CONTROLLING THE COMMERCIALIZATION OF SCIENCE ACROSS ORGANIZATIONAL BORDERS

FOUR CASES FROM TWO MAJOR SWEDISH UNIVERSITIES

Competitive

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ABSTRACT

This paper applies a multiple-case study design in order to investigate how control is applied by universities and other involved actors during the commercialization of science.Four cases from the KarolinskaInstitutet and Uppsala University (PET center, Ångström Materials Academy, Actar AB, and Karolinska Development) were selected to provide variation in the commercialization mechanisms. Our research purpose is to explore and analyzehow different types of controls are applied in different commercialization mechanisms, especially in relation to the specific actors and relationships involved in these mechanisms. We find that action and result controls dominate in linear mechanisms, while interactive and complex ones entail a combination of action, result and personal controls. However, the type of involved actors, their relationships and goals also impact on which controls are applied in a commercialization mechanism: Namely, conflicting goals between equally powerful actors, distant actors and the prevalence of financial and economic goals is associated with result controls. While action controls are applied especially when time and efficiency are a priority. We conclude the paper with policy implications and closely related needs of further research.

Keywords: commercialization of science, commercialization mechanisms, controls, measures, relationships, networks.

INTRODUCTION

Since the 1990s,the Swedish government has mandated universities to actively contribute to the Swedish innovation system with the diffusion of academic science across society.Thus, major universities, such as Uppsala University (UU) and KarolinskaInstitutet (KI), createdholding companies with the task of directing the commercialization of scientific ideas. Within a few years, KI and UU had complemented their holding companies with several other organizational units playing specific roles in the attempt to bring academic researchers, their ideas and labs, closer to industrial utilization and markets. Such roles include the scouting of new scientific ideas that have commercial potential, verification, validation and early support for the disclosed ideas, including patenting and search of potential licensors. Both universities can also provide pre-start up funding and then become part-owner if the scientific idea is turned into a spin-off company.

In 2001 KI had already established a complex commercialization structure that granted it the epithet of "Karolinska Inc."(Stone& Frank, 2001: 2374-6), and which KI managers explicitly term today asKarolinska's"innovation system". UU too has differentiated its organizational structure to better cope with commercialization tasks, but it retains a slimmer structure dealing with a more variegated set of innovation activities as opposed to KI (Baraldi&Waluszewski, 2011).KI and UU's innovation units are inspired by established international models known as "Technology Transfer Offices" or "Offices of Technology Transfer" (see e.g., Etzkowitz, 2002; Wright, Clarysse, Mustar& Lockett, 2007).However, they have to deal with a particular feature of the Swedish institutional context – the so called "teacher's exemption", whereby the intellectual property on a discovery rests with the scientist employed at a university. Therefore, compared to the American context, where universities own the commercial rights to their researchers' ideas, in Sweden, university innovation offices need to convince scientists to firstly disclose their ideas and secondly, if the idea sounds commercially attractive, they need to convince scientists to sign-off the property rights to a university unit before this can engage in its commercial exploitation.

The presence of the teacher's exemption and a simultaneous mandate to commercialize and diffuse science oblige Swedish universities to find their own individual ways, sometimes *around* the very exemption rule. This occurrence makes the Swedish contextparticular interesting from a theoretical point of view for studies of academic entrepreneurship:the resulting variety in approaches and mechanisms to commercialize science at Swedish universities can provide new insights compared to studiesin more regulated environments (Nilsson, Rickne&Bengtsson, 2010: 624). As the empirical parts will illustrate, KI and UUhave indeed created substantially different commercialization structures and apply different mechanisms, such as technology licensing and spin-offs, whichreflect a linear technology spin-out funnel (Clarysse et al., 2005), or more interactive mechanisms such as cooperation platforms (Nilsson, Rickne&Bengtsson, 2010).Different commercialization mechanisms imply also interactionsand relationships with different external actors in the surrounding networks (Baraldi&Waluszewski, 2011), spread across the three settings of developing, producing and using specific technologies (Håkansson&Waluszewski, 2007; Ingemansson, 2010). Moreover, the two universities apply different *control and measuring devices*, ranging from budgets and contracts to routines and trust (see Emmanuel, Otley& Merchant, 1990;Tomkins, 2001), depending on the specific mechanisms and the other involved organizations. Therefore,the aim of this paper is to explore and analyze *howdifferent types of controls are applied in different commercialization mechanisms, especiallyin relation to the specific actors and relationships involved in these mechanisms.*

In order to achieve this aim, we apply a multiple-case study design (Yin, 2004) and we purposefully selected four casesamong UU and KI's innovation strategies in order to show

variety in the commercialization practices of universities. More specifically, the differences among the four cases enable us to identify a wide spectrum of *commercialization mechanisms* (our first analytical dimension), as well as of *controlling and measuring devices*(our second dimension) applied by universities in their *network interactions*(our third dimension) with society and industrial actors.Reflecting these three analytical dimensions, our research questions are:(1) Which *commercialization mechanisms*do these two universities employ,and for whichspecific*goals*? (2) Which internal and external*actors*and *relationships*are involved from thethree network settings of developing, producing and using technologies? (3) *Which actors* exert *control* in these networks and *how*, including which specific outcome indicators they apply (e.g., patents, spin-offs, products, relationships)?

The remainder of the paper is organized as follows: after a review of previous research on the commercialization of science, we present our methodology. Then follow the four cases from UU and KI and their respective analysis. Finally, a discussion of the cases relating back to our key dimensions and research questions prepares the Conclusion of the paper.

PREVIOUS RESEARCH ON THE COMMERCIALIZATION OF SCIENCE: HOW DO YOU CONTROL IT?

This literature review revolves around the three main dimensions presented in the Introduction, namely the *mechanisms* to commercialize science, the *actors and networks* involved, and how this can be *controlled*. Westartfrom the general issue of the involvement of universities in diffusing their science to society, or more simplistically, the "commercialization of science" and its various mechanisms; then we moveto the various actors involved in this process, their relationships and emergent networks; and finally we consider literature on inter-organizational control andhow the process of making science useful to societyis measured.

The economic contribution of universities to society is widely recognized and includes for instance trained graduates, new instruments and methods, technical problem solving and the creation of new firms (Salter & Martin, 2001; Marsili, 1999).However, since the 1990s policy makers and other stakeholders have greatly raised their expectations on how and how much academic science should contribute to economic development(Elzinga, 2004), reflecting also an alleged "knowledge paradox" (Soete, 2002). Proponents of this paradox claim that the process whereby scientific discoveries (namely publications) are turned into innovations (namely patents) is inefficient. Exposed to this increased pressures to justify large investments in academic research, universities have continued and accelerated an historical evolution based on including new roles and tasks – from teaching to research, and now including also entrepreneurial activities (Etzkowitz, 2004a; 2004b). This evolution culminates now in what Etzkowitz terms the "entrepreneurial university" (Ibid), which focuses on capitalizing knowledge, closely interacts with government and industry, while trying to stay independent and developing its internal structures to cope with the new commercial tasks.

In practice, universities currently apply several mechanisms to make their science useful to society, such as graduates and publications, industrial liaisons offices to organize interactions with companies, technology transfer offices (TTOs) to obtain IPRs on their researchers' discoveries and license them to companies, and incubators to support and sustain academic spin-offs (Etzkowitz, 2004a: 72-3). The two latter mechanisms – TTOs' licensing and spin-offs – represent key elements in the "spin-out funnel" model presented by Clarysse et al. (2005: 187) and Clarysse and Moray (2004). Mowery (2005) and Nilsson, Rickne and Bengtsson (2010) point out that this linear model of commercializing science has also assumed centrality for university practice, policy makers and social scientists investigating the

phenomenon. A reason for this centrality might be that the model is rather simple and that its effects, namely patents, licenses and spin-offs are easy to measure and quantify (see examples of such studies in Powell & Owen-Smith, 1998; Zucker, Darby & Armstrong, 2002; Audretsch& Stephan, 1996).

However, universities apply a multitude of other mechanisms to make their science useful, which risk being neglected by the current focus on licensing and spin-offs (Jacobsson& Perez Vico, 2010; Bercovitz&Feldmann, 2006). These other mechanisms, which Nilsson et al. (2010) term as the "grey zone" of technology transfer, include:*sponsored research* (from contract R&D to materials testing, and from joint R&D to third-party sponsored projects), *informal and pre-formal discussions* with industry, *shared personnel*, *education of industrial PhD candidates*, *participation in policy/industry advisory boards*, *provision of physical labs and facilities*, *instrument development*, and *network creation and participation* (Ibid; Jacobsson& Perez Vico, 2010: 771). Each of these mechanisms aims at a particular goal in terms of external utilization of science and universities apply them by means of particular organizational structures.

