Creating value from science

Interaction between academia, business and healthcare in the Uppsala PET Centre case

Anna Launberg
Abstract

Recent decades have seen greater focus, both national and global, on universities’ role in boosting economic growth. Besides teaching and conducting research, universities are urged to contribute directly to the economy by commercialising research findings and interacting with industry.

This thesis explores the dynamics and effects of such interplay by concentrating on a particular case of interaction involving Uppsala University, Uppsala University Hospital and a large multinational corporation. More specifically, the aim of the study was to investigate how use of science and value creation from science are affected when actors belonging to disparate spheres interact closely. The thesis recounts the evolution of the Uppsala PET Centre, established as a University research institute in 1989, which has served both as a site for preclinical and clinical research and as an important resource in routine clinical work. The whole Centre was commercialised when a large firm acquired it in 2002, only to be decommercialised and returned to the University and the University Hospital less than a decade later.

Using a network perspective, this thesis analyses the journey of the Uppsala PET Centre by studying interfaces between physical and organisational resources. The basic argument is that to understand the effects of inter-sphere interaction on science use, one must consider the materiality of science and differences between the interacting actor spheres in terms of preferences, norms and goals – ‘schemes of valuation’ in the present work. The study shows that the materiality of science has a restrictive impact on flexibility of science use, and different actors’ simultaneous use of science is therefore severely constrained. Because of these constraints, the actor spheres involved struggle to control physical scientific resources in ways aligned with their particular schemes of valuation. Sharing, turn-taking and efforts to separate overlapping use contexts become the means of managing the restricted scope for science use.

Further, this thesis demonstrates that while interfaces containing physical resources are controllable and always result in some kind of value (albeit not necessarily on the scale expected), the outcomes of combinations of organisational resources connected with disparate schemes of valuation are impossible to anticipate and control.

The thesis concludes that there are reasons to rethink our expectations of the short-term economic and social effects of university–industry interaction, a complicated affair that encompasses opportunities and unforeseeable challenges alike.

Keywords: interaction, commercialisation, science, science use, value, academia, business, healthcare

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Abbreviations and concepts

*PET*: positron emission tomography

*Radionuclide*: an atom with excess nuclear energy, which means it is unstable and undergoes radioactive decay.

*Radiotracer/tracer*: a chemical compound that emits radioactivity and can therefore be used to explore biological processes in the body of a living subject.

*FDG*: fluorodeoxyglucose

*5-HTP*: 5-hydroxytryptophan

*PiB*: Pittsburgh compound B

*UUAB*: Uppsala universitet Holding AB (Uppsala University Holding Company, UU Holding)

*GE*: General Electric
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Chapter 1. Introduction

1.1 The story begins

The Uppsala Centre for Positron Emission Tomography (PET) occupies a building that is all bland colours and inconspicuous angles. Yet anyone who enters the facility soon realises that the unassuming exterior, which happens to blend perfectly with the average Nordic midwinter morning, belies the activities taking place inside. Remarkable things happen here: unstable atoms decay and radioactive compounds are synthesised, while computers depict living tissue and anti-matter emits flashes of light inside breathing bodies. Intrinsically fascinating as PET is, its history in this particular edifice, entwined with the facility’s physical constituents and individuals’ intentions and actions, is equally intriguing.

This thesis delves into the Centre’s history with the aim, through social scientific inquiry, of telling a story about science use in a period of flux. The narrative follows the singular saga of a research unit from its formation as a centre at a public university, via its metamorphosis into a fully commercial enterprise, to its re-entry into the public sector. There, the production and use of molecules and the workings of expensive machines are moulded by the ambitions and wishes of scientists, university administrators, medical doctors, business managers and policymakers. Understanding how the Uppsala PET Centre has developed means perceiving the joint action of social factors on the one hand and science and technology on the other.

With its transitions between academia and business, the Uppsala PET Centre’s evolution is essentially a tale of interaction between three spheres: academia, business and healthcare. Bringing to the fore contentious issues, challenges and opportunities associated with science use, this thesis poses its overarching question: What happens to the use of science when disparate spheres engage in science-centred interaction? From this query stem other questions that are inevitably, and perhaps necessarily, posed in any society where scientific activity takes place. How should science be utilised? Who is science for, and who decides whom it is to benefit? Who has the prerogative to define the utility, and hence value, of science? In the story of the Uppsala PET Centre, every turn of events, every action by a stakeholder and every concern expressed may be read as an approximate, subjective answer to these questions.
As the most widely trusted form of knowledge, science carries immense weight in our society. In his classic work *Autonomous Technology* (1977), Langdon Winner reflects on the reasons for the prominence of science in the western world. Science, he argues, is not the only “way of knowing” that can sketch out reality in an “intelligible, systematic and aesthetically pleasing” manner (p. 25). In Winner’s view, the triumph of science over rival modes of knowing, such as poetry, philosophy, art and religion, cannot be deduced from its ability to enlighten or its function as an organiser of knowledge. Instead, it follows from science’s capacity to yield concrete results. What makes science credible is the fact that its results may be turned into something tangible that works. Winner presents the example of space scientists demonstrating the power of their knowledge by putting men on the Moon. “The popular proof of science”, he concludes, “is technology” (ibid.). Science offers other boons, such as satisfying our curiosity by providing answers, or creating a sense of order in the jumble of social and natural phenomena around us. But science comes with one benefit that we seem to have found especially appealing since the late 19th century: the applicability of its results. Science, it is believed, carries within itself the key to technological advancement.

Below, as the PET Centre story is outlined and its context presented, we see how extensions of this notion of science and its potential for technological innovation have affected the PET Centre’s progress at the most fundamental level.

1.2 What is PET?

The empirical subject is approached with a brief introduction to the knowledge and infrastructure around which the Uppsala PET Centre revolves. (A more thorough description of PET is provided in Chapters 4 and 5.) Bringing together knowledge from the disciplines of physics, chemistry and biology, PET is a medical imaging technique that generates three-dimensional images of processes inside the living body. For a PET image to be created, the subject must first be injected with a compound called a “radiotracer” (or simply “tracer”). The tracer consists of a molecule labelled with radioactive material known as “radioisotopes”, produced in a special particle accelerator called a “cyclotron”. Emission of positrons – the anti-matter of electrons – from these radioisotopes provides the basic information we need to eventually construct a picture of the body.

PET technology has found widespread use in various medical specialities – notably oncology, psychiatry and cardiology – and the pharmaceutical industry. However, one crucial factor complicates PET use: the tracers’ half-lives. The most commonly used radioisotopes have very short half-lives:
between 20 and 110 minutes. Thus, half the radioisotopes rapidly decay because of anti-matter emission. This is a physical and (so far) unchangeable obstacle that scientists, doctors and biotechnology and pharmaceutical companies need to circumvent.

As explained thoroughly in the empirical chapters below, tracers’ half-lives are connected with their area of use, and therefore utility. The question of how science is used, and thus how science-based value is formed, is at the heart of this thesis. This introductory chapter frames this question by outlining the empirical data and describing the practical and theoretical terrain relevant to the research topic. The perspective guiding the research is then outlined, and the research questions and thesis structure are presented. Since research questions are best understood in relation to the empirical exploration from which they have emerged, a brief summary of the core empirical story comes first.

1.3 The PET Centre case in brief

The Uppsala PET Centre’s evolution involves mingling of the spheres of science, healthcare and business, and has been characterised by the efforts of these three groups of actors to use the Centre’s resources in ways that furthered their own particular goals. Founded in 1989 as a part of Sweden’s Uppsala University, the PET Centre was an unusual institution from the start, officially independent as it was from any other department or faculty. This status required a singular way of financing operations. A third of the income was intended to come from selling clinical services to Uppsala University Hospital, while regular research grants were to cover another third. The last third was planned to consist of revenues from contract research studies conducted for the pharmaceutical industry.

Although scientifically prominent, highly dynamic and extremely useful to the patient care provided at the University Hospital, the Centre struggled financially and severely strained the University’s research budget for years. Despite the University’s financial support and a growing, fairly lucrative engagement in fee-for-service research, reconciling the Centre Director’s expansive ambitions with economic reality remained elusive. Since PET is a scientific field requiring regular heavy investments in infrastructure, research calls for significant expenditure. The Centre’s leaders therefore began seeking an alternative funding source.

After being in the free but financially strained academic world for well over a decade, the Centre found something resembling a solution to its predicament through industry outreach. Fully commercialising the PET Centre was seen by both the University management and leading PET researchers at Uppsala as the answer to its financial challenges. With
industry’s help, it was thought, not only would the Centre be able to expand its operations but investments in new research instruments and a new large research facility, as well as higher staff salaries, would become attainable. In addition, commercialisation would, of course, entail a major financial injection for the University. The idea was that this money could be channelled to UUAB, the University’s holding company, which also needed to strengthen its finances.

In 2002, the large British biotechnology firm Amersham acquired the PET Centre and incorporated it under the name of IMANET. Amersham had several reasons for purchasing the Centre. It believed that owning such a cutting-edge research facility would boost the company’s valuation (it did). It hoped that the Centre would help deepen relationships with the drug industry, thereby bringing shared access to relevant intellectual property rights at the pharmaceutical companies and, in turn, facilitating development of new radiotracers (this did not happen). Another aim was for the Uppsala PET researchers’ expertise to help Amersham create commercial innovations (this happened in a sense, but many years later in a very indirect, unanticipated fashion). These expectations and this strategy did not change when Amersham was acquired by GE Healthcare, a large business in the gigantic conglomerate General Electric, in 2004. What changed was that costs and budget goals were emphasised more. To GE, a firm that was not breaking even, let alone one in the red – as IMANET had been consistently since the original acquisition – had no raison d’être.

Consequently, GE Healthcare’s take-over meant tighter budget control and greater organisational rigour overall. Favouring activities that contributed directly to revenues, the new directives entailed severe constraints on independent PET science. These caused a decline in scientific publication and a loss of research edge, as well as increased difficulty for clinical researchers and the University Hospital to get their PET scans performed. Thus, fully commercialising the Centre had not boosted research opportunities. Nor did it bring about a grand renewal of infrastructure. The spacious, top-notch PET Centre that Amersham had once pledged to construct never materialised. Neither did the new cyclotron the Director had anticipated. Tracers were being produced and used, but not necessarily for the purposes envisaged by the scientists.

At the once academically distinguished PET Centre, tracer development was flagging and discontent was rife. The cyclotron was running, the laboratories were being used and PET cameras were scanning living subjects. But the Centre’s owner controlled the use of these technologies, which frustrated the former academics and the Hospital alike. Nor was the situation ideal for GE Healthcare; results from most attempts at collaborative commercial innovation by GE’s internal research staff and the PET researchers were poor. The company’s (reluctant) commitment to providing
clinical services to the Hospital at cost price (so that no profit was generated) made matters worse. To the parent company, IMANET clearly did not count as a successful business. Thus, in a sense, none of the main stakeholder were satisfied with the available scope for creating value, whether economic, scientific or healthcare-related, from their use of PET.

After a few years GE decided it was no longer willing to sustain Uppsala IMANET, which was increasingly considered a financial drain. In 2008 GE proposed that Uppsala University and the University Hospital (the single largest user of the services offered by the PET Centre, entirely dependent on nearby access to PET technology) take the Centre back for a negligible sum. Thus in autumn 2010, after two years’ negotiations, the Centre ceased to be a company and returned to public ownership. But while its ownership ties to GE had been severed, interaction between the huge corporation and the PET Centre continued, since the former went on using the facility for its own projects. Meanwhile, the clinical users and scientists slowly but surely regained control of the Centre.

Eventually, three and a half years after GE Healthcare handed over the PET Centre to the University and the Hospital, and 12 years after Amersham’s acquisition, the first (and to date only) commercial innovation emerged from the former IMANET venture. Following approval in both Europe and the United States, a novel commodity – a tracer molecule for diagnosing Alzheimer’s disease – was launched on the European and American markets. Interestingly, although it would probably never have been developed without the Uppsala PET Centre, the PET researchers’ knowledge per se was not what had spurred the development work. Instead, the most significant role played by the PET researchers in this innovation project was as intermediary between the parent company and American academic researchers at the University of Pittsburgh. This was where the ground-breaking knowledge on which Amersham and GE Healthcare based their innovation had originated. Thus, in the only real PET innovation project pursued by GE Healthcare, the Uppsala researchers’ most crucial contribution was in mediating knowledge, rather than producing it, and the basis for innovation was knowledge that had emerged in a purely academic context. Despite controlling a world-leading PET Centre staffed with highly skilled scientists, the parent company never managed to establish fruitful collaboration, in terms of commercial innovations based on new scientific knowledge developed in-house, between the Uppsala team and its internal R&D staff.

The PET Centre story (merely outlined so far) prompts questions on how science and business interact and how their interaction affects the use of science, and thus the formation of its value, commercial as well as academic and healthcare-related. Below, this chapter approaches these questions by connecting them with policy and scholarly exchanges pertinent to the issues...
of science and utility. Paving the way for the PET Centre study, first, is clarification of how the story of the Centre relates to policy and influential theoretical currents. Second comes an outline of the approach to science and interaction that has shaped the research questions presented at the end of this chapter. An informative starting point for constructing this framework is research policy, to which we now turn.

1.4 Policy: wishes and prescriptions

The Amersham contract signed by Uppsala University in spring 2002 took the institution into unexplored territory, impelling a form of interaction between industry and academia thus far untried by the University. The venture’s timing was not random or incidental. On the contrary, the commercialisation decision was aligned with a far-reaching trend that had been gaining ground in the industrialised world since the 1980s: uniting academic science and business to achieve innovation. In industrialised nations the promotion of innovation, seen as the cure for many economic ailments, has become a top priority for governments wishing to strengthen their nations’ industrial competitiveness and economy (Farinha, Ferreira and Gouveia, 2014; Barnes, Pashby and Gibbons, 2002; Harman and Harman, 2004). The notion of innovation as a prerequisite for prosperity is no new phenomenon but, rather, an idea that has been expressed in political debates for decades (Eklund, 2007). What has changed since the 1970s, however, is where this desideratum is thought most likely to emerge (Eklund, 2007; Mowery and Sampat, 2005; Rider, 2009; Jacob, 2003).

Increasingly, debates on possible strategies to boost innovation reflect the view that innovations should be based on science. The dominant idea is that scientific discoveries constitute the fertile ground on which innovation can and should grow. Focusing on science as integral to innovation brings the role of scientific research and universities into play. As producers of scientific knowledge, universities are regarded as important contributors to, and natural starting points for, innovation (Breznitz, O’Shea and Allen, 2008; Smith, 2007; Santoro and Chakrabarti, 2002). Policymakers believe that universities harbour an innovative capacity that has not yet been used to its full potential. They therefore urge academic institutions to make serious efforts to facilitate transformation of scientific knowledge into innovations on the commercial market (Hagen, 2002; Jacobsson and Perez Vico, 2010; Cohen, Florida, Randazzese and Walsh, 1998). In response to these calls, many universities in industrialised countries have established institutional infrastructure designed to efficiently connect academic researchers with industry (Goldfarb and Henrekson, 2002; Colyvas, 2007; Fisher and Atkinson-Grosjean, 2000). This infrastructure, inspired by and modelled on the American Offices of
Technology Licensing (OTLs), consists of such bodies as incubation centres, holding companies and legal advisory units, all set up to smooth the journey from the research laboratory to industry. Put differently, universities have taken policy directions to heart, and are now determined to play an active part in creating economic value from academic research. Uppsala University is no exception.

The PET Centre was commercialised at a time when Uppsala University, much like many other Swedish higher education institutions (HEIs), had just begun building up its innovation infrastructure. As of 2017, innovation support infrastructure linked to Uppsala University consists of an innovation office with patent guidance, a pre-seed and seed-investing holding company and as a business incubator at arm’s length from the University.

This configuration was partly a response to an initiative from the Swedish Government. In Sweden, the aim of establishing closer ties between academia and society is expressed in a set of regulations that the Government began to introduce in the 1990s. In addition to teaching and conducting research, HEIs are obliged to pursue a “Third Mission”. Accordingly, their remit is to interact with the rest of society, provide information about their activities and work to find ways of ensuring that academic research results benefit society (Swedish Higher Education Act 1997, 2009). In other word, academic science must be useful.

This idea of making science useful is multifaceted, but what is clear is that HEIs’ economic and societal contributions should not be limited to the work carried out by faculty members and the knowledge diffused by university graduates entering the workforce. Although these two conduits for HEI–society exchange are certainly recognised by the Swedish Government (National Innovation Strategy, Ministry of Enterprise, Energy and Communications, 2012), it is nonetheless clear that the HEIs’ output must include research that meets specific needs in society and yields economic value. Thus, the utility of academic research is expected to be demonstrated in the research topics chosen, not least by its ability to contribute directly to economic value creation through such activities as contract research, academic–industry collaborations, patenting, licensing and formation of spin-off companies. This faith in science-based innovation has been expressed in every government research bill presented to the Riksdag (Swedish Parliament) in the past two decades. In line with policymakers’ understanding of the ties between science, technology and the economy, government bills invariably stress the need for more of the knowledge gained from publicly funded research to be disseminated to industry and the rest of society. They also underscore the importance of spending substantial financial resources on efforts to boost commercialisation of research results.

Indeed, politicians in Sweden have identified research universities and other HEIs as playing “a crucial role” in making Sweden an attractive option
for R&D investments by global corporations (ibid.). Further, academia’s capacity to fruitfully interact with industry and other organisations is perceived as essential for development and regeneration of societal functions. This emphasis on universities’ interactive performance and innovative ability is clearly a considerable addition to their traditional responsibilities. The strong focus on science as an underused hub for innovative output is also apparent in policy work in the European Union (EU) and the Organisation for Economic Co-operation and Development (OECD). Within both the EU and the OECD, science is expected to be a crucial means of fostering innovation, thereby securing sustainable growth in face of global competition. Undeniably, Uppsala University’s readiness to allow the PET Centre’s transformation from an academic research institution into a privately owned company may be understood as reflecting this international policy development.

One basic objective of the work at hand is to use the PET Centre case to examine in detail what an attempt to achieve closer interaction between scientific knowledge and business might look like. What happens to science use when aspirations to create economic value must coexist with both continued production of scientific knowledge and provision of healthcare? To the extent that a “typical” academic spin-off story exists, the beginning of this chapter made it evident that this is not investigated here. The PET Centre case is unusual in involving the commercialisation of an entire research institution, unlike the more common spin-out formations initiated by individual researchers, which are centred on specific scientific discoveries (Bercovitz and Feldmann, 2005; Siegel, Wright and Lockett, 2007; Zahra, Van de Velde and Larraneta, 2007).

Nevertheless, despite – or perhaps because of – its singularity, the PET Centre case is particularly illuminating, spanning as it does an expansive range of important commercialisation mechanisms (Nilsson, Rickne and Bengtsson, 2009; Vohora, Wright and Lockett, 2004): patenting, licensing, contract research and academic spin-outs. The PET Centre case thus encompasses some of the most salient means by which academic science is brought to market. The phenomenon of science–business interplay is approached through in-depth examination of the Uppsala PET Centre, and this institution’s circular journey from the sphere of academic science to that of private enterprise and back again. With PET science as the focal point in the description of events, the story of the PET Centre raises questions that are pertinent to policymakers’ current understanding of science-based innovation and university–industry interaction. What is meant by “making science useful”, and what constitutes “value” in terms of science? And what participants in an interactive situation benefit from the usefulness and value of the science produced?
Such questions cast a degree of doubt on the stated objectives of research policy. My interest in this policy, and the predominant discourse on science–industry interaction and innovation it has inspired, springs from its relevance to the PET Centre story. More specifically, my concern with this discourse in relation to the PET Centre case stems from the general recognition that it saturates the context in which the Centre evolved (and is still evolving). With its openness to industry and inclusion of several significant commercialisation channels, the PET Centre embodied an approach that policymakers were bound to view with approval. In a sense, existing research policy may be said to have been an ideological backdrop to the PET Centre’s journey. But how may the underpinnings of this ideology be conceived?

The short answer is that the formulation and focus of research policy have been heavily influenced by various theoretical schools concerned with the role of academia in innovation processes. Sketching the landscape in which the story of the PET Centre unfolds therefore also calls for clarification of the basic theoretical assumptions underlying current research policy. In the next section, on the issue of science’s utility, I therefore describe how these theoretical currents fit into the dominant redefinition of science’s role in our economy.

1.5 Ideas on the utility of science

A few key observations can be made from a perusal of the current discourse on science and its utilisation. The first, basic one is that science is regarded as a good that should be brought to the market as a commodity. It is generally argued that this transposition of scientific knowledge to the realm of commodities is part of a larger movement of marketisation (Djelic, 2006; Araujo and Pels, 2015). Policy documents and press editorials further reveal the ubiquitous idea that the paramount value of science lies in its utility and, crucially – in line with the drive for commodification – that this utility must ultimately be translated into economic terms. These notions constitute two cornerstones of an argument we have grown increasingly familiar with, rooted both in history and in the contemporary preoccupation with marketisation.

Although the current insistence on commodification of research as a necessary route to affluence is a fairly recent phenomenon, the more general view that academic research should fulfil a social function has a long history (Beckman, Tunlid and Widmalm, 2008; Pestre, 2005). Beckman et al. argue that science has always, throughout history, served multiple purposes. Science that pursues answers to fundamental problems has coexisted with scientific activities aimed at direct applicability. Jacob (2003) points out that policymakers and academics, perhaps surprisingly, seem to be consistently unanimous in regarding utility as a key criterion justifying the pursuit of
scientific knowledge. Nonetheless, there have been significant differences in opinion about exactly what the utility category should comprise, with both politicians and scientists seeking the prerogative to formulate such a definition (ibid.). The issue of science’s value has thus been marked by consensus on some levels, and discord on others. Since the Second World War, there has been a shift away from the post-war era’s “social contract” of science, in which autonomous research was considered the engine that would drive societal development, to what some innovation scholars would call a new social contract (Beckman et al., 2008).

This new social contract of science may be said to be embodied in various theoretical schools that began to gain ground internationally during the 1990s. In these theories, recognition of the interrelatedness of science and various spheres of society was the basic premise. Maintaining that research collaborations between university and industry have become more commonplace in industrial economies, these streams of thought have considerably influenced research policy. Among them, Triple Helix (see, for example, Etzkowitz and Leydesdorff, 1997) and Mode 2 (Gibbons, Limoges, Nowotny and Schwartzman 1994; Nowotny, Scott and Gibbons, 2001) are two of the best known. These models attempt to offer a description of the historical development of, as well as the recent changes in, the research landscape (Beckman et al., 2008). Besides Mode 2 and Triple Helix, the Innovation System is another analytical framework that has had a major impact on policymaking. The focus of this framework was originally on producer-user interaction, and science was not singled out as the factor most critical to innovative success (Lundvall, Johnson, Sloth Andersen and Dalum, 2002; Lundvall, 2004; Lundvall, 2007). The original academic proponents were reluctant to make strong assertions about the universities’ role in innovation. However, policymakers have construed a somewhat modified form of this theory as supporting the importance of interaction between academia and industry. The overall message of these theoretical frameworks is twofold: that universities should be more responsive to economic requirements and that research policy, because of the perceived link between science and innovation, should be integrated into innovation policy (Eklund, 2007).

In emphasising the significance of strong ties between universities and other institutional stakeholders, Mode 2, the Triple Helix framework and the

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1 As Beckman et al. emphasise, the social contract of science has never existed in a formal sense, but is a *post hoc* reconstruction to describe public and prevalent opinions about science in the years immediately after the Second World War.

2 The original innovation system concept, which innovation scholar Bengt-Åke Lundvall played a fundamental role in developing, differs from the version adopted by the OECD. For a thorough account of the evolution of the innovation system concept, see Eklund (2007) and Lundvall et al. (2002).
alternative version of the Innovation System approach have a distinct normative element (Mowery and Sampat, 2005; Elzinga, 2004; Martinelli, Meyer and von Tunzelmann, 2007; Boden, Cox and Nedeva, 2007). Focusing on the utility aspect of science, research is here primarily conceived as a means of promoting economic development. As expressed by Etzkowitz and Leydesdorff (2003), the Triple Helix thesis affirms that universities “can play an enhanced role in innovation” (p. 109). Meanwhile, the originators of Mode 2 advocate dissolution of existing barriers between academia and the rest of society, arguing that economic and social concerns should fully determine the course of knowledge production (Gibbons et al., 1994; Nowotny et al., 2001). What unites proponents of these frameworks is thus not only their historical observation of growing interplay between science and society, but also the belief that this interplay is key to the transformation of science into economically useful goods.

Because of this belief, the most fundamental normative stance taken within these schools of thought is that inter-sphere interplay is desirable and therefore should be encouraged. In the interactive perspective of the Triple Helix framework, the significance of science in generating innovation is illustrated by the metaphor that has given the theory its name. The three helices represent University, Industry and Government, three institutions whose intermixture is believed to boost innovation by creating new formats for the production, application and transfer of knowledge (Etzkowitz, 2003; Etzkowitz and Klofsten, 2005). In this school of thought, universities are not only encouraged to adopt a higher profile in innovation. They, industry and government are also urged to take one another's roles. In other words, over and above their traditional functions, universities should engage in industrial activities. Similarly, besides performing their regular duties, governments should act like venture capitalists, and so forth. The result is overlapping institutional spheres, with “hybrid organisations” surfacing at the interfaces (Etzkowitz and Leydesdorff 2000:111). In brief, interaction is considered key to making science produce economically useful goods. But what is the distinctive nature of these interacting spheres? On this point, views differ. From a Mode 2 perspective, the boundaries between science and the surrounding spheres are seen as disintegrating until, eventually, no distinct spheres of science or business remain (Shinn, 2002). However, the viewpoint expressed in the Triple Helix theory is slightly different. Here university, industry and government are regarded as separate strands that, combined in the triple helix, become something altogether different that enhances prospects of science-based value creation (ibid.).

The theoretical frameworks described here not only carry weight in policy circles. They – particularly the Triple Helix and Innovation Systems models – are also of high scholarly relevance in research on university–industry interaction. This research area is vast and multidisciplinary, involving
researchers from disciplines like economics, marketing and organisational studies. The study on Uppsala PET Centre forms part of this field of research. The next section discusses how this study relates to the dominant perspectives and empirical foci discernible in the literature.

1.6 Perspectives on university–industry interaction

Research on the interplay between academic science and business encompasses a variety of theoretical outlooks, empirical interests and methodologies. As for the topics explored in these studies, various themes are distinguishable. Numerous studies focus on the phenomenon of academic patenting, using both quantitative measures and qualitative methods. Topics investigated to date include, for example, how patenting relates to publication rates (Murray and Stern, 2007; Thursby and Thursby, 2010; Azoulay, Ding and Stuart, 2009); what factors affect university scientists’ decisions whether to patent (Owen-Smith and Powell, 2001); and changes in patent rates in newly industrialised economies (Singh, Wong and Ho, 2015).

Another research theme is that of university technology transfer infrastructure. This literature analyses, for example, the function of science parks and incubators (Hansson, Husted and Vestergaard, 2005; Phan, Siegel and Wright, 2005; Löfsten and Lindelöf, 2002), the reasons behind the evolution of university business incubators (Etzkowitz, 2002) and factors determining the success and effectiveness of such incubators and parks (Lee and Osteryoung 2004; Markman, Phan, Balkin and Gianiodis, 2005). Further, academic entrepreneurship makes up yet another research theme, in which particular attention is given to such aspects as the effects of resource availability on the number of academic spin-offs (Powers and McDougall, 2003), and the individual-level factors influencing the extent and forms of academic entrepreneurship (Klofsten and Jones-Evans, 2000; Clarysse, Tartari and Salter, 2011; Haeussler and Colyvas, 2010).

These research topics are interrelated and cross thematic boundaries. To some degree, they are all connected with the more general category of studies on university–industry interaction, in which neither patenting, university technology transfer infrastructure nor spin-offs are the focal point. Instead, the lines of investigation in these studies concern the broader spectrum of university–industry interplay, and the specific research topics are diverse. Belkhodja and Landry (2007), for instance, employ a Triple Helix perspective to examine the drivers for academic researchers to collaborate with industry and government, and what factors influence the barriers to such collaborations. This broader span of interactions that make up university–industry collaborations stands in contrast to the idea of the spin-out funnel (Clarysse, Wright, Lockett, Van de Velde and Vohora, 2005). This concept
portrays the formation of an academic spin-out as a linear sequence of stages, from the search for an invention suitable for commercialisation through the phases of assessment and filing of IP rights, funding and validation of the business plan. Eventually, a spin-out is founded in the hope of creating science-based innovation.

Concentrating on the full spectrum of mechanisms through which university and industry interact, as opposed to just spin-out formation, D’Este and Patel (2007) analyse the factors that affect researchers’ involvement in this wider range of interactions. In an equally inclusive consideration of various channels for commercial interactions, Martinelli et al. (2007) map entrepreneurial faculty members’ knowledge exchange and investigate these individuals’ attitudes towards the entrepreneurship-promoting measures launched by their universities. Perkmann et al. (2013) look beyond the most easily measurable commercialisation mechanisms of patenting, licensing and academic entrepreneurship. They explore the antecedents and consequences of other types of university–industry interactions, such as contract research, collaborative projects and consulting, which they refer to as “academic engagement”. Further, Cohen et al. (1998) and Jacobsson and Perez Vico (2010) examine the role of university research in, and its impact on, industrial R&D. Additionally, in their aim of contributing to a comprehensive understanding of university–industry relationships, Bercovitz and Feldmann (2006) take a highly general perspective, presenting a framework intended to highlight universities’ role in knowledge-based innovation systems.

Rich and diverse as published research on university–industry interaction is, a survey of the literature nonetheless reveals that certain aspects of this phenomenon are under-researched (Perkmann and Walsh, 2007; Ankrah and Al-Tabbaa, 2015). Studies that examine the interplay between academia and business on a micro-level are very few compared with the amount of research carried out on macro- or meso-levels of analysis. Thus, comparatively little attention is paid to the nuts and bolts of the intermixing of university scientists and firms. Notable among the relatively few existing micro-level studies is Bjerregaard (2009), who uses a micro-level perspective to investigate the collaboration strategies used by academic researchers and collaborating small and medium-sized enterprises.

How exactly does this type of investigation contribute to our comprehension of the interplay between university science and business? How can additional micro-level studies help remedy what appears to be scant attention to the real-life inner workings of university–industry interaction? The short answer to these questions is that qualitative micro-level research approaches can help illuminate convoluted processes and relationships that remain unexamined by research carried out from a more macro-level perspective. Consequently, micro-level studies can pursue inquiries that are
different from, and complementary to, those engaged in macro- and meso-studies. Given the complexity of university–industry interaction (Dasgupta and David, 1994; Ingemansson, 2010), our understanding of the phenomenon would benefit from methods and analytical tools that allow thorough probing of the network in which the various actors, and the resources they bring, meet. Employing a network approach, as in this thesis, provides scope to carry out studies of this kind (Snehota and Håkansson, 1995; Johanson and Mattson, 1994; Håkansson and Waluszewski, 2002a). The form of detailed scrutiny used to investigate the Uppsala PET Centre through such a network perspective may well enable identification of specific challenges (such as difficulties in collaborating) and opportunities (such as mutually beneficial value creation) that can arise in university–industry relationships.

1.7 Where does the PET Centre study fit?

In contrast to many studies in the area of university–industry interaction research, which may acknowledge but do not specifically address the considerable uncertainty of outcomes from this type of intermixing, the chosen angle for exploring the topic here is slightly different. This thesis concentrates on a case of interaction between academia and industry where the fallout is not unambiguously positive, despite what might objectively be deemed excellent circumstances for a commercial venture. The literature includes a comparatively low number of studies that focus specifically, and in detail, on examples that are not clear-cut success stories, or do not pay particular attention to challenges.

Given the relatively low success rate (see Hagen, 2002) of this type of interplay in terms of unequivocally positive economic accomplishment, the lack of such studies is problematic. The PET Centre case study is therefore intended to fill the gap and highlight the intricacy of interaction between the dissimilar spheres of academia, business and healthcare. As mentioned at the beginning of this chapter, this is done by delving into the issue of science use, which is particularly relevant given the discourse on the usefulness of science reviewed earlier.

In examining science use, this thesis pursues lines of inquiry that Ankrah and Al-Tabbaa (2015) have identified as requiring further investigation. The present work explores, for example, the outcomes of commercial innovation endeavours involving academic scientists and industrial researchers. It also addresses the need for longitudinal studies (ibid.), which permit assessment of various outcomes of inter-sphere collaborations in both the short and the long term. Together, these methodological and empirical choices offer additional insights into the impact of university–industry interaction on science use.
The question of how science is used is particularly relevant given the discourse on the benefits and utility of science reviewed earlier. The starting point for my examination of science use in a context of inter-sphere interaction is: first, to outline what science is in terms of the resources it spans in the network where it is embedded; and second, to appraise the differences in valuations that dissimilar actors make. These two points are addressed below.

1.8 Approaching the question of science use

To gain a more nuanced understanding of the interplay between academia, industry and other societal spheres, we need to grasp the composition of the entity around which the interaction revolves – science – and the potential differences in value preferences of the participants intended to interact in the network. I briefly address these two points below, starting with the first. My basic argument is that if we grasp the materiality of science, we can more easily comprehend the nature of inter-sphere interaction around scientific research, and the challenges of creating economic value from it.

1.8.1 The composition of science

One critical, elemental perspective of this thesis is that science is embedded in a network made up of a variety of resources, spanning people, organisations and artefacts. In this understanding, the use of science involves the interaction of these different components; in other words, science in use is the result of a combination of resources (Strömsten and Waluszewski, 2012; Håkansson and Waluszewski, eds., 2007; Baraldi et al., 2012). Drawing from insights from the sociology of science (see, for example, Latour and Woolgar, 1979; Callon, 1994), this conception breaks with the general tendency to discuss science as if it were solely an assemblage of “free-floating ideas” (Rouse, 1993:11), disconnected from substances, materials and practices.

Rather than conceiving science primarily as intangible knowledge statements, i.e. as containing only codifiable scientific information, the perspective of this thesis is that science consists as much of codified statements as of material objects, and of the know-how and expertise possessed by scientists. This is among the most basic and important findings of social studies of Science and Technology (Latour, 1986; Callon, 1994; Knorr-Cetina, 1995; Pavitt, 2001). In such an understanding of science, knowledge statements are of little use on their own. To be of any value, they

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3 Callon refers to the “intrinsic inutility of statements” (p. 403). For a detailed discussion, see Callon (1994).
require the presence of adequate instruments and the skill set needed to operate these instruments. What can be done with a scientific statement on the half-life of a specific radioisotope if no equipment is available to put this knowledge to use, and no expertise in running the equipment? Indeed, one viewpoint in this thesis is that it is through interaction between resources making up a certain body of science that utilisation of, and thereby value creation from, science takes place (Baraldi and Strömsten, 2008; Waluszewski, 2004).

This perspective is encapsulated in the analytical 4Rs tool (Håkansson and Waluszewski, 2002a; Baraldi, Gressetvold and Harrison, 2012), developed within the theoretical school of International Marketing and Purchasing (Håkansson and Waluszewski, 2002a; Wedin, 2001). The model’s “four Rs” stand for four resource categories: organisational units, organisational relationships, products and facilities. Resources in these categories are viewed as being connected in networks. Conceiving of science as a network of both physical and organisational resources implies opposition to the traditional economists’ notion of science as a public good, as formulated by Samuelson (1954). Goods are considered public when they exhibit the characteristics of 1) non-rivalry and 2) non-excludability. The former condition means that use by one actor does not limit use by another, and the latter that no actor can be excluded from use. A cluster of grapes would hence not constitute a public good; instead, like most goods, it belongs to the category of private goods. Scientific knowledge, on the other hand, has traditionally been considered a public good because, say, a chemical formula may be used simultaneously in a research laboratory in Uppsala and a chemistry lecture in Mumbai. But if we view science as an agglomeration of knowledge statements, non-codified skills and physical elements, the idea of science belonging to the category of public goods or even, as is occasionally proposed, of “impure” public goods (Kotchen, 2004) is untenable.

When the idea of science is that of a body of knowledge incorporating codifiable, tacit and material elements, its non-public character stems not primarily from the existence of various appropriation devices, such as patents and licences, or even from private actors’ involvement in a business-scientific interaction. Instead, the non-public quality of science as a good can, at the most fundamental level, be attributed to its joint incorporation of intangible and tangible elements. The material aspect of science implies that one actor’s use of a piece of science precludes the simultaneous use of the same piece by another. Given this implication, it is important to ask the question of what, for each party taking part in inter-sphere science-centred interaction, the impact of science’s materiality may be on its utilisation. This leads us to the first research question of this thesis:
1. How does the materiality of science affect its use by the spheres of academia, business and healthcare?

At the beginning of this chapter I formulated the overarching research problem of the current work: What happens to science use when disparate actors engage in it? The specific research question above addresses a particular aspect of the broader research problem: it directs our attention to everything physical involved in the use of science, alerting us to the fact that use of scientific knowledge is bound up with the use of artefacts. The question becomes all the more urgent if we take into account how disparate spheres generally have divergent ideas of what is valuable. The tendency of different actor spheres to make dissimilar valuations is addressed below.

1.8.2 What is valuable?

Whenever attempts are made to connect the non-commercial with the commercial – such as academia and public healthcare with business – there is a potential clash between different conceptions of value. It follows that in referring to the utility of science, with which (as we have seen) policy is very much concerned, we must consider for whom science is useful. What counts as useful, and therefore valuable, to a non-commercial actor may be of no or very little value to a commercial actor, and vice versa. There are various types of value and valuation, economic value being just one (Helgesson and Muniesa, 2013; Aspers and Beckert, 2011). For instance, in their work academic researchers are mainly concerned with creating scholarly value in the form of cutting-edge knowledge manifested in academic publications. In addition to advancing the current stock of academic knowledge, this plays a decisive role in furthering careers in academia (Bird, Hayward and Allen, 1993; Dasgupta and David, 1994). The ultimate goal of industry, on the other hand, is creation of economic value. Similarly, the primary aim of hospitals is to generate healthcare-related value by curing illness, alleviating pain, providing therapeutics and so forth.

Given the fairly fundamental difference in these conceptions of value, it is important to consider whether, and if so how, this divergence is a factor that to some degree affects the structure and outcome of the interplay between science and business. The second specific research question – which, like the first, focuses on a particular aspect of the overarching research problem of this thesis – concerns this very issue:

2. How does interaction between the spheres of academia, business and healthcare affect value creation from science?
With the notion that value creation results from utilisation, the second research question thus shines the spotlight on the actor aspect of science use.

1.9 The Uppsala PET Centre case: a study of various forms of use

Highlighting the variability of science use, this thesis elucidates the effects and outcome of science–industry interaction with respect to the agendas, motivations and wishes of the main actors. It is from this point of departure that the evolution of Uppsala PET Centre, with its tight commingling of academic science, business and healthcare, prompts questions on the merits of this type of close intermixing. The aim of this thesis is to explore these issues through the PET Centre case, by providing insight into an actual, ambitious real-life endeavour to create economic value by marrying an academic research unit and a large private company. Since the story told here revolves around processes of commercialisation and de-commercialisation of science, and thus shifting degrees of commodification of scientific objects and processes, economic value creation naturally plays a key role.

However, this study pays equal attention to non-financial valuations and endeavours to generate non-economic value. The PET Centre is a hub not only for attempts to create business value but also for scientific ambitions and provision of patient care to a large hospital. Accordingly, aspirations to create value relevant to science and healthcare are a significant factor in the Centre’s evolution.

In a situation resembling the PET Centre case, with efforts being made to derive both commercial and social value from science, a basic question arises: How far can these differing aims coexist? This raises further questions about the tendency, in both policy and a good deal of research, to treat this kind of interaction as intrinsically constructive in terms of value creation. How can we conceive of the implicit assumptions in current discourse concerning the malleability of science as a resource and the agility of academic researchers as (co-)creators of commercially relevant knowledge? By concentrating on the specific research questions presented above, this thesis ultimately calls into question the validity of such presumptions.
1.10 Outline of this thesis

This thesis is structured as follows. Chapter 2 presents the theoretical framework that has guided my research process. Chapter 3 discusses methodological considerations and data-collection methods. Chapters 4, 5 and 6 tell the empirical story, while Chapters 7, 8, 9, 10 and 11 cover data analysis. Conclusions are presented in Chapter 12.
Chapter 2. An interactive perspective on the use of science

The underlying idea of this thesis is that of the use of science as taking place in networks, in which organisations, knowledge, artefacts and other resources are connected to one another through relationships (Håkansson and Snehota, 1989; Snehota & Håkansson, 1995; Håkansson, 1987). More precisely, the theoretical point of departure is that science utilisation involves the interaction between resources in a network, as proposed in the Industrial Marketing and Purchasing (IMP) literature. Adopting such a network approach, this thesis looks specifically at a case which describes the use of science taking place in a space where the three spheres of academia, business and healthcare meet, while processes of commercialisation and de-commercialisation unfold. The implication of this intermingling of actors from different spheres is that the efforts to commercialise science involve attempts to marry different perspectives and thus different valuations of science. To be able to address my research questions about the utilisation of – and hence the formation of value from – science in such a heterogeneous network, this chapter aims to examine the theoretical constructs and tools I find relevant and helpful in this undertaking.

Drawing from insights from the literatures of economic anthropology, sociological valuation research, business studies and Science and Technology Studies (STS), I discuss the concepts of commodities, valuation, and value, as well as how we can conceive of and conceptualize the various preferences and norms actors harbour in relation to value production. I then proceed to explicate the IMP resource interaction perspective, the processes of commercialisation and commodification, and the conception of science. At the end of the chapter I describe the fundamental theoretical framework within which the research problems of this thesis fit, and within which the empirical story is later analysed.

I begin by directing attention to the commercial object itself, the anticipated outcome of every commercialisation journey: the commodity. In connection to this discussion follows a conversation on how commodities relate to valuation and economic value, constructs key to the PET Centre story, as well as how we can understand valuation in relation to the actors who actually make these valuations.
2.1. Commodities and valuation

In the previous chapter we learned about important shifts in the political discourse on scientific research. We saw how one of the most significant changes in the political attitudes towards the connection between science and the world outside academia has been the hopes pinned on science to contribute to economic growth. The powerful and confident premise behind much innovation policy-making is that academic excellence, smoothly and swiftly, can be translated into economic value. Academic researchers are being ushered into the world of commerce, and science, as discussed earlier, is increasingly being assessed in terms of its potential as a commodity (Kleinman and Vallas, 2001; Oliveira, 2013). Nevertheless, the sheer amount of scholarship on the subject of science commodification is a testament to the contentiousness of this development. The emotional and intellectual agitation within the academic community in relation to this type of commercialisation implies that many people view the entry of academic knowledge into the commercial arena as a phenomenon warranting much caution (see e.g. Mirowski, 2011; Sampat, 2006; Nelson, 2001; Baskaran and Boden, 2004). In brief, many people believe that science should be kept separate from the commercial realm.

But how can we conceive of this development of scientific commodification? To anthropologist Kopytoff (1986), the engulfment of science into the world of commodities would be perceived as a progression that makes perfect sense. In Kopytoff’s understanding, “the exchange function of every economy appears to have a built-in force that drives the exchange system toward the greatest degree of commoditization that the exchange technology permits” (ibid.:87). In other words, the fact that we in the developed world use such a flexible exchange technology as money would suggest that there is no limit to how far the tendency to commodify would go. However, according to Kopytoff, there are counter-forces to this drive to commodify, namely those of culture and of the individual. What we are witnessing in the case of science would thus, in Kopytoff’s perception, constitute a battle between our economy, our culture and the individuals making up our community. Now, the underlying reasons for commodification aside, what exactly *is* this thing called a commodity?

2.2 What is a commodity?

In neoclassic economics a commodity is generally conceived of as a good without qualitative differentiation, such as coal, salt, sugar or copper. But a wider definition in the same discipline designates a commodity any good or service that is marketable, which corresponds well to the commonsense
understanding of a commodity simply as something that possesses both a use value and an exchange value. Going back to the early political economists, Marx offered a very broad definition: a commodity was a “thing which through its qualities satisfies human needs of whatever kind” (1976:125), a description so expansive that it seems to swallow everything. Anthropologist Appadurai, on the other hand, proposes that a commodity is any object whose exchangeability for some other object is its “socially relevant feature” (Appadurai, 1986:13). Built into Appadurai’s definition of the commodity is the notion that any object can be thought of as possessing a “social life”, during the course of which the object may move into and out of the commodity state. This perspective is especially well elaborated by Kopytoff, who envisions the movement between different states as taking place along a continuum where absolute commodities and non-commodities (or singularities in Kopytoff’s terminology) respectively occupy the two extreme points. And, a crucial point of Kopytoff’s, no object ever reaches the “ultimate commodity end” (1986:87) of this sliding scale. Stated differently, there is no perfect commodity. Connected to this conceptualization of the continuum is Kopytoff’s basic idea that one and the same thing may be treated as a commodity at one point in time, but as a non-commodity at another. Furthermore, the same thing may be viewed as a commodity by one person, while someone else at the same point in time regards it as something else. There are thus “shifts and differences in whether and when” an object is a commodity (p. 64).

As a way to illuminate processes that may otherwise remain abstruse, such as the adoption of novel or alien objects, Kopytoff finds it meaningful to think about things as possessing biographies, much in the same fashion as humans. And just as people can be said to have multiple biographies – for instance professional, romantic or physical – things can be understood as having different types of biographies, too: economic, technical, political etcetera. Importantly, one merit of looking at objects in this manner – paying attention to their entrance into and exit from the commodity sphere – is that it tells us something about the shifts in their valuation, private as well as “objective” (or, better perhaps, official). In the words of Kopytoff, the movement of a thing along the continuum between the ultimate commodity state and the non-commodity state “reveals a moral economy” that co-exists with the “objective economy of visible transactions” (ibid.). What makes industrial monetized societies peculiar is that “publicly recognised commoditization” is taking place alongside a plethora of other “schemes of valuation” (pp. 79-80). These schemes, created by groups and individuals, most often stand in insoluble opposition to public commodification and, not seldom, to one another as well. Put in a different way, commodification in an industrial society implies that the worth of an object is translated into a price, and both this expression of worth – “price” – as well as the “quantity of
worth” – or, “what is the price?” – may lead to conflict both on an individual moral and cognitive level, and in the interaction between groups and individuals. To sum up, the biography of a thing reflects the various schemes of valuation connected to an object during its lifetime. In so doing, the biography also helps unravel the clashes between different valuations of the thing in question.

