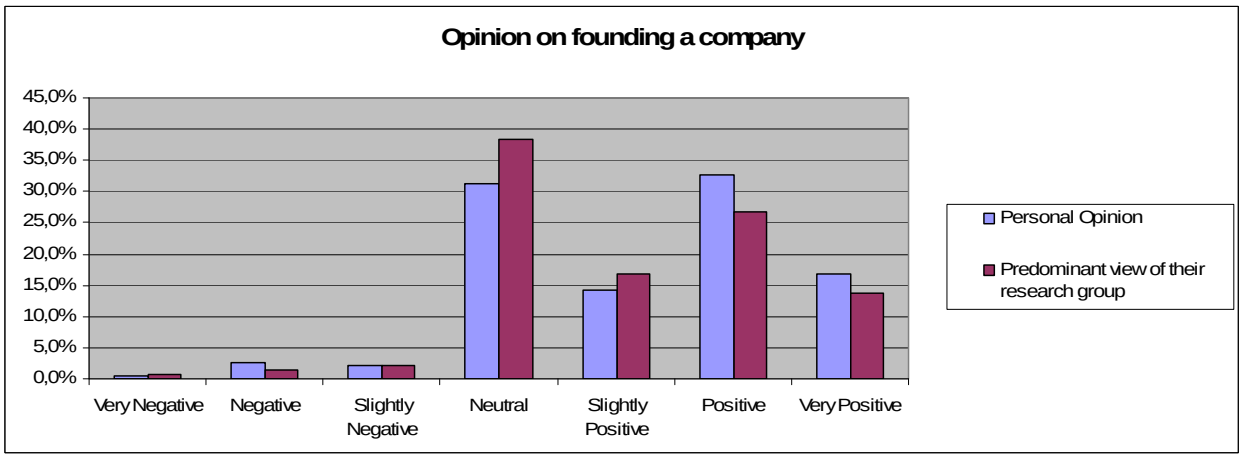

Table 2

Have you considered commercializing your research?	%
No, I do not think that university research should be commercialized	3.4
No, my research does not have any application in industry.	14.2
Yes, but I do not know how.	13.9
Yes, but I do not have time.	21.0
Yes, I am certainly going to.	10.5

Table 3. Formal training in Business and Entrepreneurship and perceived ability to start a spin-off company

		Perceived ability to start a spin-off company		
		No	Yes	Total
Formal training in Business and Entrepreneurship	No	191	61	252
	Yes	12	31	43
	Total	203	92	295

Table 4. Work experience from private firms and perceived ability to start a spin-off company

		Perceived ability to start a spin-off company		
		No	Yes	Total
Working experience from private firm	No	165	48	213
	Yes	38	44	82
	Total	203	92	295

Table 5. Inter-relationship between training and commercialization of research.

		Has commercialized research		
		No	Yes	Total
Formal training in Business and Entrepreneurship	No	181	18	199
	Yes	25	9	34
	Total	206	27	233

Table 6. Inter-relationship between working experience and commercialization of research.

		Has commercialized research		
		No	Yes	Total
Working experience from private firm	No	179	60	239
	Yes	16	15	31
	Total	195	75	270

Appendix A: List of departments included in the study

1) Fluid Mechanics

Chalmers University of Technology (Combustion and Multiphase Flow)
Royal Institute of Technology (Internal Combustion Engines)
Lund University (Combustion Engines; Continuum mechanics)
Luleå Technical University (Energy technology)

2) Inorganic Chemistry Chalmers University of Technology (SCI)
Royal Institute of Technology (Materials Process Technology; Physical Metallurgy)
Luleå Technical University (Materials Science Centre)
Stockholm University (Inorganic Chemistry)
Uppsala University (Ångström Materials Chemistry)

3) Wood Technology

Chalmers University of Technology (Forest Product/Chemical Engineering)
Royal Institute of Technology (Wood chemistry/Pulp technology)
Swedish Agricultural University (Wood science)
Växjö University (Forest-/Wood technology)
Karlstad University (Pulp technology; Paper technology)
Luleå Technical University (Wood technology)

4) Computer Science

Chalmers University of Technology (Applied Software; Programming Logic)
Royal Institute of Technology (Software Development)
Luleå Technical University (Mobile Networking/Computing)
Uppsala University (Computing Science, Computer Systems)
Mälardalens University (Computer Engineering)
Lund University (LUCAS; Computer Science)
Linköping University (PELAB)

5) Automatic Control

Chalmers University of Technology (Automatic Control Group; Automation Research Group)

Royal Institute of Technology (Automatic Control)

Luleå Technical University (Control Engineering)

Uppsala University (Systems and Control)

Lund University (Automatic Control)

Linköping University (Control and Communication; Real-Time Systems; Theoretical Computer Systems; Vehicular Systems; Embedded Systems)

6) Biotechnology

Chalmers University of Technology (Chemical Reaction Engineering)

Royal Institute of Technology (Chemical Engineering; Energy Processes)

Luleå Technical University (Chemical Engineering)

Uppsala University (Biochemistry; Separation Technology)

Lund University (Biotechnology; Biochemistry; Applied Biochemistry; Chemical Engineering)

Linköping University (Biochemistry)