Depending on the various mechanisms to commercialize science, universities not only create particular internal structures, but also enter in contacts with different types of external actors and establish particular types of relationships with them. For instance, a licensing track induces university technology transfer offices to find established companies interested in buying a license on a new science-based solution and to interact especially with their R&D personnel or patent attorneys, while the spin-off track induces these offices to seek various types of financers, including venture capitalists. Instead, informal and pre-formal discussions or materials testing might involve any type of company and both their R&D and production departments. Education and personnel sharing involve also human resource departments. Sponsored research, especially if made as third-party financed joint projects, requires universities to relate not only to firms but also funding bodies (e.g., VINNOVA, the Swedish Agency for Innovation).These various actors are all involved in different ways in trying to promote, develop or exploit innovations.

However, there are many challenges in the complex process separating a brilliant scientific idea from becoming an "innovation" in proper terms, that is, a solution that has been widely adopted by users willing to pay for it (cf. Tidd, Bessant&Pavitt, 2001: 38-9). In particular, the innovation needs to be connected to three settings populated by actors with diverging, if not conflicting logics, namely the *developing*, the *producing* and the *using* setting (Håkansson&Waluszewski, 2007; Ingemansson, 2010; Baraldi, Gregori&Perna, 2011).But the greater majority of the actors that the commercialization unitsregularly interact with through the various mechanisms above still belong to a *developing setting*, such as specific university departments and research groups, research funding agencies, venture capitalists, patent attorneys, and R&D departments of companies. The university units engaged in commercializing science rarely relate to actors belonging to the *producing* and especially *using* settings (Baraldi&Waluszewski, 2011).

The type of relationships and networks between universities and external actors vary too, depending on the mechanisms of commercialization of science. In the "spin-out funnel"(Clarysse et al., 2005) market-based arm's-length relations dominate, as TTOs search among all possible licensors to sell a license and negotiate among all possible buyers to sell their shares in a spin-off. In the case of sponsored research, however, relationships with industrial partners can instead be deeper and closer, such as in joint R&D projects, personnel sharing and provision of lab facilities. Such relationships can become full blown forms of collaboration (Santoro, 2000) or alliances (Bercovitz&Feldmann, 2007) with a long-term perspective. In these situations multiple links between the university and the industrial partner

emerge over time (e.g., formal, human resource and informal links, Vedovello, 1997: 495-4) and the relationship evolve depending also on the goals, competence and structures of the two parties (Bercovitz&Feldmann, 2007; Debackere&Veugelers, 2005), but especially on the tangible outcomes achieved (Santoro, 2000: 267). Relationships can also be unilateral, that is, oriented towards a single party, as in the case of the licensing track, or multilateral, that is, involving simultaneously several companies (and several research groups) as in the case of network creation or in the participation to advisory boards. It should however be noted that building academia-industry relationships entails several challenges due to diverging motives, time orientation and core values (Plewa, Quester &Baaken, 2005), and to the fact that universities are far from being the preferred R&D cooperation partners for firms, which typically prefer their customers and suppliers for such tasks (Håkansson, 1989).

While applying the various commercialization mechanisms, universities become variably engaged in innovation processes which are complex, open-ended, uncertain and non-linear (Van de Ven et al., 1999). Moreover, the rate of success, in terms of discoveries that really become profitable products, is discouragingly low: less than 40% according to Tidd, Bessant and Pavitt (2001: 16). However, despite this complexity and difficulties, rising expectations and investments in innovation make it increasingly important for organizations dealing with innovation to control and account whether and how their objectives – and those of their owners or financiers – are achieved (cf. Baraldi&Strömsten, 2009: 542). But control and governance systems facing innovations meet the twofold problem of a highly uncertain task and of a very open system, where external actors have a strong influence onboth the process and its outcome (Van de Ven et al., 1999). The literature on management control indicates that organizations apply different types of control tools in different moments of the innovation process and especially informal*personal* controls (e.g., recruiting trusted actors) when dealing with highly uncertainand complex tasks (Abernethy & Brownell, 1997). Formal control tools, such as *result*and *action* controls (e.g., respectively budgets and guidelines, cf. Emmanuel, Otley& Merchant, 1990), are instead usually introduced when new key actors (e.g., a new CEO) get involved, as well as when external actors start to exert control, such as when venture capitalists enter as owner of a start-up (Davila, 2005).

Considering the strong external influence oninnovation, several external actors are likely to intervene and try to control the process or that part of it which falls within their range of operations, such as developing, producing or using activities (cf. Håkansson&Waluszewski, 2007). Inter-organizational control and accounting is therefore an important issue for all organizations involved in attempting to achieve innovation, including university units. But in an inter-organizational or network setting, control is not exerted vertically as in a hierarchy, but needs to rely on horizontal information and influence (Hopwood, 1996) and emerges indeed from a mixture of coordination mechanisms including hierarchy, market-based and clan-related controls (Håkansson& Lind, 2004). As control cannot be exerted directly across organizational boundaries, indirect mechanisms such as target costing (Nicolini et al, 2000) and open book accounting (Mouritsen, Hansen & Hansen, 2001) prevail. Moreover, classical accounting techniques such as budgets, representing a form of *result* control, can be applied between separate actors, but they require nonetheless to be combined with an important form of personal control, namely *trust* between the counterparts (Tomkins, 2001).

Looking specifically at the university units dealing with innovation, there is a great variety of tools and measures whereby they are internally and externally controlled, which depend very much on thespecific commercialization mechanism at hand: hard result measures such as patents, licenses and spin-offsare applied to the spin-out model and the licensing track; while softer measures such as numbers of joint projects or relationships established, or their quality, are applied to the “grey zone” mechanisms (Nilsson et al., 2010) such as sponsored research

or network creation. In one way or another, the tendency is towards counting more and more the results of these university units and making them more accountable.But as already mentioned, innovation is a highly complex process to measure:while most EU or national agency-sponsored projects and local university initiatives have a time perspective of three years (or follow the stock exchange quarterly report pressures), the effects of commercializing efforts are typically very indirect – if any – and might take years or decades to emerge (Waluszewski, Baraldi, Linné& Shih, 2009; Waluszewski, 2004;Håkansson&Waluszewski, 2007). Still,what is measured – and how – is likely to impact not only the evaluation one can make of universities' commercialization efforts, but also the very behaviors of the involved actors and organizations, which in turn can influence the way these measures and controls are applied.Thus, to sum up, our theoretical framework includes, next to controls and commercialization mechanisms, also the very network of actors and relationships that define the *context* for a certain commercialization mechanism and *mediate* how the specific control and measuring devices are applied during that mechanism (see Fig. 1 below).

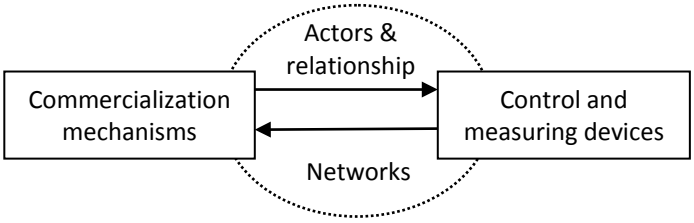

Figure 1: relating commercialization mechanisms, control devices and networks.

METHODOLOGY

We rely on a qualitative case-study approach because of the complexity of the investigated phenomenon (Yin, 1994), namely the interplay between commercialization mechanisms, controls and network contexts, as well as the explorative nature of our research purpose. The empirical basis for this paper is an ongoing data collection within a broader project named "The innovating university" aiming at analyzing the current innovation strategies of Uppsala University and KarolinskaInstitutet. We apply amultiple-case study design (Ibid) based on a selection of four cases that we encountered in our mapping of the two universities' strategies and practices to support the commercialization of science. The four selected cases are namely: "Karolinska Development" (KD) – the investment company that KI created and recently managed to float on Stockholm's stock exchange; Actar AB – the research and testing organization that KI introduced as a support to its many drug development projects; UU's "Ångström Materials Academy" (ÅMA) – a platform that brings academic researchers in material sciences and selected industrial partners together – and the "Positron Emission Tomography" (PET) center – a research laboratory that UU spun out as a company sold to a major industrial player and then had to re-acquire together with Uppsala Akademiska Hospital.