2.3 Schemes of valuation

Clashes between valuations play a significant role in the story of the PET Centre and its evolution. Finding a concept that allows us to later analyse the reasons for and ramifications of such valuation clashes in the network is therefore useful. To this purpose, Kopytoff’s term “scheme of valuation” is in this thesis used to denote the set of preferences, norms and valuations tied to a certain group of actors. Each group of actors can thus be viewed as possessing a particular scheme of valuation that ascribes a certain value to things, actions and phenomena. Thus tied to actors, these valuation schemes are understood as guiding the behaviour and actions of specific actor groups: a non-profit organisation, for instance, will make other choices and hence act differently than a for-profit organisation. But schemes of valuation should not be regarded as static and immutable. Rather, while solid in their core, schemes of valuation are to some degree susceptible to change and to influence from other schemes of valuation.

Concentrating specifically on actors’ valuations, the scheme of valuation construct differs from other concepts dealing with the mental worlds of actors that are being discussed and used within the IMP tradition. Network picture is one such concept, defined as business actors’ subjective cognitive representations of their surrounding network (Henneberg, Mouzas and Naudé, 2006; Mouzas, Henneberg and Naudé, 2007; Ramos and Ford, 2010). Constituting instruments for sense-making, network pictures are regarded as tools informing decision-making, and have been investigated in recent years in the IMP literature in terms of, for instance, their effect on managerial behaviour (Corsaro, Ramos, Henneberg & Naudé, 2011), and to better understand how managers cope in complex networks (Henneberg, Naudé & Mouzas, 2009). While both schemes of valuation and network pictures are concepts that acknowledge the role of actors’ cognition as underlying action, the differences between the two are significant. Crucially, unlike network pictures, schemes of valuation is not a concept so much concerned with an actor’s perception of what the surroundings look like as with whom the actor perceives itself to be. Simply put, schemes of valuations are centred on the “inside” of an actor, whereas network pictures deal with the “outside”. Although it can certainly be argued that an actor's understanding of its
surrounding network is a function of who it believes itself to be, and that perception of self is therefore a factor, the focus of the network picture construct still rests firmly on position in relation to other actors and resources in a network, rather than identity. An actor’s scheme of valuation, on the other hand, is tightly connected to identity in that it designates, as mentioned above, a basic set of preferences, norms and valuations as belonging to a particular type of actor.

As a descriptor of aspects of an actor’s identity, schemes of valuation display a certain kinship with the concept of *schema*, or *systems of ideas*, introduced in the IMP literature by Welch and Wilkinson (2002) as a dimension to help understand network development and actor behaviour. Still, the concept of schema is significantly broader in scope than schemes of valuation, with the former including “the perceptions individuals and organisations have about self and others, their beliefs or ‘theories’ about how the world functions, norms about appropriate behaviour, attitudes toward particular issues as well as values concerning what is desirable” (ibid.:29). In light of this extensive definition, it could be argued that schemes of valuation in fact fit as a subset of the schema construct. Indeed “norms”, “attitudes” and “values” are elements contained within schemes of valuation, and with the concept thus picked apart it does seem to make up a piece of schemas. Even so, there may be reasons not to choose a broader construct over a more limited one, regardless of the qualities of the former and despite the fact that the latter could be seamlessly incorporated into it.

More specifically, in a study such as the one about Uppsala PET Centre, where fundamentally conflicting ideas regarding valuation are identified as an essential cognitive factor affecting interaction, it may be sensible to opt for a concept that allows for analytical pinpointing of that particular observation. In other words, depending on the nature of your study – the type of actors investigated, the type of phenomenon explored and so forth – analytical benefits may be derived from leaning on a narrower concept as opposed to one broader in span. And, needless to say, when faced with very intricate empirical material it makes sense to select a concept fine-tuned enough to help create analytical clarity, instead of augmenting theoretical complexity by using a concept too rich for the purpose at hand. Such is my reasoning for choosing to include schemes of valuation in my theoretical framework. Now, a recognition of valuation as a significant parameter calls for an exploration of the idea of value. Therefore, as a next step I address this construct, as vital to the concepts of commodity and schemes of valuation as to the theme of the thesis at large.
2.4 Value, economic and other

What is really meant by “value” and “valuation”? When we look at the meaning of value in social life, we recognise that it may take many different forms concurrently; there are for instance economic value, aesthetic value and moral value, and these three distinct dimensions of value may be co-existing (Beckert and Aspers eds., 2011). Value is naturally tied to valuation, a term that may designate both the attribution of a monetary value to an object, such as the sales price of a car, and the assessment of non-monetary value, such as the quality of a literary piece of work (Helgesson and Muniesa, 2013). The act of making a valuation involves the measuring and comparison of something according to a scale. When different scales are used, performing a valuation may be utterly complex and fraught with conflict; this may be the case when one actor judges a thing, a person or an action from a moral standpoint, while someone else makes the judgment based on economic criteria or aesthetic considerations. These valuations may stand in opposition to one another, but they may also overlap or combine. Furthermore, as Marion Fourcade (2011a, 2011b) demonstrates in her case study about economic remuneration for environmental damage, translating value from one scale to another can be a challenging undertaking. In short, things can have many values and be subject to many different kinds of valuations.

When speaking about valuation and value, and especially when considering terms like Kopytoff’s “schemes of valuation”, it is difficult not to touch upon the affinity between value, valuation and values, as in moral values or norms. Valuation and values (of the latter kind) are often closely interrelated (Stark, 2011). This is also true for the converse connection between moral values and economic valuation; in fact, sociologists have generally argued that aesthetic, symbolic and moral values are key to grasping the formation of economic value (Fourcade, 2011a).† Not surprisingly perhaps, the question of how economic value is constructed has a long history; ever since the days of Aristotle, scholars have been discussing the nature of this value (Finley, 1970; Richins, 1994; Vargo, Maglio and Akaka, 2008). And Aristotelian ideas, according to which economic value is divided into two parts – exchange value and use value – have been of considerable importance in shaping the thinking of value in relation to markets (Aspers and Beckert, 2011). In his labour

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† Aspers and Beckert (2011) point out that for goods and services to have economic value and be tradable in a market they not only have to fulfill existing needs, but they must also be regarded as legitimate. Which things and actions gain legitimacy depends on social context; for instance, in our society trafficking in human organs and enslaved workers is morally condemned and therefore has no place in a legal market (even though these things are traded illegally on black markets). In other words, norms and moral convictions often determine whether and how much economic value can be derived from an object or an action. To use Kopytoff’s terminology, human organs and human freedom are singularized, that is, they are sacralized and kept in the sphere of non-commodities.
theory of value, classical political economist Adam Smith proposed that the value of a thing was determined by the labour that went into its production, a notion that later influenced Marxian economics. From the perspective of the physiocrats, whose economic theory immediately preceded that of classical economics, value was only created through working the land. Craft and industrial labour were sterile activities, merely adding more riches in the form of money; actual surplus could only be generated through agriculture (de Moonthoux, 1993; Hubacek and van den Bergh, 2006).

This physiocratic conception of value-creation, as well as the labour theory of value of the classical school, are obviously incongruous with contemporary mainstream economics; in neoclassic economics, the value of an object is determined by what someone is willing to give up to obtain the object in question. To put it another way, in our monetized world, mainstream economics understands the value of a thing simply as price. This view is challenged by numerous heterodox schools of thought maintaining that equating the value of something with its exchange value misses essential points in the comprehension of economic value and value-creation. IMP is one such school. Its basic conceptualization of economic value rests on the ideas of economist Edith Penrose (2009 [1959]). The next section deals with segments of Penrose’s theoretical contributions and how these have inspired the IMP approach on the subject of value.

2.5 Resource interaction, utilisation and value creation

In her seminal work The Theory of the Growth of the Firm (1959), Penrose lays forward her ideas of the firm as essentially a collection of resources, a perspective that has formed the very foundation of the resource-based view (RBV), where a company’s competitive advantage is seen as tied to the protection and cultivation of the tangible and intangible resources of which the organisation is composed (see for example Wernerfelt, 1984; Peteraf, 1993, Wernerfelt, 1995). In Penrose’s understanding, it is not the resources themselves that constitute the input in a firm’s production, but rather the different services that the resources can yield. For Penrose this distinction is critical; precisely because a resource can render many different services depending on how it is used, this is where the uniqueness, and hence the strength, of a firm lies. Put differently, it is the heterogeneity of the productive services available from its resources that makes each firm unique and offers opportunity for growth and expansion. Importantly, Penrose argues that it is the interaction between material and human resources (“personnel”, p. 67), which affects what productive services are available from each type of resource. It is thus in combining different resources that benefits are achieved: “...no resources [...] are of much use by themselves; any effective
use from them is always viewed in terms of possible combinations with other resources” (ibid.:76). In the IMP approach, this type of interaction is assumed to take place not only within but also between organisations, across a larger network, which can be compared to the resource-based view where resource interaction is analysed exclusively within the single firm.

Both the notion of resource heterogeneity and that of resource interaction have carried much weight within the IMP perspective. The basic proposition in this school in regard to value is that a heterogeneous resource is not inherently valuable; the economic value of a resource is instead created in interaction with other resources (see for example Baraldi and Strömsten, 2006; Baraldi et al., 2012; Baraldi and Walouszewski, 2005; Håkansson, Ford, Gadde, Snehota and Walouszewski, 2009). In other words, economic value is created when resources are combined with one another. This conception of value-creation places the focus on the combinations of resources, and not on the individual resource. Consequently, the main interest lies in what happens in between resources.

Another way – and one that is pertinent to the objectives of this thesis – of framing the connection between value-creation and resource combinations is to speak about utilisation. Indeed, the citation of Penrose above revealed her view of resources being of use only when combined with one another. In terms of the theme of the present work, we are hence dealing with a situation where the use of science equals value creation from science: through use, value is formed. Whether this use – again, in the context of this thesis, use of science – happens through the employment of the resources combined or through the effects these resource combinations have on other resources depends on the nature of the specific resources that are joined. In the present work resource combinations are namely understood as either directly resulting in science use and hence the creation of value, or resulting in some other kind of use, which in turn has an impact on science utilisation. This particular point, which is not necessarily an obvious one at this stage, is addressed again later in this chapter, as well as in the analysis of the empirical story. Yet, for now it suffices to conclude that use of resources translates to formation of value, i.e. value is formed through use.

Now, so far the focus in this section has been on economic value-creation, but the IMP conception of value-creation through resource combinations is equally applicable to non-economic formation of value. Because this thesis puts under the spotlight the interaction between actor spheres carrying dissimilar ideas of what form of value is more important – economic or social – the fact that the IMP model also extends to non-economic value is helpful. To be sure, of interest in this thesis is not merely the economic use of science, but also academic and clinical uses.

If we now compare the anthropological perspective on value presented in the beginning of this chapter with the IMP view of value-creation just
described, we notice a fundamental difference between the two outlooks. Whereas the former understanding of value is basically a relativist one – the value of a thing depends on how it is perceived by individuals – the latter understanding is interactionist: the value of a thing is realised only in combination with other things. But rather than being mutually exclusive, the two perspectives are united by the basic premise that no thing possesses intrinsic value. In fact, the views can be seen as complementary: one of them is relevant on the level of the individual actors as well as the collective – actors attributing value to a thing on the basis of their scheme of valuation – and the other one significant on the resource level – value emerging as a consequence of resource combinations. This cohesive perspective is integral to the present work.

Indeed, in this thesis I argue that there is an important connection between the relativist view of value-creation and the interactionist perspective on how value is formed, the idea being that schemes of valuation are related to resource combinations and the use that ensues from these combinations. More precisely, schemes of valuation, reflecting an actor’s preferences and values may to a certain degree affect how resource combinations are configured, and hence how science is used. This idea rests on the assumption that actors will try to mobilize and combine resources in a way that enables the kind of use, and thus generates the kind of value, in which they are interested – in other words, that the resource combination will, if possible, be aligned with their particular schemes of valuation. I return to this posit at the end of the chapter to discuss its position in the framework of this thesis.

Before doing so, however, a number of other theoretical concerns vital to the investigation of science use need to be addressed. Firstly, I continue the above discussion about resource interaction with an in-depth review of how this matter is understood within the IMP tradition, with particular attention to how examination of resources can be used as an analytical tool. Second, this revision is succeeded by an investigation of and comparison between the concepts of commercialisation and commodification. And third, the science construct is discussed so as to arrive at a clear formulation of what exactly this dissertation examines the use of.

2.6 The idea of interacting resources

In keeping with Penrose’s idea that “[a] firm is basically a collection of resources” (2009 [1959]:68), within IMP, an organisation is viewed as consisting of material and immaterial resources that are connected to one another, as well as to resources in other organisations, across networks (Dubois and Araujo, 2006; Baraldi and Strömsten, 2009; Strömsten and Waluszewski, 2012). We learned previously that it is in the combining of
resources that economic value of a certain resource is created. Therefore, to understand how economic and social value creation of a resource arises, we are interested in the network that the resource in question is a part of. Within IMP a theoretical tool called 4Rs (Håkansson and Waluszewski, 2002a) has been devised to focus specifically on the interplay between resources. It is used to investigate how resources are developed and used in relation to one another. As mentioned in the introduction, the four Rs in the model denote four different resource categories: products, facilities, organisational units, and organisational relationships. While the first two categories comprise intangible, organisational resources, the latter two categories contain physical resources. The products of an organisation are the outcome of interaction between developers, producers and users, and are made through the use of facilities, representing buildings as well as equipment and tools. Organisational units include organisations or parts of organisations and bind together physical and human resources that exist within these units. A piece of technology in one firm may for instance be combined with the routines, skills and know-how in another, and this joining of resources may result in for example a new machine, or an improved way of working. It is the organisational relationships, i.e. the relationships between organisations, which make this type of resource interaction possible. The basic prerequisites for inter-organisational interaction, relationships are therefore not regarded merely as a means to benefit from resources, but also as crucial resources in themselves (Håkansson and Waluszewski, 2002a).

In the process of resource combination, during which resources are developed and adapted in relation to one another, interfaces between the resources emerge. These interfaces can be thought of as surfaces of contact, or points of connection, and can, following the categories in the 4Rs model, be divided into three different groups (Håkansson and Waluszewski, 2002a; Baraldi, 2003; Bengtson and Håkansson, 2008): (a) physical interfaces, which are formed when physical resources are connected, such as a tool interfaced with a machine; (b) organisational interfaces, which are the result of the joining of immaterial resources, such as new work routines and administrative rules; and (c) mixed interfaces, which are created when material resources are combined with immaterial resources, such as an instrument and technical knowledge.

Within IMP, resource interaction is regarded as a process that affects the features of a resource (Baraldi and Strömsten, 2006; Cantú, Corsaro and Snehota, 2010; Lind, Holmen and Pedersen, 2010). In other words, the characteristics of a resource are created through the interplay between the resources that surround it. Consider for example the power of a car engine, where the feature “power” is shaped by, among other things, the specific knowledge of engineers, the type of fuel used, as well as various solid parts of the vehicle. In the same manner, the feature “fuel efficiency” of the car is the
outcome of, for instance, engineering expertise and the material used to build the car. We thus see that in the development and production of, or perhaps more generally, in the emergence of a resource, its features are the result of its links to other resources, both physical and organisational. For the sake of clarity it should be added that the idea that a feature is created in interaction is relevant during the process in which a resource is formed, but it is less central when we consider the features of the “finished” resource ready to be put to use.

Instead, what becomes significant about such a resource at that point in time is how to make its features valuable, i.e. how to create value from existing features. Going back to the idea that value is created as interfaces between resources are formed, we see that for the benefits of a resource feature to actually materialize, the resource must be combined with other resources. In the case of the powerful car engine, the value of this power is only formed as a driver ignites the engine and drives off (interface between the engine, car key and driver), or when sales personnel manage to sell the vehicle in which the engine sits to customers (interface between the engine, sales force and customers). And, importantly, if we swap perspectives the reverse is naturally also true; for example, the driver’s ability to drive high-powered cars (a feature of the immaterial resource “driving knowledge”), and the car key’s precise fit (a feature of the physical resource “key”) become valuable when the resources to which these features pertain are interfaced with the car engine.

But are we aware of every aspect of this car engine, or of the car in its entirety? Do we know every facet of its features? Can we appreciate the multiplicity of values that may be captured from this resource? Most likely not, would be the answer from IMP scholars and Edith Penrose. A critical proposition in IMP, as well as in Penrose’s ideas on resource heterogeneity, is that a resource contains potential for value-creation that in the majority of cases we cannot have full knowledge of. As mentioned briefly in the previous section of economic value-creation, Penrose (2009 [1959]) speaks of this potential value in terms of “productive services”, which are seen as inherent in physical resources (p. 67). Discussing this idea in the context of the firm, Penrose argues that it is in the interaction between resources and “personnel” (ibid.) that services are made available. Within IMP this notion basically translates to the conception that the value of physical resources depends to a great extent on the knowledge of the individuals who come into contact with the resources in questions.

As an extension of this notion Håkansson and Waluszewski (2002a) write about “qualities” (p. 32) of both physical and organisational resources. In their view the “activated qualities” (ibid.), i.e. the qualities that the resource is known to have and which are being “used”, do not exhaust a resource’s full potential. The reasoning parallels that of Penrose:
“[The resource] probably has many qualities that have been used earlier, or have been observed and are waiting to be used again. In the same way, there are probably other dormant qualities waiting to be found... [T]he quality of a resource is never given once and for all, but is created when embedded with other resources” (Håkansson & Waluszewski, 2002a:32).

Put another way, the great (in theory, boundless) range of possible interfaces of which a resource can become a part implies that a large variety of different values can be formed.

When studying resource interfaces it is important to note that the strength, or depth, of the bond between resources may vary, i.e. some interfaces are strong, or deep, whereas others are weak. Baraldi and Waluszewski (2007) propose that the relative depth of interfaces can be measured along three basic dimensions: an idea of how tightly the resources are interfaced can be gained by considering (a) the degree of adaptation and coordination between a resource pair, (b) the dependence between the resources, and (c) the substitutability among the resources involved in the interface (ibid.:95). Given these dimensions, great depth in a resource interface is achieved when none of the resources can be substituted, where there is high dependence and a large degree of adaptation between the resources in the resource network. But why should we be concerned with the strength, or the depth, of an interface? The notion of interface depth is important because it says something about the degree of embedment of a resource in a wider network consisting of resources that are both directly and indirectly connected to the focal resource. Embedding of a resource is understood here as the emergence of interfaces between the focal resource and other resources in the network (Baraldi, Perna and Gregori, 2011). The idea is that the deeper the interfaces, the deeper the embedment of the focal resource. Naturally, since the creation of an interface between resources is viewed as necessary for value-creation, it logically follows that for any value to be created from a focal resource, the resource must become embedded in the larger network. Embedding a resource in a network is in other words a prerequisite for the creation of economic as well as other types of benefits from that particular resource. The next section concentrates on two closely interrelated processes whose ultimate objective is economic value-creation specifically: commercialisation and commodification.
2.7 Commercialisation and commodification

This chapter began with an inquiry into commodities, a concept relevant to the exploration of an organisation undergoing a process of commercialisation. I now revisit the commodity idea, or rather the process from which commodities emerge – commodification – and discuss its relationship with commercialisation. The commonsense description of commercialisation is that of a process in which a thing is introduced on the market with the goal to create economic benefits. Is there something else to add? Well, given that this thesis centres on a narrative about events taking place in a context of commercialisation and de-commercialisation, I feel I need to be a bit more precise. In an attempt to create clarity in regard to what I perceive the phenomenon of commercialisation to be, and what it means to be commercial, I would like to briefly lay out my thoughts.

By commercialisation I refer to a process that is guided by an economic logic, where the pursuit of economic gain is the central element. But just like commodification can be construed as a development taking place along a continuum (Kopytoff, 1986), I would argue that commercialisation too can be viewed as something happening by degrees, with organisations being positioned at different points along the commercialisation continuum. The implication of this would thus be that some organisations are only slightly commercial, one example being a university research centre conducting contract research, while others are fully commercial, for instance firms, whose overarching objective is to make a profit. It is also possible for one and the same organisation to occupy different positions on the continuum at different points in time. All in all, assigning something a price does not make the assigning organisation completely commercial unless its overall goal is to create an economic surplus.

I now want go back to the brief comparison between commodification and commercialisation, which I made a few lines above. Since both of these categories are used throughout this book, I would like to discuss the connection between the two. Commercialisation and commodification are two processes that are closely related – so closely in fact that it is not uncommon in the literature to see the terms used interchangeably. That the concepts are intertwined in quite a complex manner is also manifested in the diverse interpretations made by scholars of what distinguishes one from the other. In her study on commodification of academic knowledge, Jacob (2003) proposes a working definition of commodification, to which she attributes two distinguishing characteristics. First, the commodified knowledge must be “extracted and packaged in some exclusive form which allows one to be able to lay claim to it as a discrete product”, and second, “the knowledge product must be bought and sold for its exchange value”, i.e. it must have a price (p. 131). In Jacob’s understanding contract research is therefore not
commodified knowledge “but the commodification of labour power” (ibid.). To illustrate what she perceives to be the difference between commodification and commercialisation she presents the example of further education courses for companies, which some universities offer. In a case where a university sells such a course, but where the teaching material is non-exclusive and available to all faculty and students, Jacob argues that the further education programme has been commercialised, but not commodified. On the other hand, had the university sold the further education course as a package with “specially designed course materials which are the registered property of the university” (ibid.) the programme would instead have been an example of commodification.

In Jacob’s interpretation commodification is thus a question of exchanging discrete products, such as the proprietary course materials just mentioned, whereas commercialisation seems to refer to a more loosely bound process, where economic reward is obviously key, but where the goods and services are not sold as distinct items. The general take-away is the idea of commercialisation as more of a general process as opposed to commodification, where the exploitation of economic value is tied to discrete things.

In contrast, Radder (2010) construes commodification as a phenomenon that is broader than “straight-forward commercialisation” (p.4). In the context of academia, he views commodification as a part of a “comprehensive and long-term social development” (ibid.). To be more exact, academic commodification means that “all kinds of scientific activities” are “predominantly interpreted and assessed on the basis of economic criteria” (ibid.). In other words, here commodification is not only associated with the attachment of price to specific scientific services and things, but also with an institution-wide adoption of a commercial rationale. Commercialisation, on the other hand, is seen in terms of academia more narrowly as the pursuit of profit in which academic institutions engage.

A third perspective on the difference between commercialisation and commodification is offered by Kaul (2007) in an anthropological study on paid-for traditional music at tourist destinations. Very different of course from the context of academia, Kaul’s analysis of the commercialisation and commodification of artistic expression in tourist settings is still interesting in relation to the economic use of science. In working out the differences between the two processes Kaul suggests that, first of all, commodification can be viewed as a “particular commercialising process whereby a produced thing or activity itself (italics in original) is given a consumptive market value” (p. 706); and, secondly, that commodification leads to the “loss of productive control” – in the case of Kaul’s study the loss of artistic freedom. Commercialisation is understood as a more general process characterized by the “introduction or intensification of monetary exchange in relation (italics in
original) to the production and/or consumption of a thing” (pp. 706-707),
but as long as productive control is retained by the producer, a thing or an
activity may be commercialised without being commodified. By contrast, if
something is a commodity it necessarily means that it is commercialised. In
Kaul’s interpretation the two categories are thus not distinct, but can still be
analytically separated in that one is viewed as granting the producer control
whereas the other does not. Translated to an academic setting, this reasoning
places the focus not so much on whether scientific knowledge is packaged as
discrete things, or on the proliferation of a commercial rationale within
academia as an institution, but on the degree of control that university
researchers can exercise. Instances of commercial activities where scientists
maintain their freedom, e.g. executive education or joint research projects,
would count in Kaul’s construal as commercialised, whereas instances of
activities in which researchers have little or no scientific freedom, such as
certain fee-for-service studies, would be labelled as commodified.

Although not directly addressing the discussion on the distinctions
between commercialisation and commodification, Perkmann et al. (2013)
make a contribution to the conversation about commerce and academia by
comparing commercialisation with a phenomenon they classify as academic
engagement, signifying inter-organisational collaboration connecting
universities and other organisations, especially firms. The aim of such
collaborations is typically not limited to the production of scientific
publications, but also includes the generation of utility for the non-academic
partner. The remuneration for the university researchers may be entirely
financial, or may include non-financial benefits such as access to data for
academic research projects. In other words, even in cases where the rewards
are financial, Perkmann et al. maintain that the activity should not be
characterized as an example of commercialisation, but of academic
engagement. Commercialisation, in their interpretation, represents a situation
where an “academic invention is exploited with the objective to reap financial
rewards”, typically via academic entrepreneurship (ibid.:424).

There is clearly diversity in the perceptions of what distinguishes
commodification from commercialisation, as well as which activities in
academia should count as commercial and which are merely cases of
academic engagement, as discussed by Perkmann et al. (2013). Even though
Kaul’s understanding of the difference between commercialisation and
commodification is thought-provoking (not least when applied to an
academic setting), this thesis does not consider researchers’ freedom when
choosing between the words “commodification” and “commercialisation”.
However – drawing upon both Kaul and Jacob – commercialisation is in this
thesis treated as the more general, underlying process without which
commodification cannot take place. This means that Radder’s observation of
the general social process in which science is assessed with respect to its
commercial potential is not referred to as commodification of science, as Radder proposes. Instead I speak of commodification of science as a denotation for the process in which an exchange value is ascribed to particular scientific activities or artefacts.

To sum up, in the present work commercialisation of science is regarded as the larger, general process of tying science to economic gain by connecting it to the commercial realm, and commodification as a sub-process of commercialisation, where specific elements belonging to science are itemized and given a price. With this discussion outlining my understanding of commodification and commercialisation, I now turn to a discussion about the object of these processes in the case of the PET Centre, namely science.

2.8 What is science?

Inquiring into the use of science calls for some clarification of what exactly is meant by science as a construct. Really, what is this thing called science? Of what elements does it consist? Where do we draw the boundaries between science and non-science? To be able to address this thesis’ research questions these queries concerning the composition of science must be given at least tentative answers. Consequently, in this section I work out a conceptualization of science that makes sense within the empirical context of the study, and is helpful to the analysis of the empirical material.

Grounded in the assumption that science and technology are profoundly social activities, the multidisciplinary field of Science and Technology Studies (STS) has produced a vast body of literature that focuses on the interplay between the social, the scientific and the technological (see for example MacKenzie & Wajcman, 1999 [1985]; Jasanoff ed., 2004; Jasanoff, Markle, Petersen and Pinch eds., 1995; Latour 1987). To be more precise, the field examines how technological artefacts and scientific facts are made, meaning that attention is directed to how engineers and scientists go about their work, and how society, in which this work is performed, both influences and is influenced by these scientific and technological activities (see Hackett, Amsterdamska, Lynch & Wajcman eds., 2008; Bijker, Pinch & Hughes eds., 1987; MacKenzie, 1993). Before beginning the exploration of different STS perspectives on science and technology, I wish to take a moment to, for the sake of rigor, address the most fundamental aspect of the relationship between the two, namely how to separate one from the other.

There is a general presumption that there is a clear-cut division between science and technology, where science has commonly been described as the search for truth, and technology has been reduced to the application of scientific knowledge. However, as pointed out by Bijker, Hughes & Pinch (1987), the inventors, engineers and managers active in building systems and
networks a century and a half ago surely did not separate their work into “technological” or “scientific” categories, but instead worked without constructing such barriers. Rosenberg (1982) has argued that the conception of technology merely as a practical translation of scientific results obfuscates a central aspect of technology, namely that it is a body of knowledge in its own right. In the words of Rosenberg, technology is “knowledge of techniques, methods, and designs that work” (p. 143). In the same vein, Brooks (1994) asserts that technology is not merely just things, but “also embodies a degree of generic understanding” (p. 478), which makes it resemble science. Nelson and Rosenberg (1993) for their part contend that much of technology and science “have become intertwined” (p. 7).

In other words, the boundaries between technology and science are generally hazy. This is true not least in the case of PET, where there really is no self-evident division between PET as a technology and PET as a science. This becomes apparent as we try to work out a definition of science in relation to the PET Centre case. For this reason, I will not spend time examining any (supposed) boundaries between PET science and PET technology, but instead treat the whole complex of PET as one “technoscientific” system (Latour, 1987).

2.8.1 Construction of science

I want to approach a conceptualization of science by exploring ideas dealing with the construction of scientific knowledge and notions of science as social practice. I wish to do this not because the work at hand is directly concerned with the formation of scientific facts, or scrutinizes the practice and culture of scientists, but because the science studies literature offers perspectives on how to conceive of science, in terms of both materiality and knowledge. In this section I therefore review a few approaches to how natural science is made, and consequently what is encapsulated in the science concept.

Social theorizing about the making of the natural sciences began in the 1970s, when social scientists started to venture into the laboratories of the hard sciences to inquire into the creation of scientific knowledge (Knorr-Cetina, 1995; Pinch & Bijker, 1987). Inspired by social constructivist philosophy and ethnomethodology (Doing, 2008), the scholars active within this tradition have relied on an ethnographic methodology, and in their investigation have treated scientific fact construction as a thoroughly social process. The laboratory has thus been the locus of detailed ethnographic studies on scientific activities, which have generated important insights into the cultures and work processes of the natural sciences. What, then, is so special about laboratories, and what does their role in scientific practice tell us about science as a construct?
In her in-depth exploration of laboratories, Karin Knorr Cetina (1999) highlights the crucial part laboratories play in the construction of scientific knowledge. Laboratories, according to Knorr Cetina, constitute an “enhanced environment” (p. 26) within which objects can be tampered with or manipulated so as to become a thing that more easily lends itself to scientific study (see also for example Latour, 1983; 1987). In scientists’ investigation of natural objects, Knorr Cetina proposes, there are three aspects that laboratory sciences do not need to accommodate. First, the laboratory scientists do not need to handle the object as it naturally occurs, but can work with altered versions of it. Nor do they have to work with the object where it is, in its natural environment, but can instead take it back to the home base, the laboratory, where the manipulations deemed necessary can be performed. The third aspect concerns time: possessing the ability to make specific natural processes happen frequently enough to ensure continuous study, laboratory scientists do not have to worry about catching an event only when it occurs naturally. Laboratory technologies thus open up possibilities for scientists, in Knorr Cetina’s words, to bring natural processes “home” to the laboratory (1999:28). In being transposed to the lab, natural objects are subject to “enculturation” (ibid.), which is in fact, argues Knorr Cetina, where the power of the laboratories lies: in transforming natural conditions, scientists derive epistemic effects (ibid.).

Clearly, from a perspective such as Knorr Cetina’s, the scientific knowledge obtained from experimentation is inextricable from the use of laboratory equipment: science is both machines and knowledge about (manipulated instances of) the natural world. Indeed, as noted by Callon (1995), “the [scientific] practices incorporated in human beings […] are intertwined with experimental apparatus” (p. 43), and as a consequence any attempt to extract and transform knowledge statements “into a privileged object of scientific production” means that they are taken out of their context and stripped of meaning (ibid.).

This emphasis on the part played by material aspects of science is also present within Latour’s theorizing on the making of scientific facts, where, within the framework of actor-network theory (ANT), he ascribes material artefacts agency. The implication of viewing material objects as agents is that in exploring technological development and production of scientific knowledge, the investigative gaze must extend beyond researchers, inventors, users and other humans, and include such objects as molecules, spectrometers, engines and pipettes. The ANT approach then portrays the work of science and technology, or “technoscience” (Latour, 1987), as the building of networks made up of assemblies of both human and non-human actors (ibid.; Akrich, 1992; Latour and Woolgar, 1979). Producing a scientific fact thus in fact involves constructing a network.
Putting this network together takes considerable effort on the part of the scientist: actors must be enrolled by the scientist so that they can participate, or become allies, in the construction of the fact. This is generally no easy feat, since the interests of the various actors differ, meaning that fact construction risks spinning out of control. The interests of the different actors, be it other scientists, a machine or electrons, must therefore be aligned with one another, which happens through a process of translation. When the assembly of unpredictable and undisciplined allies has been fused into an “organized whole” (ibid.:131), a fact has finally been created.

Through such concepts as “allies” and “translations” Latour thus depicts the construction of scientific facts as a collective process: a new piece of knowledge is consolidated because a strong enough network has been built. Fellow scientists, patients, machines, physical particles and a whole range of other resources have become enrolled in the fact-making enterprise, turning the development of knowledge into an evolution of a complex web.5 While ANT is not used as an analytical tool in this thesis – meaning amongst other things that science is not treated as a conglomeration of human and non-human actors – its recognition of the efforts that go into creating science is informative, as it draws attention to the abundance of things that science comprises. For this reason, Latour’s idea of the heterogeneous network, as well as Knorr Cetina’s (1999) consideration of the role of laboratories in scientific knowledge production, offer a fruitful approach to developing a conceptualization of science for this thesis.

Quite simply, this conceptualization rests on one of the most basic ideas of the theoretical approaches presented in this section: that science is both immaterial and material. This understanding of science is mirrored in the 4Rs

5 Now, given the focus of both ANT and the IMP approach on networks, it is important to briefly point out some fundamental differences between the two. First of all, there is a basic ontological difference between ANT and IMP in regard to the network concept. While networks by ANT scholars are understood as something being actively constructed by actors, in the IMP approach they are perceived as something that exists independently of the actions of any actor (or any object). More precisely, IMP regards the organisational landscape as being built up of networks, not because these have been purposely created, but because actors and resources are all assumed to be linked to one another through socio-technical relationships. Connected to this elemental ontological dissimilarity is the association of actor-networks with particular purposes and objectives: constructing actor-networks is a means to impact the world (Olsen, 2013) – hence the concern with allies, enrolment, power and so on. Put another way, contrary to IMP, network-building within ANT is a question of attempting to influence and persuade other actors. Olsen (ibid.) suggests that the consequence of these basic analytical differences between the two theories is that, in one and the same empirical context, the networks that would be identified and investigated by IMP researchers would generally not be the same as those selected and analysed by ANT researchers. In Olsen’s understanding “IMP networks would be those that are actually interacted in the real-economic, material and practical sense” (ibid.:165), while ANT would focus on the networks “that are in the process of expanding their impact, domination and extendedness in the world” (ibid.).
resource interaction model, with its division between physical and organisational resources. Translated into the terminology of this model, science can be viewed as consisting of a collection of physical and organisational resources. In the analysis of the PET Centre story later in this thesis, this is exactly how science is approached. But this theoretical vantage point is also reflected in the presentation and chapter division of the empirical narrative: based on the conceptualization of science just described, the structure and content of the empirical chapters reflect both my understanding of science and how this understanding relates to the 4Rs model.

More specifically, the constitutive resources of science are grouped into three categories, each constituting the theme for a particular chapter. First there is the category of the material scientific output, which in this thesis, where the scientific field concerned is positron emission tomography, comprises various sorts of tracer molecules. The second category is that of facilities, including the equipment, buildings and test subjects of the PET Centre. Thirdly there is the category of the organisation. Unlike the first two categories, this one contains not only organisational resources that are constituents of science, such as codifiable, codified or tacit knowledge. It also comprises resources that I do not consider to be part of the science concept – for example routines, strategies and relationships – but which are present in the environment in which scientists find themselves and where science is taking place. In this way the idea of science as an amalgam of resources linked to scientific products, facilities and the organisation provides the structure for the PET Centre story (the succeeding chapter on methodology discusses this structure further).

The following section relates the idea of resource interfaces and the analytical tool 4Rs to the specific case of science use. In light of the conceptualization of science just developed above, where science is viewed as a composite of both physical and organisational resources, how can 4Rs be helpful to the study of science use? How can the differences between physical and organisational resources be approached? How are non-scientific resources in the PET Centre network informative and relevant to our understanding of science use? These issues will be dealt with next.

2.9 Accessing the phenomenon of science using 4Rs

This section explains the specific manner in which the idea of embedment of a focal resource – and thereby the creation of resource interfaces – pertains to the particular case studied in this thesis. The basic question addressed is: how can we conceive of the connection between utilisation and value-creation, and the focal resource? This particular question is important, because it concerns the issue of what exactly it is I am able to deduce from employing the 4Rs
tool in my study. This is what I will now attempt to explicate. The first point I want to focus on is that of the differences between various resource types that are particularly pertinent to my research questions.

Although the empirical story and analytical chapters are yet to come, I want to disclose some details regarding the focal resource of my study: it is scientific and physical, and directly activated in all types of science use, which implies that it is included in all physical and mixed interfaces considered in the 4Rs analysis. As a result the 4Rs analysis of physical and mixed interfaces is directly revelatory of science utilisation. In other words, the involvement of the scientific focal resource in the particular interfaces under examination means that a direct window to the use of science is provided. Science in use becomes visible.

Organisational interfaces, on the other hand, are another story. The analytical chapters on mixed and organisational interfaces later in this thesis, in immediate connection to the data analysis, elaborate on what precisely these can tell us about science use. Nevertheless, it is helpful to prepare the terrain, so to speak, already at this early stage by discussing this point briefly, because it is not an obvious one.

Because of the transient, intangible nature of organisational resources, they can be more challenging to deal with in resource interface analysis than physical resources. This has very much been my experience in the study of the PET Centre journey. In contrast to physical scientific resources, which are directly implicated in science use, understanding the relevance of organisational resources is not always straightforward, as these often require an additional cognitive step so as to be connected to the utilisation of science. Now, naturally the kind of organisational resources that can be categorized as scientific – for example scientific knowledge or tacit know-how – are bound up in science use just as much as any physical test tube or microscope. But then there are the arrays of relevant non-scientific resources (for instance strategies and relationships) that are not involved in the actual use of science, but still just as pertinent to our understanding of this use. In fact, I contend that regardless of which category an organisational resource falls into – scientific or non-scientific – it is equally revelatory of the use of science in one particular way, and for one particular reason.

What distinguishes the information obtained from the investigation of interfaces containing organisational resources from that to be gained by analysing physical resources is what aspect of science use we access. Whereas purely physical resource interaction tells us something about the actual material workings of science in use, interfaces that include organisational resources shines the spotlight on the reasons why science is used a certain way, and hence why this use results in the creation of a certain kind of value rather than another. Organisational resources thus illuminate reasons that go beyond technical dependencies; instead they are anchored to actors and the schemes of
valuation of these actors. Another way of expressing this idea is to say that an organisational resource bears a mark of the actor to which it is linked, and that the way this resource is mobilised is therefore a reflection of this actor's scheme of valuation. So, while it can be argued that a physical resource may also be tied to a specific actor (for example by ownership), I conceive organisational resources to generally be manifestations of actors' schemes of valuation. As a consequence, the activation of organisational resources in interfaces mirrors the intentions of actors. This idea is a critical one, as it essentially serves as the motivation behind my full use of the 4Rs tool in this thesis as opposed to a more fragmentary one: because organisational resources generally carry the imprint of schemes of valuation, all organisational interfaces are informative of science use – explaining particularly why science, and hence the focal resource, is used in a specific manner. Ultimately, this is how I connect the actor, and hence agency, to resource interaction. Nonetheless, it should be added that there are naturally many other ways to study the interplay between actors, e.g. looking at their communication. For the purpose of my study, however, my approach of focusing on how organisational resources that represent actors are combined is helpful. By concentrating on which resource combinations are a good fit, and which are less so, light is shed on the relationship between the outcomes of these combinations and science use.

The aim of the succeeding, final section of this chapter is to form a framework that, first, can be used as a mental map in the reading of the empirical chapters, and, second, is the basic starting point for the analysis of the PET Centre story later in the book. The framework relates the use of science to both the composition of science – its incorporation of physical and organisational resources – and the part played by actors.

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6 Of course, as is pointed out in the analytical chapters, an organisational resource does not always merely bear the imprint of an actor, but can also constitute an actor.

7 Although the point I will address in this footnote is not very important in relation to my case study, I must, for the sake of symmetry, mention that a convincing argument can be made that physical objects can also exhibit the imprints of an actor, just as immaterial objects do (or organisational resources in terms of IMP terminology). Indeed, STS scholars have debated whether artefacts can be inherently political (see e.g. Winner, 1999), and following such reasoning it is absolutely possible to argue that the structure and features of objects may reflect e.g. the preferences and valuations of their inventors and producers. In fact, in this very thesis I know of one clear example to illustrate this idea. However, for the overall theme of the present work, I have not deemed the connection between schemes of valuation and materiality as relevant, and have thus not expended much effort to understand the histories of physical PET resources.
2.10 Towards a model of science use in a context of inter-sphere interaction

This chapter has covered a number of concepts and strands of thought with the objective of providing a theoretical basis for the rest of my thesis. I have been concerned with the constructs of commodities and value, valuation and schemes of valuation, as well as ideas of how value is created, where I presented the resource interaction model of the IMP approach as representing my outlook on value-creation. I then focused on economic value-creation specifically, in a discussion on commercialisation and commodification, and what distinguished the two processes from one another. I subsequently moved on to the very thing that is being commercialised and commodified in my case study: science. Because the object of my study is science utilisation, it was crucial to work out a conceptualization of science that fit both my theoretical sensibilities and my empirical experiences. I did so by drawing on insights from STS literature, which I interwove with the IMP resource concept. Eventually I turned to the issue of how the 4Rs model is helpful to investigating the use of science. More precisely, I detailed the differences between physical and organisational resources in terms of what questions concerning science use they help address. While interfaces involving physical resources were identified as revealing of how exactly science is used, the inclusion of organisational resources in the interfaces was pinpointed as a means to understand the reasons – stemming from the schemes of valuation of actors, as opposed to those linked to physical dependencies – why science is used in one particular way rather than another.

This last issue concerning the connection between different resource categories, schemes of valuation and science use forms the basis for the theoretical framework of this thesis. This framework is represented in a simple model, displayed below in Figure 2.1, depicting the interrelations between the research problem about science utilisation, and the constructs recognised as critical to exploring this topic. Illustrating my comprehension of the effect of actors and science itself upon science utilisation, this model serves as a theoretical roadmap for the thesis. As shown below, actors’ dissimilar schemes of valuation between the three spheres of academia, healthcare and business and the composition of science are perceived as factors having an effect on the use of science in a context of inter-sphere interaction. I now expound my reasoning behind the inclusion of these factors in the model.
2.10.1 Factor 1: Dissimilar schemes of valuation

Inspired by Kopytoff (1986), I have described schemes of valuation to be, as we know by now, a concept comprising particular norms, motivations and preferences. From this it follows that a scheme of valuation has built into it a specific stance in regard to not only the notions of value and valuation, but also to commercialisation and commodification (see Figure 2.2 below). In the context of this thesis, the concept of valuation schemes is therefore useful to discussing the use of science in a situation in which the disparate actors of academia, business and healthcare, each carrying a different scheme of valuation, interact. In brief, and as described in the past section, the idea is that the manner in which science is used is partly contingent on actors’ schemes of valuation. This point about schemes of valuation being tied to specific kinds of use is treated analytically later in the thesis as contexts of science use, i.e. the context in which a particular actor’s use of science occurs. For instance, healthcare makes use of science in one specific context, which is different from the use context of business, and so on. The concept of contexts of science use is used extensively later in the thesis to discuss the consequences of the interaction between disparate actor spheres on science utilisation. However, for the time being, and until any data have been presented, it suffices to establish that every type of actor is associated with a particular kind of use, and that this thesis considers the use contexts of academia, business and healthcare.

Now, in relation to this perceived role of the actor, a critical point needs to be made. To state that dissimilar schemes of valuation is a factor affecting science use does not imply that the effect of resources’ positions in the network on science use is disregarded. By this I mean that the question of where in a network actors are located in relation to existing resources is recognized as having a significant effect on what resources these actors will be able to mobilize, and hence on how science will be used. By this token, schemes of
valuation as an element affecting science use is in no way a determinist move through which the combinations of resources are reduced to mere reflections of actors’ intentions. Put differently, the fact that the aspect of a network position is not explicitly accounted for in the model does not translate to a view of science in use as a purely socially determined phenomenon. In addition, whatever imbalance to which the inclusion of the actor aspect could contribute is counteracted by the consideration of a second factor: the composition of science.

2.10.2 Factor 2: composition of science: material and immaterial resources, and their interfaces

The idea of science as a composite of immaterial and material elements, or organisational and physical resources, creates space for an understanding of the utilisation of science as something taking place when one or several of these resources is combined with other resources, scientific or non-scientific (see Figure 2.2 below). What this also means, however, is that when crucial scientific resources are inaccessible, science utilisation cannot take place. In other words, because science is made up of different parts, one cannot expect science as a complete entity to be available for use at all times: one or several pieces may be missing, caught up in use in some other place. This is the basic premise for inserting the composition of science as a factor affecting the use of science. In short, with a conceptualization of science as something consisting of multiple resources, science composition has an effect on how science is utilised.

Finally, I summarise my reasoning behind the consideration of dissimilar schemes of valuation and composition of science as factors affecting science use by a revision of the thesis framework model in Figure 2.1. This time, the key concepts are explicitly connected to each factor. In this revised model the factor schemes of valuation, which concerns the actor, relates to valuation, value, commercialisation and commodification. The composition of science is the second factor, and relates to interfaces between the various resources of which science consists.
Figure 2.2 Revised model

This graphic representation of my theoretical approach to the PET Centre study concludes the theoretical chapter. The focus now shifts from the theoretical framework to the thesis’ research design.
Chapter 3. Methodology: Constructing and Analysing a Story

The aim of this chapter is to describe the research strategy I have employed in studying the use of science. I explain how the object of my investigation has been chosen and how data have been gathered. On a broader note, I discuss how methodological concerns, theoretical considerations and empirical findings have shaped the way empirical data have been presented and structured, as well as how they have been analysed.

3.1 A qualitative case study about science use in an intersphere context

The research I have conducted for this thesis takes the form of a case study: this is the strategy by which I chose to explore the issues I was interested in within the field of science commercialisation. Plenty can be and has been said about case research as a strategy and a method: what kind of knowledge it does or does not produce, when it is or is not useful, what can or cannot be inferred from it, and so on. While I touch upon a couple of such general issues, my intention is not to give a comprehensive description of what a case study is (if the reader is looking for such texts, Yin’s classic works [1984; 1994] as well as Ragin and Becker [1992] are good starting points). What I do, however, is describe my experiences from carrying out my own case study on the PET Centre, and to relate these experiences to ideas from the literature that I found particularly insightful to my work process and my understanding of case research. Conducting case studies is very common in the IMP tradition, as the richness of data this strategy produces makes it well suited to handling the intricacies of network links between actors and resources (Dubois and Araujo, 2004). Because I started my research project within the IMP framework, and because I knew early on in my research process that I would be dealing with highly complex empirical material, it seemed only natural to carry out my study within the format of a case. As Holstein and Grubrium point out, “theory, method and empirical material” should be treated as dependent on each other (2012:6), which has certainly been my reasoning for this thesis. Moving on, I now want to begin the discussion of
case research by recounting how I came across the PET Centre case, and what made me decide to devote my dissertation to this story.