As we selected two cases from each of the two universities' innovation strategies and structures, we adopted an "embedded case study" design, which enables capturing also the specific *organizational and network context* (Easton, 1995: 480), that is, elements that are relevant for our research aim and represent one of our key dimensions. As for the dimension of *commercialization mechanisms*, we applied it purposefully in the selection of our cases so that they would displaysufficient variation (Creswell, 2007)in mechanisms, according to the difference identified in our theoretical review between a linear mode of promoting the classical commercialization of science via patenting, licensing and spinning-out companies

(the KD and Actar cases) and a more open-ended mode relying on closer and less structured interactions with industry (the ÅMA and PET cases).Our expectation was that these different mechanisms would also be associated with varying degrees of formalization and steering and different *control forms*, according to our third theoretical dimension.

More precisely, starting from the less steered and formalized practice, the UU's PET case illustrates how control of the commercialization process unfolds prior to the creation of established routines, or in a situation where such routines cannot be applied due to several unexpected events. Then, the UU's ÅMA case portrays control in a somewhat more formalized context, but one still dealing with a rather open-ended goal frame entailing the creation of long-term relationships with industry. Moving to the two KI's cases, Actar AB shows the situation of a component which was included in a rather formalized innovation system with a set of clear R&D support purposes. Finally, the KD case illustrates even tighter control mechanisms as a key component of the academic innovation strategy is turned into a listed company and thereby is exposed to strict accounting and accountability pressures. These four examples are part of each university's broader commercialization strategies, and play a specific role in that context, but we chose nonetheless to analyze them separately in order to investigate the variety of control approaches, both across different universities and within the same university.

The sources of empirical materials for our cases are a total of 46 interviews and meetings conducted between 2009 and 2011 mostly with representatives from the commercialization units of UU and KI: for instance, CEOs of their holding companies and directors of their innovation offices, project managers (for e.g., ÅMA), individual researchers involved in commercializing their science, as well as external actors representing companies and public administrations (e.g., IMANET and Uppsala City Council). 36 interviews and meetings are related to UU and 10 to KI. Some interviews refer specifically to just one of the four cases (17 for PET, 7 for ÅMA, 1 for Actar, 1 for KD), but the majority refers to UU and KI in general terms or covered simultaneously more than one case. Our Appendix presents a complete list of our data, includingour secondary sources.

Our method followed an abductive logic, based on a systematic combining (Dubois &Gadde, 2002) of empirical data, theoreticalconcepts and an emerging research question. We started from a broad research question, namely"How do UU and KI'sinnovation strategies and structures look like and how do they relate to the external network?"Then, weencounteredthe literature on the commercialization of science, which helped us to extract more concrete commercialization mechanisms from our data, on which we collected further data and which we could classify according to the relevant literature.The next step wascombiningour empirical material more explicitly with the IMP perspective on inter-organizational relationships, especially withthe latest concepts on the three settings of developing, producing and using for embedding technologies. Finally,control issues emerged as relevant due togrowingaccountability pressures on universities to commercialize as well as on measuring the outcomes of these processes:therefore we first consulted the literature on the different forms of management control (result, action and personal) and then we completed our data collection in order to fill the gaps related to the control dimension of the cases.

Reflecting this abductive approach our analysis of the empirical material, which was conducted in parallel with data collection, followed the following steps: first webroadlymapped the networks around the focal innovation units (see examples of these maps in Baraldi&Waluszewski, 2011: 181, 186); then we selected specific processesor commercialization mechanisms according to the logic above, specifying their goals and identifying the specific actors involved in each one, their inter-organizational relationships and networks (according to their belonging to the settings of developing, producing and

using). The final step of analysis was searching for the control and measuring devices applied within the specific commercialization mechanism and its related network in each case: this analytical stepalso implied classifying these controls on the basis of Emanuel et al.'s (1980) typology (result, action and personal controls). The discussion section of this paper finally attempts to relate the three theoretical dimensions of commercialization mechanisms, involved actors and networks, and controls applied.

EMPIRICAL MATERIALS: FOUR CASES OF COMMERCIALIZATION OF SCIENCE

The empirical sections start with a general review of KI and UU's innovation strategies and then present each of the four cases, followed by an analysis highlighting the three dimensions in our theoretical frame.

Different strategies to commercialize science at KI and UU

KarolinskaInstitutet (KI) and Uppsala University (UU) are two of Sweden's most established universities. Founded in 1810 and 1477 respectively they are regularly ranked by various institutes among the world's best 100 universities. The table below shows selected key figures about the two universities, which demonstrate their many similarities in for instance income and research budget, as well as doctoral students, but also differences such as number of undergraduate students and teachers and researchers.

Table 1: Selected figures about KarolinskaInstitutet and Uppsala University (Source: Uppsala University's Annual Report, 2009; Karolinska Institute's Annual Report, 2009)

	KarolinskaInstitutet	**Uppsala University**
Teachers and researchers	2,000	4,000
Professors	300	500
Academic publications/year	4,700	5,000
Undergraduate students	5,500	20,500
Doctoral students	2,100	2,000
Doctorates every year	390	400
Licentiate degrees/year	15	100
Externally funded research	60%	50%
Income 2009	4.9 billion SEK	4.7 billion SEK
Research budget 2009	4 billion SEK	3.3 billion SEK

Both universities have since the 1990s created sophisticated structures in order to support their commercialization tasks. At first glance these structures resemble each other: a holding company (KIHAB or UU AB) directly owns other operative companies such as industrial liaisons offices, patenting support consultancies, incubators (Karolinska Institutet's Science Park – KISP, or Uppsala Innovation Center – UIC), and especially owns shares in academic spin-off companies. Both university also pursue a "reactive" strategy based on receiving researchers' idea disclosures, evaluating them and, if relevant, trying to license or creating spin-offs around them. There are however both apparent and moresophisticated differences in the strategies and organizational structures of the two universities.

At a more apparent level, KI deals exclusively with Life Science-related commercialization, with a preference for pharmaceuticals, whereas UU reflects its generalist university profile and equally supports any type of scientific idea, even if those coming from engineering, ICT (Information and Communication Technology) and Life Science are over-represented. Another difference is that KI has made a commercial company of "Karolinska Innovation" (KIAB), the unit dealing with idea scouting and licensing, whereas UU has the corresponding unit ("UU Innovation") as a part of the university which responds directly to the vice-chancellor and also embraces many other activities beyond licensing and spinning-off, such as creating relational platforms with industry. The major difference between the two universities lies indeed in the fact that while UU simultaneously pursues *equally actively* several mechanisms to make its science useful (licensing, spinning-off, contract or joint research, personnel exchange industry-academia, relationship and network creation), KI is much more focused on the spinning-out track to commercialize science (see Baraldi&Waluszewski, 2011 for further details on these different strategies). Therefore,compared to UU, KI much more closely follows the logic and model of a venture capitalist firm, which includes direct financing of its firms until a pharmaceutical product is in Phase II of a clinical trial, when a profitable exit is hopefully possible, as well as assuming majority stakes in its spin-off companies – as opposed to UU AB, which limits itself to about 12%.

The greater risk and the very large financial resources required to pursue this strategy has led KI to build its own investment company, Karolinska Development (KD), as a firm separate from its holding company (KIHAB) just to be able to face these high risks and collect the billion kronor-level capitals required to "create the new Astra". UU's total innovation budget, however, in the last 10 years is more in the level of a few hundred million kronor. Another profound difference between KI and UU is that KI's representatives explicitly consider the structure they built as KI's own "innovation system", with very clear roles and responsibilities for the various units involved in a structured process aiming to turn ideas into sellable commercial solutions; whereas UU views its role more as part of a local eco-system where it interacts with several partners, with many overlapping responsibilities. Against this background we can now penetrate the four cases, starting from UU's PET and ÅMA, and then moving on to KI's Actar AB and Karolinska Development Ltd. Each case is followed by an analysis of the controls and measures used to steer the commercialization process, as well as the involved actors and relationships.

The PET Center

Positron emission tomography (PET) is a nuclear medicine imaging technique producing 3D pictures of biological processes, which is used as a tool both in medical practice and in research. In 1989, UU founded a research center dedicated to PET research which gained a strong position within the PET research community. However, the center had to finance its research activities without money from the university. The intention was that one third of the center's finances would be covered by income generated from contract research, one third from external research funding bodies, and that the last third would be obtained by selling clinical PET services to Uppsala Akademiska hospital, which due to its great dependence on the center's services in both research and diagnostic activities, actually agreed to use and finance a third of the center's capacity.

Due to the costly equipment needed for PET research, just a few years down the linethe center had built up a large deficit. The revenues generated from contract research and the sales of PET examinations to the hospital were thus not sufficient, and the PET center therefore depended on much funding from the university. Even if contract research took off,and in the

late 1990s accounted for almost two thirds of the income of the center, this was not enough to cover the costs.

To solve the situation, commercialization was regarded the best way to ensure that the needs of the center, in terms of equipment and research facilities, would be catered to. Furthermore, from the viewpoint of the university, selling the center appeared as the best solution available to free itself of the financial strain that the responsibility for the PET-research entailed.The commercialized PET center would thus house not only clinical services and contract research but also independent scientific research activities.

In the early 2000s, the university holding company UU AB had just been formed, and one of the functions of this organization was to engage and invest in academic commercialization ventures. It was the newly started UU AB that was also assigned the task of managing the commercialization process of the PET center. After one full year of negotiations, where the university was represented by the CEO of UU AB, the PET center was sold to the British biotech company Amersham in 2002. UU AB retained a 25% ownership in IMANET, the imaging technique company that the PET center became a part of together with two other PET centers in Finland and the UK.

It soon turned out that none of the parties really benefited from the commercialization of the PET center, not the scientists involved in doing research within the PET center, not the company which had bought the center and not the user which was dependent on the services provided by the center; the Akademiska Hospital. The PET researchers and the university had expected the new owners to provide the means needed to keep advancing the research and expanding the center, while the center in its turn would be helping the company in their research activities. Even though Amersham made an initial financial contribution dedicated to basic science projects, their idea however was that the PET center would be a financially self-sustaining commercial unit. To increase revenues the new owner wanted the center to devote more time to contract research than before, and in addition start charging higher prices for contract assignments. This greatly affected an important user of the center’s services; the Academiska Hospital, which had to pay substantially more for the services they so greatly depended on.

To further complicate the situation, in 2004 Amersham was acquired by General Electric Healthcare which had a great impact on theactivities of the PET center. The focus on profit and contract assignments became even more pronounced; a strategy which eventually resulted in a loss of research edge for the PET center, as well as creating an unforeseen financial burden for GE Healthcare. Failing to make a profit, the resources for the PET center was drastically cut down by GE. In 2006 UUAB sold off their 25% ownership share, meaning the university no longer had any formal ties to the PET center. The UU AB representative was also asked to resign from the IMANET board, and the university consequently lost whatever chance may have remained to have any impact on the way the PET center was run. The financial gain made from the sale of the shares was nonetheless significant, but the money was not channeled back to the university; instead it was used as a boost for the university holding company and its innovation unit, enabling them to finance other commercialization ventures at the university, such as spin-offs.

Despite the exit, the university and the hospital still had a great interest in the PET center. In 2008, after four years of unsuccessful attempts to turn the PET center into a profitable part of IMANET, GE Healthcare decided to sell the center. Knowing how critical access to PET was to the Akademiska hospital, GE contacted the owner of the hospital, the Uppsala county council, to see if they were interested in purchasing the center. As the scenario of having no PET center in Uppsala was simply inconceivable to the hospital there was no other option

than to sit down and start negotiating with GE. As had been the case in the negotiations with Amersham, UU AB represented the university in the negotiations with GE and the county council. After two years of discussions the PET center returned to public ownership in the fall of 2010; the county council purchased the clinical part of the center, while the university re-acquired the pre-clinical operations. The pre-clinical part, which had once dominated the center and produced excellent research, had now diminished considerably in size, comprising only a few people.

During its history PET produced clear direct economic effects in terms of revenues and costs for the involved parties. Against the losses for GE stand the large revenues from the sale of their IMANET shares that UU AB employed to finance other commercialization efforts of theirs (e.g., stakes in other spin-offs). But PET also indirectly contributed to the R&D of its pharmaceutical customers and to diagnostics activities at the Akademiska hospital. However, to commercialize the center was clearly not the answer to the long term needs of any of the settings involved; not of the research center, of its acquirer, nor of one of its most important users.

Analyzing the PET center case

In this case there are three different settings, a *developing*, *producing* and a *using* that are all involved in the activities concerning the commercialization process of the PET center. The original research setting doing mostly basic research is the developing setting primarily having scientific goals of researching, publishing and so on. Amersham/GE is the producing setting which works according to an industrial and profit-making logic, and the Akademiska Hospital represents a using setting dependent on the services provided by PET. As shown, the different settings and many actors becoming involved during the commercialization process have conflicting goals which also complicates the control of the process. UU's goals for the PET center was since the founding of the center constantly changing and was strongly affected by external actors' goals, namely those of Amersham/GE and of Uppsala county council and hospital. The PET researchers had very limited control on the center itself as the commercialization process progressed. The initial goal of UU was to secure research prominence by obtaining external financing instead of university funds; then the university's goal became to commercialize PET due to its financial troubles, while avoiding obligations to finance it. In terms of commercialization mechanism the basic goal was thus to engage the PET center in an established company, which also succeeded at first. However, Amersham/GE's strict commercial and profit-making goals clearly conflicted with UU's original goal to maintain research prominence, as well as diagnostic services to the Akademiska hospital. The new goal of Uppsala University then became to "save" PET from commercial pressures by re-acquiring it together with Uppsala county council – a goal that met GE's goal to divest the PET center.

Due to the many (and sometimes conflicting) goals in the commercialization process we can observe a mixture of different control measures that were used to keep the process "in place". The most salient forms of control and metrics were budgets, featuring for instance external grants, contract research and diagnostic sales to the hospital, but also the operation costs that were so hard to control as research excellence required advanced and costly equipment. During the Amersham/GE's ownership, corporate steering tools dominate, such as budgets and an accounting system that treated PET not as an R&D facility, but as a profit & loss account that was required to generate a profit. UU AB tried to exert its control on PET via the IMANET board, but this proved difficult because the various performance indicators of research outputs (publications), of diagnostic service (patient through-put and times) and of

contract research revenues conflicted with each other. While *personal controls* such as trust among the involved actors certainly played a role in this episode, it is mostly *result controls* that drove the twists and turns around the PET center, as various actors were more or less dissatisfied with the various result indicators (financial statements, losses, publications). *Action controls* also created rigid frames for the involved actors, such as contracts stating their obligations in terms of co-financing, share of access to the equipment capacity or purchase of service. In this case, all actorsin differentwayssimultaneously tried to control the newly created actor, the PET center (which can account for the aforementioned conflicts), but the same actors also tried to influence each other through negotiations and specific contracts stating what was expected from each of them.

Ångström Materials Academy

Uppsala University created ÅMA in 2007 with two main explicit purposes: (1) to foster connections and collaborations between its materials sciences researchers and industry; and (2) to create long-term relationships with selected industrial partners. UU Innovation managers claim that this type of cooperation platform, which they term as a "proactive" strategy, enables them to connect industry with about 2% of the research budget of Uppsala University, as opposed to a mere 0,2% that can be reached by a traditional "reactive" strategy relying on idea disclosures, selection, patenting and productification. ÅMA was founded thanks to an 8-year financing from the Swedish Agency for Innovation (VINNOVA), but is also financed by its members, both companies and university departments. Currently ÅMA includes five core company members (Sandvik, Outokumpu, UddeholmToolings, ABB, and Vattenfall), paying 150.000 kronor/year, and three university departments, paying 100.000 kronor/year, as a sign also of mutual commitment to what they define as a "strategic alliance".

ÅMA's board is formed by the director and deputy director of UU Innovation, the university vice-president from the Faculty of Science & Technology, three full-time employed project managers, and representatives of the five core company members. In 2010, ÅMA's board decided to also include five smaller companies as pilot members: they pay a reduced fee which is immediately usable as an "innovation voucher" that enables them to directly access some research or consulting services within UU (e.g., having tests conducted with some of Ångström's sophisticated lab equipment).

ÅMA covers a broad spectrum of activities in connecting industry and academia, ranging from assigning awards to innovation-oriented researchers to involving industry in education programs (master degree projects, guest speakers, company visits). But most of ÅMA's efforts are addressed to *stimulate academia-industry research cooperation*: a first step in this direction is therefore arranging meetings researchers-industry; but UU Innovation also expects these meetings to lead to some form of concrete cooperation projects between researchers and industry, for which ÅMA provides support in planning and finding co-financers (e.g., VINNOVA). ÅMA provides two types of meeting opportunities: *open* meetings, especially via a newly developed format known as "AIMday" (Academy Industry Meeting day), where *any* company and research can participate, and *focus* meetings between a single member company and selected researchers invited to deal with a specific problem.