3.1.1 Choosing the PET Centre journey

To explain how I first learned about and later selected the journey of Uppsala PET Centre as an object of study, I take as my point of departure a pre-study I conducted during my first year as a doctoral student at Uppsala. During the first semester, my supervisor and I conducted a few exploratory interviews at Uppsala University Innovation Centre. As the main objective of the new research project on which we were working (called Innovating University) was to study commercialisation of academic research results, it seemed logical to begin the investigation at an organisational unit set up exclusively to assist efforts to commercialise scientific knowledge. Through conversations with our interlocutors, a number of interesting instances of commercialisation involving Uppsala researchers soon appeared on my list. The idea was that I would select one or several of these examples as empirical tracks to pursue for my own doctoral project. In the semester that followed, I carried out a pre-study focusing on different commercial ventures at the university, one of which concerned Uppsala PET Centre.

While I was intrigued by all of the stories I was looking into, the PET Centre case stood out. Yet the reasons for the special allure of the case were also what initially made me hesitant to dig deeper: with its extensive span in terms of the number and variety of actors it encompassed, as well as the unusual circular journey it described, the story was incredibly messy. It was clearly the most complex of the cases I was exploring during this period, and thus also the most daunting and fascinating. Involving large corporations, a university administration and a hospital as highly active agents, this commercialisation effort was not limited to the business pursuits of a handful of academic scientists. Though the intricacies of the PET Centre story, with its atypical commercialisation process, at first glance made it seem inadequate as an illustration of science-industry interaction I soon realised that the exceptional nature of the case made it particularly illuminating of the dynamics I wanted to explore. Indeed, my view of the PET Centre story, what it represented, and how it fit into a larger context, is reflected in Wieviorka’s (1992) apt description of case research as a means to discover knowledge about something that is both highly specific and representative of a broader phenomenon.

The fundamental basis of my selection of the PET Centre story was that it constituted what is referenced in the literature as an “extreme case” (Yin, 1994; Siggelkow, 2007; Flyvbjerg, 2006). Extreme cases are chosen because, in the words of Eisenhardt and Graebner (2007), they are “unusually revelatory, extreme exemplars” (p. 27), and as Flyvbjerg (2006) asserts, they generally
“reveal more information [than more typical cases] because they activate more actors and more basic mechanisms in the situation studied” (p. 229). Indeed, Sigglekow (2007) also underlines the merits of choosing unusual cases over average ones, arguing that the former often provide insights that other cases cannot give: it is often possible to make inferences from extreme cases that less extreme ones will not allow, simply because the latter do not exhibit the same atypical features. So, in what way did the PET Centre journey constitute an extreme case?

To begin, in the course of the first decade of its existence, the Centre managed to establish itself as a world-leading research institution in PET science. With a director who was considered outstanding in his field – really, he was regarded as a global superstar in PET chemistry – and with a number of highly accomplished scientists, the PET Centre enjoyed an excellent scientific reputation. In addition, at the time of the commercial take-over the Centre already had several solid relationships with pharmaceutical companies, for which the PET researchers had been carrying out fee-for-service studies for years. Hence, if we were to compare Uppsala PET Centre to other research institutions that were not as scientifically prominent and cutting-edge, and also less well connected within the industrial sphere, we would most likely make different predictions regarding the commercial prospects of these units. It would not be unreasonable to assume that an organisation known for its vanguard research, and which also possesses substantial experience of business interaction, would be more innovative and have greater commercial success in terms of generating profit for itself than a Centre that enjoys none of these strengths.

Yet the outcome of the PET Centre venture still cannot be taken as a predictor of the results of other endeavours of academic commercialisation. After all, not only the case study method, but social science overall has failed so far to produce a context-independent, general theory whereby fool-proof predictions can be made (Flyvbjerg, 2006). Nevertheless, due to its extreme nature characterized by academic excellence and commercial experience, my case stills serves as an illuminating indicator of the fundamental challenges inherent to the mixing of academia and business. In short, the logic behind the selection of my extreme case has been: given the seemingly beneficial – unusually beneficial – conditions in the case of Uppsala PET Centre, and in light of the ambiguous outcome of the venture, how can we conceive of the chances of success for 1) commercial enterprises which involve less distinguished groups of researchers; and 2) more broadly, for academia-business interaction as a whole?

Now, the case of Uppsala PET Centre is extreme not only because of the special, favourable pre-conditions for the commercial undertaking, but also in the range of mechanisms for commercialisation which it has encompassed (Nilsson, Rickne and Bengtsson, 2009; Santoro, 2010). As will be detailed in
the empirical chapters, the PET Centre case comprised commercial collaborative research, commodification of scientific products and services, as well as patenting, licensing and a spin-out. Evidently, for a researcher interested in the interplay between academia and business, the PET Centre case presented a remarkable opportunity to explore the many ways in which academically trained scientists interacted with business actors.

But, this was not all. The case included one more actor with a clear stake in the science produced at the Centre: healthcare. The involvement of healthcare in the development and use of PET science added yet another dimension to the phenomena I was able to explore. Importantly, the inclusion of this major societal sector in the case permitted me to expand my inquiry into the usefulness of science, the most basic of the issues I was interested in, and one with which current research policy and innovation discourse are much concerned, as laid out in Chapter 1. To be more exact, with healthcare being a significant actor in the PET Centre journey and hence comprising a critical part of my case, I was able to investigate not only the question of what university-business interaction could look like, but also the repercussions of this interaction for another significant user of science. In other words, by being able to include three notable actors that represented different sectors and that were involved in interplay around science, I could adopt a comparatively broader perspective on this type of interaction. However, with broadness came vast amounts of data and complexity, and as a consequence, the pressing need to determine exactly which phenomena I ultimately wanted to highlight with my case.

3.1.2 A case of what?

Indeed, the above discussion of how I selected my case and what issues the specific, extreme features of the case allowed me to address brings us to the inevitable, vital question of what my case is a case of, as it were. What exactly is it that I have wanted to examine? To be sure, as pointed out by Wieviorka (1992), a case study cannot consist of merely empirical data. It must elucidate a larger phenomenon or help us interpret it by using a broader category: “[It] does not suffice to observe a social phenomenon, historic event, or set of behaviors in order to declare them to be ‘cases’. If you want to talk about a ‘case’, you also need the means of interpreting it or placing it in a context” (p. 160). In my own experience, it was precisely the continuous work of interpretation and relating the data to the wider context, empirical as well as theoretical, that constituted the processes of figuring out what my case was about. Indeed, the gradual revelation of what the PET Centre journey in my mind was a case of was completely enmeshed in the process of constructing the case.
Rather than something that was determined a priori, what constitutes the phenomenon under investigation, as well as its boundaries, is often a realization that evolves in the course of the study in question (Dubois and Araujo, 2004). My own experience was that I was building my case study, and hence discovering the principal phenomenon, through an iterative, abductive process in which I was going back and forth between data, theory and context (Dubois and Gadde, 2002). As discerningly noted by Ragin and Becker (1992), case researchers most likely “will not know what their cases are until the research, including the task of writing up the results, is virtually completed” and the question of what the case “is a case of will coalesce gradually” (p. 6, italics in original). This was certainly how I experienced the emergence of the primary theme of my case study. Through extensive data collection, theoretical readings, numerous re-readings of interview transcripts and, crucially, through writing up, the issue of science use surfaced in a context marked by the interaction between disparate actor spheres. From my perspective, this is the phenomenon into which the PET Centre case can give us particularly important insights.

Still, the description of how my case study evolved – really, how empirical material was turned into a case – does not tell us everything about how the case was created. More specifically, I have yet to discuss how I constructed the very heart of the study, namely the empirical story. This is the topic of the next section.

3.2 Creating a story

Attentive readers may have already noted that in the beginning of the first chapter of this thesis, I referred to the Uppsala PET Centre case as a “story”. Early on in the research process, I became aware that it was exactly as a story that the events of the PET Centre journey was recounted to me. The realization that my study was essentially a matter of weaving other peoples’ narratives and stories into my own rendering of a phenomenon prompted me to reflect on my own role in the making of this story, already in the initial stages of the data collection. Indeed, a basic question to ask in relation to the form of qualitative research in which I have engaged concerns what the choice to display collected information in the form of a story really means (Aarikka-Stenroos, 2010; Elliott, 2005). How did I construct my story, and on what grounds did I make decisions about what to include in it?

When telling a story within the confines of social science, the investigator and author faces the task of conscientiously, and in as balanced a manner as possible, adhering to certain ideals of rigor and, for lack of a better word, objectivity. The story, of course, does not write itself, much like the information on which it is based does not emerge from thin air. What
constitutes the story’s raw material are real people’s voices, real texts and real artefacts, impressions of which are filtered through the ears, eyes and mind of a flesh-and-blood researcher. In this sense, the challenge the author is confronted with is the consequence of both the particularities of the world of empirical data and of her own inevitable limitations as an information-processor and decision-maker. To compose a story the writer and investigator must figure out first how to conceive of the nature of the data that have been collected and then determine what pieces and strands of these data will be used as building blocks of the story.

If we consider the first point, regarding the researcher’s view of the nature of the gathered data, I am concerned with the researcher’s appreciation of the “accuracy” (Silverman, 2006) of the data, by which I mean the way the data convey information about an event in a manner that aligns with other pieces of data. More simply put, the usability of data is judged by the degree to which they harmonize with other data, written or spoken, regarding the same event. This judgment is made at the discretion of the researcher, who has neither an omnipresent eye, nor time machine, nor mind-reading powers, nor perfect cognition, but is only able to work with human levels of insight, tenacity and precision. Hence, that we are talking about stories as subjective constructions made through the interlinking of processed as opposed to unfiltered data is as evident as it is inevitable: stories are never complete, partly because the researcher's processing and selection of data are never perfect.

Now, it is important to point out that what interests me in relation to empirical data are not epistemological and ontological considerations; what “really” happened, and if we can in fact ever speak about data in terms of “veracity” and “accuracy” are not at issue in this chapter. A discussion on whether or not reality is “real”, or if there is such a thing as “truth” is not necessary to be able to address the points of concern I find most urgent in the telling of the PET Centre story. Rather, as pointed out above, the most pressing issue for me in the collection of empirical data, alongside which my story about Uppsala PET Centre has evolved, has been how to understand and appraise these data, and based on this assessment, to determine how to compose the story. To clarify how I constructed the story, in the next sections I therefore discuss how I chose to gather data and also how I conceived of and treated these data. My main method has been interviews, but I have also relied on written material from archives as well as numerical, bibliometric data. As interviews have been so integral to my overall understanding of the PET Centre journey, this method of data collection is my starting point. Subsequently I discuss my use of archival material, as well as bibliometrics.
3.2.1 Interviews: approaching past events by evoking and interpreting narratives

The history of Uppsala PET Centre unfolded before me chiefly through my listening and posing questions to people. In other words, I acquainted myself with the PET Centre journey by conducting interviews. I talked to 25 individuals and carried out a total of 46 interviews (including interviews for pre-studies), four of which were conducted over the telephone. The people I spoke with belonged to different professional categories: I interviewed clinical and pre-clinical academic scientists as well as industrial researchers; business developers and corporate managers; a lawyer, doctors, individuals with a past in University management, and representatives from Uppsala County Council. In addition I had extensive email correspondence with several of my interlocutors in instances in which new questions arose after completing an interview, or when I perceived a need to clarify certain details.

The data collection process spanned a little over four years. To select my interlocutors, I used so-called snowball sampling (Noy, 2008; Browne, 2003), starting off at Uppsala University’s Innovation Centre where the CEO gave me names of people to contact. As a next step each interlocutor was asked to name other individuals who they believed could be interesting for me to contact. I then tried to identify who the key individuals in the PET Centre journey were, based on how often they were mentioned by other interlocutors, and by tips from people most deeply involved in the activities at and around the PET Centre. My aim was not only to speak to people who possessed knowledge relevant to my research topic, but also to make sure a wide range of perspectives were represented in my selection of interlocutors, so as to increase my chances of producing a fair, balanced representation of events (Eisenhardt and Graebner, 2007).

Obtaining access proved surprisingly straightforward even as I began interviewing individuals from the business side. However, on one significant occasion I met resistance. In an effort to gain a better understanding of the development of the contract research market, I contacted an organisation which functions as a mediator between university researchers, and companies seeking academic scientists to perform fee-for-service studies. I knew such an organisation would possess hard data on the evolution of this market. I turned to the organisation with which Uppsala PET Centre had worked and tried to both arrange an interview and gain access to their data. Unfortunately the organisation in question refused to share information in any form, even though I assured them that my main interest was in approximate growth rates as opposed to specific financial details, which I promised not to disclose. In general though, I was content with both access to and the level of detail of the information I received through my interviews. Clearly, being able to speak to almost all individuals I deemed most relevant meant I was better equipped
to tell a solid story than would have been the case had interview access been narrower and more restrained.

Yet, although my access to interlocutors was broad, I still had to remain aware that the content of my interviews was not a perfect reflection of what had “actually happened”. As intriguing and informative as the great majority of the interviews were, I soon became aware of the difficulty inherent in relying on people’s accounts to get to the “truth” of a phenomenon. A widely used method in qualitative research, interviews are indeed associated with consequential challenges of which the researcher must take heed (Czarniawska, 2004; Silverman, 2006). I now wish to address a couple of these issues and discuss how they relate to my own experiences in the collection of data for my thesis. While interviews as a method afford obvious benefits, such as the chance to quite easily obtain rich information about a phenomenon or a chain of occurrences, they also require the researcher to be very attentive to and conscious of how the method is used, and how the data yielded can be understood. During the interview process for the PET Centre case, I was continuously reminding myself of, first, my own idea of the method's underlying premises and expectations – whether the information it yields will be real, actual “facts” or at least very close to it; second, how to best go about performing the interview, including both asking questions and understanding responses, given my aim to elicit and make sense of narratives; and third, how to subsequently handle – interpret, analyise and ultimately make a selection among – the pieces of information the interviews yielded. The following three sections deal with these points.

3.2.2 Interviews: uncovering reality?

Let me first address the issue concerning the truthfulness of responses and narratives which interlocutors present, and also, importantly, our expectations of them (i.e. the awareness of the non-accuracy of responses). How can we conceive of the answers we receive when asking questions, and what can we assume to gain from the interaction between an interviewer and an interviewee? While the wish of the researcher is generally to acquire facts about reality, Czarniawska suggests that most often an interview is instead, “unfortunately”, the mere “collecting [of] views and opinions on whatever topic is mentioned” (ibid.:47). Furthermore, in a study such as my own, where the subject matter concerns a development taking place in the past, obtaining data becomes a function of people’s capacity to remember historic events. This is of course problematic since, as pointed out by Czarniawska, unaided memory is always faulty. Hence, the narratives I am presented with are “not a window of social reality but [are] a part, a sample of that reality” (ibid.:49). What I have attained by speaking and listening to people in my study, namely their perceptions and interpretations of past events, thus constitute pieces of
the reality I am after, but not all of it. To put it differently, there is no way to access fully accurate information through interviews (the same can, however, be said of any other method).

Still, used with caution and with awareness of their intrinsic limitations as a research method, I have found through the empirical work carried out for this thesis that interviews, especially when used in combination with archival material (a method to which I return later in the chapter), can be an immensely valuable tool. While Silverman (2007), bothered by what he perceives to be an overuse of interviews in qualitative research, convincingly advocates for the employment of observation in lieu of, or at least in combination with, interviews, I find that interviews are still highly useful when the phenomenon under investigation forms a part of past events. If there is a living memory of social, recent history, interviews clearly constitute a tool by which we can gain insight into this history. Even so, whether used to learn about historic events or contemporary phenomena, a valid concern in relation to interviews and the question of what they help the researcher to uncover is what really happens when we ask the interlocutor to produce a narrative. Before moving on to this question, it is necessary to eventually offer a definition of what a narrative is: it often denotes written or spoken, chronologically linked accounts of an event (Czarniawska, 2004), but for some researchers it also includes brief utterances, or parts of “naturally occurring conversation” (Holstein and Gubrium, 2012:1). The next section deals with the manner in which I went about eliciting narratives and how I approached the issue of what exactly can be learned from these.

3.2.3 Interviews: asking questions and receiving narratives

The interviews I conducted in my study were semi-structured, meaning they comprised both questions formulated in advance and topics that arose during the interaction between the interlocutor and myself (Silverman, 1993). The questions were chosen to address points directly connected to my research focus. For example, to understand how PET science was used, I needed to know about how the Centre operated. To get a comprehensive understanding of this issue, I had to speak to representatives not only from the facility itself, but also from business and healthcare. Moreover, because I was interested in the dynamics between the actors involved and the effects of their interactions on both organisation and science, I again needed to pose these questions to representatives of practically all actor groups involved.

I generally had a few queries that were common to all interviews I conducted, but many of the questions were tailored specifically for the individual to whom I was speaking. Because my interlocutors involved people from such diverse professional backgrounds and with such varied roles in the PET Centre journey, it was also necessary to pose questions directly relevant
to each person’s particular part in the events to get the most out of every interview. That being said, the standardized questions the interviews contained served an important purpose, in that the answers they yielded could be compared. With several different accounts and points of information to relate to one another, I was able to not only corroborate certain elements of the topic I studied, but also to identify points of contention and uncertainty.

Hence, the semi-structured set-up of my interviews meant that I could retain a certain rigor in terms of comparability of the responses while simultaneously providing space for thorough explanations, unexpected turns, and even digressions – which would occasionally lead to relevant, previously unexplored aspects of my research topic and new, fruitful lines of inquiry. In most instances, the loose nature of the interviews mitigated the danger of the interaction turning into a strange situation of interrogation. My goal was, as is most often the case when the interview method is used (Czarniawska 2004), to elicit narratives. Since the aim of the interviews was historical description, this was generally not hard to achieve. Most of the time, the interlocutors spontaneously phrased their answers in the form of narratives, without my having to prompt the conversation with more than a few open-ended questions (see Appendix II for examples of interview guides).

Yet, as fascinating and interesting as all of these narratives were to me, I was painfully aware that they did not provide a full and exact picture of what really happened, as discussed in the preceding section. First, the memory of interlocutors could waver, as mentioned above. Not only are numbers and names difficult to recall, but in a completely retrospective study, there is also the risk that the interviewee may not have regarded a past occurrence as important at the time and will therefore not remember it when interviewed (Leonard-Barton, 1990). Second, interlocutors could also opt to answer in a certain way in order to, in Czarniawska’s words, “represent themselves”, in the sense of presenting themselves “in a good light” (2004:53) – which, by the way, is a very human thing to do. Thus, without being consciously misleading, an interlocutor could choose to produce a narrative as an act of representation (ibid.). Or, as Holstein and Gubrium (2012) propose: “truth’ or ‘accuracy’ of narratives takes a back seat to what is socially accomplished through storytelling” (ibid.:7).

According to Czarniawska, the logic of representation is used by everyone “in positions that require official accounting” (ibid.). Indeed, in my interviews I encountered one situation in particular where this practice of representation rendered the interlocutor’s responses almost incomprehensible. The account I received was so abstract and conventionalized that it was almost devoid of meaning – although it naturally conveyed something: namely, the position of the interlocutor and the confines within which this person had to navigate. At the end of the interview (which was among the shortest ones I had) the interlocutor suddenly stepped out of her role and actually apologized for the
fact that she was not able to be more forthcoming in her answers. At a later point, however, I was able to retrieve some of the information I had hoped to gain in that first interview, but this time from other interlocutors who evidently did not consider themselves bound by the same constraints and were therefore not obliged to perform the same act of representation.

If we contemplate studies of recent history more specifically, Silverman (2007) astutely notes that “all of us when faced with an outcome [...] will document their past in a way that fits it, highlighting certain features and downplaying others” (p. 39). Certainly, it is always possible that interviewees, with the benefit of hindsight, present their actions in a way that rationalizes their behaviour (Welch, 2000). In other words, narratives are in a sense, at least to some extent, invariably coloured by the interlocutor’s wish to be perceived in a particular way. As a result, again, when prompting a person to produce a narrative, the interviewer obtains a version or a portion of reality – not necessarily untrue, but inevitably fragmented. But, importantly, this incomplete rendering of reality that interviews yield is not only contingent on the interlocutor’s possible attempts at representation or their ability to correctly remember. It may also be the result of the potential unwillingness of interlocutors to reveal information they consider sensitive (Hultén et al., 2007); confidentiality agreements, loyalties and fear of repercussions can hold the interviewee back. In my own data collection there were a few instances in which I sensed such considerations were affecting interviewees’ responses.

Still, overall, I had the impression that interlocutors spoke with a great degree of candour. Studies of events taking place in a relatively distant past, such as the PET Centre case, generally have an important advantage, in the sense that the very fact that some time has passed may provide the interlocutor with a feeling of greater freedom to speak. Separation in time between the investigated events and questions about these might mean that previous dependencies or alliances have been dissolved, and that formerly sensitive material no longer needs to be held secret. Hence, in studies of history some of the most critical drawbacks of the interview method may be assuaged. In many of my interviews I indeed sensed that the temporal distance to the topics discussed put the interlocutors at ease: whatever the circumstances had been back then in terms of relationships and agreements, they had now changed and as a consequence the interviewees were comparatively unrestrained. To my surprise, even interviews with individuals from the business sphere resulted in detailed, rich narratives regarding business strategies, managerial difficulties and personal relationships.

Lastly, I want to raise a final aspect of the eliciting of narratives that has been relevant to my use of interviews. It essentially concerns the effect of the interviewer on the interaction between herself and the interlocutor. First of all, as pointed out by Huthén et al. (2007) and Eriksson and Wiedersheim-Paul (2006), some kind of interplay always develops between the interviewer
and the interviewee, which in one way or another impinges on how narratives are presented, as well as the content of these narratives. Is the atmosphere conducive to comfortable, candid conversation, or conversely, is it one of hostility, intimidation and reluctance? In my own interviews, there was generally an interest in sharing perspectives and perceptions, although there were indeed a few times when conversations were more difficult to get started or keep cordial. On one such occasion, I sensed the frustration of the interviewee in relation to the topic of conversation, translated into frustration with – and even antipathy for – me as an interviewer.

Clearly, whatever chemistry evolves between the researcher and interlocutor has an impact on the narratives produced. Secondly there is the issue, brought up for instance by Silverman (2007), of whether the interlocutors are aware of the researcher’s interests: if they are, that could affect their answers. Still, this problem is naturally not unique to interviews, but equally present in for instance the use of surveys. No method, after all, is fool-proof.

Really, at the end of the day, says Silverman, “there are no ‘good’ or ‘bad’ data”, but the value of the data all depends on what the researcher wants to do with them and what question is supposed to be investigated (ibid.:54). More specifically, what really matters is how data are analysed (ibid.: 56), given the limitations of the methods used, and of course, the research problem at hand. In the next section I address precisely this part of the research process – analysis of narratives from interviews – which, in my personal experience, I have found to be closely entangled with my own construction of the PET Centre story.

3.2.4 Interviews: Analysing equals writing equals making decisions

The basic analysis of data in my case study took place through the process of writing. Or, conversely, building the story, writing the story – where “story” denotes a narrative with a plot (Czarniawska 2004) – translated into an act of analysing narrative data. Now, it should be noted that what I have engaged in is not narrative analysis, that is, I have not aimed to understand how people create meaning through the telling of stories, and I have not been concerned with the individual stories per se in terms of how they are told. Instead, my interest in the narratives obtained through my data gathering pertains to their function as revealing of the workings of university-industry interaction.

It was through the decisions of what belonged in this story about university-industry interaction and science use that the elemental analysis happened. As Holstein and Gubrium (2012) assert, choices are “constantly made about […] what should be set aside for later, and how the stories [of the interlocutors] fit together” (p. 44). In short, writing is analysing. Therefore, to explain how I
built the story about the PET Centre, I wish to discuss issues related to the
decision-making on which this story construction was based.

I begin by once again pointing out the obvious: an interviewer is not a fully
objective, impeccable processor of data. To be sure, as noted by Czarniawska
(2004), a researcher “listens selectively” and “remembers fragmentarily” (p.
45). But, in the face of the intrinsic impossibility of being a perfect listener
and having an infallible memory, recording and transcribing interlocutors’
stories is of great value. While not cancelling out the effects of the
researcher’s potential biases and subjective perceptions, such audio and word-
for-word transcripts of an interview interaction are surely a useful aid for
making sense of and analysing narratives. For this reason, all of the interviews
I made in the PET Centre study were transcribed. Although the vast majority
of the interviews were transcribed in full, a few were not. In the latter case I
summarised parts of the narrative that contained a lot of technical data, while
transcribing the rest of the interview. The writing of the PET story then took
place in parallel with continuous comparisons between, and readings (and
iterations of re-readings) of, these transcripts. As a support to my memory,
they were thus of tremendous use.

Still, the transcripts naturally did not spell out how the PET Centre story
was to be told: this is where my decision-making came into the picture.
Essentially, what lay before me were people’s stories, and it was my task to
determine what pieces of these stories to bind together so as to construct a
new story that reflected my understanding of the events and phenomena I
was examining. The idea that stories of historic events are manufactured
rather than “found” in history has been treated extensively by Hayden White
(1973a, 1973b). He has argued that the historian must interpret his or her
“materials in order to construct the moving pattern of images in which the
form of the historical process is to be mirrored” (1973a:281). While I am not
an historian, I have indeed found myself in a situation where I have had to try
to act as one, since my research subject deals with past events. Furthermore,
as I have occupied myself with the tough task of creating something I purport
to be a valid approximation of “what happened” without having ever
partaken in those events, I have tried my best to tread lightly.

Yet, even though I have approached the assignment of representing the
past with great caution and care for details and balance, I have not been able
to escape the fact that I am indeed the one determining which data are
relevant, or irrelevant, to the story I want to tell. Taking other people’s stories
and creating your own composite version of it is, in Czarniawska’s words, “a
political act of totalizing” (2004:61). When the people involved in the events I
describe are both literate in and accomplished at what they do, as is the case
of all my interlocutors in the work at hand, the problem of re-creating their
narratives in my own story becomes “politically complex” (ibid.). Entwined
with my choice to render a story in a certain way is the possibility of my
interlocutors eloquently expressing their objections and wishes to “correct” me. Regardless, while respecting my interlocutors and paying attention to what they have to say, my responsibility as a researcher is to make my own interpretation. As emphasized by Czarniawska, the best way to express respect is not necessarily to agree and repeat everything that has been said. A researcher may be faced with opposition between interlocutors, or disagreement as to what constitutes the most significant theme of a story, but in any such situation it is the duty and the freedom of the researcher to resolve how to construct the social scientific story. The way I have solved points of conflict in the narratives of interlocutors is to acknowledge the existence of such opposition (e.g. different claims regarding the availability of scanners), which Czarniawska affirms is the researcher’s “authorial responsibility” (ibid.:62).

I began this section by stating that, in this study, the fundamental data analysis took place in the process of writing the story. I subsequently made an effort to describe the conditions under which this writing process took place: the means by which I tried to aid my capacity for listening as well as remembering (audio recordings and transcripts), and the decision-making required to turn the narratives of my interlocutors into a story. This story, I admit, is the fruit of my interpretation as opposed to a perfect reflection of “reality”, as it were, but one for which I take responsibility. White (1973b) has perceptively articulated how the re-creation of past events in the form of a story can be understood: “[a] historical narrative is at once a representation that is an interpretation and an interpretation that passes for an explanation of the whole process mirrored in the narrative” (p. 281). What I have found through the process of writing this narrative is that, as White points out, “the historical record is both too full and too sparse” (ibid.). There are simultaneously too much data for the researcher to ever include in his or her story, and, paradoxically, not enough data. In other words, when inquiring into the past the researcher undoubtedly has to deal with a situation of both empirical abundance and empirical deficiency. As a consequence the historical narrative produced will be a mix of “adequately and inadequately explained events” (ibid.). For instance, in my specific study, interlocutors would sometimes communicate their perceptions and opinions concerning certain events in great detail, while simultaneously offering rather sparse descriptions of the same events: when, how, who, sequence of events etc. While such gaps in data are inevitable, I have tried my best to not only corroborate the rendering of certain events or compare the different narratives collected in order to identify points of opposition and contradiction, but also to look for the missing pieces in my interlocutors’ narratives. My approach to doing this has been to make use of archives and bibliometric databases.
3.3 Other methods used: archival research and bibliometrics

3.3.1 Archival research

The value of archival material to my exploration of the PET Centre odyssey cannot be overstated. With two of the main actors in this journey being public institutions (Uppsala University and the Uppsala University Hospital), all formal interactions in terms of, for instance, meetings and correspondence between the two were documented and kept at the archive of Uppsala County Council. It is not an exaggeration to say that this archive turned out to be a veritable goldmine. While written records of the interactions of the two public actors and the business actor, i.e. Amersham and later GE Healthcare, unfortunately were out of reach due to confidentiality issues, the material I did have access to provided significant insight into different decision-making processes, relationships between various parties and economic considerations. All of these factors helped me to better understand the circumstances around the development of Uppsala PET Centre.

The use of archival records within the IMP research tradition is not widespread. Generally, IMP case studies rely almost entirely on interviews as the main data source (Welch, 2000). Nevertheless, the study of archival material can be tremendously helpful as a complement to interviews (ibid.). As noted by Welch, archival data are not necessarily more “objective’ or ‘factual’ than personal accounts” (ibid.:199) just because they come in a written rather than oral form. It can however be argued that they are less biased than accounts presented in interviews, as in the former case the providers of information did not know that their written output was going to be observed at a later point (Flynn et al., 1990). Consequently, in the use of archival records the researcher avoids some of the pitfalls inherent to the interview method, notably the effects of the interplay between the interviewer and the interlocutor.

What is more, compared to interviews, archival material is more likely to give accurate information in terms of dates, numbers and names. Instead of leaning exclusively on people’s imperfect memories concerning these types of facts, archival documents afford researchers the benefit not only of being able to construct a more reliable timeline of a sequence of events, but also of accessing more solid information on both the names of individuals involved in these events, and on various numerical details. Undoubtedly, meeting minutes documenting both the date a certain discussion took place, as well as what points were brought up and who participated in the meeting, are a more robust source regarding these specific details than an interview about the same event taking place twenty years later. Where interviews bring crucial insight into personal motivations, relationships and perceptions of events, archival records add specificity as well as the possibility of verification.
through the comparison between interview narratives and documents. Clearly, combining the use of archival material with interviews in a case study makes for both a more solid rendering of events and a better understanding of the research topic.

For this reason the discovery of the archives of Uppsala County Council was a breakthrough in my empirical work. The wealth of materials I found at these archives dissipated some of my concerns regarding my strong reliance on oral narratives. I was able to dig up documents that dated from the 1980s, when discussions about establishing a PET Centre began, up until 2002, when Amersham took over the ownership. As of May 2002 all documentation regarding the interactions between all three main stakeholders was classified, as it involved the private companies Amersham and, later, GE Healthcare. But among the pre-2002 material I found were meeting minutes, letters and printed emails, as well as financial data – including information on contract research sales and collaboration partners within the pharmaceutical industry – and budgets, contracts, an evaluation report dealing with assessments of the Centre’s scientific status, and even floor plans of a planned new PET Centre. I was also lucky enough to come across a few interlocutors who, during interviews, could supply more documents, including recent ones, in the form of financial spreadsheets detailing budgets, incomes and costs; consulting reports concerning suggestions for restructuring the Centre; and contracts concerning agreements between the PET Centre and commercial actors. All in all, this collection of written material was critical to my construction of the PET Centre story.

3.3.2 Bibliometrics

In the course of my interviews a particular plot became apparent in several of the stories collected from interlocutors. This plot delineated the rise and decline of Uppsala PET Centre in terms of its academic reputation. A number of narratives I gathered conveyed the message that the Centre’s standing as a research institution had been affected by the changes in ownership. More specifically, according to these narratives, the initial twelve years of public ownership had been a period during which the Centre had built excellent scientific renown by engaging extensively in independent research, which had resulted in the production of cutting-edge scientific knowledge and important scientific publications. However, the take-over by a new commercial owner had apparently meant that independent research projects were squeezed out by contract research. The space for both pre-clinical and clinical research, as well as other types of research making use of

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8 As a matter of fact I learned about the existence of this archive from an interlocutor who I happened to interview at the very place all this archival material was kept.
PET, was restrained as a consequence of the new management of the Centre. Allegedly, it was not until the Centre returned to public ownership that more space was granted for independent research activities.

As this description of the research aspect of the Centre’s development was of fundamental importance for my understanding of the PET Centre journey, I deemed it absolutely necessary to find a source of data through which I could corroborate the picture painted by many of my interviewees. The reason I felt this urgent need for verification was not due to suspicions concerning the candour and truthfulness of my interlocutors, but rather a wish on my part to find out whether their impressions and perceptions in regard to the production of scientific knowledge were based on a hunch, rather than actual developments. After some deliberation I concluded that the most straightforward and accessible method by which I could verify the accounts of my interlocutors was to investigate how much scientific literature involving PET technology had been produced from the founding of the Centre up until the present time. I thus used numbers of publications in peer-reviewed journals as an approximate measure of the magnitude of independent research activity.

The tool for doing this was the bibliometric database SCOPUS, the largest available citation database of peer-reviewed publications from scientific journals, conference proceedings and books. To retrieve the information I was looking for, I specified what institutions I was interested in (Akademiska sjukhuset [Uppsala University Hospital], Uppsala PET Centre and Uppsala University as a whole), as well as the keywords for my search. I was interested in the number of publications where positron emission tomography had been either the research topic or one of the methods used. Based on the numerical data I obtained I went on to construct graphs in Microsoft Excel. To be able to determine whether the trend I discerned from these graphs reflected a general development in PET-related research, or was specific to Uppsala University, I also plotted how much PET literature had been published globally. In this manner I was able to deduce whether apparent correlations between levels of PET publications and shifts in ownership, in my particular case, simply mirrored global fluctuations in published PET research, or could really be assumed to reveal the actual effects of ownership change on the science conducted.

The use of bibliometrics thus permitted me to establish whether the prevailing plot about the relationship between ownership and quantity of independent research had actual substance, as opposed to being the mere product of impressions and biases of a few people involved. Being able to confirm that this relationship indeed existed was of critical importance, as it allowed me to, with more certitude, discuss the impact of commercialisation and commodification of research on the use of science.
3.3.3 Summing up

Sections 3.2 to 3.3.2 have dealt with the issue of my construction of the Uppsala PET Centre story. I addressed this question by explaining the different ways in which I collected my data, as well as by discussing the concerns I had in relation to interpretation and analysis of narratives, and the decision-making needed to actually tell the story. Nonetheless, this section has not accounted for my reasoning behind the structure of the empirical story. This point is discussed in the following section.

3.4 Structure of the PET Centre story

Upon first glance the structure I chose for the PET Centre story is not necessarily the most straightforward one. By this I do not mean to say that it is complicated, but simply that it does not tell the whole of my story in a perfectly linear fashion from beginning to end. Instead, I decided to divide the story into three chapters, each one focusing on one particular aspect of Uppsala PET science, and each one also following the same chronological timeline. The compounded result is a sort of “warped” timeline, where after completion of the first chapter, the reader is moved back in time again as the second chapter begins, and so on. Each chapter is thus a temporal iteration of what came before, but with a different empirical spotlight. I opted to present my data this way for a couple of reasons, both empirical and theoretical.

The investigation of the PET Centre journey generated a wealth of detail. While abundance of empirical data does not mean – indeed should not mean – that all of it be included in the research report, I still found that for my object of research, many of the rich details I came across were relevant to the story I wanted to tell, and the phenomenon I wanted to examine. The challenge was to incorporate these details in a fashion that, instead of obscuring the core of the story, contributed to an appreciation of the complexity of the examined phenomenon, as well as an understanding of the network within which this use took place. Evidently a failure in this respect, my very first version of the empirical story prompted suggestions that I find a way to structure the account so as to avoid overwhelming the reader. In discussion with one of my advisors, breaking the narrative into three parts was my way to resolve this issue.

The decision of how exactly this division should be done was based on both empirical and theoretical considerations. Quite early in the research process, I noticed the crucial roles played in the PET Centre journey by scientific output such as molecules, and scientific resources in the form of facilities and equipment. Moreover, I also noted that in order to understand the use of these different elements of science, it was necessary to pay attention to the organisational context. Choosing a narrative structure that
reflected these empirical points seemed like an intuitive way to organise and present data.

Additionally, the basis for what would be the exact focus of each of the three empirical chapters also mirrors the theoretical considerations that have informed this thesis as a whole, namely the IMP resource perspective, as well my conceptual sensibilities in relation to science as a construct. In the preceding chapter (Chapter 2), where I elaborated on the different ways science can be conceived – as something immaterial, physical and systemic – I noted that an argument could be made that this view of science accorded with the IMP perspective on the world as consisting of physical and organisational resources (Baraldi and Waluszewski, 2005). To be more precise, the perception of science, expressed in STS literature, as both something material and immaterial, seemed to agree with how science would be viewed from an IMP resource standpoint.

This is how I arrived at a structure of the PET Centre story that was at once empirically intuitive and theoretically consistent. The chapter division (first described in the preceding chapter) reflected, first, the material aspects of science in terms of output (focus: molecules, Ch. 4), the material aspects of science in terms of facilities (focus: equipment and test subjects, Ch. 5), and second, the immaterial facet of science and the organisational environment in which science is used (Ch. 6). This last, third, chapter revolves thus not only around the immaterial aspect of science per se in the form of knowledge, but also, importantly, around other organisational resources that have played a role for the utilisation of science over the course of the Centre’s development.

With the reasoning behind the overall chapter structure of the PET Centre story thus explained, I also want to briefly comment on the form of each chapter. The structure I chose reflects the narratives of many of the interlocutors with a connection to Uppsala University and the Uppsala University Hospital with whom I spoke. These interviewees tended to make clear demarcations between different phases of the Centre’s development according to ownership. Because these shifts in ownership appeared to have had a strong impact on how science was used, it seemed to me that a division of chapter content according to ownership change would serve an instructional purpose given my research questions. Hence my decision to, in each chapter, fit the data into the categories “the university years”, “the business years” and “the hospital years”.

This section has laid out the structure of the individual empirical chapters as well as of the empirical story as a whole. However, I have yet to discuss how I delimited the network that my empirical material describes. In the same way that not all of the details yielded from interviews and archival research made it into my empirical story, not every organisation, artefact or group of individuals mentioned in this story was included in the subsequent analysis.
For natural reasons, every research project needs outer limits – no study can be about everything – and for a network analysis the setting of these boundaries translates to a delimitation of the network studied. The next section treats precisely this issue.

3.5 Limiting a network and selecting what to analyse

As laid out in the theoretical chapter (Chapter 2), the perspective of this thesis is that organisations and the ideas, artefacts, practices and pieces of knowledge to which they are connected constitute resources. These resources make up, and interact within, networks. When adopting such an understanding of the world, the wish to investigate a certain phenomenon translates into studying the interplay between relevant resources. But this is where we encounter a fundamental challenge innate to the network concept: how do we determine the boundaries of the part of the network we want to investigate, i.e. how do we decide what resources to include in our analysis and what resources to leave out? To be sure, whatever insight we gain into a topic is contingent on what factors we have chosen to consider. Consequently, exploring the issue of science utilisation in relation to the evolution of Uppsala PET Centre involved making careful decisions as to what resources were pertinent to the objectives of the study. In face of the plenitude of resources forming the network in which PET science is embedded, the question becomes: how did I go about making these choices in my thesis?

The question can be divided into two parts. First, how have I demarcated the network I examine, i.e. how have I decided which resources to include in my analysis and which to exclude? Second, what is the basis for my selection of resource interfaces, i.e. how have I singled out the resource combinations to be analysed in the network I am concerned with? The shortest answer to these two questions is that the choices I have made in regard to the demarcation of the network and the analysis of resources have been guided by the wish to answer the research questions of this thesis. In other words, I have concentrated on a part of the network and resource interfaces that help us to better understand the question of science utilisation in a context of inter-sphere interaction. Yet, this explanation does not address the issue of the means by which I have arrived at the decision to include some resources and omit others. The fact is that choosing what aspects of my data to investigate more closely has strongly resembled the process of weaving the empirical story about Uppsala PET Centre. From the multiple narratives of different individuals and the printed words found in archives, a story is formed by me through the acts of collecting, comparing, reflecting and writing. In a similar way, the choice of which facets of the empirical story to
examine further has grown out of my own reading and contemplation of the empirical material, as well as thorough theoretical considerations.

The outcome of this careful reading and deliberation has been the gradual emergence of what I can best describe as inescapable themes (inescapable to me, that is!): themes that seem to stand out and beg for attention, themes that in effect spell out the research problems to be explored. In the PET Centre case, the themes that have taken the most distinct shape in my study of the empirical data are those of commercialisation, commodification, value and valuation. As a result, the section of the resource network I have chosen to concentrate on relates to these themes in different ways. To sum up, the decision of which parts of the PET Centre case to analyse springs from the drawn-out process of becoming intimately familiar with every nook and cranny of the PET Centre story, as I have understood and presented it, as well as from careful theoretical reflections, which have aided this process not least by creating structure.

As mentioned above, from a network perspective the choice of what parts of the PET Centre story to analyse essentially corresponds to a selection of the resources that span the section of the network one is interested in. Put in another way, choosing areas to concentrate on means choosing resources. But this is not all. Because it is in the interaction between resources that value is created – where things happen, where use takes place – it is necessary to study the combinations of resources (Gressetvold and Torvatn, 2006; Baraldi and Strömsten, 2006). The implication of this viewpoint is that yet another decision must be made: which resource combinations should be studied, i.e. which are the resource interfaces that ought to be closely examined so as to approach an answer to the research problem? In a network consisting of a multitude of resources, making these selections is not an obvious task. From the intricate web of combined organisational and physical resources, which together constitute a complete portion of a network, individual resource interfaces of particular relevance to the themes investigated must be identified. How, then, is this accomplished?

Essentially, the first step has been to cautiously study my empirical data and take note of where in the network PET-related activities, and hence utilisation of PET science, have been the most intense. This focus on PET activity reveals in quite a straightforward manner what interfaces involving physical resources have been critical. Yet, in order to understand what, apart from the physical properties of the material resources in question, has affected the mobilization of these combinations of physical PET resources, it is necessary to pinpoint relevant interfaces containing organisational resources. Organisational resources tell us something about why certain types of science use are given time and resources, while others are not. As a second step I have therefore paid attention to activities involving organisational resources around or in direct connection to the physical resources. Guided by the
question of how the actions, intentions and needs of the main actors have impacted the use of science, I have considered interfaces reflecting these actors. Basically, whether purely physical, organisational or mixed, I have selected resource combinations that have been of major importance to at least one of the main actors and that relate to one or several of the themes I identified as key to the PET Centre journey, i.e. commercialisation, commodification, value and valuation. Included in the analysis are resource interfaces that: 1) are activated every day or that condition everyday use of PET; 2) resource interfaces that have had, or have been believed to eventually yield, a significant economic impact; 3) resource interfaces that have been of considerable scientific importance; and 4) resource interfaces that have been crucial to clinical practice. Some of these interfaces have been active more or less continuously over many years whereas others have existed during a shorter time period but have had a momentous impact on the Centre.

It is precisely by being mindful of the impact of resource combinations on PET science that I have stayed clear of zooming in on interfaces too far out in the periphery. When a combination of resources does not significantly affect the use of PET, it has been left out of the resource analysis. I have had a similar approach in working out exactly where, in a cluster of connected resources, to draw the line between which resources to include in the analysis of a specific interface and which to omit. The guiding principle has been to include enough resources in a constellation that a particular situation of use is adequately described and examined, but to exclude resources that are not relevant to, or do not provide an added dimension to, the situation to be recounted and analysed. The result is a selection of resource interfaces that are comparatively complicated: although I do investigate a few dyadic combinations, most of the interfaces I have examined are between three or more resources. This state of things is not a result of any warm feelings for complexity that I may harbour, but simply a reflection of the complicated nature of PET, in itself, as a science and a technology, as a research area and a tool at Uppsala, and as a means to reap economic benefits.

When using resource interfaces as an analytical tool, and especially when handling such complex interfaces as the ones I have singled out in the PET Centre case, it is imperative to present them according to a clear plan and structure. The logic for the presentation of my analysis is a division into five different chapters. In the first analytical chapter (Chapter 7) I provide an analytical overview of the empirical material so as to: first, simply offer an overall understanding of the evolution of the PET Centre in relation to the key concept of commercialisation, commodification and schemes of

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9 In the analytical chapters the connection between actors and organisational resources will be treated in more detail.
valuation; and second, to prepare for the comprehensive resource interface analysis to follow in succeeding chapters. This succeeding analysis is presented in Chapters 8, 9 and 10, and focuses on physical interfaces, mixed interfaces, and organisational interfaces, respectively. In the last analytical chapter, Chapter 11, I synthesise the four preceding chapters and discuss the main findings.

To conclude, for the analysis of PET science in Uppsala, I have made choices regarding what parts of the network, and hence what resources to concentrate on, as well as what interfaces between these resources to examine in greater detail. These choices are based on my own judgment and understanding of the collection of narratives and documents that constitute my oral and written empirical data, as opposed to the use of any type of numerical measurements (my bibliometric data were not instrumental here). Still, this section has revealed that, despite resting almost solely on my grasp of words, the selections I have made are far from arbitrary, but rather emanate from a deep familiarity with my empirical material and the themes I have detected therein.

3.6 Summary

In this chapter I have explained the research strategy used in my thesis. I began with a description of my use of the case study approach and my reasons for selecting the case of Uppsala PET Centre. I subsequently went on to delineate the methods used for collecting data, an account that I fit within a framework of storytelling. As I have seen the creation of my PET Centre narrative as exactly that – a story constructed and told by me – I found it important to relate the data generated from each of my employed methods to this process of storytelling. The next section dealt with the structure of the empirical material: the theoretical and empirical reasons for arranging the story and dividing up the chapters in a certain way. Lastly, I addressed analytical issues concerning choices I made in setting the limits for the network under study, as well as in selecting the resource interface to concentrate on in this network. My methodological approach and concerns thus untangled, it is now time to move on to the empirical story of the PET Centre journey.
Chapter 4. Scientific output

This chapter follows the commercialisation journey of the Uppsala University PET Centre, with an emphasis on radiotracers. There are sound reasons for choosing tracers as the focal point, as opposed to any PET technique. In the overview of the empirical story told in the Introduction (Chapter 1), the Centre’s scientific turnout was shown to encompass multiple elements: publications in scientific journals, studies conducted for and in collaboration with the pharmaceutical industry and results of clinical research projects run by doctors at Uppsala University Hospital. These are all instances of scientific production at the PET Centre.