The AIMday arrangements typically bring together about 20 companies, with 40 participants, and at least twice as many researchers. It has received positive reactions from both researchers and industry, and therefore UU Innovation has decided to expand this concept to other scientific domains, such as Energy and Life Sciences. Traditionally,it has been difficult to measure and account the results of all of ÅMA's activities, as they deal with an open-ended goal like "creating industry-academia relationships". In particular, it is hard to follow up

which actual cooperation and joint projects emerge out of the meetings arranged by ÅMA, as there is no duty to report them. ÅMA has however attempted to probe into this issue by conducting surveys with participating companies, which showed that 65% of the companies directly evaluated the solutions which emerged during the AIMday workshops. Such a measure is however not really indicative of whether projects, especially joint ones, are initiated. A tentative assessment is that there are about a dozen joint R&D projects directly related to ÅMA as for mid 2011.

UU Innovation and ÅMA are certainly interested in all kind of indicators of the performance of their platforms: as for "softer" indicators pointing at the satisfaction of participants to AIMdays in terms of perceived values, UU Innovation and ÅMA have supported a study of ours which identified for instance "job and recruitment opportunities", "getting innovative insights and perspectives on technical issues and problems", "finding new sources of unique competence", and quite interestingly "networking for networking sake" as important values (Baraldi, Lindahl&Severinsson, 2011). However, ÅMA is becoming increasingly interested in producing, and accordingly being able to measure, some more concrete effects emerging from its mediating role and the meetings it arranges. Therefore, a new strategy, which has also been put into use, is to offer "seed money" for the researchers and companies whopresent the most interesting joint R&D project proposals. The practice of providing direct financing to, and thus being able to record, specific cooperation projects is becoming increasingly important for UU Innovation and ÅMA: for instance, their newest cooperation platform termed SMURF – which addresses small and medium-sized firms – has the explicit goal of creating 42 joint cooperation projects, all to be financed from a budget of about 11 million kronor obtained for a 3-year project from the EU Regional Development Fund via the Swedish Agency for Economic and Regional Growth (Tillväxtverket).

Analyzing the Ångström Materials Academy case

ÅMA represents an attempt to create an interface between a developing setting consisting of academic research departments and researchers, and a producing setting consisting of various industrial actors. In doing so the goals of ÅMA are quite explicit: to foster connections between researchers and industry and to build long-term relationships as a way to access a larger portion of UU's research budget. As for the actors in this mechanism, ÅMA is a new actor employing three full-time managers and substantiated by a board representing its members. Other key UU-internal actors involved are UU Innovation, one faculty and several departments. The external actors directly involved are ÅMA's 10 company members; but at the same time all companies participating in open meetings, such as AIMdays, intervene in this platform. VINNOVA and Tillväxtverket (EU Structural Fund) are two external financing actors which are particularly important for ÅMA.

ÅMA evaluates its own performance by means of both numerical metrics and "softer indicators". As for the former, ÅMA measures the number of participants (firms and researchers) to their meetings and other activities, the number of AIMdays or other meetings they arranged, and the number of ideas followed up after a meeting. Most importantly, ÅMA strives to keep track of the number of actual cooperation projects they have contributed to, but as there is no obligation to report it from researchers, it is difficult to have correct figures. In this context, having introduced seed financing of selected projects now enables ÅMA to have a systematic account of the projects they have catalyzed. As for the "softer" indicators, ÅMA conducts surveys among participants of its events in order to evaluate their degree of satisfaction, such as perceived values by researchers and industry. The information to account for the above *result controls* comes primarily from ÅMA's internal records (number of

participant actors, of events, of members, and recently of seed-financed projects). But ÅMA is increasingly dependent on *external* actors for parts of this accounting information: numbers of ideas that are followed up, which can only be revealed by firms and individual researchers, and satisfaction indicators, which are occasionally probed into by external consultants or UU research units. As for the actors exerting control on ÅMA, a first important group is its member companies, via the board meetings and budgets, but also via the *personal controls* entailed by the trust in each established relationship. The external funding agencies, namely VINNOVA and Tillväxtverket/EU, rely mostly on*result controls*, such as reports on reached objectives, and *action controls*, such as directives stating how ÅMA can or cannot spend the funds it received.

Actar AB

Founded in 2000, Actar (standing for *Ac*ademic *Tar*gets) works as research and test facility at the Karolinska Institute for research projects which seem to have potential to become commercial ventures. Actar's role in the innovation system at KI as well as its ownership has however not always been self-evident. Actar was founded as an answer to the need of *validating* the results fromacademic research from a more commercial standpoint within the KI innovation system. It started out as a small company which would work as a facility for developing new pharmaceuticals. The idea was that it would be available as a test facility not only to researchers at KI but also to other universities with commercially interesting research projects. In 2002, two years into the process of getting started there was no more funding and all activities were put on hold. Three years later, in 2005, Karolinska Development (KD) had been able to raise more funds and Actar was re-established. Located at the KI Campus the company is close to the researchers and also to the projects and companies within KI's innovation system.

The current model of how Actar is run, applied by KI innovation managers, sets KD in avery central position as KD is basically the sole owner of Actar. It also owns the spin-off companies which may come out as a result of the continued research atActar, and therefore controls them and the eventual profits that are made from their exits. The original idea of the architects behind KI's innovation system was that once Actar engaged in a project it would also own the resulting company before selling it off. However, in the current modelActar earns its profitsby charging KD for the validation and research services it provides.Actar also functions as a contract research organization (CRO), which performs research activities for other companies. However, they do not have any long-term relationships with larger corporations that might be interested in new research ideas or projects. The validation work conducted for KI's spin-offs is therefore held separate from the companies' CRO activities.

Actar works closely with KIAB (Karolinska Innovation) in evaluating and further developing new research ideas which come mainly from researchers at KI. Sometimes researchers approach Actar first and then Actar works as an advisor in terms of what type of results that the researchers have to be able to present to KIAB in order to be selected. When evaluating new ideas KIAB and Actar work according to a *checklist* in terms of both market analysis and pharmaceutical considerations. Actar assess the projects based on three factors: 1) if the new idea corresponds to a medical need, 2) if there is a potential market, and 3) if investing in the commercialization process presents a reasonable risk. If the project is deemed to have good commercial potential according to these three factors it is presented to KD as a possible investment, which KD might or might not proceed with. Actar is bound by a deal-flow agreement which obligates them to present the new ideas to KD first (before anyone else gets an investment opportunity).

In total Actar has engaged in about 15 projects of which two have become companies. One is called NovaSAID and focuses on drugs for inflammation, pain and fever, and the other is called Clanotech and focuses on cancer treatment. Both companies are however still in a preclinical phase which means that they need further financing to proceed with the subsequent clinical trial phases in order to produce actual pharmaceuticals. Apart from these 15 projects Actar has evaluated about 30 projects which were dropped either in the evaluation process or after Actar had performed initial tests and experiments. With their major owner (KD) as a publicly listed company, Actar now cannot share all information with the KI innovation office or the researchers at KI. This might have a negative effect on the original idea of the innovation system as it might reduce the number of potential projects coming in and consequently also the chances of truly succeeding with one or several projects.

Analyzing the Actar AB case

In regard to the services provided for the KI innovation system Actar is working mainly in a developing setting, but with the purpose of preparing the projects they work with for entering a producing setting. Actar's goals have slightly shifted since its creation: originally KI expected it to act as a pharmaceutical developer and own the spin-offs, but now it simply runs the scientific part of the drug development projects. Actar's goals are restricted to two areas: (1) to help KI's innovation system in evaluating, selecting and validating commercially attractive projects; and (2) to help all companies in Karolinska Development's portfolio to proceed through their drug development process via continuous R&D services. As for the mechanism for research commercialization, Actar is clearly a component of KI's "spin-out funnel" model (Clarysse et al. 2005), even if it conducts some limited activities of contract research, which are kept separate from the two main goals above.

The most important actors in the network around Actar are individual researchers, mainly at KI, acting as sources of scientific ideas, KIHAB (KI's holding company), KIAB (with which Actar has a close interaction for selecting attractive ideas), and especially KD which formally owns Actar. Moreover, Actarhas connections to some of the above mentioned 30 companies in KD's portfolio. Finally, Actar has a few pharmaceutical companies as external customers, but it has developed no long-term relationships with them. All in all, most of the actors that Actar interacts with belong to KI's internal innovation system.