What all these scientific outcomes have in common is their dependence on radiotracers, which are thus the fundamental requirement for all the Centre’s scientific activities. Tracers are at once the subject of independent research, the technology necessary for contract research studies for the pharmaceutical industry to be performed and the technology on which the University Hospital depends to conduct PET scanning. Given the objective of investigating the use of science at the PET Centre with a focus on scientific output, tracers are therefore a good place to start. Before diving into the PET story again, however, I want to supplement the explanation of PET science provided in the Introduction, with a slightly more detailed description to clarify exactly how radiotracers come into the picture, how the technique is used and what equipment is needed.

4.1 Positron Emission Tomography: what, when and how

Positron emission tomography (PET) technology has been in use for medical purposes since the late 1960s and early 1970s. Over the decades there has, of course, been continuous development of the equipment and chemical substances involved. Needless to say, PET rests on previous scientific advances. The technique would not exist without the cyclotron invented by Ernest Lawrence and his co-workers in the 1930s, the discovery of artificial radioactivity by Frédéric and Irène Joliot-Curie in 1934, or the development of scanners and tomographic imaging, to list just a few of the scientific discoveries that made PET possible. As a tool used in both medical practice and research, the PET method produces three-dimensional images of
biochemical processes in the body, revealing what is going on in the organs and surrounding tissue.

Medical uses of PET abound. It is used extensively in oncology to detect cancer tumours, to differentiate benign and malignant lesions and to monitor response to treatment, for example (Wagner, 1999; interview, Gunnar Antoni, 2010). It is also used in neurology to better understand, diagnose and treat brain pathologies, such as Alzheimer’s and Parkinson’s diseases, and in neuroendocrinology, which is the study of the interplay between the nervous system and the endocrine system. Cardiology is another important area of application, as is psychiatry, where PET is widely used to study depression, schizophrenia and substance abuse, for example. Another major field where PET is used is pharmacology. PET technology can be employed to study both how a pharmaceutical drug is distributed in the body (biodistribution\textsuperscript{10}) and to what extent a drug blocks a certain protein (drug occupancy\textsuperscript{11}).

For a PET image to be generated, the patient needs to be injected with a substance labelled with radioactive material: “radionuclides”. The radionuclides are usually produced in a cyclotron, a type of particle accelerator. The substance on which the radioactive tag is placed can be a natural chemical that is normally used by our bodies, such as glucose, water or ammonia, or molecules resembling pharmaceuticals that are designed to bind to specific receptors in our cells. These tagged compounds are known as “radiotracers”, or simply “tracers”. When the tracer is injected in a subject’s body, a positron is emitted from the radionuclide as the radioactive matter decays. The positron travels a short distance, just a few millimetres, through surrounding tissue until it loses most of its energy. It then collides with an electron, whereupon the mass of both particles is converted into pure energy. The particles are said to have been annihilated and the result of the annihilation, i.e. the energy, is visible as two 511 KeV photons travelling almost 180 degrees apart, detectable by a camera, the “PET scanner”, as points of light. In other words, the radionuclides function as light beacons\textsuperscript{12} (see Figure 4.1). But how does the tracer know where in the body to go?

\textsuperscript{10} In biodistribution studies, the tracer used is thus a drug molecule labeled with an isotope.
\textsuperscript{11} Basically, a drug occupancy study investigates what doses of a pharmaceutical drug are needed to block a certain percentage of the protein the drug binds to, so as to achieve the right therapeutic effect. In this type of study, a PET tracer that binds to the same receptor as the study drug is used.
\textsuperscript{12} The idea that a molecule could be replaced by a radioactive isotope of that same molecule, since they are chemically indistinguishable, originated with the Hungarian radiochemist Georg von Hevesy, who was awarded the Nobel Prize for his work in 1943.
As the tracer enters the body it functions more or less like a robot searching for its target and accumulates in the part of the body it is modelled to seek out. For instance, if the aim is to find out where cancer tumours are located in the body, a tracer known as fluorodeoxyglucose (FDG) is often used. FDG molecules are analogues of glucose, i.e. essentially sugar molecules, but tagged with the radionuclide fluorine-18 (18F). Since malignant tissue has a higher metabolism for glucose than healthy tissue, FDG builds up in heavy concentrations in the tumours. The tracer molecules become trapped in the cells as the tumours metabolise the FDG. The presence of FDG in the body is then visible as illuminated spots in the PET scan.

In a pharmaceutical study, when the distribution or occupancy of a pharmaceutical drug is under investigation, the radionuclide is incorporated into a pharmaceutical molecule. Although the tracer does not function like a drug and has no therapeutic effect, it resembles and binds to the same receptor as the regular pharmaceutical. In other words, the tracer and pharmaceutical have the same target in the body. Consequently, the tracer will accumulate in the relevant part of the body and give information on where in the body the drug travels to or how far a particular receptor is blocked, depending on what type of study (distribution or occupancy) is being conducted.

Working with very small amounts of the radioactive compound and yielding absolute values and high-resolution scans, PET is the most sophisticated technology there is for distribution and occupancy studies in humans. Another, somewhat similar radioactivity-based technology called

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13 A receptor is a protein molecule, embedded in a cell, to which various kinds of signalling molecules (such as neurotransmitters, hormones, pharmaceutical drugs or toxins) may attach.
SPECT (single-photon emission computed tomography) is available, but unable to give absolute values and, compared with PET, produces images of lower resolution. There are also other methods for animal biodistribution and receptor occupancy studies, using radionuclides which emit particles that do not penetrate the body. This procedure does not require removing the animal’s organs and measuring their level of radioactivity at different points in time. But the only way to get pre-mortem information on how a substance, such as a drug, is distributed in the human body, or the degree to which another substance blocks a certain protein, is through SPECT and PET, the latter being the more advanced option.

So, on a practical level, what are the steps needed to generate a PET image of physiological and biochemical processes in a living organism? The sequence is as follows. When the radionuclide has been produced in the cyclotron, it is transported to a shielded fume hood, also known as a “hot cell”, where “hot” refers to the radioactivity of the material. Inside the hot cell, the radionuclide is chemically converted into a more complex molecule, a PET tracer, such as a drug like FDG (fluorodeoxyglucose), water or ammonium, depending on the purpose of the PET scan. This step, in which chemical methods are applied to integrate the radionuclide into a larger and more complex molecule, is nowadays largely automated. The outcome of this synthesising process is the radiotracer. For standard molecules such as FDG or drug-like molecules, the process is sometimes entirely automated. Once the synthesis is completed, the product is subjected to quality control to confirm its identity and purity before it is approved for use on humans and transported to the PET clinic. Subsequently, the tracer is injected into the subject and the PET scan is carried out.

The scanner measures the radioactivity distribution in the subject and a computer reconstructs data into a three-dimensional, time-resolved image of radioactivity in the part of the body that has been examined. Next, the numbers in the dataset are replaced by colours, resulting in a coloured contour map (see Figure 4.2). Interpretation of PET images requires careful measurements and complex modelling, and is generally done by physicists and mathematicians.
Figure 4.2 Examples of PET scans of human brains.

Image courtesy of Klunk, Engler, Nordberg, Wang, Blomqvist et al.

With its ability to trace substances in our body, diagnose disease and evaluate treatments, PET has become an extremely important tool in research, clinical practice and the pharmaceutical industry alike. Figure 4.3 displays the growth of PET research in terms of scientific publications globally. “PET research” refers here to both research about PET and research where PET is used as a method. As we can see, there has been a clear increase in the number of PET-related research publications over the past three decades.
Figure 4.3 Number of PET-related publications 1966-2015 globally.

As a field PET is highly interdisciplinary, bringing together a vast spectrum of expertise. For PET to be a useful instrument, people with various scientific vantage points – chemists, nuclear chemists, computer scientists, oncologists, physicists, biologists, mathematicians, neuroscientists, psychologists and psychiatrists, for example – therefore all need to interact, making PET not only very exciting but also quite challenging.

4.2 Tracers at Uppsala University

In the early 1970s Bengt Långström, a PhD student in chemistry at Uppsala University, started experimenting with substances tagged with the radioactive isotope carbon-11. Back in the 1960s and early 1970s, only a few very rudimentary substances labelled with radioactive material existed. Researchers worked mostly on sugar molecules, which were used to study cancer tumours, but there was not much else. The introduction of modern PET scanners in the 1970s, however, boosted interest in working on the chemistry in PET, i.e.
the synthesis of radiotracers. In other words, the question of how to build chemical compounds that could be used as tracers began receiving more attention. In 1972, Långström published an article on how to make a very simple organic molecule. The molecule could be used to label plenty of different substances, and the finding constituted a scientific breakthrough that created scope for important new research in chemistry. Suddenly the researchers had a new tool: a whole new way of making tracers. This discovery brought a veritable flood of research on tracer synthesis.

Långström’s innovative contribution consisted primarily in his use of methods for making radiotracers. In chemistry there are a huge array of methods for producing various types of compounds, and as a chemist he was familiar with many of these. He began trying to apply these methods, which are normally used in chemistry, to PET with the intention of finding out whether a chemical process usually taking days, weeks or even months could be done in a significantly shorter time. Since speedy handling is of the essence for short-lived radionuclides, methods that require days or weeks to complete the synthesis of a tracer are of no use. Långström’s main achievement was that he actually succeeded in using chemistry methodology to produce radiotracers in much less time than had previously been possible. Instead of spending months in a chemistry laboratory making a substance, the researchers could now synthesise the most common tracers in 40–120 minutes in the PET laboratory. In the early stages of PET research, in which Långström soon became a leading figure, most efforts were concentrated on developing and refining these tracer production methods (although new tracer molecules were also being developed). Today, PET researchers tend to think of some of this methodology as basic and routine, but back then it was somewhat revolutionary (interview, Antoni, 2011). In Uppsala in the 1980s, most PhD students in radiochemistry were working exclusively on method development, rather than creating new tracer molecules. Comparatively little pre-clinical experimentation and basically no clinical experiments at all were in progress.

As time passed, however, the focus of PET research began to shift from method development to applications of PET. Accordingly, the focus nowadays is on pre-clinical experiments, in which researchers try to evaluate whether they can create any useful and interesting molecules, and later test them on animals or in vitro. Much research is also devoted to clinical applications of PET. Put differently, it is more common for PET researchers’ studies today to have biological aims, since the requisite methods and chemistry already exist. However, research on methods remains important and every now and then, novelties in methodology are introduced, but not to the extent as in the 1970s, throughout the 1980s and well into the 1990s. A significant number of the higher-impact methods to synthesise tracers originated from Bengt Långström and his research group (including 28 PhD
students over the years) at Uppsala. Essentially, this is what made Långström famous in the world of PET, and also how PET research at Uppsala University gained its renown.

When PET technology began to be employed in the 1970s and 1980s, its introduction into operations was usually spurred by inquiries from medical doctors wishing to locate cancer tumours or investigate specific bodily organs. In Uppsala, however, the gradual adoption of PET started at the other end. Instead of a medical researcher asking for PET technology to help explore cancerous tissue, the suggestion that PET might be an interesting technology for medical and biological scientists to try came from the chemistry laboratory at the University. In the laboratory where chemist Bengt Långström was developing his new technique for making radiotracers, a multitude of new molecules were appearing. Indeed, from the depths of the basement laboratory at the Gustav Werner Institute at Uppsala University, where the PET researchers worked, came a large array of different molecules. The question was now what the scientific needs of researchers in the life sciences were and how they could benefit from these substances. Although the reaction from medical doctors and biologists was sometimes an incredulous “What are we supposed to do with this?” the chemists always had biological usefulness as their focus (interview, Antoni, 2010).

Nevertheless, the fact that PET technology at Uppsala was first approached and explored by trained chemists, as opposed to medical doctors, set the course for its ensuing development. The chemists’ perspective was quite simply that of chemistry: their efforts were concentrated on the chemical aspects of PET, i.e. on designing various tracer molecules. Soon the Uppsala PET researchers were so successful that they were gradually becoming world-leading in PET chemistry. Their foremost speciality was developing and producing molecules tagged with the radioactive isotope carbon-11. This radionuclide has a short half-life, only 20 minutes, meaning that after 20 minutes half of the radioactive atoms will have decayed. As a result, carbon-11 can be tricky to work with: it must be synthesised quickly and then immediately injected into the live tissue to be examined. In other words, radiotracers labelled with carbon-11 cannot be transported, but must be used directly on site. It was primarily in designing and making such short-lived tracer molecules that the PET group at Uppsala excelled.

4.2.1 Developing and producing tracer molecules

Developing tracers is a complicated enterprise. The human body contains between 10,000 and 20,000 proteins, each of which has a specific function. To study the function of each protein we would need an equal number of tracer molecules. This may be compared with the actual number of radiotracers in clinical use today, which hovers around roughly 30–40. In
addition, some 100 tracers are used mainly for research purposes in animals and humans. When PET research was in its infancy and only one or two tracer molecules were in use, there were two main questions: how to find out which molecules bind to specific proteins and how to produce these molecules.

Let us address the former question first. To identify which molecule should be used in order to understand a certain disease – corresponding to a certain protein – pre-clinical experiments are conducted. In these experiments, molecules are screened against known proteins to see whether one of the molecules may be a suitable candidate for studying one of the thousands of proteins in our body. But how do the PET scientists even know which molecules to begin with? One common way is for the researchers to look at molecules found in pharmaceuticals, since the proteins to which these molecules bind are already known. Put differently, the logic is that something resembling a pharmaceutical might be a good tracer. The researcher begins with the basic structure of the molecule of interest and subsequently rebuilds it by adding to or removing something from this structure, creating around it a sort of “library” containing rebuilt variations of the original, fundamental structure. The goal is for the remodelled molecules to have properties that make them suitable as tracers: to target a specific part of the body without having any therapeutic or other effects on the body. In the pre-clinical screenings in the laboratory the researchers decide which molecules, now radiolabelled, actually work and can continue to the next experimental stage: animal testing. Through series of animal tests in which the tracer candidates are injected into rats, pigs and primates, for instance, the researchers may eventually develop a tracer molecule that can proceed to be tested clinically in human subjects.

The development processes for tracer molecules and pharmaceuticals are alike, in that the same funnel principle is used in both processes: a broad set of candidates is successively narrowed down to one substance to be taken through the necessary trials. However, where the pharmaceutical industry has the resources to screen tens of thousands of substances and pick out the ones that work, the numbers of candidates PET researchers begin with are decidedly more modest, usually between 10 and 15. Because of the vast number of substances that drug companies investigate, the pharmaceutical libraries of this industry are an important source of knowledge for PET researchers. These libraries contain information on molecular structures that may be very helpful to tracer development. This type of information can be acquired by PET researchers either by collaborating with a pharmaceutical company that may decide to share molecules or simply by purchasing them.

\[\text{Statistically speaking, of these 10–15 substances, only about one will actually be developed into a functioning radiotracer.}\]
Information on interesting pharmaceutical molecules may also be found in scientific publications. When IP rights are not at stake and publishing does not disturb pharmaceutical development, drug companies may allow their scientists and external collaborating researchers to present their data in peer-reviewed journals. In addition, there is also a large pool of well-known substances in which PET researchers can begin their search for promising molecular structures.

In sum, PET researchers generally do not themselves – although a few such cases exist – invent the chemical templates of radiotracers. For the most part they depend on external information on molecules. Developing a useful molecular basic structure from scratch takes time, but the PET Centre in Uppsala has worked with the Department of Medicinal Chemistry, where development of molecules has taken place without any prior template to start from. In such cases they may have begun simply with a peptide\(^\text{15}\) that was known to bind to something in the body. From this peptide, the researchers have attempted to build a tracer – an undertaking that it takes a couple of generations of PhD students to finish (interview, Antoni, 2011).

The other question researchers struggled with in the early years of PET concerned the production of tracer molecules: how to produce compounds containing a radioactive label fast enough for the radioactivity to stay at a desirable level. Given the speed at which the radioactive matter used in PET decays, the production process has to be rapid. Otherwise, there is nothing left of the radionuclides by the time the radiotracer synthesis is complete. (Table 4.1 gives an overview of the half-lives of some isotopes.)

\(^{15}\) Simply put, a peptide is one of the building blocks of life on our planet and can perform a broad range of functions in the body. Peptides are generally linked together in long chains, and when they exceed a certain length they turn into a protein. Both peptides and proteins have been widely researched for many years, since they contain information on how the body works.
<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-11</td>
<td>20.4 minutes</td>
</tr>
<tr>
<td>Fluorine-18</td>
<td>110 minutes</td>
</tr>
<tr>
<td>Oxygen-15</td>
<td>2.1 minute</td>
</tr>
<tr>
<td>Nitrogen-13</td>
<td>10 minute</td>
</tr>
<tr>
<td>Zirconium-89</td>
<td>78.4 hours</td>
</tr>
<tr>
<td>Gallium-68</td>
<td>271 days</td>
</tr>
</tbody>
</table>

Table 4.1 Half-lives of isotopes.

The synthesis itself may not be difficult if performed in a regular laboratory and with ample time, but under time pressure in a hot cell conditions are different, making the process arguably more demanding. As mentioned at the beginning of this chapter, the major contribution of Långström was to develop chemistry that made this type of synthesis feasible in very little time.

4.3 The PET research group at Uppsala

Långström found methods that allowed scientists to achieve in 40 minutes something that would take weeks in a conventional chemistry lab, or in 5 minutes a synthesis that normally required 48 hours. Radically changing the premises for PET research, these new methods gave impetus to a real surge of scientific work in PET. Years of PET chemistry research had yielded highly useful tools that simplified the production of tracer molecules, and with these methods available PET scientists were now able to take on other questions.

The Uppsala PET Centre group who, led by Långström, had excelled in developing PET methodology and invented numerous novel and high-impact methods was no exception to this trend. It now concentrated on how to make interesting molecules, which meant that more pre-clinical experiments took place. Whereas only minimal pre-clinical testing and barely any clinical testing at all were done in the early years of PET research, such trials became vital when the objective was to design useful molecules and investigate their function in the body. In the 1980s, PET research in Uppsala was still to some
degree characterised by “tinkering in the basement” (Antoni, 2010), the synthesis still largely manual rather than automated and the in vivo experiments conducted were almost exclusively on animals, as opposed to human subjects. However, the mid-1980s saw the beginning of clinical trials and clinical use of PET in Uppsala, and in the 1990s the clinical side of Uppsala PET expanded dramatically. Clinical application of PET was now the area where most innovative research was being done, and like most PET scientists Långström and his group were now engaged largely in scientific endeavours tied to clinical questions.

Forming his research group in the early 1980s, Långström was a charismatic, strong-willed scientist with a compelling ability to enthuse people around him. As the person behind the revolutionary PET chemistry that had opened the door to so much new PET science, he set the scientific agenda in his group of skilled researchers, many of whom he had supervised in their doctoral research projects. After years in the Gustav Werner basement making radiotracers for patients, the PET research team had been able to show that the science they were doing actually worked, and they believed that now was the time to either abandon PET research completely and concentrate only on radiochemistry or “make something real out of it” (interview, Antoni, 2011). What Långström really wanted was to create an environment where science would flourish: a place exclusively dedicated to PET where he and his group could pursue their work under the best possible conditions. This was the idea he presented to the University management, and in 1989 the wish to create a PET research centre at Uppsala was eventually fulfilled. The centre would not be a place for PET research only: the financing model adopted by the University gave a clear indication of the various contexts that would feature tracers henceforth, and what purposes they would serve.

4.3.1 The three activities

In the discussions surrounding the founding of the PET Centre, three activities – contract research, independent research and PET scans for the University Hospital – were selected for the Centre to pursue. The tracers would consequently be employed in PET operations in three different ways. In the following sections the spotlight will be on precisely these activities and how they relate to radiotracers. I will begin with the first stage of the PET Centre’s odyssey, when Uppsala University was still the owner and in charge of the operations; continue with the period of commercial ownership; and finally describe operations after the return to public ownership.
4.4 The University years (1989-2002)

4.4.1 Contract research

Complicating – or, some would say, compromising – the idea of academic freedom, contract research is a contentious phenomenon in much of the academic community. The level of disapproval, of course, varies among disciplines, and as for the field of PET the degree of acceptance has changed considerably over time. In the 1970s, when PET began to take shape as a research area, the attitude towards commercial agreements with industry was unambiguously negative. While pharmaceutical companies handed PET researchers substances to develop tracer molecules, actually engaging in a commercial exchange with industry was considered “ugly” and contract research was consequently frowned on. Nevertheless, in the course of the 1980s this mindset started to change, and by the 1990s it became apparent that, as far as the PET Centre in Uppsala was concerned, its survival was contingent on the revenues generated from doing fee-for-service assignments for industry. The pharmaceutical companies were evidently interested in working with PET scientists. In the mid-1980s the PET researchers at Uppsala had already anticipated the pharmaceutical industry’s need to use PET technology for drug development, and this is indeed what happened.

Starting in the late 1980s, when the new PET building was still unfinished, the Uppsala researchers began working on projects assigned to them by the drug industry. Using Långström’s broad network in the pharmaceutical industry, and from the late 1990s Quintiles, a contract research organisation, the PET Centre managed to bring in a substantial number of contract research projects. The most important contract research assignments can be divided into two types, those of occupancy and biodistribution, briefly mentioned at the beginning of this chapter. Occupancy studies concern the questions of whether the drug candidate reaches its target organ in the body, how far it blocks a certain protein and how long it remains in the target organ. The second type is biodistribution studies, in which the task is to follow the distribution of a substance in the body. Such a study can help a pharmaceutical company to select candidates to pursue in more comprehensive studies. Basically, a PET scan can give immediate information on whether or not a medical drug candidate is performing in a desirable manner. This means that a pharmaceutical company knows straightaway whether it should abandon a particular drug candidate at an early stage, thus potentially avoiding enormous expenditures on dead-end projects. For this reason, PET is an extremely important tool for pharmaceutical companies, and the Uppsala group appreciated the economic usefulness of the technology from a very early stage.
Fee-for-service studies are generally time-consuming endeavours. This is not so much because of the time needed to carry out the research. Rather, the early phase, in which research problems and design are discussed and the actual contract content is settled, is the most protracted. This work, taking some one to three months, is followed by a stage where numerous administrative tasks are performed. Protocols are written and applications need to be sent to ethics committees and the Medical Products Agency, the Swedish national authority responsible for regulating and monitoring development, manufacturing and marketing of pharmaceuticals and other medicinal products. For confidentiality reasons, apart from the writing of certain documents, which requires the scientific expertise of the academic researchers, administrative work is primarily handled by the drug company itself. If a contract research organisation like Quintiles is involved, it may handle this step. Awaiting the Medical Products Agency’s reply adds another month or two to the process, so that it can take up to nine months until the scientists can actually begin working on the research study. This stage is normally the shortest. A small, straightforward study can be completed within a few weeks, while others that are more extensive may require months. Overall, however, the actual performance of the study takes much less time than all the discussions and formal paperwork preceding it.

The bulk of the contract studies in which the PET Centre has been involved over the years comprises early Phase 1 trials, in which the researchers test an experimental pharmaceutical on a small group (numbering 20–80) of healthy individuals for the first time, to determine its safety and the optimal dosage range, and to identify adverse effects. There have been some exceptions, however: the researchers have occasionally carried out testing in a later phase, primarily to evaluate treatment efficacy. The knowledge that PET researchers possess and the drug industry needs is the ability to radiolabel various compounds. Not all studies in which the Uppsala scientists participate are restricted to clinical testing alone; sometimes they involve strictly pre-clinical trials in animals and at other times a combination of both. Not seldom, a study has consisted of several parts, starting with the chemists developing a way to attach a radioactive tag to the substances under investigation – a step that often requires considerable innovativeness – and proceeding to testing of the labelled compounds in animals, and finally in humans.

On a few occasions, the fee-for-service studies in which the PET Centre has been involved have yielded new tracer molecules that the collaborating

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16 Clinical trials of a new drug or treatment are divided into five test phases, 0–4, which are designed to give information about the safety, side effects and efficacy of the drug among a large population (up to 3,000 people in the final phases).
pharmaceutical company has chosen to patent\textsuperscript{17}. The most frequent output of the studies is nonetheless not patents, but scientific publications. More often than not, the academic researchers at the PET Centre have been permitted to publish their findings, not least owing to the pronounced policy of many drug companies to publish. Unlike the publishing procedure for purely academic projects, where the publication is submitted very soon – no more than a month – after the completion of the experiments, the routine for publishing results from fee-for-service studies is usually considerably slower. Although there have been instances of the pharmaceutical company wanting to have a publication submitted immediately, as a rule there is a time lag. The reasons for this are connected with the legal aspects of a study: the firm must evaluate whether the findings entail any important IP rights that need to be secured and, if so, when would be a safe time to publish or whether publishing is an option at all. Sometimes the obstacles to publication have nothing to do with receiving permission from the pharmaceutical firm but are, rather, bound up with the extra work necessary to complete the study with a few more experiments, or a contact person leaving the company’s employ. Differently stated, deriving publications from fee-for-service research is generally feasible, but often entails a certain waiting period, may be difficult to achieve owing to missing details and is conditioned by the company’s decisions regarding disclosure of potentially confidential information.

To be able to run the tests specified by the pharmaceutical company buying a fee-for-service study, the PET researchers would produce the tracer molecules in their facility. While the tracers most commonly used for research at Uppsala were based on carbon-11, the fluorine-18-tagged tracer FDG (fluorodeoxyglucose) mentioned above was growing in importance. Whereas much of the early work in PET radiochemistry revolved around carbon-11, fluorine-18 was not widely used until the late 1980s and early 1990s. With a total of 30–40 years’ development, the modern version of FDG has been in use for the past 20 years and is entirely dominant as far as clinical utilisation is concerned. One of the reasons for this dominance of FDG is the fact that the fluorine-18 radioisotope has a half-life of about 110 minutes, against carbon-11 and oxygen-15, whose half-lives are merely 20 and 2 minutes respectively. In addition, fluorine-18 has the most optimal decay properties of these radionuclides. Nonetheless, other radioisotopes are used clinically as well: notably gallium-68 and carbon-11, but also to some extent nitrogen-13, oxygen-15 and some other radionuclides. The principal advantage of a compound with a comparatively long half-life is obvious: the radiotracer can be manufactured in bulk and transported to hospitals without cyclotron or a

\textsuperscript{17} A number of tracers have also been developed through contract research where the company has chosen not to patent. None of the tracers emerging from the fee-for-service studies at the PET Centre have become part of clinical routine, but some of them have turned out to be useful in other ways, mainly in research.
radiochemistry laboratory. This is impossible for tracers tagged with short-lived isotopes such as carbon-11 or oxygen-15. There is therefore an industrial and clinical preference for molecules labelled with fluorine-18.

4.4.2 Independent research

Although the substances with the greatest commercial potential would be those labelled with relatively long-lived radioisotopes such as fluorine-18, the Uppsala researchers’ speciality was, as mentioned previously, short-lived tracers. One of the most important tracers developed by the Centre was 5-HTP (5-Hydroxytryptophan), a compound labelled with carbon-11. This radiotracer was the fruit of the collaboration between Långström and the endocrine oncology group at Uppsala University Hospital that began in the mid-1980s, and then expanded further after the Centre had been established. With Långström, the endocrine oncology group developed target-seeking substances specifically for endocrine tumours, and 5-HTP was one of the very first of this set of radiotracers. The PET Centre originally developed these tracers not for clinical reasons, but purely for scientific purposes. As for 5-HTP, the PET researchers had designed it to investigate dopaminergic and monoaminergic systems, and it was in discussions with clinicians that they realised that some of them might be of clinical use as well. As expressed by a medical doctor at Uppsala University Hospital:

“Then they [PET researchers] developed this tracer that was really meant for a pituitary tumour, a completely different type of tumour. But then they knew what I was doing down at the Hospital so they just invited me to a seminar where I presented this type of [endocrine] tumour, and they were just aflame with enthusiasm and said, ‘But we have the right substances for that!’”
(interview, Öberg, 2013).

5-HTP is absorbed by nearly all hormone-producing tumours, and using this tracer in a PET scan is the most sensitive method to reveal very small, endocrine tumours. FDG on the other hand is used to detect larger tumours, but works poorly as a tracer for the types of tumour that concern the Department of Endocrine Oncology at the University Hospital.

The first three or four times 5-HTP was tested on humans (in the mid 1980s), the procedure followed an unusual script. Since there was no proper cyclotron in Uppsala at the time, Långström would produce small quantities of the substance in Stockholm, put it in a small box and drive it to Uppsala at high speed. There, at a nearby PET scanner factory, he would join the patients along with Kjell Öberg, Professor of Endocrine Oncology, and Öberg’s PhD student Barbro Eriksson. Before being shipped abroad the scanners at the factory needed to be tested, and since the University had no full-body PET camera at the time, the soon-to-be-shipped scanners were used
in its experiments. This unorthodox way to scan patients stopped, however, when the PET Centre was established and the PET researchers obtained a scanner of their own.

The tracer development and employment of PET in endocrine oncology research proceeded as usual, but it also became clear that the use of 5-HTP was unlikely to spread to other PET facilities. While these radiotracers were highly useful for finding the exact position of small tumours, they were extremely tricky to produce: the synthesis of 5-HTP involves 21 enzymatic steps, which means that highly skilled chemists are needed to make it work. Furthermore, since carbon-11 has such a short half-life there needs to be a cyclotron in the Hospital’s immediate vicinity. In addition, the process itself is costly and requires numerous employees. Nevertheless, given the great sophistication of this method of localising small endocrine tumours, over the years several research groups have come from abroad to learn how to synthesise 5-HTP at the Uppsala PET Centre. To this day, however, the only PET research group outside Uppsala that has mastered the process is one at a Dutch PET centre in Groningen. As a consequence, patients showing signs of hormone-producing tumours and needing to have the tumours localised have only two places in the world to go: the Netherlands and Uppsala. Being the pioneers and foremost specialists in the method, Uppsala University Hospital has attracted a great number of patients over the years, including distant countries like the US, Canada, Australia and Saudi Arabia.

The development of 5-HTP was thus a collaborative effort between the PET research team and medical doctors at the Department of Endocrine Oncology at the University Hospital. The boundary between patient care and clinical research is often blurred, and genuine examinations of patients become seamlessly integrated into research projects. This was very much true of the development of 5-HTP, where research efforts included the use of the tracer as a diagnostic tool for patients with suspected endocrine cancer.

4.4.3 International collaboration in independent research

The development of 5-HTP was thus the product of home-grown collaboration, but other joint research efforts of the PET Centre extended well beyond the borders of Uppsala and Sweden. One such international project was initiated soon after the PET building was finished in 1991. A Japanese institution, the Research Development Corporation of Japan (JRDC), decided to fund free research at the PET Centre for a period of five years – from 1 January 1993 to 31 December 1997 – to enhance its

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18 The Research Development Corporation of Japan (JRDC) merged with the Japan Information Centre of Science and Technology (JICST) in 1996 and became the Japan Science and Technology Corporation (JST). The organization changed name in 2003 to the Japan Science and Technology Agency but retained the same acronym (JST).
knowledge of PET and expand its international collaboration. Japanese researchers had been coming to work with Långström for almost a decade prior to the research agreement with JRDC, and the collaboration was set up thanks to one of Långström’s Japanese colleagues. Although the Centre was also supported by the Swedish National Board for Industrial and Technical Development (NUTEK)\(^{19}\), it was JRDC that funded the entire endeavour. The PET Centre received approximately SEK 25 million a year, which covered the Centre’s financial needs for the period as far as independent research was concerned.

The topic of the project was sub-femtomole biorecognition, where “sub-femtomole” denotes a concentration of \(10^{-15}\). The central idea was to use the strength of PET to obtain enough information about biological matter, such as proteins, from very low chemical concentrations by means of radioactive isotopes. Under the direction of Långström and Professor Yasuyoshi Watanabe of the Osaka Bioscience Institute, the researchers used PET not only as an imaging technology, but as a tracer molecule technology. Making extremely small amounts of substances, they sought to define the molecular mechanisms of biological communication with chemical compounds labelled with radioisotopes. Methods for labelling substances with specific isotopes, such as carbon-11 and nitrogen-13, were developed, and through these methods over 50 types of radiolabelled compounds were produced. This culminated in a new evaluation method in which slices of living brain, still metabolically alive and thus not just dead tissue, were used to study brain function in rats. The researchers managed to find the locations of information processing in the brain for colours, smell and sleep, for example, and in autistic children compared dopamine receptor levels before and after treatment. They also succeeded in illustrating how intake of a specific compound (acylcarnitine) affected various parts of the brain. Given the broad scope of the project, the researchers had considerable freedom to add new research issues that fitted into the general framework. One of the Uppsala PET researchers remembers the collaboration:

> “It wasn’t like you had a target, that you do this clinical study. Rather, it was general science within the field, biology and PET. You could put many different things into it. It was new ideas, it wasn’t like somebody had said, ‘This is what we’re going to do’ and then you had to stick to that. It was more ‘Now we can do this.’ It was like free research money (…)” (interview, Antoni, 2013).

Overall a highly fruitful scientific collaboration project, resulting in a large number of publications, it ended as planned in December 1997.

\(^{19}\) NUTEK was closed down in 2009 and merged with two other governmental agencies into the Swedish Agency for Economic and Regional Growth (Tillväxtverket).
A few years later a new collaborative undertaking began, and the findings generated in this project would soon prove to be of considerable scientific importance. The focus of the project was pathologies in the brain, a topic that had been attracting massive attention from researchers for decades. In 1983, well before the Uppsala PET Centre was founded, Bengt Långström had conducted the world’s first occupancy study jointly with an American research group. Using PET, they had succeeded in imaging dopamine receptors in the human brain. Making it to the front page of Science in September 1983, the images from the PET scans displayed the brain with butterfly-shaped colorations indicating regions of activity – today a common type of brain visualisation that we may recognise from popular science articles on brain research findings. Among the PET researchers, the study results aroused intense interest in such brain diseases as schizophrenia, depression, dementia and Huntington’s disease, and today most tracers are actually designed to study and diagnose various brain pathologies.

The collaboration project in which the Uppsala PET Centre became involved a few years after its collaboration with JRDC ended had a research problem revolving around Alzheimer’s disease, a form of dementia in which parts of the brain begin to degenerate, eventually leading to death. At the University of Pittsburgh in the US a geriatric psychiatrist, William E. Klunk, and a radiochemist, Chester E. Mathis, had identified a compound that they believed could be used as a PET imaging agent to investigate Alzheimer’s. This disease can be definitively diagnosed only by finding out whether “beta-amyloid plaques” and neurofibrillary tangles are present in the brain tissue or not. The presence of these plaques and tangles are the distinctive indication of Alzheimer’s disease, but the exact diagnosis can typically be made only at autopsy. Consequently, although the gradual cognitive deterioration of the patient can be analysed, clinicians are unable to monitor the pathological progression of the disease.

As a result, there is no clear understanding of how amyloid deposition in the brain is related to the cognitive degeneration induced by the disease. The need for a way to examine the process of amyloid deposition has been prompted by the development of drugs designed to remove beta-amyloid, a peptide that is a component of the amyloid plaques in the brain. When these therapeutics enter clinical trials, a tool is needed to evaluate their effectiveness, and this naturally has to be done while the patient is still alive, obviously ruling out post-mortem examination of the brain. The findings of the Pittsburgh team addressed precisely this need. What Klunk and Mathis identified was a class of neutrally charged substances with properties that made them suitable as a PET imaging agent. One compound in particular ([N-methyl-11C]2-(4-methylaminophenyl)-6-hydroxybenzothiazole) turned out to be especially useful: tagged with the radioisotope carbon-11, this substance images beta-amyloid plaques in neuronal tissue. The PET scan thus indicates
whether the human subject suffers from Alzheimer’s disease and how the
disease is progressing. Wanting to move the project forward, the group at
Pittsburgh contacted the Uppsala PET Centre to have the compound tested
in humans for the first time. The Centre was renowned for its capacity to
rapidly manufacture various types of tracers, and Klunk and Mathis were also
aware that permission for the type of trial they wanted to do was easier to
obtain in Sweden than in the US. Since it was the second substance sent to
Uppsala from Pittsburgh, the PET researchers called it “Pittsburgh
compound-B”, and it is now known by its abbreviation “PiB”.

In this first clinical trial of PiB, conducted in February 2002, amyloid
plaques that had hitherto been studied only post-mortem in brain slices from
Alzheimer’s patients became visible in living human beings for the first time
ever. Not surprisingly the results of the study attracted major attention in the
scientific community, leading to a number of very well-cited publications for
the Uppsala researchers and the Pittsburgh team. After this initial study in
Uppsala, several other research institutions began using PiB as a research tool.
Uppsala, meanwhile, expanded its collaborative activities further.

4.5 Research involving industry and free science

In the 1990s, the partnership with the Japanese research institute was not the
only important and well-funded collaboration under way. The PET Centre
was also engaged in a five-year research project with pharmaceutical giant
GlaxoSmithKline (GSK), focusing on radiochemistry and pre-clinical PET. In
the contract between the two parties the PET scientists were able to propose
research topics, and all major studies on humans had a budget of their own,
separate from the general contract. By and large the collaboration was fruitful
for everyone involved, generating a great deal of academic publications and
new knowledge that was useful to GSK.

20 The reason for this lay in an idea called micro-dosing, a concept that had originated with
Långström and two other researchers at the Centre, Mats Bergström and Anders Grandén. In a
publication the three scientists had argued that in clinical studies where only extremely small
quantities of a new substance – a micro dose – were being injected in humans, there ought to
be a mitigation of the rules in terms of the toxological data needed to do the trials. The
introduction of a new compound for testing on human subjects normally requires extensive
toxological information so as to minimize the health risk of the participants in the study. But
the proposition if the Uppsala researchers to allow a relaxation of these safety regulations for
trials involving micro doses gained widespread support. Eventually micro-dosing was formally
adopted by EMEA, the European Medicines Agency. In 2006 the Food and Drug
Administration (FDA) in the US followed suit.
4.5.1 PET services for the University Hospital

The Hospital’s involvement in PET activities has already been touched on in the account of the development of the radiotracer 5-HTP, where scientific work and diagnosis of patients with endocrine cancer merged. Over the years the University Hospital has used PET to precisely diagnose disease, but also to oversee response to treatments. The bulk of the PET scans performed use FDG to find out whether patients have cancer tumours and, if so, how many. Since PET is an expensive technology, and because there may in some cases be cheaper alternatives, the actual number of PET procedures that have become part of clinical routine is limited. However, if the goal is to really understand a medical condition, PET constitutes a very valuable tool. At some point, PET applications that have not yet been integrated into clinical routine may also eventually become more than just the subject of research, as the example of 5-HTP shows. After years of extensive research, use of the tracer 5-HTP to detect neuroendocrine tumours, as well as to monitor therapies for endocrine cancer, is now standard routine in medical practice, enabling Uppsala University Hospital to annually diagnose and treat about 120 patients suffering from endocrine cancer.

When the decision to turn the PET Centre into a privately owned enterprise was made, the PET scientists at Uppsala had been at the forefront of their research field for well over two decades. Major discoveries and developments tied to radiolabelled molecules had been made at the Centre, in collaboration with international teams as well as with medical doctors and clinical researchers from the University Hospital. As an indispensable component of PET technology, radiotracers had not only been the focal point of independent research endeavours, but had also been utilised for routine PET scans as part of clinical practice at the University Hospital as well as for contract research. With the ownership of the PET Centre being transferred to the commercial sector, tracers were now to be used under new conditions. Much in the same manner as I have so far attempted to describe the evolution of tracers and the associated scientific activities at Uppsala, the next part of this chapter continues this exploration, but in the changed landscape that followed the purchase of the PET Centre by Amersham.

4.6 The private sphere (2002-2010)

The world outside the walls of the University as imagined by the research group at the PET Centre, not least its Director Bengt Långström, was one of opportunity. Långström and his co-workers, most of whom had never been employed outside academia, looked to the future with confidence, convinced that great science would be duly recognised in the world of business. In addition, and importantly, they believed that the business sector would
translate recognition of their innovative ideas into the form ultimately necessary for taking any scientific exploration a step further: money. This was the expectation with which the Uppsala researchers entered Amersham. A steady influx of resources from the parent company would, they thought, ensure the PET Centre’s continued scientific success.

While this concern of the PET Centre to maintain its ability to conduct cutting-edge research was not at odds with Amersham’s wishes as such, the interpretation of what exactly made great science great, and what kind of greatness was required for the researchers to access financial resources, would prove to be a cause of serious dissent. In fact, this issue was to become the subject of much debate between the Uppsala researchers and Amersham, and later between the researchers and GE Healthcare. The PET Centre remained a centre for PET throughout. PET scans were performed continuously, although the relative proportions of hospital services, fee-for-service studies and free research were changing as a result of the new ownership structure.

4.7 A new scientific direction

As described in the Chapter 1, when Amersham stepped into its new role as the owner of the Uppsala PET Centre it had essentially two strategic objectives. It was intent on gaining knowledge in PET science, and it wanted to get close to big pharmaceutical companies through the wide network that the PET researchers had built up over years of industrial collaboration. Understanding the scientists’ wish to keep up their independent research despite the new management, Amersham started off with a generous gesture. By offering a large sum of money to be used as a research fund for life science projects, the company clearly signalled its appreciation of academic science. The portion of this money granted to the PET Centre was enough to keep the researchers there busy for some time, but the need for more research funding would soon become pressing.

However, research resources were not handed to the PET Centre in the way the Uppsala scientists had imagined. The simple rule in Amersham was that, in order to receive financial or other support for research, the Centre had to make a contribution to the parent company in terms of commercially interesting ideas. And although the Uppsala PET Centre did not suffer from any lack of innovative spirit or scientific skill, its staff were having a difficult time coming up with research ideas that appealed to the owner. As a company concerned with revenue – an inescapable feature of any profit-seeking organisation – Amersham was mainly occupied with PET applications that somehow involved molecules labelled with fluorine-18. With their comparatively longer half-life and the resulting shipping option mentioned previously, fluorine-18 is the only isotope of any real industrial
significance to this day. For the Uppsala team, which consisted of highly accomplished chemists, working with fluorine-18 was not a problem per se. However, the fact remained that the primary expertise of the group lay in carbon-11, which was the research area once pioneered by Långström. Thus, research based on fluorine-18 may not have involved scientific questions closest to Långström’s heart. Fundamentally, in its attempts to generate commercially promising ideas the Uppsala group was guided by its members’ scientific interests. These did not generally coincide with the interests of Amersham and, later, GE Healthcare. The parent company wanted to gear the research towards topics connected with common, widespread ailments, where a broad, lucrative market would await whatever PET applications came out of the research. However, the PET researchers tended to focus their energy on illnesses that were considered more “niche”. At one point Långström suggested a collaboration project aimed to take 5-HTP into the commercial clinical market, but was met with scepticism since, after all, endocrine cancer is not one of the most common cancer forms. In other words, the Uppsala researchers still wanted to investigate tracer molecules that targeted very “narrow” diseases. Thus, their prospects in terms of markets and business opportunities were correspondingly restricted in scope.

4.8 Tracers at the Hospital

As far as the University Hospital was concerned, the agreement was for services to the Hospital to be delivered as before the acquisition. However, while the Hospital’s needs had not changed, the pricing of imaging agents had. The tracer molecules, which had hitherto been sold as a package deal with the PET scans priced below actual production cost, would no longer be sold at a loss. Instead, the University Hospital was to be charged the cost price of producing the tracer and performing the PET scans. Nevertheless, being a public institution with limited funds, the University Hospital reacted strongly against Amersham’s approach to pricing, arguing that it could by no means afford such sums for tracers. After some discussion, adjustments were made, making the price of FDG lower than Amersham had first suggested. On the other hand, with its labour-intensive and difficult production process, the 5-HTP radiotracer was deemed to warrant a significantly higher price than before, thus balancing out the fall in the price of FDG. Consequently, PET scans for patients with endocrine cancer became much costlier to perform.

From time to time GE Healthcare would voice considerations about cutting down on the clinical services it offered the University Hospital – a prospect that caused concern among its doctors. In addition, some of these doctors experienced access to the PET facility to be lacking at times, partly
because the cyclotron would sometimes break down. This was seen as particularly troublesome given the rising demand for FDG scans. The Hospital also had some financial considerations regarding the FDG service, which eventually resulted in a purchase of a PET scanner of its own, to be placed in the Department of Nuclear Medicine. Having its own PET scanner, the Hospital no longer needed to buy the entire service package from the PET Centre – a package including tracer manufacture, PET scan and analysis of the scan. Instead, it was now able to choose to buy only the tracers from the PET Centre, or in the event of occasional unavailability at Uppsala, could opt to purchase FDG from Turku, Finland, or from Karolinska Hospital in Stockholm.

Interpretation and analysis of scans broadly call for medical expertise. The Hospital thought it more cost-effective to ask its own doctors to perform these tasks, instead of using the doctors engaged by the PET Centre on a day-to-day basis. The reasoning was that the doctors who worked full-time at the Hospital could tend to other duties between scan analyses, while the doctors who would be appointed by the PET Centre were stuck at the facility all day, with little opportunity to complete other patient-related tasks between one scan reading and the next. Furthermore, with a PET scanner of its own the Hospital saw an opportunity to sell FDG scans to hospitals in other counties, thereby bringing in some revenue.

4.9 Research: independence versus fee-for-service

Bringing in a more pronounced emphasis on profit, or at the very least economic sustainability, the acquisition of Amersham by GE Healthcare meant that costly aspects of operations at the Uppsala PET Centre had to be either made less burdensome or eliminated altogether. This put the Centre’s independent research in a precarious situation. Having managed to retain a good portion of the free research during the initial phases of Amersham’s takeover, the PET researchers now saw how GE Healthcare’s emergence on the scene seriously jeopardised their output of novel science. Since the resources needed to conduct experiments were being cut so as to alleviate the financial problems of the company, the scale of independent research began to decrease so far as to risk being almost entirely squeezed out. Apart from dampening the spirits of the PET researchers, this dwindling of free research had an adverse effect on fee-for-service business.

The Uppsala PET Centre had always had a distinct scientific profile, never doing contract research solely to make money, and accepting only industrial assignments it was certain of being able to carry out with great precision. However, although the ability to make exact measurements and flawless deliveries is vital to obtaining new contract research assignments, it is not the
only factor considered by pharmaceutical companies when they look for academic collaboration partners. To stay attractive on the fee-for-service market, a PET Centre has to maintain a certain academic quality, which is feasible only if a considerable part of the Centre’s operations is devoted to free research. Since the priority at Uppsala was now contract research and opportunities to pursue independent research projects were seriously constrained, the Centre started to lose status and attractiveness on the contract research market. In spite of this development, GE Healthcare’s strategy did not change: tracers continued to be produced primarily to be used in PET experiments conducted for industry and in clinical applications for the University Hospital.