The effects of Actar's operations are of three main types: (1) discarding scientific ideas which are deemed not to have pharmaceutical and commercial potential; (2) selecting and validating ideas for further commercialization and increased investments by KIAB and especially KD; and (3) bringing KD's projects and portfolio companies closer to market or an exit. Out of about 15projects evaluated and validated by Actar (and another 30 which were discarded), only two have been turned into companies, which are however still in the preclinical phases of drug development. As creating these effects requires expensive tests and laboratory equipment, they are associated with costs but also with revenues, most of which come however from inside KI's innovation system, namely KD's service fee paid for its projects and companies that utilize Actar's R&D support.

The major control on Actar is exerted by its owner KD via budgets and payments from its other portfolio companies. Further, budgets and profit & loss accounts require Actar to generate revenues to cover at least part of the costs from the above activities, but when KI had troubles in finding finance for Actar's operations, it even froze its activities for three years. As KD applies a venture capital logic based on*milestones* to control the operations of its portfolio companies, which are Actar's main "customers", this form of *action and result* control indirectly also affects Actar, which is required to help these spin-off companies meet their

milestones. A more specific form of *action control* is instead the deal-flow agreement which requires Actarto propose the attractive ideas it identified to KDfirst. KD is in turn exposed to control pressures which become translated as *action controls* over to Actar: after KD's listing on the stock exchange, Actar faces more restrictions in terms of the information it can share with other units within KI, namely KIAB and individual researchers. Finally, a form of *lateral action control* is the checklist for selection of ideas for commercialization (stating clearly the criteria of "medical need", "potential market" and "economic risk"), which Actar applies jointly with KIAB. All in all, the dominating control forms in the case of Actar are result and action controls.

Karolinska Development Ltd.

The innovation strategy at KI is based on the hope of bringing forward one or several completely new pharmaceuticals. However, as drug development is an expensive and risky endeavor, maintaining this type of system requires large financial resources. In 2007 the holding company in the KI innovation system, KIHAB, established KD as apublicly limited investment company based on the earlierventure capital funds (named KD1, KD2 and KD3). Compared to the funds, which had been applied since the late 1990s, KD would be able to make more long-term investments. Today KD is the majority owner of about 30 companies, which run 40 development projects. The number of portfolio companies and its value of about 1.6 billion kronor make KD one of the largest investment companies focusing on pharmaceuticals in Scandinavia and Europe.

The basic strategy of how to create a new pharmaceutical within KI's innovation system is to process new potential pharmaceutical substances through the early phases of clinical trials. Both Phase I and II are typically carried out within KI's innovation structure; Phase I tests for toxicity and appropriate dosages and Phase II for side effects (this requires tests on several hundred patients). This process can take as long as five to ten years and generally costs several hundred million SEK. If a substance is approved, the ambitions are to license it (or form a company) and sell it to a pharmaceutical company, which has the financial resources to proceed with the remainder of the clinical trial as well as the marketing and sales activities. KD will then receive up-front and milestone payments, as well as royalties if the substance continues to progress and eventually becomes a new approved drug. The pharmaceutical companies can get engaged at different stages by either supporting the project from the start or evaluating it at later points in time and then make an investment by buying the license or the company. This way KD is creating connections to some of the major pharmaceutical firms such as Pfizer and AstraZeneca. However, there are no guarantees that even the early phases of a clinical trial will succeed, despite large investments, nor that the remainder of a clinical trial will bear fruit once the license is sold to a company, or that any of the companies are interested in buying the license. This means that a great part of the risk, as well as the costs, of trying to develop a new drug has been transferred from the pharmaceutical companies to KD, which performs the basic research as well as the early clinical phases.

KD operates under venture capital logic in a number of ways. Together with other investors it takes the majority shares in the investments, and when a company is formed KD appoints the CEO and board. The portfolio companies are also run in the most cost-efficient way by keeping the number of employees at a minimum and outsourcing research and development to specialist companies (such as Actar). In addition, in order to further reduce the risks, the portfolio companies are financially managed so that they only get enough capital to reach the next milestone, typically within a period of six to 18 months. Another crucial factor in this risky and capital consuming system is timing in when to create an exit for the investments, in terms of a licensing deal or selling off shares in the portfolio companies, to maximize the return on investment.

Every year, about 100 ideas are evaluated by KIAB (and Actar) from which 10 ideas are selected to be presented as possible investments to KD. Out of these 10 ideas KD often chooses one or two which they proceed with. However, so far the innovation harvest from KI's innovation system is modest, which is not very surprising since all of the projects have had less than ten years to show progress.In total, there has only been one exit by sales of a portfolio company. The company markets software for short-term memory training for people with concentration problems. Despite being sold to the multinational publisher and education company Pearson this does not correspond to the high hopes of launching a pharmaceutical block buster, which would create the needed return on investments to support the continuation of KI's innovation system in its current form. Many of the projects are also currently entering a more mature as well as cost-demanding phase in which it will become crucial to raise funds for their continuation as well as to show positive results in terms of clinical efficacy: the yearly burn-rate is about 250 million kronor for the whole portfolio. The financial issue has temporarily been solved by KD being floated on the stock-market in early 2011, which raised about 600 million kronor, bringing its equity to about 2 billion kronor. But the floatation also implies that KD will need to live up to financial expectations and comply with quarterly based accounting practices. Now there are thousands of shareholders next to the previous owners of KD, among which the largest was the Third Swedish Pension Fund. KIHAB, the holding company, still retains a golden share awarding about 30% of voting rights.

While KD has been successful in raising equity capitals, things have been more problematic when it comes to generating revenues from its portfolio of companies.As a listed investment company, its evaluation and stock price will be strongly influenced not only by the book value of its portfolio, but especially by the cash-flow and ROI that KD will generate from exits and licenses, and from the market expectations that such exits are within reach. It therefore becomes pivotal for KD to show a strong pipeline of company projects showing a good advancement towards Phase II or market launch: as of today two pharmaceutical companies have nearly completed Phase II and two med-tech companies are ready to launch their products on the market.

Analyzing the Karolinska Development Ltd. case

KD is mainly working within a developing setting where investment decisions have to be made upon speculations of whether a newly found molecule or biological mechanism can be turned into a commercial product or not. In most cases there is no actual producing or using setting that has become activated in relation to the new idea or finding, which means that these decisions of whether or not it is a commercially feasible finding are based on what works or does not work within an academic research context. In trying to achieve successful innovation by making large investments in very early development phases of a project, KD applies a clear "spin-out funnel" model (Clarysse et al., 2005) and does so by even taking the responsibility of *directly providing* the main financing for its spin-off companies, which it typically majority owns. In many respects, KD's goal is to be an important player among venture capitalists focusing on the Life Sciences.

We can review the actors involved in the network around KD by starting from those closer to science and then moving towards the market: individual researchers provide KIAB and Actar with new research results (which they then evaluate and present to KD as potentially attractive commercialization projects); 30 portfolio companies that KD controls with majority shares; and a few big pharmas that can become potential buyers of KD's spin-offs. The relationships with KI's internal units are functional and regulated by the directives that set the specific role of KIAB, Actar and KD. As for big pharmas, KD is now starting to build relationships with these actors hoping they will buy into some of its projects or companies.Other important actors influencing KD are its various investors and owners:

KIHAB as main and long-term owner (which has set KD's strategy and led it to an IPO), and the Third Swedish Pension Fund. In addition,there are now a few thousands of small shareholders which became involved after the IPO in 2011.

The effects of KD's operation can be divided into *operative* and *financial* effects. As for the former, the projects and spin-offs which KD has engaged in results in a pipeline with projects at different advancement stages. But now the challenge for KD is accomplishing the other effects for which it was built, namely to cash in by selling these entities. So far the financial effects from actual revenues have been modest: only one trade sale without any significant financial impact. KD's financial performance is more successful in terms of equity: about 2 billion kronor of collected equity and a portfolio of companies valued at about 1.6 billion kronor in its balance sheet.