4.10 An instance of successful collaborative research

Several aspects of the IMANET venture, of which the Uppsala PET Centre was part, did not go as well as planned. The research ideas of the scientists at the parent company and those at the Uppsala PET Centre never really seemed to coalesce into joint projects, and the fee-for-service business did not generate enough revenue to fill the financial gap resulting from the expenses of running the PET Centre. Moreover, the most salient part of Amersham’s original business plan, to access drug companies’ information on failed molecules, largely fell through. Gaining access to the intellectual property (IP) rights to these compounds, and thereby securing information of tremendous value to tracer development, was much more difficult than anticipated. But in at least one particular respect, scientific activities at the Uppsala PET Centre were a source of excitement for Amersham and later, when it took over, GE Healthcare. Addressing the burning topic of Alzheimer’s disease, the collaboration project between Uppsala and the University of Pittsburgh captured Amersham’s attention. As the most common type of dementia among older people, irreversibly depriving sufferers of their cognitive capacities, Alzheimer’s disease is in urgent need of a cure. Consequently, the research on PiB being conducted at Uppsala and Pittsburgh was of massive interest to Amersham and, later, GE Healthcare.

Nevertheless, the substance that the teams at Pittsburgh and Uppsala had been working on, and the PET centres at both Hammersmith and Turku had been testing before they too became part of IMANET (in 2001 and 2003 respectively), had one important flaw from Amersham’s and GE Healthcare’s point of view: the radiolabel of the compound was the short-lived carbon-11 isotope. As pointed out above, a half-life of 20 minutes rules out any possibility of shipping, and the radiotracers are therefore of negligible, if any, commercial value to a company. To have any positive commercial implications for the producing organisation, the molecules would have to be
relabelled with the more long-lived fluorine-18 (110-minute half-life). However, making this kind of modification, with all the development work and testing it requires, entails a great deal of work. Even so, Amersham quickly realised the value of a transportable tracer that permitted imaging of amyloid plaques, and signed a licence agreement with the University of Pittsburgh.

Developing and testing PiB thus ceased to be the concern only of the researchers at Pittsburgh, Uppsala, Hammersmith and Turku. Instead, the testing was now being directed by Amersham and, as soon as Amersham had been acquired, by GE Healthcare. Now, to be precise, the subject of research was no longer PiB, but rather a fluorine-based analogue of PiB called flutemetamol F-18, which possessed all the properties of the original PiB but with a 110-minute half-life. Knowing that this tracer would be of crucial interest to the pharmaceutical industry in its attempts to develop drugs for Alzheimer’s disease, Amersham and later GE Healthcare were prepared to invest much time and money in this project. Ownership of the PET Centre was transferred to Uppsala University Hospital in autumn 2010, but development work on F-18 flutemetamol continued with the same Uppsala PET researchers as before. The terms of the researchers’ employment had changed, but certain aspects of scientific activities at the Centre would remain the same.

### 4.11 Back in public ownership (2010-)

All parties with a stake in the scientific activities at the PET Centre in Uppsala – GE Healthcare, Uppsala University, the PET researchers and, of course, the management and doctors at the Hospital – had ideas as to how PET would be used after the University Hospital had assumed ownership of the Centre. The doctors, for instance, expected faster handling of PET scans for patients suffering from endocrine cancer. The University hoped to see a revival in academic research, perhaps including development of new tracers. The PET researchers wished for good conditions in which to do research. And importantly, GE Healthcare, now freed from any responsibility for infrastructure and personnel, still wanted to assign work to the Centre’s researchers. The new contractual arrangements included a “guarantee sum” of SEK 15 million, to be paid out by GE Healthcare to the Hospital for three consecutive years, in exchange for having the PET Centre at its disposal. What GE Healthcare wanted was to have the Uppsala researchers conduct experiments for the company’s own research studies, as well as doing fee-for-service business for the drug industry, but with GE Healthcare as the contractor.
In other words, in return for the guarantee sum GE Healthcare would be able to purchase services from the PET Centre, the cost of which would be deducted from the sum. Unless the entire sum had been used up, GE would have the right to conduct contract research at the PET Centre and keep the revenues that amounted to the remainder of the guarantee sum. GE had obtained exclusive rights to carry out contract research in which experiments were carried out on humans, while the PET Centre now had the right to manage its own contract research studies only when experiments involved animals. Thus, on the one hand, the PET Centre would have a guaranteed inflow of money through the payment GE made every year, but on the other it would not have the opportunity to carry out lucrative clinical contract research studies. As disadvantageous as some perceived this part of the contract to be, the County Council felt it had little real choice and, given its own constrained finances, was obliged to accept the offer.

This arrangement affected the use of tracers. In agreeing to cover a good portion of the annual running costs of the PET Centre – essentially the function of the guarantee sum – GE Healthcare had significant influence over what type of isotope to produce, which tracers to synthesise and when to perform these tasks. Basically, tracer production had to match requirements. The tracers produced were therefore the ones needed to carry out fee-for-service studies, not seldom carbon-11-based, as well as whatever compounds were needed for GE’s own internal development projects. Manufacture of fluorine-18 was crucial too, mainly owing to the large-scale production of FDG, but also because it would be needed for several years in the continuing testing of F-18 flutemetamol, the modified PiB tracer described above. Some researchers in the Uppsala group were involved in helping to perform this testing until the very end of the development project, jointly with research teams in the US and India. GE Healthcare’s hope was that this project, which started in 2003, would yield not only a much-desired tracer that would most likely be of great clinical use, but also an entire system around it to facilitate on-site production.

The Uppsala PET researchers’ contribution to the project was to determine whether the molecule was good enough for actual clinical use – a step requiring extensive clinical testing. To justify the claim that the tracer met clinical and regulatory demands, PET scans needed to be run on at least 100 patients and an equal number of healthy volunteers. This undertaking was much too costly for an academic institution to ever carry out on its own. At the PET Centre, clinical testing of substances was generally limited to 10 or 20 people. In 2014, after a decade of development and testing, F-18 flutemetamol, under the product name Vizamyl, was approved by the Federal Drug Administration (FDA) in the US as well as the European Medicines Agency (EMA), and it is now available on both the American and European markets.
Part of the PET Centre facility was also being used by GE Healthcare to produce FDG. Running the PET Centre’s cyclotron at night about three times a week, GE Healthcare made enough FDG to serve the needs of nearby hospitals as well as Uppsala University Hospital. From mid-2011 a marketing licence was required to produce and sell FDG in Sweden, and while the Uppsala PET Centre lacked such a permit, GE Healthcare acquired one. The trend of using FDG, a highly useful tool in oncology, for PET scans of cancer patients shows no sign of diminishing. Although relatively slow to incorporate PET in oncology routine, Uppsala University Hospital eventually increased its use of FDG in the diagnostics and monitoring of cancer. Indeed, FDG scans are the most frequently performed scan at the PET Centre and the Hospital. Nonetheless, the radioisotope that dominates in terms of production is not fluorine-18, but carbon-11, a circumstance that can be partly explained in terms of utilisation efficiency. While every batch of FDG can be used by up to ten patients, each load of carbon-11-based tracers covers only one to three patients. In addition, carbon-11-based substances are still the ones most frequently used in research at Uppsala.

During the first year after the County Council and the University had taken over, there were complaints from the Department of Endocrine Oncology. It was claimed that the wait for PET scans was too long for the Department's patients, who, as mentioned earlier, required 5-HTP to be diagnosed and monitored. The feeling among staff at the Department had been that GE Healthcare, during its last few years as owner of the Centre, had not been particularly responsive to the Department’s need for the carbon-based specialty tracer and its wish to give its patients prompt access to the facility. Basically, from some doctors’ point of view, GE’s contract studies blocked their access to the cyclotron and scanners, causing waits of several weeks – delays they deemed unacceptable. Staff at the PET Centre, on the other hand, argued that the scanners were hardly ever fully booked, that there were always chemists working in the lab capable of synthesising the desired tracers, and that a few weeks’ wait should be compared with the long months the average patient had to wait for surgery. Either way, one year into the University’s and the Hospital’s takeover, clinical routines had fallen into place for the Department of Endocrine Oncology as well: it no longer experienced any problems in terms of either long waits or slow handling of scan analysis.

A major change that has affected operations at the PET Centre, as well as the stream of revenues, is the decline in contract research business. It is unclear what has caused this decline and whether it is something affecting the Uppsala PET Centre alone or other PET centres as well, but part of the explanation for the decrease in business is probably the restructuring of the pharmaceutical industry. As drug companies started to acquire one another – for instance, Pfizer buying Wyeth and Merck buying Organov – the number
of pharmaceutical customers consequently shrank. Companies the Uppsala PET Centre used to work with disappeared as they were purchased by other firms. Additionally, the past decade had seen a decline in the number of new pharmaceuticals launched on the market, possibly also affecting the drug industry’s demand for PET studies. Nonetheless, although the number of fee-for-service studies conducted by the PET Centre over the past few years has been very low, it still has at least one project under way at any time. However, there is no indication that the number of studies will be increasing in the near future.

With the low activity in fee-for-service research, the bulk of science that is being conducted after the decommercialisation of the PET Centre is independent. At the pre-clinical section of the facility, efforts are concentrated on mapping biological processes in the body and developing new tracer molecules – something that cannot happen overnight with a team consisting of just a handful of chemists. On the clinical side, where the bulk of the operations is devoted to clinical routine, ongoing research mainly concerns testing, for instance, how well a certain PET tracer works in terms of providing information about the effectiveness of a therapy. To put it differently, the PET Centre has adapted to the new circumstances and, although the development of new radiotracers has not yet been as fruitful as some may have wished, new knowledge is being produced and tracers are still being manufactured and used in both research projects and routine clinical work.
Chapter 5. Facilities

It is difficult, if not impossible, to identify a field in science where equipment does not play a critical role in scientists’ ability to conduct their research. PET is no exception: without the apparatus it would not exist. PET scanners, cyclotrons and hot cells, as well as facilities safe enough to permit handling of radioactive materials, are the main components of the indispensable hardware without which no PET science or clinical use of PET would ever take place. What is more, development of PET tracer molecules requires not only machines, but also living subjects on which to run tests to assess the effectiveness of tracers and methods. In other words, the physical resources necessary to do PET research comprise both technical devices and living organisms.

In attempting to trace the evolution of the Uppsala PET Centre, it helps to keep this dependence on physical research resources in mind. In fact, it may well be that the PET Centre’s journey of commercialisation and decommercialisation can be understood only in light of the expectations, hopes, conflicts, tensions and excitement surrounding the very artefacts that make PET research possible. Much as the previous chapter used radiotracers as the point of departure in its rendering of events, in this chapter the story of the PET Centre will be told from the perspective of physical facilities. Here, the word “facilities” is used broadly to encompass not only buildings and technical instruments, but also various species of laboratory test animals. We will thus retrace our steps and start the PET odyssey anew, this time focusing on the scanners, cyclotrons, computers, monkeys, laboratories and other tangibles that have all formed a part of the Uppsala PET Centre.

5.1 Machines

On stepping into a facility where PET research is conducted, one is struck by the size and complexity of the technical system that PET comprises. The cyclotron, which in Uppsala is located in a separate room protected by thick concrete walls adjacent to the main laboratory, is monitored and controlled with the help of computer software. The output of the cyclotron, i.e. the radionuclides, is automatically fed into the hot cells, which are shielded nuclear radiation chambers where the chemistry is done to synthesise the
tracer molecules. When a synthesis is completed it is, in most cases, transported automatically to the room housing the PET scanner, where the subject is injected with the tracer. The room containing the scanner must be shielded because of the radioactivity of the tracers handled there. The scanner collects the data, which are then modelled in a computer and eventually interpreted and analysed by a specialist. This brief account of how a PET scan is done roughly sums up the machine park of a PET facility: hot cells, scanners, computers and a cyclotron. Although each part of this complex chain of technologies is essential for the working of the total system, two instruments in particular stand out, in terms of both cost and their role in PET: the cyclotron and the PET scanner. The next three sections briefly explain how they function and provide some background on the two machines.

5.1.1 Cyclotron

A cyclotron is a circular particle accelerator in which charged particles are made to accelerate from the centre in an outward trajectory, following a spiral path. The acceleration is caused by a varying electric field and the spiral motion is maintained by a static electric field (see Figure 5.1). The charged particles accelerate until they have reached a certain energy level, after which they come out through a pipe. They are subsequently made to collide with some material, and at the collision site the desired nucleotides are created. Depending on the types of material the particles collide with, various radionuclides are created, i.e. the nature of the colliding material determines what type of radionuclide the original particle becomes.

![Figure 5.1 The cyclotron principle](Image courtesy of Rod Nave)
Invented by the American physicist Ernest Lawrence and his group at Berkeley in 1929, the cyclotron has a long history as a tool for research. For decades, cyclotrons were used to make high-energy beams for experiments in nuclear physics. From the 1950s, which saw an increased interest in conducting biomedical research using short-lived radioactive isotopes, cyclotrons were used to produce the radionuclides the scientists wanted: carbon-11, nitrogen-13, oxygen-15 and fluorine-18, the simplest atom building blocks of living organisms. Hammersmith Hospital in London was the first hospital to have a medical cyclotron on its premises. It was built in 1955, and the success of the experiments it was used for prompted the Washington University Medical Center, the University of California at Los Angeles (UCLA) and the University of Chicago to have cyclotrons installed as well (Wagner, 1998).

Cyclotrons are also used in particle therapy to treat cancer, penetrating the body and killing tumours by radiation damage. Over the years, the cyclotron has been greatly developed and improved, not least positively affecting the safety of its operation. One of the most conspicuous differences between new and older cyclotrons is in size: while modern cyclotrons are compact and powerful, older machines with the same power can easily fill a room. The one at the PET Centre in Uppsala is quite large, measuring 180 centimetres in height and a few metres in diameter. Figure 5.2 depicts the cyclotron at the Uppsala PET Centre.

![Figure 5.2 The cyclotron at the Uppsala PET Centre](image)

Photo courtesy of Patrik Nordeman
5.1.2 PET scanner

In the late 1950s David E. Kuhl and Roy Edwards introduced the notion of emission tomography – “tomography” refers to imaging by sections by means of a penetrating wave – and this soon resulted in the design and building of several tomographic devices. In the early 1970s Kuhl and Edwards built a tomographic imaging instrument for single-photon emission, and around the same time James S. Robertson constructed the first positron scanner with detectors arranged in a ring. The introduction of these cameras marked the beginning of fully developed PET scanning. The basic principle of a PET scanner is detection of pairs of gamma rays. As explained in the previous chapter, the tracer that flows through the body emits positrons, which are positively charged electrons. The positrons travel up to a few millimetres before crashing into an electron, resulting in the annihilation of both particles as well as the simultaneous emission of two gamma rays moving in almost opposite directions, nearly 180 degrees apart. Every minute millions of positrons are released, each one resulting in a pair of gamma rays.

The PET scanner is a hollow cylinder in which the living subject is laid (see Figure 5.3 for a picture of one of the PET scanners in Uppsala). When gamma rays are emitted, they are captured by hundreds of crystals inside the scanner. As the gamma rays collide with atoms in the crystals, photons of light are released. These photons subsequently travel through the crystals to small tubes where the light power of the photons is magnified. This magnified light is registered by light detectors, which line the entire circular perimeter of the scanner. The scanner is so designed that when two detectors are set off at almost exactly the same time, the machine “assumes” that a positron must have been released on or very close to the line connecting the two crystals where light has been detected (see Figure 5.4). The scanner collects the data in the form of “slices” of the investigated part of the subject, much like the slices of a loaf of bread. Compiled, these slices of data render a three-dimensional PET image.
Figure 5.3 PET-CT scanner at Uppsala University Hospital (in the picture: Mimmi Lindholm, Kaisa Lyon, Dr. Gunnar Antoni and Dr. Jens Sörensen)

Photo courtesy of Uppsala University Hospital
5.1.3 Hot cells and what they contain

As explained in the previous chapter, synthesis of tracers, i.e. the process of combining a chemical substance with a radioactive label, takes place in a “hot
cell”. Hot cells are shielded containment chambers specially designed to enable chemists to handle radioactive material in a safe manner. Today, when most synthesis is automated, computers and robots are important tools involved in the process.

5.2 Use of the facilities

The remainder of this chapter will deal with the use of the machines described in the preceding section, as well as of other important physical scientific resources. The first part will delineate the use of the facilities during the years of University ownership, while the other two parts will deal with the same topic during the years of commercial ownership and of the joint Hospital–University ownership.

5.3 The University years (1989-2002)

The basement of the Gustaf Werner Institute for Nuclear Chemistry, a research centre founded in the late 1940s, was where Långström and his research group started experimenting with carbon-11 labelled molecules. Lacking a suitable cyclotron and a full-body PET scanner, their research experiments generally entailed certain logistic challenges. First of all, the nucleotides had to be produced. Since the scientists had no cyclotron of their own, they used the tandem accelerator located at the Institute. They would then rush back to the laboratory with the carbon-11 atoms in a container to do the synthesis. From there, they would drive to the nearby factory of Scanditronix, a producer of both PET scanners and cyclotrons, where the scanning was performed in one of the scanners at the facility. The situation was thus not ideal. Apart from the tandem accelerator being suboptimal for the type of particle production the PET researchers engaged in, the other scientists did not appreciate the wear and tear of their accelerator to which the PET group allegedly contributed. In the words of one physicist using the tandem accelerator for other experiments at the time:

“... Besides, we didn’t like them [the PET group] so much because they wanted to produce as much carbon [-11] as possible to make compounds, so they tortured our accelerator quite a bit. It was often pretty badly battered. So we often had discussions...” (interview, Sundqvist, 2010).

As for PET scanners, the University actually had one around this time. In the late 1970s, three neurologists at Uppsala had turned to the University management to ask for funding for a PET brain scanner. Tired of the inconvenience of having to transport their nucleotides all the way to...
Stockholm University to have the scans done, the researchers wanted to have a PET scanner at their disposal in Uppsala. Despite the heavy cost of the camera, the Faculties of Medicine and Mathematics & Science at Uppsala agreed to co-finance the purchase jointly with the County Council, and the neurologists were soon able to obtain interesting results thanks to the new PET brain scanner and, of course, the proximity of the isotope production. The brain scanner was purchased in 1982 and placed at the Department of Diagnostic Radiology. Initially it was used primarily in clinical research, but over time it was increasingly used in direct clinical application, eventually becoming a crucial tool in the care and management of patients.

A brain camera was thus in place. Nonetheless there was no full-body PET scanner at the University at the time. As far as Långström and his team were concerned, such a camera was needed, along with an accelerator suitable for efficient isotope production in PET research. Not only was the tandem accelerator suboptimal for the type of particle production PET requires, but access to the machine was also becoming more difficult. Since the use of PET in both research and clinical practice had increased, more time at the accelerator was needed. Multiple research teams from various disciplines were using the tandem accelerator at the The Svedberg Laboratory (this was the new name of the Gustaf Werner Institute as of 1986), and having the machine only one day a week – the time allotted to the production of PET isotopes – was not enough. Thus, when the efforts to collect financial support for a PET centre began in 1984, a cyclotron and a full-body PET scanner were obvious items on the wish list, along with an updated brain scanner and new synthesis equipment.

The chemistry work had hitherto been carried out in laboratories that belonged to the Department of Organic Chemistry, but these were considered insufficient to accommodate the increasing production of tracers and scans. Hot cells were therefore an essential item on the wish list, along with sterile spaces where the compounds could be analysed and controlled and a new regular chemistry laboratory to use for preparatory work.

The list included, however, not only new research instruments and an extra laboratory but a whole new building to work in. Ready to move out of the basement, the scientists wanted a proper facility designed for PET research. With the help of Martin Holmdahl, who as Chancellor of Uppsala University at the time had considerable influence, PET centre advocates managed to raise enough money to realise the PET Centre (in 1989). Both the cyclotron and the hot cells in the laboratory were donated by the Wallenberg Foundation, and a loan made the purchase of the PET scanners possible. It should be noted that this donation was expected also to benefit other medical institutions in the region. As a gesture of generosity the PET Centre therefore provided FDG tracers at low price to healthcare facilities lacking access to PET infrastructure of their own. The sum paid by the recipients was
negligible, and barely covered the production costs of the tracers. The County Council, who viewed the founding of a PET centre as a bold endeavour, and realised the importance of such a facility to the University Hospital, offered to finance the building on condition that the University would be paying rent. The new building, measuring 1200 square metres, would contain, in addition to the PET apparatus and hot cells, a section that allowed an increased influx of patients and healthy volunteers. The building was consequently to contain a reception and waiting area, as well as a room for pre-scanning medical preparation of patients by, for example, inserting catheters, adjacent to each scanner. Further, safe and swift transport of patient beds would be ensured by a corridor connecting the PET Centre with the Hospital. Moreover, to accommodate the PET Centre’s research activity, special rooms needed to be built for animal testing. These rooms would be adjacent to, but strictly separated from, the space used for the scanning of human subjects. In addition, the fact that some researchers would have the PET Centre as their place of work called for a kitchenette, a seminar room, a faculty lounge and, of course, offices. A small workshop would be necessary, too, for maintenance of the technical equipment. All in all it came together nicely, with each item on the list crossed off, and by 1991 the PET researchers and their equipment had been installed in the new building. The Centre was up and running.

One unfortunate aspect of some technical equipment is that it does not age well, or ages fast, in the sense that so much technological improvement is under way that machinery rapidly becomes obsolete and even antiquated. Alternatively, machines may in fact age fairly well and last for a long time but spare parts, if required, are hard to come by. Unluckily for PET researchers, both these forms of deterioration are true of their equipment: for PET scanners the former type and for cyclotrons the latter. A cyclotron can function for a long time, but its electronic components need to be changed once in a while, which can be tricky since spare parts for old machines are generally difficult to track down. An old cyclotron also needs continuous maintenance. As for PET scanners, they are good for about a decade but should then be replaced by an up-to-date model. In other words, the equipment the Centre obtained in 1989 had become, if not obsolete, then at least slightly outdated ten years later. This did not make them entirely unusable, but their performance was discernibly inferior to that of the machines available around the turn of the new millennium.

While the cyclotron and cameras had aged in an undesirable fashion in the researchers’ eyes, the PET Centre had in fact seen a new important addition to its facilities in this first decade of its operations. During the collaboration with the Japanese research team in the mid-1990s, a new pre-clinical laboratory had been built in an area called Glunten. It was located close enough to the PET Centre for the two units to be connected by culverts.
These enabled the researchers to transport tracers without having to go outside, and the new laboratory was a shared facility. Two-thirds belonged to the PET Centre and the remaining third to the Department of Chemistry. Moreover, in 1999 the Wallenberg Foundation made a timely contribution of some SEK 40 million to be spent on new PET scanners. Accordingly, the older cameras could be disposed of: one was sold to a research unit in the US, while the other was purchased a few years later by Lund University. As mentioned above, although the equipment was no longer state-of-the-art, it was still usable.

Nevertheless, the addition of a pre-clinical lab and new scanners did not change the fact that Långström and his group were dissatisfied with the cyclotron. It did not always work well, and there were discussions about buying a new one, and in that case where to put it. What Långström really wanted, apart from a new cyclotron and new scanners every ten years, was a new building for the Centre. First of all, the Centre was growing. The pre-clinical laboratory had enabled new exciting research problems to be tackled, and collaboration with the Japanese scientists during this period was fruitful. New people were being hired and the fee-for-service business was expanding. Långström wanted a place large enough to contain all these people and all this new, intense activity. In Långström’s own words:

“That’s when we outgrew the suit. That’s when I told the University, that if we are to continue with this we need a bigger facility, because we had built this [the original PET building] for another purpose” (interview, Långström, 2011).

Second, the current PET building was in need of reconstruction as a result of the imposition of new requirements on the laboratory environment and other matters. The PET researchers now had to adhere to a set of regulations called Good Manufacturing Practice (GMP), whose purpose is to protect patients’ health. While not providing instructions on how production should be carried out, GMP contains a collection of basic principles that direct the manufacturing and testing of medical or pharmaceutical products. The purpose of these is to guarantee a product of good quality. For quality control to conform to the new GMP guidelines, the PET Centre facility (built in 1991 when GMP was still unknown to the Uppsala PET researchers) would have to be adjusted. Faced with the new rules, coupled with the expansion of the Centre, Långström came up with a proposal.

What Långström and the researchers in his group envisioned was a new building: a spacious one with brand-new labs, brand-new hot cells and, needless to say, a brand-new cyclotron: it would be an amazing PET Centre. The only thing standing between the researchers and this building was a lack of money: the University had no means of paying for a new cyclotron, let alone a completely new building. Its academic pockets were simply not deep
enough. It was clear to everyone involved that, if the goal was to acquire financial resources for such a massive project, including funding for a new cyclotron and new scanners when needed, the PET Centre would have to turn to industry. The wheels were set in motion, and Amersham stepped on stage.

5.4 The private sphere (2002-2010)

No one should doubt the sincerity of Amersham’s interest in the Uppsala PET Centre. It persevered in the complicated one-year negotiation preceding the purchase in 2002, agreed to set up a fund for independent research in the life sciences at the University and, finally, paid a handsome sum (SEK 150 million) to the University for the Centre. All these actions bore testimony to Amersham’s zeal and determination to acquire the Uppsala PET Centre. The researchers, for their part, were pleased with the idea of changing owners, looking forward as they were to the perks they assumed went hand in hand with being part of a big corporation. One benefit would be higher salaries; another, they hoped, would be a generous supply of the research resources necessary to do excellent science. In particular, there was one part of the agreement – or what the PET scientists had perceived to be part of the agreement – that had struck a chord with the research team. As the team understood it, Amersham had made an important promise: to build the new facility, the large, well-equipped building that would contain everything a team of PET scientists could ever need for their research.

Planning of the new building began soon after the contract between the University and Amersham had been signed. A group consisting of a couple of consultants and a few researchers started the hard work of designing the new facility. All the scientists who used the PET Centre were given a say in the project, which is why the first version of the floor plans revealed an edifice that promised to be the embodiment of every PET researcher’s most extravagant scientific wishes. With the help of an interior decorator, the group had planned the layout of the facility in great detail: where the refrigerator would be; where the rooms for the lab animals would be located and what these rooms would look like; what material the desks in the laboratory would be made of; what the new hot cells would look like and how many they would have; how many parking spaces there would be; and where in the building the sauna they wanted would be. Had the plans ever left the drawing board and materialised into actual slabs of concrete and real-life steel rods, the structure would surely have been a scientific dream castle. A researcher at the Centre who participated in the planning of the building comments:
“So, it was a finished building that would cost in the ballpark of half a billion [SEK] to put up. Of course it became way too expensive, way too big. Everybody’s wishes were fulfilled. The chemists got everything they wanted, the pre-clinicians got everything they wanted, et cetera, so it became enormous” (interview, Antoni, 2010).

At 16,000 square metres, the planned building was “completely incomprehensibly large” in the words of Göran Beijer, who was appointed CEO of IMANET Uppsala in the midst of the planning of the building:

“I thought to myself: ‘How is this possible? How can they put such a big stake into it?’ It was going to cost so much money (…). When I came in they were hard at work, and there were lots of people from various consultant agencies involved in the planning. And there were architects, and there were lots of meetings and other things, so they were entirely serious about it. (…) At some point there was someone in top management in Amersham who looked at it and said: ‘No chance in hell. This will never happen. It’s way too big and way too expensive’” (interview, Beijer, 2011).

Faced with Amersham’s sudden unwillingness to pay for a building of such considerable size, the working group went back to the drawing board to work out how to downsize the building. All in all, it was reduced by approximately 5,000 square metres in an attempt to appease management. A few compromises were made and some aspects of the building that had bothered the British owners were changed. The PET researcher who helped to plan the new building commented as follows:

“In Sweden it’s self-evident that senior researchers have their own offices. In England it’s the boss who sits in a little glass office, while the other people sit together in the same room. But then we agreed that ‘in Sweden we don’t do it like that’ and ‘we have a Swedish culture here [at the Uppsala PET Centre].’ It was stuff like that, so we had to make compromises and make it smaller” (interview, Antoni, 2010).

While the planning of the new PET building reached its last stages, Amersham had, unbeknown to almost everyone at IMANET, entered into negotiations with GE Healthcare. Completion of a new facility for the Uppsala PET Centre was not high on the company’s agenda. Meanwhile at the Centre, people began to sense that no new building, regardless of size, was going to be erected after all.

“So towards the end of the planning work people knew it all was probably going to come to nothing. Relatively soon it became clear that no building would be constructed, and that pretty much sucked the air out of the organisation” (interview, Antoni, 2010).
Thus, despite all the efforts put into the preparations of the building project – not to mention the cost of this work, amounting to roughly SEK 20 million, enough to buy at least one new PET scanner – the project eventually came to naught. The scientists were deeply disappointed. The new building had been an essential ingredient in their vision of the research Centre and its future development:

“(…) That was the concept: we were going to expand. We’d hired people and gone from 35 to perhaps 45 or 50. And we saw how we would be about 70 to 90 people here after a few years, after we had moved into the new building, which would have been amazing. It would have become a world-leading place” (interview, Antoni, 2010).

“We were going to put up a new building – that was the promise. We did a fantastic planning and layout design for [SEK] 20–22 million, but in retrospect you realise that it was only a charade. That building would have been Mecca today, had it been built. But that wasn’t in the interest of Amersham (…). What they said was that they were going to build that research institution. It was an amazing building. It would have given us that integration of genetics and proteometrics. At that point we’d been working with these things for ten years, and we had so much knowledge” (interview, Långström, 2011).

The global head of R&D at Amersham Health, Bill Clarke, remembers the Uppsala researchers’ insistence on the importance of the new PET building:

“And all Bengt [Långström] really wanted was a new PET centre. He wanted God knows how many tens or hundreds of millions of kronor for the PET centre. And I spent days walking around fields in Uppsala looking at places where we could put this PET centre. I spent days talking to architects in Sweden, learning that in Sweden every office needs to have natural light coming into it, so you had to have a hollow centre of the building. (...) You know, that’s the level of detail we got into. And that was an incredible waste of my time, an incredible lack of insight on the part of those people. We hadn’t set – and this is everybody’s fault in Amersham – we hadn’t set (because we didn’t know) clear expectations of what this is about. This is about us getting paid expertise, yes, supporting some of their academic mission because we knew they could do interesting things and they still had to have some freedom.” (interview, Clarke, 2012).

However, meeting the researchers’ need for capital proved impossible. The truth of the matter was that, while money was being spent on designing the new building, losses had been accumulating. Running the PET Centre was expensive and there had been difficulties landing contract research deals with the drug industry. In addition, the whole business strategy, centring on the idea of securing IP rights tied to “failed molecules” from pharmaceutical companies, had been unsuccessful to date. In light of this financial and strategic gloom, the University’s representative on the IMANET Board, Lars Jonsson from the University’s holding company UUAB, did not feel he was
in a position to push for a completion of the construction project. The Uppsala PET Centre therefore had to resign itself to its building from 1991, including the barracks that had been added to the facilities, primarily to accommodate new administrative staff after Amersham’s takeover in 2002. Two years had now passed since the PET Centre left the University, and GE Healthcare was the new owner. The cost-effective mindset of the giant corporation was immediately perceived in the Centre, not least with the imposition of new restrictions on a research resource considered vital by the scientists: animals.

5.4.1 Monkeys, pigs and rats

For many years, the PET Centre had access to a primate facility that belonged to the University. The origin of the lab dated back to the 1960s when a Swedish professor of obstetrics and gynaecology at Uppsala, Carl Gemzell, was running experiments on monkeys as a part of his research on reproduction. In the 1980s these animals became available to Långström and his group, and the primate facility soon became one of the Centre’s most important research resources. As is often the case with animal testing, and with testing on primates in particular, the facility was at times the object of controversy. The animals were kept separately, each in its own little cage, and inspection reports were critical in their assessment of the conditions in which the monkeys lived. In response to criticism, the University had a new facility built in 1994 in Törneby, a few kilometres south of the University, to which a group of monkeys – rhesus monkeys and marmosets – from the original facility were relocated. This time, the University took care to establish good relations with animal activists, and worked jointly with an animal rights group, the Swedish Society Against Painful Experiments on Animals (NSMPD), in planning the facility. The new space for the monkeys was large and similar to an aviary at a zoo, and the facility and the animal keeper in fact received a reward. The only real cloud on the horizon was the price tag: at an annual cost of almost SEK 6 million, the primate facility was extremely expensive.

Nevertheless, when time came to negotiate the terms of the commercialisation of the Uppsala PET Centre, the hefty running cost of the primate facility was initially not the major concern. Granted, one of the reasons for the slow progress of the negotiations was indeed the existence of the primate facility, but what particularly bothered Amersham was not so much the cost as the prospect of owning infrastructure that would be likely to attract unwanted attention from British animal rights activists. Owning a primate facility was considered too dangerous. What complicated matters further was that the University was not willing to be in charge of the facility either. They argued that hardly anyone used the monkeys apart from the PET scientists, save for the few occasions that researchers from the Departments
of Psychology and Sociology would go down and run some experiments on
the animals. Eventually, however, the two parties worked out a compromise.
Uppsala University would remain the owner of the primate facility, since it
was considered less dangerous for a University than for a company to back it,
while Amersham would put up the money needed to ensure the monkeys’
well-being, paying for all measures approved by its own veterinary officer.
With this arrangement, the researchers’ access to the facility was secured.

However, two years into GE Healthcare’s running of the PET Centre the
IMANET Board – following an initiative from Sue Matthews, CEO of
Uppsala IMANET at the time, and the University’s head lawyer, Marianne
Andersson – decided to stop funding the primate lab. This facility had
consumed some 10% of the PET Centre’s budget and everyone, including the
scientists, agreed that the cost was unacceptable. This did not mean that the
researchers were in favour of giving up the primate lab, the “unique world
resource” that had been of such crucial importance for their work (interview,
Långström, 2011). Långström, for one, wanted to own his resources, even
those he used only sporadically, which, after Amersham’s acquisition of the
Centre, had turned out to true of the primate facility. Lars Jonsson, the CEO
of UUAB who still had a seat on the IMANET Board at this time, advocated
a solution whereby the researchers would have continued access to the
monkeys, but would not pay the full yearly cost of a facility they now used
only on an irregular basis.

The answer to the problem was an agreement with the Swedish Institute
for Communicable Disease Control (SMI) whereby the PET Centre would
rent monkeys from the Institute. One of the PET researchers worked out a
deal with a person he knew at SMI: for SEK 600,000 a year the Centre would
have access to eight primates. The facility at Törneby was closed down and
after 12 years’ service the monkeys were sent to retirement homes. In a sense
the monkey problem was now solved, at least from GE Healthcare’s point of
view. The PET researchers, on the other hand, saw matters differently. While
the question of where to obtain their monkeys had been settled satisfactorily
– though perhaps leaving the researchers with a slight sense of having been
deprived of something valuable – the unresolved questions of how frequently
the animals could be used, and for what purposes, left the researchers feeling
discontented.

One of the cost-cutting measures introduced by the new owners had been
to stop the use of primates in independent research studies. Whereas
monkeys had been used both in free research projects and in contract
research prior to the commercialisation of the PET Centre, the animals could
now only be used in fee-for-service studies owing to the extra cost they
entailed. Requests from the researchers to use other animals, such as pigs and
rats, resulted in similar discussions, as did their inquiries about other, non-
living resources. This regime frustrated the researchers, especially since they
had previously viewed internal resources, such as animals, as in effect free of charge, being “covered by the budget” and thus not requiring any use of external funding. The consequence of the new structure was that academic research was essentially put on hold and the resources available were used almost exclusively for contract research.

From GE Healthcare’s point of view, this way of running the organisation made perfect sense. IMANET Uppsala was struggling with a sizeable deficit and, in the management’s eyes, the researchers had not been making the kind of contributions they had hoped for in terms of commercially promising ideas. Given these circumstances, and following a rationale of reciprocity, granting the scientists in Uppsala resources for academic research projects would be an indulgence entirely inconsistent with GE Healthcare’s philosophy. Overall, in other words, the PET Centre’s facilities were being used primarily for fee-for-service studies, and to some extent for collaborative research with GE Healthcare’s own scientists. This focus on research for industry was perceived not only by the PET scientists, but also by the University Hospital.

5.4.2 Dissatisfaction at the Hospital

The fact that the scientific activities at the PET Centre revolved around contract research meant that a certain schedule had to be followed for the Centre to be able to finish the studies they were being paid to carry out. One of the consequences of this was that the cyclotron, hot cells and scanners would often be tied up in projects for weeks at a time, making it harder for clinicians to access the equipment. This made it difficult for doctors to get routine PET scans done on patients, and near impossible to use the machines for clinical research. GE Healthcare’s priority list was roughly as follows: contract research and other industrial collaborations first, then clinical services, and pre-clinical and clinical research last. An oncologist at the University Hospital recalls the situation:

“They could say, all of a sudden, ‘Next week we won't be doing anything at all [i.e. no PET scans for the Hospital or its clinical researchers] because now we’ve got a contract with a Japanese firm.’ That was financially convenient for them, and something we couldn’t control” (interview, Haglund, 2011).

The problem of long waits was not a wholly new one, however. During the years when the University ran the Centre doctors would sometimes grumble over the time it would take to get a PET scan done and PET images analysed. What changed when Amersham and GE Healthcare came into the picture was essentially the magnitude of these problems, which were further aggravated by the fragile condition of the cyclotron. For two months every summer, when the staff would be away on holiday and the PET Centre closed
down, the cyclotron would be on a break as well, getting some well-deserved maintenance so as to be able to spit out radionuclides again come the autumn.

In combination, these problems made the PET Centre somewhat unreliable as a provider of clinical services, according to some doctors. This applied particularly in cases involving cancer patients, since these patients cannot afford to wait a whole month for a PET scan or analysis of results. As far as the Hospital’s oncologists were concerned, the situation reached a tipping point during the years GE Healthcare was managing the Centre. As a remedy for its problems the University Hospital, as mentioned in the previous chapter, purchased its own PET scanner, which enabled the doctors to have scans done whenever they wanted. Since most tumours are detectable with FDG (one exception being endocrine tumours, as discussed in the previous chapter), and the tracer no longer needed to be bought from Uppsala, the oncologists were not dependent on the old cyclotron. Nevertheless, the Hospital deemed the situation unacceptable and the University, anxious to give its clinical researchers the opportunity to use PET as a tool, agreed that something needed to be done. This is why they approached GE Healthcare in 2008, an action that resulted in GE Healthcare’s proposal that the Hospital and the University buy back the Uppsala PET Centre.

5.5 Back in the public realm (2010-)

The long, laborious negotiations between GE Healthcare, the University Hospital and Uppsala University strained the participants’ perseverance and patience. While the negotiations between the County Council and the University were fairly frictionless, the discussions that involved GE were more time-consuming, mainly because every decision and item on the contract needed to be firmly agreed with the US head office. Although many discussions dealt with IP issues, a great deal of time was spent regulating the use of the PET Centre’s facilities for the various parties. The question of how to divide responsibility for, and access to, the laboratories and machines had no obvious answer. To begin with, the cyclotron, the hot cells and one of the PET scanners had been owned by the University all along, even after the commercialisation of the PET Centre. Since the laboratories, the scanner and the cyclotron alike had been donated by a foundation – the Wallenberg Foundation – ownership was non-transferrable, i.e. these items could not be sold. When Amersham took over the PET Centre in 2002, it agreed to pay a yearly rent to the University for using the facilities, and when GE Healthcare took over, a similar settlement had been worked out. Now that it was the Hospital’s turn to run the greater part of the Centre, the terms concerning rights of use had to be renegotiated.
Whereas the University owned much of the equipment, the Hospital owned the actual buildings in which the equipment was kept, meaning that each party would, in a sense, be lending the other its share of the facilities. In the new deal the idea was that the University would own and be in charge of the pre-clinical part of the PET Centre, while the Hospital would take over the clinical activities, which constituted the major portion of the operations. Although this division meant that the University and the Hospital would be using the facilities somewhat differently, their needs would also overlap to some extent. One concern was the four hot cells: hot cells 1 and 2 were designed in accordance with GMP standards, and designated to be utilised exclusively in the manufacturing of radiotracers intended for clinical use. Hot cells 3 and 4, on the other hand, were used for research. The tracers produced here could be used in vitro or in animals, but not in humans. As for the question of who would be assigned which hot cell, there was no debate on either side that the Hospital would need hot cells 1 and 2, while the University had to have hot cell 4. Nevertheless, hot cell 3 was the cause of a lengthy discussion. Since it was slightly more advanced than hot cell 4, the University wanted access to it – a wish it shared with the Hospital, which at times also needed that particular hot cell to carry out certain steps of a process. Eventually the issue was settled, with the two parties deciding to share hot cell 3, but clinical needs in terms of patient care were to have priority as usual. In the words of Andy Browning from UUAB, one of the University’s representatives in the negotiations:

“It could be that the University needs the entire hot cell 3 two weeks in a row – if that’s okay, can one schedule it in a way that works for the Hospital? And there’s always the principle regarding the Hospital’s operations, which is that clinical work comes first” (interview, Browning, 2010).

A contract was worked out that would formally regulate both parties’ use of the facilities: the Hospital was given the formal right to use the cyclotron, the hot cells and the old PET scanner, while the University was also guaranteed access to the equipment and the laboratories. The University still owned some instruments that GE Healthcare had been leasing, and the Hospital now took over the leasing agreements, whereby a few payments remained before the cost would be fully written off. One of the many contracts contained a price list specifying, for example, the University’s hourly charges for using various items of equipment or for having tracers delivered.

Just as responsibility for the upkeep of the facilities had lain with Amersham and GE Healthcare when they owned the PET Centre, it was decided that it would now be the Hospital’s duty to ensure the equipment was being properly maintained. The ageing cyclotron was clearly the main challenge, with its old and thus barely replaceable electronic components. The cyclotron was, in fact, the subject of a bundle of issues that became
something of a stumbling block in the negotiations. It took some time to find satisfactory answers to such questions as, “Has the cyclotron been adequately maintained?”, “Can it be guaranteed that the cyclotron is in good shape?”, “Should we set up some type of damage control clause?” and “If it breaks within a certain period of time, who will be responsible?”

Yet another important issue connected with the cyclotron was GE Healthcare’s use of it. GE Healthcare wanted as much time on the cyclotron as it could possibly get, since it intended to manufacture FDG in bulk to sell to hospitals in nearby regions. However, the suggestion of using the PET Centre as a production site for FDG, and thus the University Hospital as the formal producer, was not received well by either the researchers or the Hospital. This was especially since the Hospital, as an actor in the public sector, was prohibited by law from engaging in this type of production for commercial purposes. The idea was therefore abandoned. Finally, GE Healthcare resolved to set up its own production unit adjacent to the PET Centre laboratory containing the hot cells, which would be dedicated solely to producing FDG. As mentioned in the previous chapter, however, GE still depended on the cyclotron at the PET Centre for its isotope production. GE Healthcare’s presence in the PET Centre had to be regulated and decisions made on how much time to reserve for research and PET scans for patients respectively.

Nonetheless, despite the ambition and care taken to put together an agreement that would please all parties involved – regulating their access to the facilities in a manner that corresponded to their respective needs – getting the plan to work in practice was not easy at first. As described in the previous chapter, the fact that the Hospital was now in charge of the greater part of the PET Centre did not mean that all medical doctors felt they had easy access to the cyclotron and the scanners. The problem from their point of view was what they perceived as the long wait for the scans they needed. A few months into the new ownership, one of the doctors at the Department of Endocrine Oncology described the typical sequence he would go through to get a PET scan done for a patient:

“I dictate a letter of referral, and then I go to the PET Centre. And then not much happens. Then I usually let my nurse at the clinic make a phone call, because she knows the nurse who works in the part [of the PET Centre], and then they usually have a discussion and a little combat, and [the nurse at the clinic] says ‘Yes, the patient will be back for a return visit on such and such a day – can’t we get an examination [PET scan] done?’ And after some juggling you get your examination. But it shouldn’t have to be like that. It should just be click-click-click” (interview, Öberg, 2011).

However, as explained in the previous chapter, this problem was resolved after a year. A change for the better was also soon observed where animal
testing was concerned, with pigs and rats being used in academic research once more. The rats were kept in the Rudbeck Laboratory at the University, while the pigs were rented from SMI. Since the public takeover, not one single monkey study, either fee-for-service or independent, had been carried out as of 2014. Regular research funding for academic projects does not cover the costs of the monkey experiments, which involve the cost not just of the animals, but also of the accompanying anaesthetic nurses and transporting the monkeys.

As for the regular machine park, it would need an update in the not too distant future. In 2013 the hot cells were considered old, worn and in need of replacement, as was the cyclotron (interview, Skogseid, 2013). In fact, the question of how long the old cyclotron would be kept was largely contingent on the maintenance person employed at the PET Centre. Hired in 1994 and with a background in GE’s cyclotron business, this repair man had specialist knowledge of the exact type of cyclotron placed at the Centre. In its service life of some 25 years, the cyclotron required a great deal of maintenance and, what was more, needed very specific spare parts. In fact, the know-how necessary to keep the cyclotron running was so specialised that a new cyclotron would have to be purchased on the day the PET Centre’s maintenance person left the job.

The PET Centre also possessed another piece of equipment whose unique nature ruled out the option of simply buying new standard gear the day it broke down. Uppsala’s ability to synthesise 5-HTP, which involved an extremely complicated process comprising 21 enzymatic steps, depended on a particular robot built by Bengt Långström, specifically designed to perform this synthesis only. The previous chapter mentioned that the only other institution in the world capable of synthesising 5-HTP is the PET centre in Groningen, in the Netherlands. This happens to be the only centre that also has a 5-HTP robot made by Långström. In contrast, the PET centre at Cornell University, US (whose staff visited Uppsala to learn the production sequence of 5-HTP), has a different robot (not put together by Långström). This may (or may not) explain why the Cornell researchers have yet to master the synthesis. Thus, when the day comes that Långström’s robot ceases to work, it is not obvious what the replacement – on which the future of 5-HTP is contingent – will be.

A new, arguably more straightforward investment will have to be made in the near future to erect the building that will house a new machine the PET Centre recently received funding to purchase. In competition with a number of other universities the PET Centre was selected by the Swedish Research Council to host the national infrastructure for PET–MRI (Magnetic Resonance Imaging), an advanced imaging technology (costing about SEK 43 million) that exists in only a handful of places worldwide. Moreover, in 2016 the Uppsala PET Centre was selected, along with only one other PET centre
in the world, to evaluate a new PET-CT scanner. Adding significant status to
the University and the University Hospital, the establishment of PET–MRI
and the testing of the new scanner indicate a bright future for the Centre and
the Hospital, despite the battle for financial resources that is the reality for
many public institutions.
Chapter 6. Organisation of the PET Centre

In the two previous chapters, the ambition was to recount the story of the Uppsala PET Centre by concentrating on two different aspects of the Centre’s evolution. Moving chronologically through 30-odd years of the Centre’s history, I described the PET venture with a focus, first, on the scientific output and, second, on the PET facilities. In so doing I presented relevant information on various forms of scientific use in terms of both tracer molecules and larger physical scientific resources, and in the process described some of the interactions between the people, units, departments and companies involved. For this third and last empirical chapter, the goal is to pay closer attention to the organisational aspects of the PET Centre.

The term “organisational aspects” warrants some clarification. In a sense, everything happening at and around a PET centre is somehow connected with tracers, cyclotrons, hot cells, scanners and animals. These, plus the flesh and blood of the researchers, are the tangible ingredients of a PET centre. Nevertheless, they are obviously not everything that makes up a centre. Like all organisations, the Uppsala PET Centre comprises incorporeal aspects, such as administrative routines, budgets, culture, leadership, relationships, mindsets and knowledge. Leaning on the empirical accounts of the previous two chapters, this chapter seeks to elucidate these intangible aspects precisely and see how they relate to, and what role they play in, the Uppsala PET journey. Put differently, the story will be revisited, but this time following some new trails and lingering on certain spots previously rushed past, in a quest for more detail. To paint a richer picture of the evolution of the PET Centre, this chapter will cover financial issues, the operations of the Centre and organisational change.

6.1 Beginning

Concentrating on the role of equipment and laboratories, the previous chapter identified research facilities as crucial in the progression of the PET Centre’s journey. Given this importance of physical objects, it follows that the PET Centre story is also one about money: lacking it, dreaming of it, gaining its power, generating it and losing it. In other words, money is an inescapable theme of this narrative, running from the quest for funding in the 1980s
through the years of commercial ownership to the reinstitution of the Centre in the public realm.

First things first: let us begin back at Uppsala University, some 30 years ago. The years leading up to the founding of the PET Centre in 1989 were marked by efforts on the part of Bengt Långström and the then University Chancellor, Martin Holmdahl, as well as a few other influential proponents of PET research, to gain enough support and raise enough money to start a PET centre at the University. Initially, Holmdahl had in fact been somewhat hesitant, but he soon grew very enthusiastic and his support was instrumental in getting other powerful individuals on board. The team was quite successful in arousing key figures’ enthusiasm about the idea of having a research centre dedicated exclusively to PET. Establishing a PET research centre was seen as a valuable progression of the University’s historically strong background in chemistry and radiophysics, and the excellent standing of the Uppsala researchers in the field of PET was considered a continuation of this scientific tradition. Uppsala University had five faculties with expertise in chemistry. Four of these had life sciences as their main focus, and there was a long history of accelerator-based science, as well as radiophysical and radiobiological research and development. A report from the Chancellor’s Office, issued about a month before the decision to start the Centre was made, stated:

“(…) through this, a leading position has been attained in research, development and clinical application of a method as advanced and complicated as PET. An (...) expansion of this research, which would enable broader clinical trials and yield opportunities for more multidisciplinary research initiatives, would provide Uppsala University and the University Hospital with very good conditions for sustaining its internationally leading position in the field” (Sanner, Uppsala University, 1989).

Differently put, the prospect of both increasing clinical application and boundary-crossing research endeavours and enhancing the University’s scientific renown were clearly strong motivating factors behind the decision to start a PET centre. What was needed now was money. A major drive was undertaken to encourage PET scientists to apply for research funding, and Långström and his allies used all the contacts they had. Holmdahl had a good relationship with the Wallenberg Foundation, an organisation that gave the PET advocates “incredible support” (interview, Holmdahl, 2011). Holmdahl also managed to get funding from the Söderberg Foundations and PKbanken (a major state-owned bank that makes up the Nordic financial corporate group Nordea today). Basically, in Holmdahl’s own words, the donors they were dealing with were not “unwilling” (interview, Holmdahl, 2011).

Along with the donations came a request, as briefly mentioned in the previous chapter, from the some of the donors for the PET Centre to assist
other institutions in Sweden in need of PET. Another welcome contribution came from the County Council, which offered to finance the new PET Centre building in exchange for the University paying rent. The estimated cost of the building was around SEK 50 million; the County Council set aside SEK 10 million for the project and decided to borrow the remainder. Being responsible for healthcare in the county, the County Council has an obvious interest in safeguarding the vitality of medical science. Thus, as soon as an initiative involving medical research is proposed, especially one requiring massive investment like the PET Centre, the County Council steps in. In Holmdahl and Långström’s efforts to secure support, that of the County Council was much appreciated. The County Council and the University agreed that as far as PET was concerned, it was a field in which they would be “the first and the best” (interview, Sundqvist, 2010).

All in all, the fundraising went very well. But when all the contributions had been added together the PET Centre project was still SEK 18 million short – a problem solved by Långström and Holmdahl borrowing the money from the Academy Trust. As for the money coming from the foundations, one small detail remained to be settled. For the donations to be actually paid out to the University, a promise had to be made to the State that the University now had enough financial resources to cover all investment costs as well as running costs. At Holmdahl’s last Consistory (University Board) meeting as University Chancellor in May 1989, such a promise was made.

Nonetheless, aware that the costs of running the PET Centre would be considerable, Holmdahl for one had some doubts as to its ability to cover them entirely. At the same Consistory meeting in spring 1989 at which the decision to start the PET Centre had finally been made, Holmdahl had been startled by the insistence of the professors heading the Faculties of Pharmacology, Medicine and Science & Technology on their respective faculties’ exemption from sharing their funding with the new PET Centre. Unable to give a definite promise, Holmdahl could merely assure them he would do his best and instead, if the need arose, use money from the University’s reserve fund. This measure would also, in fact, affect the faculties, albeit indirectly, and would at any rate work only as long as deficits were kept at a modest level. Despite the slight uncertainty regarding future running costs, Holmdahl believed in the idea of the PET Centre. In the 1989 Consistory meeting, attended by politicians, researchers and student representatives, one of the participants, also taken aback by the faculties’ unwillingness to contribute to the PET Centre, voiced his concern. In Holmdahl’s words:

“Then Gustav Persson asked (...) ‘Isn’t the Chancellor at all worried that this will become a great burden, and isn’t there anything in the investigation that’s (...) weak?’ Then I said, ‘I believe in this, and I first and foremost believe in the human capital we have here. I feel a certain concern, which is that Bengt
Långström will have a cardiac infarct.’ But he never did” (interview, Holmdahl 2011).

On the contrary, Långström was all healthy vigour and drive when he took up his appointment Director of the Uppsala PET Centre in 1989. As far as Holmdahl was concerned there was no doubt who was best suited for the task. Långström had been pushing for the PET Centre project all along. Besides, Holmdahl did not wish to appoint a clinical doctor for the position; he wanted a chemist. Since Långström was the most illustrious PET chemist in Uppsala, even one of the most renowned in the world, the choice was obvious as far as Holmdahl was concerned. Thus, Långström became Director, while Holmdahl served as Board Chair for the first three years. Apart from Holmdahl, the Board included Långström in his capacity of Director and nine other members: three from Uppsala University, one from the Swedish University of Agricultural Sciences (SLU), three from the County Council, a union representative and a student representative. The Board’s responsibilities included determining the direction of the PET Centre’s operations, setting fees and prices of the Centre’s services, approving contracts for the fee-for-service business, adopting the budget, reviewing the financial situation and compiling the annual accounts. The question of finances, as mentioned above, was contentious from the start.

6.2 Working out the numbers: donations, costs and deficit

The total estimated yearly cost of the PET Centre, specified in the contract in 1989, was approximately SEK 25 million, including capital costs. This weighty sum was to be divided evenly between the three parties that were intended as the Centre’s users. As mentioned in the Introduction, the PET Centre would rest on three legs, with clinical work making up one third of the Centre’s operations, fee-for-service activities the second third and independent research constituting the last third. The SEK 25 million included the costs of the building and furniture and of keeping the substantial set of equipment up and running. It was also intended to cover salaries: in addition to chemists, the PET Centre would employ clinical doctors, nurses and a technical engineer, among others. For instance, the cost estimate for the cyclotron, which fortunately had been nearly fully funded by the Wallenberg Foundation with SEK 12 million (almost covering the purchase price of SEK 14.1m), amounted to SEK 970,000 a year. Included in this sum were a service agreement, costs of spare parts and other consumables needed to run the cyclotron. Similar yearly costs were expected to be incurred for the brain scanner, body scanner and chemistry laboratories.
Everyone agreed that the numbers appearing in these cost estimates were significantly higher than the sums normally discussed in connection with research projects. A report issued by the Chancellor’s Office explained why:

“This [the large cost] is mainly contingent on the fact that capital costs, interest and depreciation (SEK 8.5 million) are included, as well as cost of the building (SEK 2.4 million), that all other miscellaneous costs have been accounted for and that the facility will be completely run by its own staff. The reason for this method of accounting is naturally that for contract research costs must be fully covered, and that contract research can’t, in this case, be handled as a marginal activity” (Sanner, Uppsala University, 1988).

Differently put, costs were admittedly high, but since the PET Centre would be carrying out a considerable amount of contract research, probably generating sizeable revenues, the accounting was done following a full cost-cover philosophy, signalling that the Uppsala PET Centre was no ordinary research centre. Having thus set it up as an organisation with a fairly distinct commercial element, the parties involved still opted against running the Centre as a company. Nor did they want it to be managed as a foundation. The preferred organisational form, they all agreed, would be that of a “special institution”, directly under University management. In that way the Centre would be safe in the University, tucked away so as not to unduly burden the faculties with its costs while also enjoying the boon of collaboration with industry.

However, dealings with industry had a slow start. Knowing there was a genuine interest in PET among pharmaceutical companies, the University had anticipated that the contract research business would bring in ample funds from the very start. The idea had been to use the profit yielded by the contract research to repay the initial loan of SEK 18 million. Nevertheless, the first few years saw only a modest stream of income from fee-for-service studies. As a consequence, the Centre was unable to cover all its expenses and needed a contribution from the University’s “reserve fund”. This measure was not necessarily appreciated by everyone in the University. Money, as we know, is a scarce resource at most universities, and the distribution of funding is therefore a key issue for anyone leading a department or faculty. Still, the PET Centre was such a young organisation, and although its incapacity to meet the budget was unfortunate, it was not a source of great concern for Holmdahl during his three years as Board Chair of the PET Centre:

“But sure, we made losses – in relation to budget. Let me put it that way. But I had a strong connection with the pharmaceutical industry so I knew it would all turn around for the better, because there was such intense interest coming from that direction. (…) I was never worried about the deficit” (interview, Holmdahl, 2011).
The fact remained that the PET Centre was not making enough money in its fee-for-service business to cover either the running costs of the facility or amortisation payments on the loan. The cost of independent science projects, which the researchers only partially managed to fund with research grants, also played a part in the poor financial performance. Slowly but surely a large deficit, growing from the initial loan of SEK 18 million needed to set up the Centre, was accumulating, and towards the late 1990s it reached close to a staggering SEK 30 million. To be more precise, from the vantage point of the University management a deficit was building up, but from the researchers’ point of view there was no such thing as a deficit:

“... and it [the deficit] was the subject of much debate. In our opinion it didn’t exist. The University said that the Academy Trust had given the PET Centre a loan […] to get this started. We felt that you can’t really get an operation started without having to spend any money. So we felt, ‘This is what it costs to get us started, and THEN we’ll get to zero.’ But in their view we were […] behind, and had to pay that back” (interview, Antoni 2010).

There was thus a fundamental difference in outlook on what constituted a cost and a deficit, and what did not. In regard to the quality of the science conducted at the Centre, the University had no reason to complain. In autumn 1996 the Uppsala PET Centre invited an international committee to assess its work. The committee, consisting of prominent researchers selected by the Centre and representing the disciplines of chemistry, physics, cardiology, neuroscience and oncology, concluded that the level of research was excellent (p. 1) and the scientific infrastructure outstanding:

“The PET Centre at Uppsala University is one of international dimensions and is arguably the best in the world in the chemistry of carbon-11 (...). The technical and scientific infrastructure has no equal elsewhere. This having been said, the power in collaboration and support for basic science facilities and general clinical efforts presents almost limitless possibilities. As such, these interactions need to be nurtured and supported. The University of Uppsala should be justly proud of having this unique facility in their midst. (p. 1) (...) With the respect to funding, the Centre’s income which arises from the hospital, research grants and industrial collaboration is impressive. This is further underpinned by support from the University of Uppsala” (MRC scientific review, p. 2).

In other words, if there was ever a doubt in anybody’s mind about the wisdom of sustaining such an expensive research unit, the report affirmed that the Uppsala PET Centre should be a source of pride. The evaluation was carried out during the period when the PET Centre was collaborating with the Japanese research institute, whose funding covered a good deal of the independent science conducted. These were good years in terms of research, but a certain discontent was now being expressed by the University Hospital.
Coincidentally, the only blot on the otherwise strikingly enthusiastic assessment of the Uppsala PET Centre made by the international committee concerned the state of clinical research. The delegation concluded that there was “a less than appropriate commitment from collaborating clinical scientists, and as a result there is a below-critical mass of clinical scientists resident in the PET Centre” (ibid.:3). The procedure of clinical services from the PET Centre now became a topic of discussion.

6.3 Meeting the clinic’s needs

At the end of 1996 the University Hospital voiced a concern. Far from all the PET scans the County Council had, in 1989, committed to buying every year as part of the agreement made when the Centre was founded were, in fact, being used by clinical doctors. With a lump sum paid for a total of 800 PET scans annually, the actual number of scans performed in 1992, a year after the operations at the Centre had begun, was 717. The following year the number was lower still, 629, and it fell even further in 1994, 1995, and 1996, when scans numbered 506, 586 and 546 respectively. Although the PET Centre was commended by the international evaluation delegation for its research in 1996, it was also noted that “the status of the collaborations with clinical scientists is seen to fall short of that expected of such a formidable scientific and technical resource as the Uppsala University PET Centre represents” (MRC scientific review, p. 3). Clinical research, the delegation asserted, was thus an area “requiring development” (ibid.). The numbers listed above comprised two parts: first, clinical PET scans for diagnostics and monitoring of results of treatment, and, second, PET scans performed research and development projects. And while the number of scans approved for research and development at the Hospital was in fact increasing21, the number of clinical scans was dwindling. In a letter to the PET Centre Board member Dr Bo Lindberg, dated November 1996, Dr Per-Olof Osterman described the situation:

“... the clinical utilisation does not seem to be increasing. This is worrisome. As you know, using PET is hard work for a clinician, it requires extensive efforts. This is certainly an impeding factor. Another explanation is likely to be that many have experienced the response time for the PET scans done at the clinic as too long. For several years, I’ve worked for improved response routines, partly through comments to the PET Board” (Letter, Osterman, 1996).

21 This increase was largely a result an initiative that enabled clinicians to utilize a part of the county council’s yearly PET scan quota of 800 for research projects. Hence the clinical researchers needed no external funding to have their scans performed.
In an effort to deal with this issue new routines designed to facilitate and speed up the handling of referrals and scan results were set up at the PET Centre. Nonetheless, a few disclaimers were made for instances when it might be difficult to operate within the new time frames. First, some less common types of PET examinations might call for a literature review to “benefit from experience” that the staff at the Centre did not themselves possess (report, Valind, 1996). Second, given the highly specialised nature of PET as a method, where the interpretation of scan results is based to a significant degree on personal experience, a certain amount of “sub-specialisation” among the doctors is necessary (ibid.). Dr Sven Valind at the PET Centre pointed out some possible inconvenient consequences of such niche expertise:

“Due to holiday, conferences, courses etc., the necessary competence may not always be immediately available for evaluation of certain examinations” (ibid.).

The complaints had come not only from doctors wanting the scans purely for patient care, but also from doctors wishing to use PET in their clinical research. At times, the division of labour seemed to be far from crystal clear. In the words of a long-time chemist at the PET Centre:

“If you do a research study [using PET] the researching doctor must take part in the evaluation [of results]. You can’t just say, ‘Do this and give it back to me when it’s written and finished.’ That’s not how we collaborate. We do a PET scan, and then you take care of the data together. I think there was some misunderstanding there. Some have thought that in a PET scan you get a finished answer: ‘The publication is written – now I just need to put my signature there and I have a publication.’ (...) Maybe it’s been poorly specified (...) who does what. I think there have been some conflicts there, with people thinking ‘you do this,’ while in our mind it’s been a collaboration, ‘but you are supposed to do this’” (interview, Antoni, 2010).

Regardless of the cause of the delayed handling of scan results, the uncertainty regarding response time was allegedly one of the main reasons why most oncologists – except the doctors of endocrine oncology – at the University Hospital were only very gradually adopting PET in clinical operations. Långström invited the doctors to the Centre to show them what the PET facility could offer in terms of diagnostics and monitoring, but for several years the oncologists preferred to rely on imaging techniques other than PET. As for the use of PET in clinical research projects, these were difficult to fund owing to the high cost of PET scans, and as a consequence scans were sometimes performed at a discounted price.

There were basically two types of PET-related clinical research projects. In one kind, the medical researcher simply wanted a certain number of scans
done as part of a project. The researcher then paid for the service provided by the Centre. Nevertheless, the situation changed if the researcher decided to run a project jointly with the PET researchers, where the object of the study was of interest to the Centre as well. For instance, the clinical researcher might offer patients of a unique kind on whom Långström could run tests. In such cases the price the doctor would be charged for the scans would at times be lower than that of scans performed for projects that did not coincide with Långström’s area of interest, and on occasion there would be no charge at all. It was also possible to get a quantity discount if a clinical researcher needed a large number of scans. The price per scan is naturally lower if ten patients can be fitted in for a batch of FDG on a single afternoon than if just five patients are admitted for the same batch of tracers. There were thus sometimes ways for the clinicians to mediate the weight of the costs of using PET.

6.4 Battling the budget and searching for remedies

While the collaboration difficulties between clinicians and the PET Centre were being addressed, the economic problems persisted. There was no denying that the negative discrepancy between the money generated and the money spent was troublesome, and in December 1996 the budget situation was described as “serious” (12 December 1996). In March 1997 the Administrative Director and Financial Director at the University met the PET Centre management to discuss the large deficit from the previous year. The PET Centre representatives emphasised that the large loan taken out during the initial phase, when the Centre was starting up, was a heavy burden. In the ensuing two years, the University and County Council had been contemplating various solutions to help the PET Centre escape the financial quagmire.

In a meeting between the University and the County Council in June 1998, it was suggested that a contributing factor to the “vulnerability” (3 June 1998) of the PET Centre might be the fact that it constituted an independent centre, as opposed to being part of a department. A number of measures devised to help the Centre were presented. First, the accumulated debt of about SEK 30 million would be taken over by the University centrally, so that the PET Centre would no longer be burdened with the capital cost of the loan. Further, the rent for the facility that had been renegotiated with the County Council was lowered by SEK 1.5 million a year. In return, the PET Centre was now expected to adhere to its budget each year and continue to pay for overhead costs. In short, the organisation was to be treated as an ordinary university department. The faculties, for their part, were to consider how much they would contribute annually to help cover the basic operations
at the PET Centre. In this sense, the PET Centre was nothing like an ordinary department.

Since July 1993, a third of the rent for the PET Centre building had been transferred to the Faculties of Medicine, Pharmacology and Science & Technology, to be paid out yearly. The reasoning behind this was based on the division of the PET Centre’s operations. Since a third of the PET Centre’s operations were supposed to be dedicated to independent science, the Centre was entitled to a subsidy for one-third of the rent. The three faculties connected with the PET Centre all received extra grants to be able to cover their share of the rent. Whereas the Faculties of Medicine and Science & Technology had complied with the 1993 decision to share the cost of the building, the Faculty of Pharmacology had resisted, and as of October 1998 the sum it should have paid amounted to about SEK 1 million.

Whereas the new situation, when the initial loan for the PET Centre and the accompanying capital cost had been transferred to the University, had rid the PET Centre of a significant economic burden, it had also put increased pressure on the Centre to henceforth manage its own finances without the University’s assistance. In light of these new circumstances, the money that the Faculty of Pharmacology had resisted disbursing for five years increased in importance. In a letter to the University Vice-Chancellor at the end of 1998, Långström and the PET Centre’s Board Chair called attention to this problem. Six months later, the Faculty of Pharmacology reached the decision to indeed pay out the money, thereby improving the Centre’s finances a little further.

Overall, the PET Centre’s financial situation was beginning to look less bleak. An investigation of the finances carried out in autumn 1998 had concluded that, although there was evidence of inadequate “budget control” and insufficient “budget discipline” – for instance, costly purchases of machinery that had not been covered by the budget – there were chances that the PET Centre would be able to “stick within given budget frames” in the future (Haglund, minutes of meeting on 12 October 1998). In fact, it was even possible that the Centre would generate a small profit, provided that the organisation began to pay closer attention to the budget and future revenues turned out to be as large as expected. Judging from the flourishing development of the fee-for-service business, there was no reason not to believe in substantial revenues.

6.5 Booming business

Until 1998 the contract research business had led a modest existence, yielding less money than the hopeful prognosis from the late 1980s had indicated. But finally, at the end of 1997, an unprecedented stream of representatives from
prominent pharmaceutical companies had started visiting the Centre, and in 1998 the picture changed entirely. The Centre started to negotiate with Quintiles, the contract research organisation (CRO) mentioned in previous chapters, about a formalised collaboration in which Quintiles would act as an intermediate organisation between the PET Centre and pharmaceutical companies. When asked about the contract research prospects in a meeting held in December 1998, Långström replied that it had “so far never looked this bright before” (14 December 1998). The following year proved equally fruitful, with industry partners including large companies such as Procter & Gamble, Pfizer, Merck, GlaxoWellcome and Novartis. Suddenly revenues were exceeding budget, while expenses were more or less kept within set boundaries. In fact, despite the funding for independent research being lower than expected, a small profit was now created thanks to the millions rolling in from industry (and also, of course, because of the Centre being relieved of the capital cost). Two-thirds of the PET Centre’s revenue now derived from the fee-for-service business – a fact that provoked an array of questions.

First, Långström expressed confusion as to the division of duties and responsibilities between, on the one hand, himself as the Director of the Centre and, on the other, the PET Centre Board and the University. For instance, while the PET Centre was responsible for the budget, it was the University that determined salaries, and Långström wished for more freedom in this area. Given the prospect of rising revenues from the contract research activities, he wanted to have the option of giving his staff bonuses. This suggestion met strong disapproval from Professor Charles Kurland, Board Chair of the PET Centre, who underlined how sensitive the idea of bonus remuneration was for the University. Another question concerned the possibility of saving a future surplus to be used for procuring new cameras later on. However, this idea too clashed with the way the University handled both investments and surpluses. Like all Swedish state authorities Uppsala University, a public institution, was obliged to borrow money for investments except where a purchase could be financed through donations or subsidies. In addition, there were regulations limiting the size of surpluses allowed in a public authority, and this was a governmental order Uppsala University had to follow.

University protocol was also at the heart of the issue that Långström brought up next, where he called for clearer and more efficient routines in relation to the fee-for-service business. For every contract between the PET Centre and an industry partner that exceeded a certain sum, approval was currently needed from the University’s Administrative Director. Ultimately, the new situation called into question the suitability of the PET Centre’s current organisational form, and at a June 1999 meeting the University Director expressed the view that an alternative organisational structure might indeed be necessary if the contract business continued to expand. The Vice-
Chancellor of the University was asked by the PET Centre to put together a team to investigate this issue, as well as the question of division of responsibility between the PET Centre Director, the PET Centre Board and the University. A year later, in June 2000, a proposal for a new organisational setup of the Centre was presented by Anders Grundström, the person in charge of administration and human resources at the PET Centre, and Jan Mellberg, an external consultant. This report was one of a handful of documents on the same topic produced during this time, but the bold message of Grundström and Mellberg’s investigation made it stand out. Their proposal was to turn the entire PET Centre into a company.

6.6 A new avenue

The first formal mention of the idea of connecting the PET Centre with the world of commerce, beyond the fee-for-service business, was at the June 1998 meeting when the measures to improve the Centre’s financial standing were adopted. The question the parties involved wanted to look into – and Långström, Grundström and Kurland, the PET Centre’s Board Chair at the time, had already raised at a meeting with the Vice-Chancellor four months earlier – was whether there might be any external potential stakeholder interested in investing in the PET Centre. The issue of future funding and investment had to be approached in a new manner now that the organisation had been relieved of its loan. This sudden financial relief had, as mentioned above, been accompanied by counter-performance expectations: no more negative numbers and no more additional contributions from the University. As recalled by a PET researcher:

“Then, sometime in the late 1990s, a decision was taken. I think it was like, ‘Now you won’t be getting any more money as long as you are showing red numbers, but on the other hand we have hidden the [30] million (…) so that [the debt] will disappear, you won’t see it and we won’t ask for it. But on the other hand there won’t be any extra money.’ And that’s when thoughts about forming a company first came up, I suppose” (interview, Antoni 2010).

The report that came out in June 2000 thus treated a matter that had been both informally and formally discussed for two years, but the content of the document still managed to stir up some emotion. Grundström and Mellberg had been assigned the task of working out how best to commercialise the contract research branch of the PET Centre, and present an outline business plan. The University wanted only the fee-for-service part of the Centre to be turned into a business, while leaving the basic research segment of operations untouched. For this reason, the team had not received directives to look into an option of commercialising the PET Centre in its entirety. For technical
reasons, however, Grundström and the consultant did just that: after much deliberation they reached the conclusion that the only solution that would work was one whereby the whole Centre would function as a company. A key strategic measure in this reorganisation included the adding of an extra shift both to enable more PET scans to be performed and to expand the fee-for-service business.

On seeing the report, the University's Administrative Director, Mats-Ola Ottosson, became “furious” (interview, Grundström, 2011), and another consultant was subsequently hired by the University’s holding company to re-evaluate viable commercialisation options. This consultant had experience from restructuring parts of Pharmacia and did a thorough investigation (interview, Jonsson, 2010), giving a signal in early 2001 that the PET Centre could be completely commercialised. The path the University management, along with Långström, eventually opted for was therefore full commercialisation of the PET Centre. The University’s basic expectation was that a company would finance the PET Centre, enabling the scientific work to continue as usual.

Not all stakeholders were equally engaged in the discussions preceding the sale. Whereas the University Hospital, the single most important user of the services offered by the PET Centre, was very much involved in the talks surrounding the commercialisation, primarily voicing concern over possible changes in pricing and future access to the technology, the County Council kept a very low profile. From the perspective of the University Vice-Chancellor at the time, Ulf Pettersson, the laid-back attitude of the County Council was peculiar, given the vital role played by the PET Centre in clinical practice. Importantly, PET was not only valuable to the Hospital for the opportunities it created in patient care, but also had clear economic value. The Department of Endocrine Oncology – which, as pointed out before, was entirely dependent on the availability of 5-HTP tracers – was the most profitable department at the entire hospital since it attracted patients from all over the world (interview, Pettersson, 2010). In the County Council’s view, however, the risks of raised prices and restricted access to the PET technology had to be balanced against the likely drawbacks of keeping the Centre in public ownership, which would probably also entail higher prices to cover the yearly losses at the PET facility. In other words, the County Council’s reasoning was that increases in costs of patient care would be the likely outcome no matter which path was chosen for the PET Centre. Therefore, no objections to commercialisation were raised by the County Council (interview, Karlsson, 2011).
6.7 Preparing for commercialisation

With the exception of one or two employees, the entire staff of the PET Centre stood behind the commercialisation plans, confident as they were about the prospect of increased salaries and a steady supply of equipment. Even so, there were some discussions among the employees about possible negative consequences for independent research, and also some concern regarding possible changes in organisational culture and atmosphere. No staff at the Centre had any prior experience of working in industry; they had only worked in academia, and some for the County Council as hospital employees. Still, by and large, there was a positive attitude among the staff. As Director of the Centre, Långström’s stance carried the most weight, but there were a handful of people at the Centre without whose consent the commercialisation would not have been realised. Fortunately for Långström, who very much believed in the idea of the PET Centre merging with a larger company, nobody in his key staff group objected. So began the process of finding a suitable partner to pair up with, a business actor with the means and the will to guard the unique knowledge of the PET Centre, and sustain its scientific and economic development.

The first discussions took place with representatives from the pharmaceutical industry, which had a few interesting candidates. Nevertheless, Långström was hesitant: he knew he wanted to work on issues connected with pharmaceutical development, but since the same complex of problems naturally existed across the entire industry he was reluctant to limit himself and the Centre to collaborating with only one pharmaceutical firm in particular. Being acquired by a drug company would automatically preclude any chance of working with other pharmaceutical players. The PET Centre was also approached by General Electric: early in the spring of 2001 a group of eight GE employees visited Långström and Lars Jonsson, wanting to initiate negotiations. The thought of being part of a company with such a distinct engineering profile filled Långström with doubt:

“I know I said to them, ‘My concern about GE is that you are just engineers, and this [what we do] is more than just being an engineer, this is science, this is medicine etc.’ And engineers aren’t always scientists” (interview, Långström, 2011).

Shortly afterwards, Amersham appeared and caught Långström’s attention. He had never really looked at the British biotech firm before but he found the organisation interesting and worth investigating further. Besides, Amersham had a CEO, Bill Castell, who struck Långström as a true visionary who understood how extraordinary a technology PET was and what a great role it could potentially play for the company. As opposed to General Electric (which is mainly, although not exclusively, centred around hardware),
Amersham’s foundation was essentially biology and medicine. The roots of the company could be traced back to a British centre that had been established immediately after the Second World War to develop and produce radioactive substances for use in medicine, research and industry. Making important contributions to the manufacturing of radioactive isotope tracers, this centre underwent a series of reorganisations over the following decades and was then privatised in 1982. In 1997 Amersham acquired both the Norwegian contrast solution company Nycomed and the biotech division of the Swedish firm Pharmacia, which operated in diagnostics and pharmaceuticals as well as biotech.

Wanting to be close to its collaborators from Uppsala University, Pharmacia had moved its operations to Uppala in the 1950s. While the organisation was renamed Amersham Biosciences after the acquisition, the collaborative relationship between the former Pharmacia biotech division and the University researchers did not end. In other words, when Amersham turned up and showed interest the University had a fairly good idea of what type of company it was dealing with. Nonetheless, the past collaborative experience with Amersham, which had largely been positive, had been limited to Biosciences. This time, however, the potential partner was Medical Diagnostics, another Amersham division of which neither the University nor the PET researchers had any prior knowledge. Regardless, working with “soft” issues – molecules – and not with hard technology like General Electric, Medical Diagnostics quite appealed to Långström and many of his research colleagues. Still, not everybody understood what was so alluring about Amersham and its interest in the PET Centre, and why Långström was so drawn to the idea of being acquired:

“Many of us said: ‘We don’t understand what’s driving Bengt [Långström]. These companies just want to make money.’ But I think he nurtured a hope that they would want to invest in science” (interview, Grundström, 2010).

Indeed, many believed that joining Amersham would create scope for generous research funding. But what set Amersham apart was the fact that the Centre would not be barred from working with every conceivable company in the drug industry if it so wished. A business developer from Amersham, who had been in charge of the acquisition of Hammersmith PET centre the year before, recalls how the arguments were presented to the PET centres that Amersham wanted to be part of IMANET:

“I also remember the discussions that we certainly had with Hammersmith, and I think that my colleagues had with Uppsala. We certainly would have said to them: ‘You’re probably better off working with us because we’re not one pharmaceutical company. The pharma industry is our customer base, so we’re totally neutral. We’re not involved in selling therapeutic drugs ourselves – the
pharmaceutical industry is our customer, so we have the same sort of set of business motivations as you do and we can act as an honest broker.’ And we were very keen never to want to allow ourselves to be taken over by a single pharmaceutical company. Because that might make it extremely difficult for our life-science research business to work on very, very confidential research projects, discovery-stage research” (interview, Lee, 2011).

Soon enough it was settled: Amersham would purchase the Uppsala PET Centre.

6.8 Negotiations

So began the negotiations, with the University management, University lawyers and Långström on one side, and Amersham’s representatives and legal team on the other. They spent a full year working out the deal that would make the Uppsala PET Centre part of Amersham’s PET imaging business, IMANET. It was not just the valuation of the Centre that had to be determined, but also contracts regarding the transfer of staff and equipment, as well as a general agreement on the future direction of the Centre. Although the general spirit of the negotiations was friendly, cordial and free from serious conflicts, the hours spent debating the contracts were clearly taxing. Discussions were long and complex, and Amersham had to meet and talk with three groups of stakeholders – the PET researchers, the Hospital and the University – making sure “that they all three saw the potential benefit” (interview, Peak, 2011). Due diligence also needed to be done, and this was time-consuming. Intent on getting the numbers straight, Amersham spent a great deal of time trying to work out whether the accounting of the PET Centre had been done correctly over the years. Because of the nature of British corporate law, the proposal for the contract filled several binders. The University had never been involved in anything like it. In the words of the then University Vice-Chancellor:

“But how do you sell such a project? It’s not something that the University does every day. It’s a big deal (...). But there were pros involved and the negotiations went back and forth. I remember that when we signed [the contract], the entire table, 15 metres long, was covered with documents and six British lawyers were running around. So it was an unbelievable effort, and you can imagine all the patent and ownership issues. It was extremely burdensome” (interview, Sundqvist, 2010).

For Amersham’s main negotiator, conceptualising how the acquisition would benefit the University was particularly difficult. Moreover, Långström had to be convinced that he would not be too constrained by Amersham. Unequivocally in favour of the whole commercialisation enterprise – indeed,
adamant that they must go through with it, or else he and the other
researchers would leave – Långström still appeared somewhat torn. On the
one hand he wanted it to happen, but on the other he was afraid of losing
control (interview, Sundqvist, 2010).

Långström did, in fact, lose control of something. When the negotiations
seemed to be almost finished, Amersham suddenly found out about a small
company that Långström had started recently. With a couple of colleagues at
the PET Centre, Långström had a side project that he wanted to keep and
believed was of no interest to Amersham. The company, Syntia, was centred
on the development of a synthesis technology in which various chemical
substances could be produced. What Långström was unaware of was that
Amersham had been engaged in parallel negotiations with GE about
developing a very similar technology jointly with GE Healthcare. Långström’s
involvement in Syntia therefore meant a radical conflict of interest.
Consequently, when Amersham suddenly learnt about Syntia it was outraged,
and the University’s chief negotiator, Lars Jonsson of the University’s holding
company, was equally displeased about this late disclosure. Syntia was a deal-
breaker, and an external assistant mediator from KPMG had to be called in to
help Jonsson, now serving as the chief mediator, negotiate a deal regarding
Syntia. Finally, after discussions lasting several months, a compromise was
reached: Amersham purchased Syntia at a price that ended up exactly halfway
between what Amersham was willing to pay and what the researchers who
owned Syntia demanded. Neither party was satisfied with the solution, but
both accepted it in order to move on.

Now that Syntia was no longer a side project at the PET Centre,
Långström had to come to terms with putting on hold his vision of the
versatile synthesis apparatus he had wanted to create. What was more, his
ambitions for the technology were at odds with that of Amersham. What he
had envisaged was a sophisticated machine that, in Jonsson’s words, would be
a “Formula 1 car”, whereas “Amersham was fully satisfied with a Ford”
(interview, Jonsson, 2010).

In Jonsson’s view, this tendency of Amersham’s to seek “standard gear”
coloured the negotiations between Amersham and the Uppsala team on a
general level. Knowing that the strength of the PET Centre lay in highly
specialised activities and items, in which it was in fact world-leading, the
University underlined that to make full use of the PET Centre and help it
continue to thrive, the focus should not be on standardisation. If this was
what Amersham was after, there were other PET centres in existence that
could implement standardised solutions better, and potentially more cheaply,
than the Uppsala PET Centre.

However, Amersham was resolute in its decision to get this particular
centre, and agreed to keep the academic research side as it was and also, as
mentioned in previous chapters, set up a fund designated for research
projects in the life sciences. As for the clinical operations of the Centre, Amersham’s plan was to later spin these off and place the University Hospital in charge of them, while the contract research business would be expanded. All this was well received by the University. The County Council, for its part, also felt reassured that the clinical work would continue, and a deal was worked out on how the prices would be negotiated.

However, one issue required more time to be settled: salaries. On entering the negotiations Långström had been open about the need to bring the PET Centre staff’s salaries up to par with those of industry. In fact, one reason for the PET Centre staff’s wish to commercialise the organisation was the prospect of being able to enjoy and offer market-oriented salaries:

“One of the reasons we wanted to do this [commercialise] was that it’s difficult to keep people in academia if you have a good chance of making money in industry. Back then, salaries at the PET Centre were a third less than you get in industry. So if you leave [the PET Centre] you get another 30% in salary. It was hard to fight on that market, so we kept losing people. So one reason [to commercialise] was to create an environment where salaries were adapted to the market. That would be the attraction for the staff, to join this [commercialisation of the PET Centre] to get a higher salary” (interview, Antoni, 2010).

Amersham did not object, so the salaries of all PhD chemists were raised by 30%. Unfortunately, the Centre’s nurses did not get the increase they had asked for, also 30%, since their salaries would then have exceeded the earnings of County Council nurses and industrial workers alike.

Whereas part of the reason for the employees’ favourable attitude towards commercialisation lay in their expectation of higher salaries, the University for its part was partially motivated by factors relating to the finances of the University as a whole. The SEK 30 million deficit had not been forgotten although the sum, as mentioned above, had been shifted from the PET Centre to the University in 1998. This financial blemish was something the University was determined to remedy. As expressed by Bo Sundqvist, Chancellor at the time:

“(…) I can say that my picture is that, when the purchase was being done, it was pro primo that the deficit of [SEK] 30 million be removed (interview, Sundqvist, 2010).

The deficit was thus a problem for the University that it was thought the acquisition might solve. Even more important was the scope for improving the newly started University holding company’s finances.

“And most important of all (…) was that the holding company through this deal… it was something complicated, that they got shares they could sell within
three years. This meant that the holding company was given a fair amount of muscle. This was before they had very much money” (interview, Sundqvist, 2010).

Indeed, it was agreed that while Amersham would be the majority shareholder, owning 75% of the PET Centre, Uppsala University would retain the remaining 25%. Now, not only are public universities prohibited by Swedish law from making excessive profits, but it is also illegal for them to take on any financial risk. For this reason, the University was represented by its holding company UUAB. Put differently, the shares belonged to UUAB, and whether or whenever the company might opt to sell its stock, the proceeds would be funnelled to its own organisation. At the time of Amersham’s acquisition of the PET Centre, UUAB’s financial situation was weak, and attaining ownership of Amersham’s new venture was therefore a welcome injection of capital. The idea was that, once sold at a later date, the shares would constitute the capital needed by UUAB to make investments in academic ventures. All these reasons taken together – the University’s financial health, the future needs of an expanding PET Centre and the need for capital in the holding company – justified the decision to sell the Centre to Amersham. As expressed by Sundqvist, University Chancellor at the time: “We felt that, from the University’s point of view, we could sell [the PET Centre] with a clear conscience” (interview, Sundqvist, 2010).

The valuation of the PET Centre, which was carried out following common risk-capital logic, was generous. Amersham paid about SEK 175 million for its 75% stake. The money was to be invested in new equipment and a new PET building, and a portion, SEK 42 million, was to be set aside for the aforementioned research fund dedicated to the life sciences. Around SEK 25 million would be used to rent equipment that belonged to the University, and Amersham also committed itself to paying for the maintenance of the apparatus. The remaining 25% stake belonging to UUAB was consequently valued at around SEK 50 million. This was undeniably a large sum of money for the University, but from Amersham’s perspective the price of the acquisition was high only in relative terms. On the one hand, Amersham had made far more expensive acquisitions in the past, purchasing other companies that had invariably cost more than the academic institution. On the other hand, a commercial venture could be expected to yield profit right away, or to do so in the very near future, thus meriting a high valuation and a substantial selling price. In contrast, acquiring the Uppsala PET Centre was an experimental high-risk venture, and while the price of the organisation was not overwhelming in absolute terms, its financial value as an asset was unclear. A return-on-investment calculation on the PET Centre further down the line might reveal that this acquisition was in fact more expensive than Amersham’s past commercial ventures, but Amersham was nevertheless
determined to get the Uppsala PET Centre, since it was central to the plans of the company.

As described in the Introduction, these plans involved building up strong PET expertise by creating a new company, IMANET (short for Imaging Networks), which would comprise a few world-class PET research centres. Part of the reasoning behind the strategy was that, as mentioned above, acquiring skills and expertise in something as attractive as PET and working with University researchers would boost the valuation of the company:

“The analyst community was very interested in [Amersham]. It was a company unlike most companies in the UK that was doing really neat stuff in science and technology. So this was the sort of thing that the investors loved to hear about: ‘Oh, working with universities, starting a new business model, doing research and development in a different way’ – they love that. They don't necessarily know it or understand it, they just love that stuff. And so this had a big positive impact on the share price” (interview, Jeans, 2011).

“The analysts saw that this was a new business model, an interesting new way of getting R&D, an interesting new model of getting access to the drug companies and an interesting new model of bringing world-leading scientists like Bengt [Långström] and others into the company’s fold” (interview, Peake, 2011).

The basic premise was that the new PET capabilities would attract the pharmaceutical industry. Since PET was a tremendously important tool in drug development, the industry would turn to IMANET to buy its services, and in the process relationships between the big drug companies and Amersham would emerge. These relationships, the thinking went, would be instrumental in building up enough trust between the parties for Amersham to be permitted to enter the well-guarded cave where the pharmaceutical companies’ holy grail is kept: their molecular libraries. What Amersham wanted to access in these libraries was the intellectual property associated with failed pharmaceutical molecules – substances that, as detailed in the Introduction and the empirical chapter about radiotracers, are often a fruitful starting point in tracer development. But to even begin to steer attempts in this direction, Amersham needed to set up a working structure with its three PET centres. On 29 April 2002, when the protracted and demanding negotiation process ended, the University signed the deal and the Uppsala PET Centre became one of the centres in this structure.

6.9 From Uppsala PET Centre to Uppsala IMANET

The other two PET centres in IMANET, Hammersmith and Turku, were just like Uppsala’s centres of excellence, doing cutting-edge science and enjoying
world renown in their respective areas. The Hammersmith centre, known as the “cyclotron unit” until it was acquired by Amersham, was the first institution in the UK to have a cyclotron installed, and had a long history of conducting medical research using radioactivity. Funded by the Medical Research Council (MRC), this centre was located adjacent to Hammersmith Hospital, a large site that has accommodated a variety of activities over the years. It had existed both in the form of a public hospital within the UK National Health Service, and as the main teaching hospital for Imperial College Medical School. In the late 1990s the MRC had begun to express concern about the costs of the cyclotron unit, and Amersham’s interest was therefore welcome. The joint venture established in 2001 between the MRC and Amersham was identical to the set-up in Uppsala: Amersham owned 75% and the MRC 25%. Further, just as the University Hospital was the main customer of the PET Centre in Uppsala, keeping its commitment to purchase a set number of PET scans annually, MRC was the primary customer of Hammersmith IMANET, having agreed to fund a certain amount of scanning work at the unit each year.

Contrary to the cases of Hammersmith and Uppsala, Amersham had no ownership shares in the Turku centre, which had been established in the 1970s and was connected with the University of Turku, Åbo Akademi University and Turku University Hospital. Since Finnish law prohibits sale of a university institution, an alternative solution was found. Joining IMANET in 2003, i.e. a year after the Uppsala PET Centre, the centre in Turku essentially retained its independence in regard to basic science, but signed a deal with Amersham that regulated its fee-for-service activities. The interface between the Turku centre and Amersham was a small organisation consisting of a few people tasked with managing incoming requests from pharmaceutical companies about contract research studies. Put differently, Turku received payment for carrying out fee-for-service studies that were mediated by Amersham.

IMANET was, in other words, a relatively heterogeneous construction. Relations between Amersham and the Hammersmith and Uppsala centres were characterised by direct involvement, albeit to varying degrees due to geographical location. In contrast, the dealings between Amersham and Turku were more at arm’s length, the latter being more of a third party than a unit supervised by the parent company (interview, Jeans, 2011). But despite the similarity in ownership structure between Hammersmith and Uppsala, it soon turned out that the two centres had to be operated according to somewhat different schemes. Whereas the British site could be managed by Amersham on a day-to-day basis without any serious complications, the PET Centre in Uppsala proved to be a hard nut to crack.
6.10 Making formal changes

The Uppsala PET Centre’s transformation into one of IMANET’s units was not unimpeded. In fact, some would argue that the metamorphosis never took place at all, other than on the most superficial level. When Amersham made the purchase it was aware that the Uppsala PET Centre was characterised by a strong academic spirit. Nevertheless, a decade of industry collaborations indicated the organisation’s openness to commercial work. The leader of business development at Amersham, who had done the negotiations for the Hammersmith partnership, recalls the reaction of one of his co-workers to the culture in Uppsala:

“I remember some of my colleagues coming back from Uppsala saying, ‘This is going to be quite an epic battle because it’s very, very academic.’ There was a great level of comfort just spending an unquantified period of time just looking at something, and if it works it works, and if it doesn’t it doesn’t matter, they’d spend some more time looking at it” (interview, Lee, 2011).

Evidently aware of the unambiguously academic culture at the PET Centre, Amersham saw the need to introduce new routines and administrative functions, and standardise part of its operations to make it all fit into the idea of what IMANET was. First of all, it wanted a transparent menu of all the services offered by the Uppsala PET Centre, as well as a price list, to make it easier for pharmaceutical companies to see what they could buy and at what cost. The price list had to be same for all the IMANET centres to avoid competition between them. In Uppsala, the price list for tracers purchased by the University Hospital had to be adjusted, since the pre-acquisition pricing had not reflected the actual cost of producing the molecules. While Amersham did not necessarily aim at making a profit by selling tracers to either of the hospitals in Uppsala and Hammersmith, it also did not want to lose money. At Uppsala, this meant that the price of 5-HTP, which had been kept low despite the manufacturing process being fairly labour-intensive, had to be raised: from SEK 14,000 to SEK 40,000 per batch and scan. Conversely, recognising that the price charged for FDG at the Uppsala PET Centre had been higher than in many other places, the Centre slightly lowered the price of FDG. From a business perspective, this made sense: the substance that Uppsala was more or less alone in the world in producing should be more expensive, while the standard compound FDG that could be produced in bulk at any given PET Centre should cost less. For the individual clinician using 5-HTP for a research project, this shift in price was, of course, unfortunate.

Apart from the change in pricing, delivery of scanning services to the Hospital would continue as before, with Uppsala IMANET committing to doing 700 PET scans per year from 2003 to 2005. The new contract between
the two parties signed in 2003 entitled Uppsala IMANET to raise prices in line with the consumer price index, or to a level that covered the total production cost.