The commercial mechanism applied through KD provides a set of sophisticated controls and metrics, especially of a financial type. But for the interactions between KD, KIAB and Actar, the most important control forms are internal procedures, routines and assigned roles, which represent a form of *action control*. Other action controls are the series of contracts applying to researchers, who release thereby their IPRs to KI, and to KIAB and Actar. KD thenexerts its control directly on its portfolio firms by owning the majority of their shares, by appointing their CEOs and boards (which is a form of *personal* control), and by monitoring their operations according to milestones that open for increased financing if reached (a combination of *action and result* control). In this sense KD controls its portfolio firms in a way which is similar to a venture capitalist, but with the difference that KD is typically the majority owner of these firms. While KD controls the above actors, it is in turn controlled by a set of other actors, especially by KIHAB and other major shareholders, such as the Third Swedish Pension Fund. However, also the whole stock exchange system exert an important control on KD by setting a set of rules on the actions KD can undertake and the information it has to release on a regular basis, such as quarterly reports. This information is in turn the basis for shareholders to exert their *result control*on KD. Therefore, KD needs to show concrete financial and economic results in order to find more financing or maintain its share price high. The share price level becomes an important indicator that can steer KD's strategy and daily choices considerably. And the share price is related to the results provided in KD's quarterly reports, including such key performance indicators as burn-rates, ROI, cash-flows, or the status of KD's project/company pipeline. All in all, the KD case entails much more action and result controls than personal controls such as trust and selection of relevant partners: after all, the relationships with major pharmas are only emerging, while shareholders are daily concerned with KD's share's price.

DISCUSSION:RELATING MECHANISMS, CONTROLS AND NETWORKS

By looking across the four cases, we can now analyze differences and similarities in how control types (Emmanuel, Otley& Merchant, 1990) are related to the specific commercialization mechanism (cf. Jacobsson& Perez Vico, 2010) and to the involved actors and relationships acrossthe developing, producing and using settings (cf. Håkansson&Waluszewski, 2007). Table 2 below summarizes the findings from our analysis of the four cases in the previous section. Next to (1) the type of mechanisms and their goals, as well as (2) the involved actors and their relationships, the table also indicates (3) the effects of the commercialization efforts in each case and (4) the control and measuring devices applied to evaluate outcomes in each case, including to what specific object and by whom they are applied. As the issue of control is central to this paper, next to discussing the specific objects being measured (e.g., patents, licenses, spin-offs, revenues, selling/exit prices, number

of relationships, number of researchers/companies participating to activities, number of collaboration projects initiated/financed, satisfaction by participants), we will also assess the relative importance (see row 4 in Table 2) of these *result and action* controls as opposed to *personal* controls (Emmanuel, Otley& Merchant, 1990), such as *trust* (Tomkins, 2001).As we will demonstrate, the relative importance of the various control types depends not only on the goals and structure of a commercialization mechanism, but also on its network context, namely which specific actors apply the various controls*in relation to* which other actor.

Table 2: Mechanisms, actors, effects and controls in the four cases

	PET center	**ÅMA**	**Actar**	**KD**
1- Commercial-ization mechanism& goals	-Shifting, unclear, negotiated goals -*Contract research turned into an unexpected spin-out*	-Open, partly unspecified goals -*Strategic alliance, sponsored research*	-Initially shifting, but now specified goals -*Spin-out funnel, partly contract research* -Precise role in KI's inno.system (select, validate, support)	-Very specified goals -*Spin-out funnel* -VC/lead financier role in KI's inno.system
2- Actors& relationships	-*Only three actors* (UU, Amersham/GE, hospital) -But very different actors, conflicting goals -UUAB comes in as "negotiator"	-*Many actors*: dozens firms, 100+ scientists -2 external financiers -Deep long-term relationships, networks	-*Mostly from inside KI* (researchers, KIAB, KIHAB, KD) -Functional predefined ties inside KI and to 30 KD's portfolio firms -Loose relations to CRO customers	-*Internal*: KI scientists, KIHAB, KIAB, Actar, 30 portfolio firms -*External*: large financers/stock exchange, big pharmas -Functional predefined ties inside KI -Loose external ties to shareholders and big pharmas
3- Effects	-Complex and unexpected: -*Commercialization + de-commercialization* -Decline of research -Losses for GE -Exit revenues for UUAB, finance to other spin-offs -Indirect contribution to drug R&D and diagnostics at hospital	-*10 relationships* to ÅMA members -Dozens of firms involved in activities -Knowledge exchange -New perspectives -Networking for networking sake -Many minor projects -A dozen large projects	-Discarded ideas -Selected/validated ideas -Progress in drug R&D for KD's companies -2 ideas of 30evaluated now in preclin. Phase -Revenues from KD's service fees -Harder cooperate with KIAB after KD's IPO	-*Operative:* 30 spin-offs and 40 projects; pipeline with 4 "exitable" projects -*Financial:* 2B kronor equity collected, 1.6 B kronor portfolio; but only one exit with no financial impact
4- Control &measures	-*All actors try control* PET and each other -*Mix of personal, action and result controls* -*But* result controls cause twists & turns -Diverging controls and metrics reflect conflicts	-*Limited control by external actors* (members/financiers) -Increased use of result controls (figures and softer indicators) -Dependence on external actors for info -Financiers apply result & action controls -*But balanced mix of the three controls*	-Strong control by KD -*Result &especially action controls dominate* (budgets, milestones, deal-flow agreement, checklists) -Stock exchange control pressure translate from KD into *more action control* to Actar	-*Financial metrics and result & action controls dominate* -Action controls dominate inside KI (routines, roles, contracts, *milestones*) -Shareholders' external control via action controls (info disclosure) and result controls (*burn-rates, ROI, pipeline*)

We now discuss and compare the four cases starting from the more complex and unstructured mechanism and then moving progressively to the more linear and structured ones, following the order in which they were presented in the empirical sections. The most complex commercialization mechanisms appear in the PET case, which combines both a contract research mechanism (Jacobsson& Perez Vico, 2010) and an unplanned reverse spin-out funnel (Clarysse et al., 2005), and where consequentlyvery heterogeneous actorsfrom the three different settings (Håkansson&Waluszewski, 2007) of developing (UU), producing (GE/IMANET) and using (Akademiska hospital) are involved: this particular situation is

associated withthe application ofa *fluid combination* of many different types of controls and measures, even if conflicts between the actors on how to commercially exploit the same scientific resource increase the importance of*result* controls (budgets and profit & loss accounts), which directly influence the twist and turns in this case.

The ÅMA case displays a somewhat lower degree of complexity compared to PET, entails clearer and less shifting goals, as well as a reliance mostly on a proactive mechanism of sponsored research and strategic alliance building. Here, the actors represent at least two of the three embedding settings, namely the developing and producing ones, with an explicit goal of creating an interface between them.Control can be said to be evenly distributed between ÅMA, UU and the other external actors, namely companies and public financiers. The presence of the latter increases the importance of *result* and *action* controls, but the very goal of building relationships, as well as the fact that these have been created, confirms the importance of *personal controls* and *trust*. Here, the resulting pattern is also, but for different reasons than in the PET case, a *balanced mixture* of controls and measures applied.

The Actarcase representsan application mainly of the linear spin-out funnel, even if Actar partly pursues a contract research mechanism and its goals have shifted in the last years. This makes it somewhat more structured than the two previous cases, but less structured and linear than the KD case.Another important difference compared to the PET and ÅMA cases is that Actar mostly interactswith actors within the developing settings (KI and UU's researchers and KD's start-ups), with minimal interactions withthe producing settings, despite the ambition to provide services to pharmaceutical firms: thus almost all actors involved in Actar'scommercialization mechanism are internal to KI's "innovation system". What are then the controls applied in this configuration of commercialization tasks and the involved network?As most actors involved belong to the same functionally oriented system, *action* controls (routines, checklists, and contracts) and *result* controls (budgets)dominate in this case. As the goal of this system is speeding up product development, time-related controls on actions, such as milestones, play an important role. But also the external control from the Stock Exchange on KD entails more action controls translated on Actar's operations, namely which information can or cannot be exchanged between parties.

KD is the case thatmost clearlyillustrates the linear spin-out funnel, with a high degree of functional orientation and a very clearly defined goal (bringing drug projects to an exit in Phase II). KD appliesa venture capital logic, but as it owns the majority of most of its spin-offs, it can more directly steer the interactions among the involved actors. Strong time pressures and the floatation on the Stock Exchange – the only external actor together with a large pension fund who externally control KD's system – seem to stimulate the application of mainly strict action controls (routines, contracts, roles, and milestones) and financial result controls (burn-rate, ROI, and drug pipeline).

Therefore, by looking across all cases, we can notice that there seems to be a connection between the type of commercialization mechanisms (namely the clarity of their goals and their linearity), on the one hand, and how control is exerted, on the other hand. However, this connection is not clear-cut: a main reason is that the number and type of involved actors (namely which settings they belong to), the involved relationships (their internal or external nature, as well as the degree of goal convergence and conflicts)*also influence* how controls are applied. If we revert the order of our review above and start from the cases *closest to the linear spin-out funnel and with clearest goals*, we can see that in the KD and then Actar cases *result and action control dominate*: as for KD – the case where goals are even clearer and which covers the whole "spin-out model"– control is even very formalized and expressed in financial terms. The two cases that are *farthest away from the linear spin-out funnel and with shifting or unclear goals* (PET and ÅMA) entail instead a *mixture of action, result and*

personal controls. It should however be noticed that the case with the most unclear, shifting and negotiated goals, namely PET, is in its main events driven to a large extent by *result* controls (profit & losses): the prominence of result controls can be related to the fact that PET per se represents a mixed mechanism including also unwillingly a spin-out track, with all the financial control and metrics that it entails. Moreover, PET is surrounded by three equally powerful actors with diverging goals concerning PET, which makes them pay particular attention to the results it produces. ÅMA is instead less influenced by external control, except for the need to account how it utilizes external funds from two agencies. To sum up, our first finding can be formulated as follows:

Finding nr 1: How control is applied to the commercialization of science depends on thespecific commercialization mechanisms, with more *linear and clear-cut* mechanisms being associated with more of *action and results* control and *interactive or more complex* mechanisms being associated with *a combination of* action, result and personal control.

However these associations do not depend only on the type of mechanism, because result control can assume salience also in complex and interactive mechanisms such as PET. In fact, that case reveals how having a limited number of equally powerful actors with diverging goals and potential conflicts induces them to apply extensively result controls. This holds even more because the actors in the PET case are very heterogeneous and belong to different settings (developing, producing and using), which makes *economic* results one of the few common grounds for interactions. Our second finding is therefore the following and specifies into two additional ones:

Finding nr 2: Not only the type of commercialization mechanisms, but also the specific actors involved and their relationships influence how control is applied, and more specifically:

Finding nr 2.1: The presence of a restricted number of equally powerful external actorswith*conflicting* goals increases the importance of*result* controls also in complex interactive mechanisms (PET case).

Finding nr 2.2: The absence of external actors (Actar case), or the presence of many external and "distant" actors with loose relationships (KD case) further increase the importance of*standardized result and action* controls in linear mechanisms.

Findings 2.1 and 2.2 may at first seem contradictory, because,taken together, they state that both the *presence* and the *absenc*e of external actors capable to control a mechanism increase the use of result controls.But at a closer analysis, those findings reveal the different role of result controls in different network configurations. This leads to our third finding:

Finding nr 3: Result controls (e.g., a budget) can be applied either as a *key common ground*for interaction among heterogeneous and potentially conflicting actors (PET), or as a *standard control tool* for a multitude of loosely connected external actors (KD) and for internal actors (Actar).

Looking across Table 2 it is also revealed that there isa connection between the type of effects the actors aim for and the control and measuring device they apply.First all, if actors' maingoalsconcern financial and economic effects, they apply predominantly *result* controls such as budgets, profit & loss accounts, ROI, pipeline value, burn-rates: the extreme case is in this sense KD. Instead, ifactors aim not only at financial effects but also of other types, such as research results or diagnostic services (PET), knowledge exchange or networking (ÅMA), idea screening or progress in R&D (Actar), then the measures applied are more varied (also softer and open-ended) and a wider array of controls appear.This holds for *personal* controls in the PET and ÅMA case, as well as for *action* controls especially in the Actar case. In particular, *action* controls seem to be important when the effects of a commercialization effort need to be produced within a *short timeframe* or *efficiently*, as in the case of Actar's idea screening-validation-drug R&D support. This discussion leads us to specifying our fourth finding:

Finding nr 4: The *configuration of actors' goals*in a mechanism is related to different patterns of application of control and measuring devices, and more precisely:

Finding nr 4.1:*Financial and economic* goals induce actors to use mostly *result* controls.

Finding nr 4.2: A broader array of actors' goals than just financial ones is accompanied by the use also of *personal* and *action* controls.

Finding nr 4.3: *Action* controls are applied especially when *speed and efficiency* are an important goal for the involved actors.

Moreover, reconnecting to finding nr 2.2, action controls seem to be easier to apply when the actors involved belong to the same organization or "innovation system", as in the Actar case.

CONCLUSIONS

This paper has analyzed four cases of commercialization of science in order to answer a few key questions concerning how control is applied to the commercialization of science, including which actors are involved and how their efforts are measured. Our case analysis and discussion identifies a tendency to apply predominantly result and action controls tolinear commercialization mechanisms based on the technology spin-out model (Clarysse et al. 2005), and especially when the direct influence of particular external actors is limited. Moreover, the prominence of financial and economic goals for the involved actors induces even more to use result controls; while the importance of speed and efficiency in a mechanism calls for the use of action controls.Complex and interactive commercialization mechanisms (Jacobsson& Perez Vico, 2010), on the other hand, with important external actors directly involved, entail a combination of controls – formal and informal, personal, result and action-oriented. However, result controls can assume salience also in this type of mechanisms as a common ground for interaction for heterogeneous actors with conflicting goals.

Our results entail a set of *policy implications* for the authorities involved in the commercialization of science.The choice of how to measure a commercialization effort can have far reaching consequences onits development and effects. In fact, *what* is measured (e.g., number of patents, spin-offs, cash flows, exits or relationships), *how* and *when*is not only a matter ofevaluating the performance of universities' innovation units, but will also *orient their actual behavior*: for instance counting *products* (licenses and spin-offs) as opposed to counting *relationships* with industrial partners is likely to induce these units to focus on quite different things.On the basis of the "what", "how" and "when" of control devices, we can therefore formulate three questions, which arerelevant for policy but are also important avenues for *further research* on the commercialization of science.

The first question is: how are such different commercialization outcomes as products and relationships actually evaluated? Namely, what are the commercial or other values of a product as opposed to an industrial relationship? And how much does it cost to create each of these two different outputs? It is typically more difficult to measure the value and costs of a relationship than those of a product: sometimes networking happens for networking's sake (Baraldi, Lindhal, &Severinsson, 2011), with the expectation that it will lead to something positive in the long run.But this difficulty or "lack of precision" in measuring relationships might make them a less popular innovation target (and measuring devices) for universities' commercialization units. In fact, McKelvey et al. (2007) stress that even though the Swedish innovation policy recognizes the importance of relationships and close interaction industry-academia to promote the diffusion of science in society, it still applies measures and KPIs typical of the linear spin-out model (Clarysse et al. 2005). A first policy implication is therefore that those controls and measuring devices that are easier to apply can restrict the

commercialization strategies of universities by orienting their behaviors only in the direction measured by these devices. But doing so would mean neglecting a wider range of commercialization tools and targets.

The second policy and research question is a broader one and concerns whether we are *satisfied or not*with these indicators and control and measuring devices affecting the commercialization of science.Now there are many small "local" measures focusing on some spots in the whole network embracing an innovation. But what about the *actual economic valuecreated in different parts of the network around an innovation*(Håkansson&Waluszewski, 2002; 2007).How can an innovation be measured on a systemic level? The challenge here is to devise measures that better can represent and capture the whole innovation process and network without becoming too "aggregated". Our second policy implication is accordingly that we need to develop more appropriate control and measuring devices to capture the complexity of innovations on a systemic level.

The third issue relates to "when", namely which is the appropriate timeframe for controlling and measuring the commercialization efforts of universities? Projects and other temporary organizations (e.g., ÅMA) are applied as tools to steer and control the production of resultsby means of*time pressure*countable in explicit terms.However, the phenomenon of innovation is known to be a time-consuming process which produces many *unexpected* effects (Van de Ven et al., 1999). There are accordingly many challenges in (1) measuring, (2) controlling and (3) steering the universities' complex innovation initiatives towards desired goals: many actors are directly or indirectly involved, they might have potentially conflicting and different perspectives, the process is very uncertainwith open boundaries, fuzzy goals/ends, and a great complexity. It would certainly be problematic if policy makers and university themselves went about measuring, controlling and steering these processes as if they were any other type of administrative tasks of theirs.Our third policy implication is therefore that commercialization efforts by universities need to be controlled and measured according to a broader time perspective and horizon (certainly broader than a company's quarterly reports, but also broader than a classical three-year project financed by EU): this broadening would really help to capture the delayed and unexpected effects of commercialization strategies.

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