New contracts were needed for the drug industry as well, and Amersham invested ample time in drafting clear, transparent documents that left no room for misunderstanding. The goal was to provide pharmaceutical companies with precise information, in terms of both content and delivery dates, about the services they purchased. In other words, Amersham put considerable effort into the business front end, as evidenced by its choice to appoint a CEO with solid business experience, rather than a scientist. A human resource manager and other administrative staff were also engaged, and a routine to measure the performance of the Centre was instated. Fundamentally, Amersham wanted Uppsala IMANET to develop tracer molecules and carry out contract research, and the system whereby the organisation was evaluated reflected this wish. Measurement of Uppsala IMANET’s achievements was based on two variables: first, the number of formal patent applications (it was asked to patent as much as possible) and, second, the number of commercially promising research proposals. The Centre’s employees were supposed to follow a set process that gave them credits in accordance with a certain points system.

Amersham valued the academic profile of Uppsala IMANET and wanted the Centre to keep its excellent reputation, since the prestige was considered an asset that would help attract pharmaceutical companies. For these reasons, the scientific qualifications of the staff were regarded as important and there was consideration of the need of PhD students, researchers and professors to publish their findings in peer-reviewed journals. In fact, there were no clashes between academic publishing and patent applications, and Amersham’s overall intention was to respect the academic nature of all the PET centres in IMANET. In addition, mindful not to make the scientists feel out of place, most individuals that Amersham assigned to leading roles in IMANET had a scientific background.

“(…) we weren’t trying to interfere too much with the academic heart of the facilities, really. (…) I was trying to facilitate really good relationships that, yes, would have commercial terms and pricing attached to them. But it was very important that we didn’t destroy the academic culture and try to turn into some product offering or sales machine” (interview, Lee, 2011).

Notwithstanding this acceptance of the particular scientific nature of the PET centres, there were undeniable difficulties associated with managing Uppsala IMANET as a company.
6.11 Organisational culture

In truth, there was probably no straightforward way in which any external party, commercial or otherwise, would have been able to come in and try to take command of an organisation that had been firmly managed, much like a university department, for well over a decade. Any attempt to take charge of such a unit was bound to meet resistance. The fact that the very nature of the new regime differed at the most basic level from everything, in terms of management, that the researchers and their former Director, Långström, had previously experienced certainly did not help. In other words, the clash precipitated by Amersham’s sudden entrance into the unit was, perhaps, inevitable. With the new set-up the PET Centre was no longer supposed to be run by a professor, but by a CEO, who in turn would report to higher management in the UK. To Amersham’s great frustration it soon turned out that this formal organisational restructuring did not facilitate communication and control to the hoped-for degree. While the team in Hammersmith came across as reasonably approachable and accessible, the PET unit in Uppsala presented more of a challenge to the parent company. Having always been a tightly run ship, Amersham found the organisation difficult to connect with.

The CEO at Uppsala IMANET, Göran Beijer, often felt caught between the different worlds that the PET Centre and Amersham represented, and struggled to reconcile the often conflicting demands and expectations emanating from the two. On the one side was the unwavering academic focus of the PET unit, while on the other were the business interests of Amersham:

“Personally, I sort of ended up in the middle. [...] On the one hand I had to defend the PET Centre, what we had and what we could do, but at the same time I had to live up to the demands of the owners. It was a kind of never-ending balance act, it was incredibly... it was one of the most difficult jobs I have ever had” (interview, Beijer, 2011).

Beijer was left quite alone with the demanding task of reconciling the ideas of Långström, delivered persuasively and convincingly, with those of Amersham (interview, Jonsson, 2010). Since there was nobody from Amersham headquarters who could be a sounding board for Beijer, he spoke to Jonsson, who was now a member of the Uppsala IMANET Board. Before Board meetings Beijer and Långström would both meet Jonsson, the CEO of UUAB, to express their views – a preparatory step to help him express their interest at the meeting.

Each side was grappling with what it perceived as the somewhat alien elements of the other. Amersham, for its part, felt that it was being “very tolerant and supportive”, taking measures not to “interfere with the quality of” the Centre’s “academic environment” (interview, Lee, 2011). The culture at Uppsala IMANET remained very academic, with up to 17 PhD students...
always present in the facility. Although management would remind the students that they were employed not by the company but by the University, they would attend company meetings and also work on projects that were important to IMANET. Integral to the Centre, these students further contributed to the distinctly academic feel of the Centre. Needless to say, this was the environment in which the researchers felt at home, especially since (as mentioned above) they had no prior experience of working in industry. As a result, they did not quite like how the rules of the game were changing. They also felt, to some extent, that Amersham was not clearly communicating to them what they were supposed to do, apart from carrying out studies for drug companies.

To crown it all, the British corporate culture was more top-down than the Swedes were accustomed to. Indisputably, the Centre had long been used to firm leadership when it was part of the University, but this power had been exercised within the relatively loose confines of academia and in a way, after all, this made sense. In academia, the focus of leadership had been primarily to steer the organisation in a manner conducive to scientific exploration. With its new commercial owner, on the other hand, control seemed remote and grounds for decisions obscure and questionable. To sum up, many researchers were critical of the way Amersham tried to manage Uppsala IMANET. Whereas there was a certain degree of understanding in the management group for this adverse attitude on the part of the employees – who, after all, had originally been academics – their perceived negativity was also a cause of irritation for the managers directly involved. How could the researchers have such firm ideas on how operations should be organised, despite having no or very limited knowledge of how a large international company is run and how products are commercialised? To Beijer, coming from the outside, the employees seemed to want to stick to their habitual work process:

“I think one wanted to keep working in the same way as before. That is, working on research, working with fee-for-service, but to sort of keep doing it, in a way, like: ‘Well, this came out this year, and next year there’ll be something else, and...’ In industry you have more of a plan: ‘Now you reached that this year, next year you’ll reach a little higher,’ and so on. [At the PET Centre] they didn’t really want anyone to steer and interfere. They wanted to be left alone and carry on as usual. Keep on doing what they were good at. They didn’t want to comply with the agenda and objectives of a big company” (interview, Beijer, 2011).

Långström, too, was largely dissatisfied with the new leadership, and Jonsson and representatives from Amersham had discussions about how best to handle the tension created by the discontent. Långström’s high scientific status was of enormous importance to pharmaceutical companies seeking
IMANET’s services, and Amersham was aware that the success of IMANET depended to a significant degree on its being able to offer Långström’s expertise to its customers. Consequently, keeping Långström on its side was a top priority in the company.

6.12 Contract research

With the other celebrity scientist in the venture, David Brook from Hammersmith, Långström was to accompany IMANET’s sales and marketing representatives to meetings with drug companies. The task assigned to Brook and Långström was clear enough: to excite the pharmaceutical firms and draw them closer to Amersham by establishing fee-for-service collaborations.

As mentioned previously, the idea of attracting the drug companies was at the core of Amersham’s strategy. Basically, it constituted the less evident part of the twofold purpose of contract research, the other part being simply to generate revenue. Brook and Långström both had long and extensive experience of talking to and working with the pharmaceutical industry, but their relations had never been managed in the context of an actual commercial venture. However, after the scientists became employees of Amersham the communication between them and the drug companies had to be handled with slightly more caution, which was not always easy. One of the developers of IMANET and a former chemist, Stephen Peake, recalls what it used to be like to try to create a balance between the academic tendency to candidly share knowledge and strict business considerations:

“Oh, they absolutely loved it. I mean, big pharma loves people like that, absolutely loves them. Partly because they’re not interested in money, they’re not... What shall I say? They’ll tell you absolutely anything. I mean, you know, they have no sort of commercial constraints, I suppose, on what information they provide. So they’re wonderful people to have in a big pharma company, just what you want. But certainly my position really is trying to restrain them, trying to keep them on track, trying to make sure that we’re actually looking for the things that we want to work with (...) and so on. And not to be led... 'cause I mean, Bengt and David, you know, were the best (...) in the world, they were sort of led down avenues everywhere. (...) And we had a few, you could probably call them bust-ups, when they did or said things that were utterly unacceptable from a business point of view” (interview, Peake, 2011).

Another challenging aspect of the new business routine vis-à-vis the pharmaceutical industry was to get the researchers to adopt the cost structure Amersham had created, indicating the prices of all IMANET’s services. Ensuring that the PET scientists were following this price list proved easier said than done. In their dealings with drug companies, Långström, Brook or
researchers from their teams would sometimes agree to carry out assignments that were not listed in the standardised cost structure, and make up their own prices along the way. That the work should be quoted at the list price and that possible discounts had to be worked out in a negotiation process were thus points that the researchers in IMANET did not automatically take to heart:

“They’d say, ‘Oh yeah, don’t worry about our cost structure, because what you’re talking about isn’t really covered by that. We’ll do it for X’” (interview, Peake, 2011).

In short, Brook and Långström did not necessarily possess the requisite business savvy and discipline Amersham may have wished for, but they were absolutely vital in bringing in fee-for-service contracts.

Still, no scientific fame in the world could help even out the irregular nature of the contract research business. Ever since the Uppsala PET Centre had begun its collaboration with the pharmaceutical industry in the early 1990s, the stream of contracts had been unsteady and hard to predict. One year there would be almost no business at all, only to be followed by a year when companies would be queuing to have studies carried out. What was more, if a drug company suddenly cancelled a planned study, the PET Centre would miss out on up to several million kronor in revenue, and it would generally be hard to find a replacement project to make up for this loss of expected income. The difficulty of replacing projects was mainly due to the considerable lead times for setting up clinical studies, which usually takes around six months.

The flow of income from contract research was thus prone to considerable fluctuations from year to year. This was the way it had always been, and the switch to commercial ownership did not change the capricious nature of the fee-for-service business. What did change, however, was the pricing. As mentioned earlier in this chapter, prices were adjusted to bring them more in line with the market, but they also needed to be high enough to cover the employees’ hefty 30–40% salary increase. As a result, the IMANET centres were soon the world’s most expensive PET facilities for contract research studies. There was concern that business would be lost because of this, and one idea was to do only more advanced fee-for-service studies, while simpler FDG studies would be handled by other PET centres. Jonsson, Uppsala University’s representative on the IMANET Board, worried that prices had been raised too much and too quickly. Nevertheless, when he pointed this out to Amersham he was assured that the company had strong connections with the pharmaceutical industry and that the situation was under control. Marketing and sales functions for IMANET were soon transferred to London, since the ambition was to be a global player, but for some reason contract research business seemed to be stagnating. It was Jonsson’s
impression that, in the first few years at least, most fee-for-service contracts were won by Långström and a few others in the organisation, in negotiations with industry contacts established well before the IMANET venture came into being.

Despite the unpredictability of the contract research business, the company was persistent in its efforts to form close ties with drug companies. As mentioned previously, the primary reason for the wish to build relationships with big pharma was the ambition to access the IP rights associated with the pharmaceutical industry’s failed drug molecules. This plan never came to fruition, however, since these molecules – although they would never be developed into pharmaceuticals – did indeed possess a certain kind of value to the pharmaceutical companies. They were regarded as valuable because they might serve as leads for new therapeutics, since researchers “could go back to it [and say] ‘Oh, this could be the very thing!’” (interview, Peake 2011). If the researchers wanted to go back to failed molecules in that way, only to find that access to these substances had been already granted to another party, the drug company would potentially face serious problems concerning patent rights. In other words, the pharmaceutical industry was unwilling to loosen its grip on the molecular vaults. As a result, the doors to the much-coveted molecular libraries remained closed.

Nonetheless, this did not mean that the pharmaceutical companies’ R&D people were uninterested in working with Amersham and sharing the failed molecules. On the contrary, they were excited about it; but the teams handling IP issues at the drug companies knew to guard their assets, just in case. So while the outcome was not the hoped-for access to molecular IP rights, Amersham did in fact manage to arouse some interest in the drug industry. It established comparatively wide-ranging collaboration with Pfizer in the US, and this teamwork continued after GE Healthcare had taken over. The collaboration that began shortly after IMANET’s creation had the goal of finding overlaps in areas where both companies operated. They looked for corresponding interests, matching a therapeutic programme in Pfizer with a complementary diagnostic programme in Amersham Health. A scientific committee, including Långström, was formed and met regularly to review and redefine their research interests. For each area where there was an overlap, a working group was set up. The idea was that the working groups would take away from such meetings new knowledge that would be helpful in their respective development projects.

Parallel to this organised knowledge exchange, IMANET was being paid by Pfizer to conduct fee-for-service imaging. These studies were in themselves of no particular scientific interest to Amersham in terms of molecules, but brought in well-needed revenues. For Amersham, one of the greatest benefits of this collaboration – considered valuable by both parties – was the insight it gained into the inner workings of a large pharmaceutical
company. Big pharma organisations had always seemed impenetrable to the British biotech firm. As for the most coveted end result, access to discarded pharmaceutical molecules, the outcome of the Pfizer collaboration was mixed. Unlike many drug companies, which, in the words of one of the business developers at IMANET had a “I want to be wedded to these molecules”-type of attitude towards their failed chemical substances, Pfizer had a less “emotional” tie with its molecules (interview, Peake, 2011). Although Pfizer in no way wished to relinquish its IP rights, there were in fact a few instances where Amersham’s topic of interest was exciting enough for Pfizer to actually grant Amersham access to enough IP to explore a few molecules. But apart from Pfizer, Amersham and, later, GE Healthcare had limited success in setting up collaborations with other pharmaceutical companies.

In summary, the interaction between IMANET and the pharmaceutical industry was largely limited to contract research, since the plan to obtain IP rights to the drug companies’ failed molecules did not succeed. However, there was another obvious way in which the IMANET centres could make themselves useful to Amersham: in collaboration projects with the parent company’s own R&D department.

6.13 Collaboration between IMANET and Amersham’s R&D

As mentioned earlier, setting up interorganisational research collaboration with IMANET, Amersham and, later, GE Healthcare involved considerable friction. From Uppsala IMANET’s point of view, it was unclear how it was supposed to contribute to the parent company’s internal research projects. There was a general sentiment among the Uppsala PET researchers that their knowledge was not being fully utilised and that their commercial owner was responding with indifference to their in-depth scientific expertise.

“We thought we should do some sort of review of what we ought to devote our time to, but we didn’t get much guidance from Amersham as to what they wanted us to do. We thought they’d come to us with their research problems: ‘We think you should delve into this and get back to us’ and ‘You can work on this.’ But we carried on on our own, we never heard from them (...)... when they never came there was something like a vacuum here. We were just carrying on with what we could and wanted to do. That’s why there was a mismatch between what we did and the expectations. So they weren’t using us very well. They bought us and then nothing happened, except there were demands that we bring in some money” (interview, Antoni, 2010).
Uppsala IMANET’s CEO, Beijer, also perceived the interaction with Amersham as weak. Early on, he sensed an atmosphere of confrontation, with many of the most qualified Uppsala researchers seeing the research at Amersham as ordinary and scientifically bland. The Amersham researchers also appeared to care little about what was going on at the PET Centre in Uppsala. The decision that Amersham’s researchers would collaborate with IMANET had, at least initially, met “huge resistance” from the parent company’s researchers (interview, Clarke, 2012). The Uppsala PET scientists’ feeling that the Amersham researchers wanted to have nothing to do with IMANET was thus not unfounded. As time went by, however, the PET researcher who served as IMANET’s R&D representative, Sajinder Luthra, grasped that the problem was frustration, rather than animosity or tension. Distant Uppsala was difficult to work with. Hammersmith, with its geographical proximity to the London-based Amersham’s head office – and later that of GE Healthcare – was easier to link to the parent company’s own researchers. In her capacity as interface between IMANET and the bigger company, Luthra was able to sway managers towards funding certain projects the researchers were interested in. This influence was, perhaps naturally, easier to exert face to face than from a distance.

By the same token, although Bill Clarke, the global director of all R&D for Amersham Health, often visited Uppsala, he too found it much easier to drop in at the Hammersmith facility to discuss collaborative research ideas. As a consequence, the researchers in Uppsala, far away from London as they were, were somewhat disadvantaged compared with their Hammersmith colleagues. Moreover, as mentioned in the preceding chapter, the Uppsala PET Centre had a long history of working in carbon-11-based chemistry, an area it had once pioneered. Aligning with the fluorine-18-centred research agenda was therefore done with a fair amount of reluctance. In addition, from Amersham’s point of view, the dissatisfaction Långström felt with the whole IMANET set-up made the engagement slightly more cumbersome than it perhaps could have been. For Amersham, it was simpler to approach Brook, the head of Hammersmith who, as a medical doctor who still saw patients, had a keen understanding of what was pure science and what was research directly geared to exploring potential treatments for disease.

“From my standpoint, David Brook made Hammersmith work because he got why what we wanted was clinically important and not just interesting” (interview, Clarke, 2012).

Once Hammersmith’s research ideas, a few of which matched some of the core interests of Amersham, became integrated into the company’s R&D team, Hammersmith developed a closer bond with Amersham:
“(….) they were much more part of the team, whereas the Uppsala IMANET team was always separate from our research team. And the Uppsala team was always kind of… having placed all of their value in their independence rather than their collaboration” (interview, Archer, 2011).

In other words, at Hammersmith there was acceptance and understanding of what type of research was valuable to Amersham. In Uppsala, on the other hand, it was more difficult to come up with or embrace research ideas that were commercially promising but generally lacking in scientific edge. The heart of the collaborative problems between Uppsala IMANET and Amersham, and later GE Healthcare, thus went beyond geographical location and the researchers’ individual attitudes. Although these factors were certainly key in explaining the arduous nature of the cooperative efforts, what was perhaps the most fundamental constraint was the gap in scientific knowledge between Uppsala IMANET and the internal R&D in Amersham and GE Healthcare.

Prior to the acquisition of the Hammersmith and Uppsala PET centres, Amersham’s own R&D team had primarily been involved in developing contrast media products and molecular imaging products, but had no experience of working with PET. For this reason Amersham, besides securing PET knowledge by purchasing world-famous PET centres, was making additional investments in PET expertise during the period when IMANET was being formed, by recruiting PET researchers to work in this new area in the company. Notwithstanding this new internal PET knowledge, Amersham naturally looked to IMANET to support and strengthen its PET research capacity. One of the strong forces behind IMANET, Clarke remembers the role played by Uppsala and IMANET as repositories of knowledge:

“We were starting to make our own PET imaging molecules, and our people were just really struggling with the chemistry because they didn’t understand PET chemistry that well, because they didn’t do it. (…) One of the advantages of all three of these centres was that people would come from industry or from outside, other researchers would come to them and say: ‘I’m really interested in where this molecule goes in the body. Can you make me a PET version of this molecule?’ And they would kind of figuratively look at the molecule and go: ‘Yeah, we probably can go back ten steps and make it.’ They were brilliant at that” (interview, Clarke, 2012).

Accordingly, the expertise available at the PET centres had a hugely positive impact on Amersham, and later GE Healthcare, in terms of furthering knowledge in the larger organisation. However, in the attempts to collaborate and exchange ideas for joint research and development projects it was not evident how to bridge the differences in the two organisations’ knowledge bases. Luthra, then a PET researcher at Hammersmith, recalls what the interaction with Amersham R&D was like:
“Sometimes they’d sort of ask questions, and you were thinking ‘Why on earth are they asking that question? It’s so obvious.’ I think the two organisations differed in their pace of understanding” (interview, Luthra, 2012).

Not surprisingly, the PET centres were far ahead in their understanding of what the technology could offer and what they themselves could do with it. As a result, there was a sense of frustration at the IMANET centres, and particularly at Uppsala, because Amersham did not fully recognise and appreciate the versatility of PET and was unable to make use of all the knowledge available within the organisation. As for the R&D team in Amersham, Beijer had the feeling that the researchers at the parent company, aware of the skill within IMANET, viewed the PET scientists as competitors. In the words of Luthra, the two organisations were essentially “five years out of sync with each other” (interview, Luthra, 2012). Thus, when GE Healthcare became the new owners of IMANET after acquiring Amersham in 2004, what the enormous corporation took over was no well-oiled collaboration machine.

6.14 GE Healthcare’s takeover

After 18 months’ negotiations with Amersham, for which GE Healthcare had paid several billion pounds in 2004, Uppsala IMANET found itself lodged within the gigantic structure that is General Electric (GE). As described earlier, GE had been one of the first to approach the PET Centre back in 2001, when Uppsala University had been looking for a buyer of the facility. In the discussions with Amersham a few years later, IMANET struck GE Healthcare as an interesting concept, and it was a part of the total Amersham package that it valued highly (interview, Jeans, 2011). Nonetheless, when GE Healthcare found itself actually owning and managing IMANET it soon realised it was less of an asset than it had initially thought. Even so, now that the PET centres belonged to GE, the giant corporation was determined to run IMANET the way it ran all its businesses.

While keeping the overall strategy and business model that Amersham had once developed for IMANET, GE Healthcare found it necessary to instate new routines and maintain tighter budget control. IMANET had been losing money from the day Amersham purchased it, but in GE there was no clemency with regard to businesses operating in the red. In short, IMANET had to shape up if it were to survive. Sensing that GE Healthcare was not the company for him, and that managing the PET Centre under Amersham had been challenging enough, Beijer, the CEO of Uppsala IMANET until then, decided to leave a few months after GE Healthcare’s takeover. He was replaced by a British manager from former Amersham, Sue Matthews, who
would soon be running Uppsala IMANET with less consideration for Långström’s wishes and opinions. But it was the new CEO for the whole of IMANET, an American named Eric Stahre, who faced the overall task of rapid cost-cutting, as well as introducing measures that would enhance both the efficiency and effectiveness of the organization. One example of the new regime was the way fee-for-service business was handled. At the monthly telecom meetings now held with each of the three IMANET centres, every fee-for-service contract was reviewed and updated in terms of progress and income. In addition, the organisation became more proactive in seeking fee-for-service contracts, as opposed to just collaborations.

The new, tougher commercial attitude also dictated a different way of planning contract studies. The idea was that the Uppsala PET Centre should accept reservations for more studies than they could actually accommodate (much as airlines overbook flights to ensure that the aircraft seats are filled even if there are last-minute cancellations). This proposal incurred Uppsala’s disapproval; there, it was argued that overbooking studies would jeopardise the Centre’s relationships with pharmaceutical companies, possibly resulting in a company never coming back should its study be cancelled owing to IMANET’s overbooking. As for the collaborative research projects involving IMANET scientists and the parent company’s own researchers, GE Healthcare pushed for better alignment of IMANET with the commercial and R&D needs of the former Amersham. The most radical change in the organisation, however, was the major reduction in staff: to slash costs, Stahre made some 25% of the Uppsala IMANET employees redundant. Among them were several accomplished researchers. At least the cost of salaries would now be somewhat less burdensome for GE Healthcare, and the size of the deficit less daunting, in periods when business was slack. However, for the Uppsala PET Centre the staff cutbacks were a hard blow.

Inherent in GE Healthcare’s way of running IMANET, with the pronounced focus on economic sustainability, was very restricted tolerance of the PET centres’ academic component. Since, of the three IMANET sites, Hammersmith was the centre that most resembled a business, it was naturally the one that was the easiest to manage as a business. The Turku PET centre did not pose too much of a problem either, since it was not actually owned by GE Healthcare. With its strong sense of independence, its markedly academic culture and its wish for more research resources – a wish it shared with Hammersmith – Uppsala presented the biggest challenge to its owner. Correspondingly, under the new regime the Uppsala team struggled even more than they had done under Amersham.

The previous chapter elaborated on GE Healthcare’s strict policy regarding resources for independent research, and the part these restrictions played in breeding discontent among the researchers. Långström, who now had a general role for all of IMANET, as well as heading clinical research at
the PET Centre, was not in charge of staff any more. On top of this, he was no longer able to dispose of available research resources as he saw fit. Instead he had to go to the person in charge of the chemistry division at Uppsala IMANET, who happened to be one of his former PhD students, and ask for money and chemists to work with him in his projects. Needless to say, this arrangement, which overturned traditional power relations, did not improve the situation. In addition, the PET Centre was in no way exempt from following GE’s processes and procedures. While having a professionalising impact on the organisation from a business perspective, these new routines also had a somewhat alienating effect, reinforcing the negativity and low spirits that already existed. Before leaving his position at IMANET, Beijer experienced what it was like to follow the new routines:

“Most of it was electronic. You were supposed to sit at the computer and do a number of things: evaluation of staff, health, safety and environmental issues. Each area was supposed to have a champion and there were 21 different areas. And I said: ‘We’re 50 researchers. Should I select 21 champions of health, safety and the environment?! People don’t know what this is – it doesn’t work.’ And then it was just like: ‘Just do it.’ They gave firm instructions and said how they worked globally, everybody does the same, so ‘you too’” (interview, Beijer, 2011).

Stahre, the IMANET CEO, expected every number to be “analysed, turned around and about, and presented”, which caused anxiety in Uppsala where they lacked a system able to carry out these types of calculations in a simple way (interview, Beijer, 2011). But elements such as presentation of numerical data, monthly meetings regarding fee-for-service activities, and regular evaluations certainly gave management better control of the Centre and in some ways enhanced certain functions of the organisation. Nevertheless, after GE Healthcare's takeover the decision process, which had not been smooth and quick in the past, slowed down even further. Board meetings became less engaged, issues were postponed and the GE team assigned to run Uppsala IMANET appeared to be unsure of what mandate they actually had to make decisions. During the years with Amersham the Swedes had usually travelled to London for meetings, but after GE Healthcare came into the picture most meetings were conducted by telephone, thus amplifying the sense of being far removed from head office (interview, Jonsson, 2010). Meanwhile, the University Hospital was struggling to make its voice heard.

6.15 GE Healthcare and the University Hospital

During the two years that Amersham ran the Uppsala PET Centre, the then University Hospital Director, Erik Hemmingsson, felt there was some sort of
working dialogue between the two organisations. According to Hemmingsson, the biotech company exhibited a certain degree of understanding for the needs and wishes of the Hospital and County Council in relation to the PET Centre. The relationship with GE Healthcare, on the other hand, was fraught with frustration. The decision process in GE was regarded by the Hospital as very slow, with practically every decision needing approval from top management. In addition, the Hospital management had the distinct feeling that the owners were impossible to influence. Nevertheless, the Hospital Director did not interpret any of this as signs of ill feeling or antagonism, but rather as a consequence of GE Healthcare being part of a gigantic multinational corporation headquartered on the other side of the Atlantic (interview, Hemmingsson, 2011). In the colossal complex that was GE, IMANET was most likely just a minuscule appendix, and the likes and dislikes of a hospital in Uppsala were consequently not of prime importance. Amersham had been somewhat more responsive to the Hospital's needs and expectations than GE Healthcare, but on the whole, both companies had been largely uninterested in the quality of the clinical research and clinical practice.

In contrast, during the years when the University managed the PET Centre, well-run clinical research projects and patient care had been what the University wanted. The founding and development of the PET facility had constituted a part of this ambition. Interactions between the PET Centre and the University Hospital, which had been fairly informal in the University years, were routinised under Amersham and GE Healthcare. For instance, where doctors had previously been able to call the Centre and ask for a certain tracer to be produced, the new system required letters of referral and response times could be long. On occasion, it would take months to get the desired tracer. Similarly, running tests on patients as part of clinical PET research projects became more complicated since these projects had to be approved by a committee with representatives from Amersham or GE Healthcare. This arrangement was vastly different from the pre-acquisition era, when the standard procedure had been to obtain Långström's informal acceptance. Medical researchers perceived the new system as more rigid and bureaucratic.

In the new commercial reality, the position of the University Hospital was quite weak, particularly as the County Council had no ownership stake in Uppsala IMANET. One consequence was the Hospital's inability to negotiate prices of products and services. Essentially it had to agree to purchase what it needed from Uppsala IMANET on conditions set by the commercial owner, be it Amersham or GE Healthcare. And in 2006 the last shred of public power over the PET Centre was lost when the University gave up its minority ownership.
6.16 The University’s holding company

Two years after GE Healthcare took control of IMANET, the University holding company UUAB decided to sell its 25% share of the company, and Jonsson was consequently asked to resign from the IMANET Board. Development of the PET Centre prior to the commercialisation had in no way been contingent on UUAB, but since the Centre’s commercialisation the financial well-being of the holding company had depended on the PET Centre in every way. Released from its tie to IMANET, UUAB now possessed SEK 50 million – money indispensable for carrying out new academic ventures. In the words of the former Chancellor of Uppsala University, Sundqvist, thanks to the capital yield from the sale of the shares, the holding company in a sense “became one of the products” (interview, Sundqvist, 2010) of the entire PET commercialisation endeavour.

6.17 Third hand-over of the Centre

Towards the end of the period under GE Healthcare, the research team in Uppsala had been increasingly engaged in developing the fluorine-based version of PiB. In this collaboration project, the Uppsala researchers were given the chance to use their knowledge in a way that was interesting both to them as scientists and to the Centre’s owners:

“Yes, then we [were] useful within GE, on both the pre-clinical side and a bit on the clinical side. With things that you think: ‘This is what you should have done in 2002. Then you would have seen what we’re good at and how we can help you in your research and your organisation’” (interview, Antoni, 2010).

In some years, too, revenues from fee-for-service projects had been fairly high, albeit not enough to generate a profit, or to break even – although they did come close one year, making only a very small loss. Impressive as these earnings might have been for a regular R&D department, for a business such as IMANET they were very poor. Accordingly, despite the efforts in contract research and use of the researchers in the PiB project, GE could not overlook the fact that Uppsala IMANET constituted a drain on finances. Keeping the Centre within the corporation was therefore unjustifiable. Thus, two years after UUAB sold its shares in IMANET came the announcement that GE Healthcare would be selling the Uppsala PET Centre to the University Hospital. A factor contributing to this sale was GE Healthcare’s threat of radical price rises for the clinical services to the Hospital. Given this prospect, the University Hospital saw no way to save the situation other than to take over the PET operations jointly with the University.
Having lived with rumours of a shutdown for a couple of years, the PET researchers were not surprised by this decision. Nevertheless, the time preceding the announcement, coupled with the lengthy negotiations between the University, the County Council and GE Healthcare, took its toll on the PET organisation. A major reason why the negotiations progressed at such a sluggish pace was the contention regarding IP rights. One of the hardest issues to resolve concerned tracers for which GE had patents. To be able to use these tracers for research in a lawful manner, Uppsala University needed to obtain a “right-to-use” (RTU) licence. However, GE was willing to grant the University only the RTU licences for basic research, refusing to let the Centre buy the licences to use the tracers for contract research.

For the University, this issue was a deal-breaker: if it was not entitled to buy the licences for all types of tracer uses, no contracts would be signed. It took considerable time for GE to reach a decision, since the information had to pass through the entire organisation, all the way up to top management, via the patent and the financial divisions. In other words, the red tape was substantial. The issue was eventually resolved by adjusting the price of the licence, making it more expensive to use it for contract research than for basic research. In sum, while rumours about the fate of the PET Centre were circulating and IP issues were being deliberated in negotiation sessions, the staff at the Centre “lived in a vacuum”, and every now and then someone would resign without being replaced (interview, Antoni, 2010). A change was badly needed. When the PET Centre was eventually handed over to the University Hospital and the University in late 2010, at least the long-drawn-out uncertainty was over.

To an outside observer with only hard data at hand, the most significant, measurable change that took place after the takeover by the University Hospital and the University may have been the increase in scientific production in terms of academic publications. As the bar charts (see Figures 6.1a, 6.1b and 6.1c) below shows, the years following the PET Centre’s return to the public sector were marked by growth in PET publication output. Clearly, the change of ownership entailed a new emphasis on academic knowledge production. The bar charts show the number of PET-related articles and conference proceedings published over the years at (a) Uppsala University, and (b) the University Hospital in Uppsala. For reference the development displayed in these two charts can be compared with Figure 6.1c (displayed also in Chapter 4, section 4.1), which shows the number of PET related articles and conference proceedings published globally.
Figure 6.1a Number of PET-related publications 1983-2015 at Uppsala University

Figure 6.1b Number of PET-related publications 1983-2015 at the university hospital in Uppsala
However, the increased focus on academic science was not the only change. The years that followed the return of the PET Centre to public ownership were a period of adjustment among the needs of the various parties involved. Medical doctors, academic researchers and GE Healthcare had to negotiate the terms for their interaction and use of the facilities. With GE as a mere external collaborator, the question of how to fund operations became the responsibility of the two public institutions.

What this meant was that financial losses had to be kept within manageable boundaries, while good academic science had to be produced at the same time. The cost of the Centre’s infrastructure and activities remained very high, but from 2014 adjusting organisational size to the funds available kept the financial hemorrhaging within reasonable limits. The Centre’s preclinical section derived its primary funding from three different sources: the University, the Government and Uppsala researchers who conducted their projects partly at the PET Centre, and paid the Centre from their own pockets for the PET services they needed. In addition, the Centre began renting out a section of the facility to a service organisation that helped
scientists with advanced biological visualisation technology. Nevertheless, the persistently low demand for fee-for-service studies was palpable in the PET Centre budgets. In addition, the regulations passed in 2011 regarding tuition fees for non-EU international students had a negative economic effect, since they entailed a dramatic decrease in the number of master students enrolled and thus in revenue for the organisation. Furthermore, the expiry of the contract between GE Healthcare and the University Hospital at year-end 2013 marked the end of the guarantee sum structure. As mentioned in Chapter 4, until then this structure had given the Hospital SEK 15 million a year to cover the running costs of the PET facility.

Irrespective of the PET Centre’s financial circumstances, the economic importance of PET to the University Hospital nonetheless remains unchanged. Faced with the heavy costs of owning and running PET infrastructure, the ability to offer PET services to patients from other regions is critical. The Department of Endocrine Oncology continues to attract many international patients – some 200–250 a year. Servicing this group makes up almost a third of the unit’s operations, and in proportion to its size this department is the most profitable one in the entire hospital. Moreover, the overall requirement for PET scans at the University Hospital is expected to triple in the near future, and with it will come a corresponding increase in income. Most important, perhaps, is recognition of the Centre’s particular expertise – evidenced, as mentioned in Chapter 4, by the Uppsala PET Centre being selected to have both PET-MRI and the new PET-CT scan. Clearly, the journey continues, with more molecules, powerful machines and financial considerations.
Chapter 7. Relating science use to commercialisation, commodification and resource interfaces

The case study of the Uppsala PET Centre tells a story about the utilisation of science in a setting marked by processes of commercialisation, commodification, and subsequently, de-commercialisation. It is an account in which three distinctly different worlds meet – academia, business and healthcare – each one with its own set of expectations, motives, norms and preferences, i.e. its own scheme of valuation. Every twist and turn of the commercialisation, commodification and de-commercialisation processes, as well as the journey’s outcome, bears the imprints of the actors with a stake in Uppsala PET science. This chapter makes up the first part of the analysis of this journey. Its objective is two-fold. Firstly I present an analytical overview of the Uppsala PET journey, so as to establish what schemes of valuation have been at play, and how these schemes have affected the degree of commercialisation and commodification. Secondly I prepare the terrain for the in-depth resource analysis that follows in Chapters 8, 9 and 10.

7.1 Analysing commercialisation and commodification with respect to schemes of valuation

To address the first objective of the chapter, I will map out the relations between schemes of valuation and the processes of commercialisation and commodification of science. Commercialisation and commodification define the context in which the PET journey takes place, and grasping the association between these phenomena and schemes of valuation is critical in order to understand the research problems of this thesis. To be more precise, both research questions deal with the question of the utilisation of science in an inter-sphere landscape. One of the components in this inter-sphere environment is the presence of business, which has affected the movement both toward and away from commercialisation and commodification. Because of the centrality of commercialisation and commodification in the development of the PET Centre, and hence ultimately to the use of science, the first part of the chapter is structured around these two concepts.
With the goal of analytically establishing a connection between schemes of valuation, the main actors and the degree of commercialisation and commodification, I present the empirical material chronologically, following the course of ownership succession and the changing principles of operation entailed by the changes in ownership. The first step in examining the interrelation between schemes of valuation and the degree of commercialisation and commodification is to address two basic issues: first, what schemes of valuation do the main actors in the story embody?; and second, what exactly has been commercialised and commodified?

7.2 The main actors and their schemes of valuation

The empirical chapters of this book showed how the efforts of three major stakeholders – Uppsala University, Uppsala University Hospital and Amersham/GE Healthcare – to make PET science fit their individual ambitions, impinged upon the course of development of the Centre and the scientific activities taking place in the facility. Part of the reason the commercialisation process was so fraught with conflict can be found in the differences in objectives of the three actors. While the most fundamental aspiration of the University, besides teaching, was the production of scientific knowledge, the foremost mission of the Hospital was to provide healthcare to its patients. Amersham and GE Healthcare on their part were at the most basic level driven by the ambition to create profit. In other words, in the evolution of the Uppsala PET Centre there has been a situation in which three distinct schemes of valuation, those of academia, healthcare and business, have had to coexist. Figure 7.1 below depicts precisely this coexistence of valuation schemes, in terms of their relative proportions during specific phases of the Centre’s development: before the full commercialisation, during the commercial years and after the return to public ownership. The different schemes of valuation are mapped out on a timeline, and the size of the font of the valuation schemes indicate the their relative importance during each specific phase. Section 7.3 discusses these different phases and how they relate to the three schemes of valuation with which we are concerned.
Now, as the analysis progresses, we will see that these schemes of valuation do not in every instance correspond to a “pure” mode of operation of one kind or the other; rather, the value categories are dynamic in that they can be influenced to some extent. Nevertheless, to appreciate the complexity of the account it is crucial to recognise that the elemental spirits of academia, healthcare and business respectively are essentially different, and that they cause the various actors to make very different valuations of PET science. This is an understanding we will take with us as we continue to examine the data.

7.3 Complete commercialisation of science

What was commercialised at the Uppsala PET Centre was not simply a scientific product, which is the typical case in business ventures based on academic research; the “normal” course is when university scientists identify the business potential in a piece of their research, and form a company around it so as to derive economic value from its exploitation (Vohora, Wright and Lockett, 2003; Clarysse and Moray, 2004). In the PET story, on the other hand, we see how every aspect of the PET Centre, and not solely an isolated piece of science or technology, was comprised in the commercial undertaking. Indeed, it was science as a complete set of physical and organisational resources, as conceptualised in the theoretical chapter (Chapter 2), which was commercialised (Dubois and Araujo, 2006; Ciabuschi, Perna and Snehota, 2010). In other words, in the transformation of the PET Centre from a university unit to a business actor in 2002 every single component of
which PET science consists was affected: the organisation, the knowledge, the machines, as well as the tiniest basic physical building blocks of PET, the tracers. Amersham’s acquisition of the Centre meant that the organisation was restructured so as to align with the company’s scheme of valuation; knowledge was increasingly used to engender economic value for the mother company; the use of machines was to a large extent devoted to activities with a commercial goal; and the use of tracers was affected by the new objective of the organisation to create commercial value – or, to be more exact, to create enough commercial value at the end of the day to yield a profit somewhere in the chain. This distinction between achieving enough economic value so as to be self-sustaining, and that of making a profit, is crucial, since it points to the rudimentary difference between the attitudes of the first two owners of the Uppsala PET Centre (i.e. Uppsala University and Amersham/GE Healthcare) in regard to commercialisation and commodification. Whereas the University was happy if the Centre broke even, the commercial owner wanted profit. The next few sections take a closer look at how this difference was manifested.

7.3.1 The semi-commercial form: self-sustaining

If we move back from 2002, when what I above called a complete commercialisation metamorphosed the PET Centre into a commercial player, to 1991 when the PET Centre began its activities, we find a research institution which operated on premises that could tentatively be labelled semi-commercial. The overarching goal of the PET Centre’s operations was clearly to produce new cutting-edge scientific knowledge, interesting and original enough to be published in academic journals. But, as recounted in the empirical chapters, the financial means to achieve this goal would to a significant degree be the responsibility of the PET Centre itself. The way to meet the financial needs of the Centre was the commodification of science as a process, as well as the commodification of science as a clinical service. If we begin with the first type of commodification, that of science as a process, we see that it constituted one of the three pillars that were meant to finance the Centre, namely that of contract research. By applying their knowledge of PET chemistry, and through their command of PET as a technology, including the running of all of the machines forming part of the PET infrastructure, the researchers at the Centre were expected to bring in revenues by conducting science for the pharmaceutical industry. Similarly, by using their knowledge of

The expectation of where exactly this profit would materialise differed somewhat between the two commercial owners. During Amersham’s ownership the goal was for the activities at Uppsala IMANET to contribute in such a way that profit was created for the mother company as a whole, whereas GE Healthcare demanded that Uppsala IMANET not only contributed to the mother company in the longer term, but also made a profit for itself.
tracer production and of the operation of PET scanners, the scientists were also expected, in return for payment, to deliver scientific clinical services to Uppsala University Hospital, a commitment which made up the second supporting financial pillar of the Centre. The basis for the set-up was thus that commercial activities would aid the Centre in becoming self-sustaining.

What made this arrangement “semi-commercial” rather than “fully commercial” can be summed up in five points. First, although the goal was for the Centre to be self-sustaining the unit was in practice being given a free pass to operate in the red, and was continuously receiving substantial contributions from the University without ultimatums, demands to downsize or in other ways alter operations so as to gain control over the financial muddle. Second, when the point was eventually reached at which University management deemed the situation untenable, a little short of a decade after the founding of the Centre, it was the University that relieved the PET Centre from the burden by taking over the Centre’s loan and placing it centrally under the University. With this measure the PET organisation, now liberated from the weight of capital costs, was ordered not to allow a new deficit to build up. But at this point the fee-for-service activities, i.e. the sale of science as a process, started to garner so much revenue that the Centre was soon beginning to show a little profit. As a matter of fact – and this brings us to the third point evidencing the semi-commercial character of the Centre – one year the profit margin exceeded the percentage allowed for a public university unit (which is, in fact, set rather low). In other words, the PET Centre was being too commercial.

A fourth circumstance pointing to the aptness of labelling the set-up pre-2002 as semi-commercial can be found in the pricing model. Despite treating elements of PET science as commodities, how pricing for PET related services and goods was handled implies that the commodity perspective did not go deep enough within the University management to be completely followed through. It is telling that no differentiation in price was made for the various types of tracers that the PET Centre sold; every year Uppsala University Hospital bought a fixed number of PET scans for a predetermined sum of money, but the model did not reflect the actual manufacturing costs of the different kinds of tracers. The price for the standard tracer FDG was the same as for the specialty tracer 5-HTP, the production of which was difficult and labour-intensive, thus incurring significant cost. As a consequence, in the case of FDG the Hospital ended up paying a price that surpassed that of the production cost, while 5-HTP was sold at a price set much lower than the actual cost of its manufacture. As pointed out in the empirical chapters this arrangement was peculiar from a business point of view: the standard tracer, which could in reality be purchased from other sites, was sold at a high price, while the “boutique” tracer, which almost no one else in the world knew how to produce and for
which there was consequently not a trace of competition in terms of attracting patients, was sold at a comparatively low price.

A final, fifth, point can be made to illustrate the approach of the University and the PET Centre toward commercial exchange. With the expectation that had arisen with the donation of equipment from the Wallenberg foundation – that the Centre be of assistance to healthcare facilities in the region – the organisation had worked out a semi-commercial procedure. Because the tracers were sold, it was clearly not a question of offering batches of FDG as regular gifts. At the same time, because this type of exchange did not create any profit for the Centre, but in fact often incurred a small loss, there was in fact a tendency among the researchers to think of these special batches of FDG as “gifts”. In this sense FDG tracers could be described, if we employ Kopytoff’s (1986) idea of “commodityhood” as a sliding scale, as semi-commodities: there was a monetary value attached to the good, but because this currency value was set lower than the production cost, the PET researchers would not see the tracers as conventional commodities, but instead as a means to build relationships and help clinicians.

Thus, during the years as a university-owned organisation the dominant scheme of valuation affecting the PET Centre was that of academia, reflecting the goals, norms and values of the researchers and University management. However, its operations were not unaffected by the scheme of valuation of business, although the application of commercial principles was decidedly fragmentary and partial, making the PET Centre a semi-commercial unit. Figure 7.1 displayed previously in section 1.2 shows the relative proportions of the different schemes of valuation during the semi-commercial phase.

7.3.2 The fully commercial form: making a profit

The acquisition by Amersham in 2002 marks the onset of what we may call the fully commercial management of the PET Centre. While up until that point the commodification of PET science had been regarded by the University and the researchers as a way to try to sustain the Centre financially, commodification had never been a goal in itself. The basic purpose of the PET Centre had all along been to produce new scientific knowledge to be shared with the rest of the research community, in line with the scheme of valuation of academia. As Amersham and GE Healthcare assumed ownership, what had previously been solely the means to survival now became the end. Commodification of PET science was now not only the manner in which one could attempt to keep the finances of the Centre together, but actually became a goal in itself as it served the basic aspirations to create profit from the venture. The pronounced hope was that the PET Centre would be able to contribute to internal research projects, the objective
of which was to produce science-based commodities. Whatever did not contribute to economic value creation was being cut short. The squeezing-out of academic science was entirely logical from a business perspective, as were GE Healthcare’s “threats” (as they were perceived by the other parties) to drastically raise the price of clinical services in the near future, or even that the provision of clinical services would stop altogether.

The fact that GE Healthcare did not go ahead with the major increase in price, or cease to offer PET services to the Hospital, is interesting in itself. We know that the Hospital management were shocked by the price list for PET scans and tracers that Amersham presented in 2002, but the fact was that new prices more correctly reflected the actual manufacturing-and labour costs of the services and products purchased from the PET Centre by the Hospital. As a business actor, there was no way Amersham or GE Healthcare could have accepted selling services to the Hospital at a loss, but interestingly enough they agreed to charge a price low enough that no profit was generated for them. In other words, selling PET services to the Hospital added no economic value to their business. Their business scheme of valuation was thus susceptible to the influence of healthcare in determining the new price list; Amersham/GE Healthcare took into consideration that there was a limit to how much the Hospital, a public institution with weak finances, would be able to expend to access a technology on which it was absolutely dependent in order to deliver patient care. Charging a price that would have generated a profit for Amersham/GE Healthcare would have meant depriving the Hospital, or greatly reducing its use, of a tool crucial in maintaining an adequate level of healthcare. In the case of pricing for clinical services the company was thus sensitive to the needs of one of its non-business discussants: the scheme of valuation of business was not untouched by that of healthcare.

Where explorative research was concerned there was initially, at the beginning of Amersham’s ownership, some room for an academic valuation scheme to exist alongside a straight business rationale, but this freedom was soon curbed, as independent science was increasingly being pushed out into the margins. The attempts at research collaboration often evidenced the fundamental differences in the schemes of valuation of the two actors; whereas company management wanted to see research and development work geared toward inventions with the potential of becoming successful commodities that generated economic value, the Uppsala PET scientists were still deeply engaged with the curiosity and novelty aspects of research, which was reflected in their development project proposals. In accordance with their scheme of valuation and the academic culture into which they had been socialised and of which they still considered themselves to be a part, the PET researchers clearly valued topics that they considered challenging and interesting enough to warrant further exploration. However, the commercial
potential of these research propositions was highly uncertain, if not sometimes non-existent, and therefore of limited value to Amersham/GE Healthcare.

To sum up, even though the PET researchers were making efforts to contribute to the company they now worked for, it was very clear that an academic scheme of valuation was part of who they were. As a consequence what they as scientists valued differed from what the mother company saw as most valuable. Even though the mother company made some room for the schemes of valuation of academia and healthcare to exist, the Centre now operated chiefly in alignment with a business scheme of valuation, as shown in Figure 7.1 (displayed previously in section 7.2), depicting the relative importance of the three valuation schemes during the fully commercial phase.

7.3.3 …and back to the semi-commercial: healthcare, business and academia

The transfer of the Uppsala PET Centre back to the University and Uppsala University Hospital took place after GE Healthcare had concluded that, while there was indeed economic value to be gained from PET science, owning and being in charge of every aspect of this science, from individual scientists and tracers down to hot cells and scanners, incurred more costs than it gave back in revenue. From simple arithmetic GE could deduce that the commercial value of PET would be more efficiently captured by the giant company when freed from the burden of ownership. On its part, Uppsala University Hospital regarded its takeover of the clinical section of the PET Centre as a chance to tailor the operations to fit its clinical needs, thereby increasing the value of the technology from a healthcare perspective. In other words, the clinical part of the PET Centre would be put to use in a way that accorded with the scheme of valuation of healthcare.

Nonetheless, it should be noted that the Hospital had all along had a secondary economic interest in PET which had been running alongside the primary healthcare-focused activities for many years: to a certain extent the scheme of valuation of healthcare thus harmonised with a scheme of valuation of business. The first economic concern was tied to 5-HTP; bringing in substantial streams of revenue for the Hospital, the offering of 5-HTP scans to both domestic and international patients was a service of great economic value to the Hospital. Secondly, when the Hospital purchased its own scanner during GE Healthcare’s ownership there was an underlying idea that it would be selling FDG scans to patients from neighbouring counties. But, all in all, the overshadowing motivation behind the Hospital’s wish to take over the clinical section of the PET Centre was to secure the healthcare value to be gained from PET in clinical application. Given the Hospital’s uncertain financial situation, however, the County Council deemed that the
most viable arrangement would be one in which a relationship with GE Healthcare was maintained. The agreement was that GE Healthcare would be partially funding the operations in exchange for promises of access to the PET facilities, where it wanted to perform contract research and other projects. Interestingly, the business for bulk production of FDG that GE Healthcare had been intending to set up while it still owned the facility was not actually put in place by GE until after the Centre had been sold back to the University and Uppsala University Hospital. This meant that full commodification of tracers in Uppsala was not established during the fully commercial phase, but instead began after ownership had been transferred back to the Hospital and the University.

With the University owning and running the now significantly reduced pre-clinical section of the Centre, where the dominant scheme of valuation now was that of academia, the three main actors thus remained closely intertwined even after the shift of ownership was a fact. The Hospital hoped that the generation of economic value from PET science could continue without encroaching on the needs and use patterns of healthcare. And even though some doctors were discontent with the business-healthcare balance during the first year after the Hospital’s takeover, the coexistence soon became relatively unproblematic. In fact, recognising the importance of contract research for the operations, the pre-clinical section of the Centre desired increased commodification of research, but knew that the dwindling fee-for-service market for PET meant that business was hard to find. Thus, the majority of PET research currently being carried out at the Centre takes place for the sake of its value for scientific knowledge production.

7.3.4 Looking at what we have: three schemes of valuation and their effects on the commercialisation and commodification of science

Each of the actors involved in the PET Centre carries into the venture its own understanding of what makes PET valuable, and the degree to which the various elements of PET science ought to be commercialised and commodified. In the first phase of the PET Centre journey, during which the University owned and managed the facility, science was valued both in terms of its economic benefits (through fee-for-service research and the sale of clinical PET services) and its scientific knowledge contribution, with a clear emphasis on the latter type of valuation. We thus see how science – including knowledge, machines and tracers – both as a product and as a process occupied different positions on Kopytoff’s commodity-singularity continuum (1986) at different points in time, depending on the end, and recipient, for which a certain scientific procedure (e.g. a PET scan, the writing of a research report, the synthesis of a tracer) was performed. For instance, a contract
A research report for a pharmaceutical company would be at one end of the commodity continuum, while the performance of a clinical PET scan would be somewhere in the middle, and so forth. In contrast, the full commercialisation of science, which came with Amersham’s acquisition in the second phase, meant that the economic valuation gained overall precedence over that of academia and healthcare. Consequently, decisions were chiefly based on what would bring the most favourable economic outcome for the company. And of course, the commercial value of PET science emerged when research activities that were not directly geared toward the company’s most immediate areas of interest were diminished.

But this dominance of economic valuation notwithstanding, it can still be noted that small fragments of the schemes of valuation of academia and healthcare were incorporated into the prevailing business rationale, making the company’s interaction with PET scientists and the Hospital, if not smooth, at least more manageable. In terms of Kopytoff’s continuum, science tended during this stage to be located toward the commodity-end of the scale for most of the time, albeit not at every instance. During the third phase of the PET Centre journey when the Centre was de-commercialised, PET science was once again primarily valued for its contribution to knowledge production as well as, now that the Hospital was in charge of the clinical part of the Centre, for its role in healthcare. But just as in the preceding two phases, the new management also harboured a (modest) wish to harness the commercial value of PET science so as to help finance the operations. This meant that the extent to which science was commodified varied and so, much like during the early years of the University’s ownership of the Centre, science now moves between the two end-points of Kopytoff’s continuum.

Table 7.1 and figure 7.2 below summarise the findings made so far. Table 7.1 shows the various forms of value created through different types of utilisation. The left-hand column lists the three different types of value created from science at the PET Centre. The middle column presents the mechanisms by which these different forms of value were created, i.e. the means by which PET science was put to use. The right-hand column lists the recipients of the different types of value created.
<table>
<thead>
<tr>
<th>Type of value from science</th>
<th>Mechanism for value creation</th>
<th>Recipient of value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Contract research, clinical services, sale of tracers, new commercial products (tracers, notably Vizamyl), Amersham/GE – PET Centre collaboration</td>
<td>Amersham/GE Healthcare, PET Centre, Uppsala University, Uppsala University Hospital</td>
</tr>
<tr>
<td>Healthcare</td>
<td>PET scans (diagnostics, monitoring of treatment)</td>
<td>Patients</td>
</tr>
<tr>
<td>Academic knowledge</td>
<td>Independent pre-clinical research, independent clinical research, contract research</td>
<td>PET researchers, medical doctors, patients, pharmaceutical companies, Amersham/GE Healthcare</td>
</tr>
</tbody>
</table>

Table 7.1 Overview of value creation from PET science.

Figure 7.2 depicts the level of commercialisation of the PET Centre organisation in relation to the level of commodification of the scientific output at the Centre. Six outputs have been identified and included in the figure: clinical services, PET Centre’s sale of tracers, GE Healthcare’s sale of tracers, Vizamyl, independent research and contract research.

The graph shows how clinical services went from being a semi-commodity to being at a higher level of commodification after the full commercialisation of the Centre, albeit not being a full-fledged commodity. On the other hand, from the time the Centre started to engage in this form of assignments, contract research was always a full commodity. Vizamyl and GE’s sale of FDG after the return of the PET Centre to public ownership have likewise been full commodities. Furthermore, independent research and the PET Centre’s gift-like “sale” of FDG have always been at the lowest end of the commodity continuum (Kopytoff, 1986).

The figure graphically demonstrates some of the key findings made thus far in this chapter: 1) the degree of “commodityhood” of a certain type of scientific output shifts over time; 2) the level of commercialisation of the PET Centre during a specific phase did not correspond to a uniform level of commodification of all types of scientific output during that phase. Hence, as demonstrated in the figure, there has never simply been a one-to-one ratio between the level of commercialisation and the level of commodification.
Figure 7.2 Commercialisation of science in relation to the commodification of science

So far, the first objective of this chapter has been addressed. I have identified what schemes of valuation have been involved in the PET journey, and also provided an analytical overview of the PET Centre story with attention to how these different schemes of valuation have affected the choices made by the main actors in their running of the Centre. We have seen that schemes of valuation influenced the degree to which science was commercialised and commodified, both as a product (tracers) and as a process (fee-for-service studies and clinical services). More generally, this chapter has, in broad strokes, demonstrated how the schemes of valuation of the actors involved relate to the utilisation of science.

But to gain a more thorough understanding of this use, not least of efforts to commercialise and commodify, it is necessary to closely examine the resources that make up the network in which science is embedded. At the beginning of this chapter I underlined that science underwent “complete commercialisation” during the course of the PET Centre’s development. This meant that every aspect of science – science as output, organisation and facility – was commercialised and subsequently de-commercialised, resulting in a change in the use of key resources such as machines and knowledge. So as to fully grasp the nature of the utilisation of science at the Uppsala PET Centre, it is helpful to study how these resources are combined.

The following three analytical chapters do just that. The interplay among resources is carefully explored so as to delineate, on a fine-grained level, the
effects of the materiality of science on use, as well as the impact on utilisation by the interaction between different actor spheres. Given the connection between actors and how resources are combined and put to use, schemes of valuation will continue to function as a relevant concept in this investigation of science utilisation. In the remainder of this chapter I address the second objective of the chapter as a preparation for the comprehensive resource interface analysis that follows in Chapters 8, 9, and 10. I do so by explaining my reasoning behind the choice of a focal resource, and what aspects of science use the analysis of different types of resource interfaces help uncover.

7.4 Understanding the use of science through the study of resource combinations

The odyssey of the PET Centre is in a very real sense characterised by struggles for, negotiations over, and discussions about resources. In the succeeding three chapters I therefore analyse the interaction between resources making up the network in which PET science is embedded. The goal is to demonstrate how the utilisation of, and hence the value creation from, science is affected by the materiality of the same entity, as well as by the interaction between actors who belong to different spheres and therefore carry different schemes of valuation. The first chapter of the resource analysis (Chapter 8) centres on the combination of physical resources, while the second (Chapter 9) and third (Chapter 10) chapters deal with mixed and organisational resource combinations respectively.

7.4.1 The tracer as a focal resource

The resource analysis to be presented is extensive, but it is anchored to a focal resource to which all interfaces (Cantú, Corsaro and Snehota, 2010), are tied, directly or indirectly. The resource selected for this purpose is the tracer, and the reasons for that choice echo those briefly laid out in Chapter 4, where the absolute centrality of radiotracers to PET technology was emphasised. Firstly, the chemical compound constitutes the object of pre-clinical research, the tool for biological scientific exploration and for pharmaceutical development, as well as a critical element in the use of PET in clinical routine. Secondly, and crucially, the tracer is the only malleable physical component of PET technology. The changeable chemical design of the molecule determines what is being targeted in a PET scan, and affects the molecule’s own life span. Taken together, these aspects point to the pivotal role of tracers in determining the economic viability of PET technology as a whole, as well as its non-commercial value to scientists, doctors and patients. In other words, choosing the tracer as the focal point does not mean we are only able to
analyse the usefulness and value creation of tracers. Instead, tracers are used as a probe (Waluszewski, Baraldi, Linné and Shih, 2009) into the technoscientific system (Latour, 1987) constituted by PET, allowing us to understand the utilisation of, and thus the creation of value from, Uppsala PET science in its entirety. Importantly, the tracer help structure the analysis. In the vast expanse of resources, the pinpointing of one such concentrates our gaze, ensuring an analysis centred on the elements most vital to the use of PET science.

7.4.2 What do resource interfaces tell us about the use of science?

Understanding what has fashioned the use of PET science at Uppsala University involves digging into the network in which this science is embedded (Uzzi, 1996). The tracer, our focal resource, is surrounded by a wealth of physical and organisational resources. While the direct connections between tracers and other physical PET resources can be grasped intuitively, the relationship between tracers and purely organisational resource combinations is possibly less obvious to the reader. For this latter interface type, the point I wish to make clear is that the organisational resource combinations under investigation are always indirectly connected to tracers. Furthermore, because changes in one part of the network will induce changes in the rest of the network (Håkansson and Snehota, 1995), the interactions between organisational resources will have ramifications for the tracers and the interfaces they are part of. In other words, what goes on between organisational resources in the network will have consequences for the interaction taking place within physical and mixed interfaces (of which tracers form a part). This means that the analysis of organisational resource constellations enhances our understanding of why critical physical resources are being used in a certain fashion.

Having thus established the centrality of the tracer in the network, as well as the nature of its connection – direct and indirect respectively – on the one hand to physical and mixed interfaces, and on the other to organisational interfaces, I wish to approach the manner in which the analysis of these different resource interfaces helps me deal with the research problems of this thesis. First, the detailed study of the outcome of interfaces containing physical resources, i.e. physical and mixed interfaces, takes us straight to the issue of the materiality of science and the repercussions of this materiality for science utilisation. Examples of such interfaces are, for instance, those between a machine and a chemical compound (physical interface), and between a machine and knowledge of how to operate the machine (mixed interface). As we explore the consequences of the material character of science it will become apparent that the use of science is contingent on both the location of
and the dependencies\textsuperscript{23} between resources in the network. We will also observe that, with science partly bound up in materiality in a context of intersphere interplay, where physical scientific resources are scarce, meeting every actor’s needs in terms of science utilisation becomes very difficult.

The impact on science utilisation of the interaction between different types of actors is then investigated in greater detail by studying organisational interfaces. Examples of such interfaces include those between routines and staff, or between knowledge and work processes. Working from the premise that organisational resources essentially reflect a certain actor and hence its scheme of valuation (Baraldi et al., 2011: 268-269; Mouzas and Ford, 2012; Håkansson and Waluszewski, 2002a: 36-37; Håkansson and Waluszewski eds., 2007: 48, 156-9) – this idea was presented in Chapter 2 and is further developed in Chapter 10 – the analysis of the interplay between organisational resources reveals how the utilisation of science is also influenced by the schemes of valuation of the actors involved. Moreover, building on the analytical discussion earlier in this chapter about the connection between schemes of valuation and degrees of commercialisation and commodification, the attention paid to organisational interfaces essentially offers insight into the various forms of use, both commercial and other, that are the outcome of the relationship between different actors and the resources they are connected to. All in all, through the study of combinations of organisational resources, and the schemes of valuation they mirror, we are able to address the issue of how the interaction between actors from different spheres affects the use of science.

In summary, the research problems of this thesis are approached by examining three types of resource interfaces. The study of physical (Chapter 8) and mixed interfaces (Chapter 9), both of which contain physical elements, allow us to address the question of the materiality of science and how it relates to science use. Additionally, close investigation of organisational interfaces (Chapter 10) shed light upon the actor aspect of science utilisation, and more specifically how the interplay between dissimilar actors spheres affects the use of science. The analysis of each of these interface types is presented in the following three chapters.

\textsuperscript{23}These dependencies between physical resources concern the relatively concrete requirements for how different pieces of PET technology need to be linked together in order to function as a complete system.
Chapter 8. Exploring the material aspects of science: physical interfaces

8.1 Investigating the purely physical

In the empirical chapters we learned that, for a PET scientist, machines are what make the world go round. Under the skilled hand of the researcher machines produce radioisotopes, automatically synthesise imaging agents and collect information on radioactive decay in living beings. In short, machines are important. If for a minute we were to imagine the Uppsala PET Centre as a breathing body (much like one of the bodies in the scanner), these pieces of vital research equipment would be the throbbing heart of the unit, the indispensable hardware pumping the blood. And, to continue the metaphor further, radiotracers would make up the bloodstream, transient and fluid. These things – scanners, hot cells, cyclotrons and tracers – are the primary physical constituents of the Uppsala PET Centre and of PET science. For that reason, and also because our three main actors each bring into the context their own distinct schemes of valuation, it is understandable that the use of these physical resources has at times been an object of contention.

Regardless of who is the user of science, the same apparatus is used. It does not matter whether the tracers are destined to be utilised in an independent research experiment, a fee-for-service study, a routine PET scan of patients or if they are to be shipped to a nearby hospital. Radioactive isotopes must still be produced in a cyclotron and synthesised in hot cells. In order to give any useful information the tracers must subsequently be injected into a living subject who is then scanned by a PET camera, irrespective of what the scan results will be used for. To put it another way, all use contexts contain deep, direct interfaces between tracers and PET equipment. No matter who the PET user is, the context of use contains tight interactions between the tracers, cyclotron and hot cells, and equally strong interfaces between the tracers and the PET scanners.

In the next few sections these three interfaces are expanded upon to clarify how the use of science is affected by its materiality. Section 8.1.1 investigates the combination of PET scanners, tracers and human subjects; section 8.1.2 concentrates on PET scanners, tracers and the cyclotron; and section 8.1.3 explores the interface between the cyclotron, radioisotopes, hot cells and tracers. These three resource interfaces have been singled out on the basis of
their relevance to the operation and the evolution of the PET Centre. The selected physical interfaces pinpoint the most important activities and events taking place at the Centre, allowing an in-depth exploration of the most significant aspects of science use. The analysis of these particular interfaces contributes to a deeper understanding of the endeavours of the PET Centre stakeholders to utilise PET science in a space undergoing change.

8.1.1 The interface between PET scanners, tracers and the cyclotron

As has been illustrated continuously throughout this thesis, the complexity of PET as an infrastructure is tied to the inalterable physical properties of the radiotracers. It is the emission of positrons from the radiotracers which constitutes the basic principle around which the PET imaging technology is built, and also, at same time, delimits the how, where and whens of its use. For anyone wanting to engage in PET tracer development, make use of PET as a research tool, or employ it for clinical applications that extend beyond the utilisation of the relatively long-lived FDG tracer, it is not enough to have just a scanner. Access to a cyclotron on site, in absolute proximity to the PET scanner, is mandatory. This non-negotiable cyclotron-scanner interface not only renders PET more complex as a technical system, but also makes it more expensive. For the PET researchers in Uppsala, efforts to obtain scanners and a cyclotron began well before the founding of the PET Centre. As recounted in the empirical chapters, the need for such machines was ultimately to propel the research unit into the commercial sphere as the need for equipment went past what the university was able and willing to provide.

Beginning in the 1970s, the history of the cyclotron-scanner interface at Uppsala is as long as the university’s use of PET. For many years this interface, which must be tight and stable to enable efficient and secure utilisation, was shaky and insufficient to say the very least. The neurologists at Uppsala who in the 1970s began to employ PET for brain scans would have the radioisotopes produced in Uppsala, but would then have to transport their tracers to the PET camera at Stockholm University to get their scans. Because of the inconvenience of this arrangement Uppsala University soon purchased its own brain scanner. Still, for the purposes of the PET chemists neither the brain scanner nor the available tandem accelerator was the answer; they needed a full-body scanner and a real cyclotron. Furthermore, the two machines would have to be in the same location. If we consider the example of 5-HTP presented in the empirical chapters, we see that the development of this tracer and the first few instances of testing on humans of the same compound took place before these rudimentary pieces of equipment had been purchased and installed. Because there was neither a cyclotron nor a scanner in place, there was no cyclotron-tracer-scanner resource interface on
site in Uppsala to speak of. Instead, researchers had to make do with the resources that were available to them. This resulted in a cyclotron-tracer-scanner interface that was loosely tied together across some 70 kilometres: as described in the empirical chapters, the short-lived carbon-11 isotopes were produced in large quantities in a cyclotron in Stockholm. They would then be transported to Uppsala where the tracer was synthesised and subsequently injected into the patient in a camera in Scanditronix’s scanner manufacturing plant.

The energy and resourcefulness of the researchers notwithstanding, driving all the way to a factory with a jar of tracers, a patient and some scientists all crammed in a car was not a tenable solution for the long term. If 5-HTP or any other very short-lived tracer was to be established in a clinical use context at Uppsala University Hospital, and was to be regularly employed in an academic use context at the PET Centre, a stronger interface would have to be created between the cyclotron, the tracer and the scanner. Pointing to the obvious need for these machines, Långström and his colleagues were able to make a case for the purchase of both a full-body scanner and a proper cyclotron. To sum up, a snug interface between the cyclotron and the PET scanner was a prerequisite for proper functioning of the academic and clinical use contexts alike. Furthermore, as pointed out above, during tracer development this interface was often crucial in both contexts at the same time, as academic research and clinical use converged (see Figure 8.1 below for a representation of the interface in question).
This elemental resource interface presents a variety of possibilities for PET science utilisation. As far as healthcare is concerned, the main use consists in making on-site PET scans with short-lived tracers such as 5-HTP. For academic scientists on the other hand, the primary area of use opened up by the tight interface between a cyclotron and a scanner is that of experimentation, whether for PET tracer development purposes or in the utilisation of PET as a research tool in other disciplines. The value created through this use is chiefly non-economic, although it can be argued that the interface also carries indirect economic value for the researchers. Indeed, a complete PET infrastructure, of which the cyclotron-scanner interface forms a crucial part, makes possible research experiments and PhD projects. This research may result in important publications, the number and quality of which constitute a significant variable in funding bodies’ allocation of research grants.

From such a perspective, a possible future indirect economic value for scientists would lie dormant in any resource combination, enhancing conditions for research. From a business viewpoint, the most important utilisation of this constellation of resources is the commodification of science as a process, i.e. the production of contract research studies, which in the case of the Uppsala PET Centre is reliant upon a supply of short-lived radioisotopes such as carbon-11. Even though the value yielded from such use is predominantly economic – hence its importance for business – the utilisation of these resources in contract research has at times created
academic value as well, in instances where findings from contract research studies have been published in peer-reviewed journals.

As we know, the history of using the cyclotron-tracer-scanner interface for contract research at the Uppsala PET Centre dates back to the organisation’s inception, and the relationship of the research institution with business and the allocation of economic value has shifted during the Centre’s development. As pointed out in the previous chapter, well before the complete commercialisation of the Centre in 2002, the PET Centre had followed up on the demand from University management to finance its operations independently. Recognising the commercial value of PET within the pharmaceutical industry, the Centre had realised that considerable revenues could be gained through commodification of its knowledge.

But while the economic value of PET science, accrued in the form of direct income through contract research, was regarded by the PET researchers pre-2002 largely as a boon that facilitated continued independent knowledge production, the same value under Amersham and GE management was viewed in a different light. Whereas under the academic regime the PET Centre had treated the utilisation of PET science for fee-for-service projects as a marginal offshoot from the main purpose of the Centre, the chief concern of Amersham and GE was to obtain as much economic value as possible through this type of commodification. Economic value was thus attributed great prominence, and contract research, for which the cyclotron-tracer-scanner interface was needed, turned out to be the most heavily employed means for attaining this value.

We have learned that a strong cyclotron-tracer-scanner interface is indispensable in clinical, academic and business use contexts alike when very short-lived tracers (essentially all commonly used radiotracers except those based on fluorine-18) are involved. Unless a strong interface between these resources is established, a key feature of the tracer, the tracing function, which depends on the radioactive emission of positrons (the rate of which determines the tracer’s half-life), is of no value at all. In other words, none of the different kinds of values described above would be created were it not for the tracing feature. On a more general level, the cyclotron-tracer-scanner interface pinpoints an important duality of the tracing function, the feature that perhaps most distinctly characterises the tracer. This duality can in a sense be extended to PET science as a whole; the phenomenon of positron emission on which PET rests constitutes both the fundamental strength and the greatest weakness of the technology. While radioactive decay, which enables us to obtain visual information about what is happening in living tissue, is evidently what makes PET so powerful, it is simultaneously what makes PET such a complicated technology from an infrastructural point of view, illustrated clearly in this example of the cyclotron-tracer-scanner interface. This infrastructural complexity would present less of a problem had
it not been directly translated into substantial economic cost. In practice, what this means is that in order to reap the extraordinary benefits of the tracing feature of tracers, one must also accept the cost feature of the cyclotron and scanner. Given the financial constraints under which most organisations operate, this feature of high cost restricts the number of machines a PET Centre can afford to own. From this it follows that technical resources in the form of equipment that the quick radioactive decay of tracers necessitates will be scarce in number.

The effect of this scarcity is profound. With the perspective that science is an entity to a large part inscribed in material objects, any lack of availability of these objects will entail reduced freedom to make use of science; science will be temporarily and locally incomplete. In the case of Uppsala PET science, with its need for costly pieces of equipment, this situation of a restriction in science use was indeed the normal state of things. These circumstances are summarised in Figure 8.1 above, depicting the examined interface. In essence, with the utilisation of science being tangled in the employment of specific pieces of apparatus that happen to be greatly limited, the end result is an overlap of use contexts of different actors. By overlap of use context I refer to a situation where the science use of multiple actors from different spheres happens in the same space and involves the mobilisation of the same scientific resources that this space contains. While the actors’ use of science is mainly temporally separated – for instance, the use of the cyclotron and PET scanners for contract research does not normally take place alongside the clinical use of the same resources – it is not spatially separated: it takes place within the same walls, in the same building. I refer to this situation as the overlap of science use contexts, or the use contexts of science.

We have seen how the situation at the PET Centre was one in which, for technoscientific reasons, the utilisation of, and hence value creation from, science could only be achieved on a regular basis by strengthening a complex physical interface. This tightening of the resource combination required massive investments, meaning that to a certain degree economic considerations shaped the use of PET science from the very beginning. More precisely, cost concerns set a limit on how the PET facility would be equipped. One cyclotron being cheaper than two, four hot cells representing less expenditure than eight such units etc., the cost feature of the equipment thus partly explains the existence of context overlap: letting the use contexts of the spheres of academia and healthcare overlap has been a means of reducing the costs of the operations. As will be demonstrated in the examination of both physical and mixed interfaces in this chapter and the next, this spatial and sometimes temporal overlap of use contexts only began to pose a real problem with the addition of a use context of business. When actors with largely incongruous schemes of valuation found themselves sharing the same space and the same resources, unforeseen challenges arose.
8.1.2 The interface between PET scanners, tracers and human subjects

While it is impossible to single out one resource interface as more crucial than any other, one of the perhaps most obvious, or at least most fundamental, resource combinations is that between the tracer itself, the PET scanner and humans, represented in Figure 8.2 later in this section. The interface here exists in a triad combination where all three resources are simultaneously interfacing with each other: the tracer enters the human body, which is placed inside the scanner, while the scanner detects the positron emission of the tracer. As mentioned previously, this part of PET technology is common to all use contexts. But importantly, as touched upon in the previous passage, for this particular combination of resources some of the use contexts are not merely spatially overlapping, but on a few instances they are also temporally so. For instance, an experiment carried out in an academic research project as a step in the development of a new tracer may also, if the tracer explored is simultaneously being used clinically\textsuperscript{24}, exist in a clinical use context. In such a case the tracer and the human body interface with the PET scanner in two different contexts of use simultaneously, those of academia and healthcare.

One prominent example of the occurrence of such an overlap was the development of the radiotracer 5-HTP. While PET scientists were doing the chemistry development in the laboratory, employing the scanner in their tracer experiments, clinicians – in their capacity as both researchers and physicians – were also taking part in the development efforts by involving their own patients in the testing. But the testing did not solely serve a research purpose: since the tracer under development also helped in a very real way to diagnose the patients, it was simultaneously being used clinically. This also meant that the humans inside the scanner assumed two coinciding identities. For the researchers developing the tracers, the people injected with the tracer were simply living test subjects, while the clinical researchers, who were also medical doctors and used the tracers for their research and medical practice, also viewed the test subjects as patients.

Even though this order of things, with the scanner-human-tracer interface inhabiting the use contexts of academia and healthcare simultaneously, is inevitable and even desirable for a university hospital, the doctors eventually felt it necessary to purchase their own scanner, a few years after the commercial takeover of the PET Centre. Although the staff at the Centre argued that there were always scanners open for the clinicians, the doctors regarded the situation otherwise. At the time they experienced the commodified form of science, in terms of contract research projects going on at the PET Centre under the parent company’s oversight, as disruptive to

\textsuperscript{24} It is not uncommon for academic, clinical research experiments to be part of patient care. In fact, the boundaries between clinical research and patient care are often blurred.
their own clinical use, causing an obstacle to patient care. The doctors wanted immediate access to the scanners without having to wait, and they wanted the tracer of their choice, generally FDG, produced right away.

In other words, the physicians desired a scanner-human-tracer resource combination lined up at a point in time that perfectly fitted their patient schedule, as well as the body of the patient. In terms of use context overlaps, issues sprung up in instances when the clinical use context would unfavourably overlap with the business use context. In addition, Uppsala University Hospital received recurring warnings from GE Healthcare that the provision of the clinical services could be terminated. The solution to what the Hospital perceived as a deficient and uncertain scanner-human-tracer interface at the PET Centre was then to acquire a scanner of its own to be devoted exclusively to the clinical routine use of FDG. This meant that for certain types of scan the clinical use context had physically moved out of the PET Centre and into the Department of Nuclear Medicine at the Hospital. But the change of location of the use context for clinical FDG routine was not the only aspect that changed in the utilisation of PET at the Hospital. The scanner-human-tracer interface changed at a very basic level, as the supplier of the widely used FDG tracer was no longer necessarily located in Uppsala. At times when the production of FDG was low in Uppsala, the Hospital would purchase the tracer from Turku in Finland, or Stockholm, sometimes for a lower price than in Uppsala. As far as FDG scans were concerned, the clinical use context was thus separated from the other use contexts.

This separation, made possible by the fact that funding was available to purchase a new scanner, as well as by the existence of multiple FDG vendors, can essentially be described as the creation of new terms for how the materiality of PET science was to be handled by Uppsala University Hospital in the case of FDG. With the existence of sufficient financial resources to buy a much-needed piece of equipment, and with a range of available tracer suppliers to choose from, the materiality of PET was no longer synonymous with the overlap of use contexts. The fact that the Hospital now possessed a scanner of its own not only meant that it controlled a resource critical for its use of PET. It also gave the organisation improved means to constrain costs and create direct economic value by performing FDG scans on patients from other counties, i.e. to engage in their own, small-scale science commodification. As far as the use of tracers other than FDG was concerned, however, the clinical use context still overlapped those of the other two main actors. For the use of all tracers other than FDG, Uppsala University Hospital still relied on the PET Centre’s scanner-tracer interface, depicted in Figure 8.2 below.
With the return of the PET Centre to the public sector, Uppsala University Hospital expected to eventually be in command of the scanner-human-tracer interface in the clinical use context, and to be able to have patients scanned at the Centre at short notice with access to whatever tracers were needed. The first year of the new regime, however, proved frustrating, as reality did not match the expectations of some of the doctors. Although the PET Centre staff did not at all agree that scanner and tracer availability was lacking, there was a certain discontent among some clinicians, who felt that GE development projects and fee-for-service studies adversely affected the scanner-human-tracer interface in the clinical use context. At the end of the first year after the public takeover of the Centre, dissatisfaction in regard to clinical use among clinicians nonetheless subsided.

As we have seen, scanners, tracers and human subjects are key resources in all three of the use contexts, and the interfaces between them are of considerable value to academia, healthcare and business alike. The above close-up of the activities and situations linked to the interfaces demonstrates how differently healthcare and business have perceived the role, and hence the use, of science. For the main business actor, the primary value of science, in line with a typical business scheme of valuation, has been purely economic, as evidenced by the mobilisation of the scanner-tracer interface to create commodities, notably in the form of fee-for-service studies. The value
derived from science by healthcare, on the other hand, has been both commercial and non-economic.

It cannot be stated with certainty whether or not the access of the Hospital to scanners and tracers was reduced due to the amount of ongoing contract research studies. As mentioned above, views differ on this point. Yet the Hospital made the decision to purchase its own scanner so as to increase its authority over the scanner-human-tracer interface in the clinical use context. There was a belief within the healthcare actor that being in command of its own scanner and FDG supply would increase the usefulness of science for patients, whose health – to which we hesitate to attribute a monetary value – would benefit from the diagnostic and monitoring capabilities of PET. But simultaneously, Uppsala University Hospital viewed its enhanced authority over these material aspects of science as a way to generate economic advantages in terms of both cost control and possibilities to sell scans to other counties.

This meant that both business and healthcare were concerned, albeit to varying degrees, with the economic use of PET science. Still, for both actors to simultaneously attain economic value from PET with the equipment available at the facility proved very difficult because of the overlap of use contexts detailed above. The establishment of the Hospital’s own scanner-tracer interface can be seen as healthcare’s first, albeit comparatively moderate, step to gain at least partial control of the social and economic use and value creation of PET science. The more radical move to secure this value was the subsequent decision to take over ownership of the clinical section of the PET Centre when faced with GE’s decision to close down Uppsala IMANET in its current form. The alternative, not having a PET Centre near or on its premises, was unthinkable for a healthcare provider such as the Uppsala University Hospital. The value of having an interface between scanners and all types of tracers (see a graphic representation of the interface in Figure 8.2) translated not only into the care for human lives, the chance to control costs and revenues, but also the possibility to engage in scientific knowledge production, an imperative to any university hospital. In other words, the scheme of valuation of healthcare expanded to also include considerations of the economic and academic utilisation of science.

This recognition of the value of PET for the advancement of knowledge is the point at which healthcare and academic science met when deciding to jointly take over the PET Centre. While the overarching preoccupation of academia in relation to the Centre had always been to use science to produce more scientific knowledge, and that of healthcare had been to meet the needs of the patients, they each shared an understanding of the other’s motivations and goals. The example of the development of 5-HTP shows how the scanner-human-tracer interface was activated without conflict in two overlapping use contexts, indicating the fruitful joining of two valuations of
PET science: the value of clinical and pre-clinical academic science, and the value of healthcare. Only later did it turn out that the outcome of the joint development project, 5-HTP, was going to be of significant commercial value to Uppsala University Hospital.

This physical interface demonstrates that when a collection of resources are closely linked, and thus firmly embedded, in multiple contexts of science utilisation, while simultaneously being subject to attempts at value creation by different actors with largely dissimilar schemes of valuation, capacity constraints will likely occur. In other words, context overlap paired with conflicting schemes of valuation will most probably result in difficulties for the different stakeholders to use science as desired. The response of the actors in face of such capacity constraints in an interface may be either to substitute the interface, or to make an effort to tighten the control over it. In the PET Centre case, we noted how the Hospital chose the former alternative so as to secure its use in the clinical as well as the academic use context (for clinical research). Furthermore, we noted that the Hospital wished to attain both economic and academic value, in addition to ensuring that its main objective was met, i.e. the creation of value for healthcare, consistent with the core of its scheme of valuation. In order to more easily fulfil some of its own needs, the Hospital chose to separate the clinical and academic use contexts (although only for use of FDG), meaning that part of the problem of context overlap for healthcare was mitigated.

8.1.3 The interface between the cyclotron, radioisotopes, hot cells and tracers

Section 8.1.1 elaborated on the necessity of establishing a close interface between scanners and a cyclotron to enable the use of short-lived tracers. If we subtract the scanner from this interface, a piece of equipment integral to any PET study but not employed for the production of tracers per se, we are left with the cyclotron. The cyclotron is in a sense the engine in tracer production and as such a key physical resource. Without it, no radioisotopes would be produced, meaning that the most fundamental feature of the tracer, i.e. its tracing function, would not exist – there would be no tracers at all. As a consequence, it is in a way in the cyclotron, the first step in the manufacturing of tracers, that all PET related activities must start; for any patient scan or research study to be performed, there must be radioactive tracer molecules. Without the cyclotron, all other pieces of the PET infrastructure would be idle, meaning that the potential value of the features of these technical resources (e.g. the synthesising capabilities of the hot cells, the data processing and automation functionalities of the computers, the high resolution of the scanners etc.) would not be realised, as these technologies would not be put to use. Furthermore, unless combined with the tracer,
which itself would not have its valuable tracing feature were it not for the radioactive label created in the cyclotron, these pieces of equipment would not generate any sort of value. In other words, value creation from this network of physical resources, presented in Figure 8.3 later in this section, is absolutely dependent on the presence of the tracer, which in turn is contingent on the cyclotron for its existence.

We can thus conclude two things: first, that there would be no tracers without a cyclotron; and second, and importantly, that the production of tracers is the prerequisite for any use of PET science to take place. No matter for what purpose PET is intended, be it independent science, clinical routine or generation of revenue through commodification of aspects of PET science, all types of utilisation are dependent on the correct function of tracer production. Therefore, when trying to pin down how the materiality of science relates to its use, the study of tracer production is informative, complementing the perspectives offered by the examination of the two interfaces presented previously in this chapter.

In terms of the Uppsala PET Centre, a fundamental challenge for the material facets of science is tied to the fact that the facility houses only one cyclotron. From this it follows that only one type of radioisotope can be produced at a time, meaning that tracers requiring different sorts of radio labels cannot be manufactured simultaneously. FDG tracers, which need F-18, cannot be made at the same time as 5-HTP, for which C-11 is necessary. As a consequence the production of tracers requires a kind of turn taking system so as to grant all three actors the opportunity to use PET science. Some tracers, like 5-HTP, which are produced in small quantities in Uppsala, entail a cost-intensive manufacturing process and are of value to healthcare and clinical scientists, while the widely used tracer FDG is made in large batches and has greater cost-efficiency, thanks both to a comparatively straightforward production process and to economies of scale.

Thus, because of the variation in the tracers’ features such as cost, commercial potential, chemical constitution, user friendliness and targeting, to name a few, different tracers carry different types and extents of value for the various users. An ideal tracer production system would therefore, obviously, be one that succeeded in accommodating the needs of all PET users to equal degrees. As described in the empirical chapters, this was generally not the case at the Uppsala PET Centre. In fact, tracer production was for many years an object of contention between the three main actors.

Indeed, what characterised the PET Centre during the fully commercial phase was the not always peaceful coexistence of three objectives, corresponding to three distinct schemes of valuation, where tracers were

25 A discussion of how PET production technologies and tracers relate to the varying needs and routines of the PET users will follow in the next chapter, but for now we will concentrate on the purely physical interfaces.
produced alternately for commercial exploitation, for healthcare and for scientific knowledge production (or at times, mixes of these). Compared to regular industrial production where the aim is quite simply for the good produced to be a commodity and as such sold at a profit, the productive set-up of the PET Centre has always been something else entirely. Even during the years it existed in the form of a company, it was more or less fragmentary in its commercial orientation. Non-profit (in relation to the PET Centre) tracer production for clinical routine has existed side-by-side with tracer production for fee-for-service studies. As a matter of fact, the most industry-like commercial usage of the cyclotron did not begin until after the Centre had been taken over by the Hospital and the University, at which point GE Healthcare was granted marketing rights (marknadsföringstillstånd) for FDG from the Medical Products Agency in Sweden, in 2011.

As mentioned earlier, the versatility of FDG as a substance as well as its comparatively reasonable half-life are features that make it possible to ship this resource to users in nearby regions, meaning that the compound has a clear commercial value. For this reason it made economic sense to GE Healthcare to get full-scale production running. While the Hospital was hindered by municipal law from engaging in profit-seeking activities such as selling FDG, GE Healthcare could seize the opportunity to make money on the standard PET tracer. By operating the cyclotron at the Centre every night when the machine was not needed for other activities, the company could produce the batches of FDG they wanted to sell. Thus, as GE Healthcare received an income by simply producing and selling tracers, direct economic value was created for the company from the interaction between a segment of the facilities – the cyclotron and hot cells – and scientific elements, the radioisotopes.

By using the PET infrastructure at night, GE Healthcare managed to partly separate a segment of its business use context from the use contexts of the other actors, thereby creating a free space for handling tracers purely as a commodity. Now, strictly speaking it is not entirely correct to be speaking about separation here, as there still existed a spatial overlap, with GE Healthcare using the PET Centre facilities. Nevertheless, using the term of separation would make sense if we were to understand the site as two temporally distinct spaces: the busy daytime and the idle night-time. With such a perspective, GE Healthcare indeed succeeded, through a temporal shift in use, in separating part of its use context from those of the other parties.

The resource combination examined here, depicted in Figure 8.3 below, is important because it highlights the different ways in which the main users conceive of tracer production in relation to their use of PET science. To GE Healthcare the production of tracers could itself constitute a full use of PET, because the objective of the company’s utilisation was at times simply to
commodify tracers. In contrast, for PET scientists and clinicians, the mobilisation of hot cells and the cyclotron was generally only the first step in their utilisation of PET science; the next step would be to inject the tracers produced into a living subject and have a scan performed. This resource combination is hence valuable to all three of our main actors since it results in the tracer, without which PET would not exist. Nonetheless, it is worth noting that for academia and healthcare the activation of this interface enables only part of the work to be carried out. The rest of the utilisation occurs when tracers are combined with other resources (e.g. medical knowledge, PET scanners, patients etc.).

"The engine of tracer production": Heavy cost of cyclotrons precludes Center’s acquisition of additional cyclotron. Implications: use context overlap inevitable ➔ night-time use of cyclotron enables GE Healthcare to relieve context overlap

- Created in cyclotron and determines the tracing feature of the tracer.
- Carbon-11 isotopes financially valueless to IMANET

Figure 8.3 The interface between the cyclotron, radioisotopes, hot cells and tracers

The focus of this section of the resource analysis has been on tracer production, a process mandating the joining of certain physical resources, which are few in number. We have noted that the scarcity of these resources creates a situation of use context overlap, which negatively affects the opportunities for the involved actors to steer what tracers are produced. In addition, we have seen how a single basic interface can generate various forms of output depending on the specific features of one of the components in the interface, in this case the radioisotopes. Crucially, the type of tracer produced determines the potential forms of science utilisation; the variation of this one component conditions the possibilities for both commodification and use in clinical practice and academic research. Since commodification of
science is the foremost goal of only one of the main stakeholders in the PET Centre, and because the other two primary actors have claims on the same physical interface, the PET Centre must also be a site for tracer production conducive to forms of use that extend beyond the generation of commercial value.

This is therefore a situation in which the production of tracers, and thus the opportunities to utilise science in all of the different ways the three main actors wish, is under great pressure. The stressful circumstances in which the users find themselves are fundamentally a result of the fact that there is only one cyclotron. While, in the case of the PET scanner, the Hospital was able to navigate the materiality of science and separate a segment of its use context by obtaining its own machine (as recounted in section 8.1.2), no such move is possible as far the cyclotron is concerned, due to its massive cost (SEK 14.1 million at the time of the purchase). The closest any of the users came to separating a piece of their use context was GE Healthcare’s move to utilise the PET infrastructure at night when nobody else needed the apparatus. This nightly use of PET was the only situation at the Centre where the mobilisation of the cyclotron-radioisotope-tracer-hot cell interface followed a logic similar to that of a conventional industrial production facility. That is, products were sold at a price exceeding the cost price, and to external customers who would use the purchased product in their own facility.

To conclude, the interface examined here is absolutely indispensable to every type of science use, as it results in the production of tracers. Because of the critical significance of the interface to all users, coupled with the scarcity of the resources it contains, as well as the involvement of actors with diverse schemes of valuation, the interface is subject to considerable stress. An overlap between the use contexts of healthcare, academia and business is therefore inevitable.

8.1.4 Discussion on physical interfaces

The analysis of the main physical interfaces presented in this chapter has concentrated on the relationship between the materiality of science and science use. Conceiving of science as something inscribed in, among other things, material objects, one of the objectives of this chapter has been to demonstrate how the utilisation of science is taking place through the combining of physical resources. In addition, the chapter has aimed to display how the scarcity of these resources has affected the opportunities for the main actors to use science in a fashion that accords with their schemes of valuation. A couple of critical observations have been made.

The analysis made evident that in a situation of limited and physically interconnected scientific resources, one actor’s context of science utilisation temporarily overlaps, and thereby makes idle, the science use context of another actor.
Therefore, and despite a few successful attempts to partly separate the use contexts for certain aspects of PET utilisation, the use of science by different actor spheres generally boils down to an issue of sharing something as basic as physical machines. In terms of value creation, the act of sharing translates to reaching an agreement on whose context of science use should be favoured at a certain point in time, i.e. whose preferred form of value creation should take precedence over another actor’s.

Use context overlap is thus understood as a consequence of both the scarcity of physical resources and the wish of actors to use these resources in a way that aligns with their particular schemes of valuation. In addition, use context overlap can also be described in terms of the interfaces that bind these resources together. When resources are scarce, it means that there are very few, if any, other identical resources available to be used as replacements. Scarcity therefore results in strong dependency on the few resources available (Håkansson and Waluszewski, 2002a, 2002b). This difficulty of replacing one resource with another means that the interface between the resources is deep (Baraldi and Waluszewski, 2007). It is this considerable interface depth that characterises the physical aspects of the PET science network and makes it challenging for the involved actors to engage in use easily and without obstacles.

With intensifying pressure for commodification and commercialisation came dissatisfaction on the part of healthcare and academic researchers in regard to their access to PET. Interestingly, despite being in control of the technical PET resources during the fully commercial phase, the business owner too was dissatisfied with the situation, a circumstance that was essentially rooted in the dissimilarity between the actors’ schemes of valuation.

By concentrating on the interaction between physical and organisational resources, the next chapter deals in greater detail with the effects of these disparate schemes of valuation. Special attention to organisational resources in relation to physical ones will deepen our understanding of the reasons behind the complexity of science use in a setting of inter-sphere interplay.
Chapter 9. The joining of organisational and physical resources: mixed interfaces

9.1 Mixed interfaces: considering both materiality and schemes of valuation

As laid out in the analysis of physical interfaces, the root of the disagreement between Amersham/GE Healthcare, the PET researchers and Uppsala University Hospital concerning the use of science during the commercial years can essentially be traced to the differing schemes of valuation of the three main actors. The dissimilarity of the valuation schemes made the overlap of use contexts, engendered by the materiality of science and the scarcity of physical resources, challenging to deal with. Factors contributing further to the complexity of the interaction around the PET infrastructure were, as discussed in the previous chapter, certain features of key physical resources, notably the short half-lives of tracers and the high cost of equipment. Indeed, the former feature became problematic as a result of the latter: the cost feature of equipment entailed a clear limitation in the number of machines present at the Centre, inducing an unavoidable use context overlap. Furthermore, the tracers' short half-lives presented a challenge partly because of this scarcity of required apparatus.

In fact, the disagreement between the three parties can fundamentally be viewed as a consequence of each organisation’s needs concerning tracers. While the Hospital wished to get any tracer the doctors asked for produced quickly and at short notice for both patient care and clinical research projects, Amersham/GE primarily wanted tracers to be used for experiments within contract research and company-specific internal development projects. On their part, the PET researchers wanted to use tracers not only for contract research but also for independent research projects in which they were interested. During the years the university owned the PET Centre, this latter goal was generally possible to reconcile with the needs of the Hospital as far as tracer production was concerned.

These diverse preferences, mirrored in the schemes of valuation of the actors, are closely considered in this chapter by studying the interplay between physical and organisational resources. The combinations between physical resources such as tracers and technical equipment on the one hand,
and organisational resources such as routines and knowledge of the main actors on the other, make up a collection of mixed interfaces (Baraldi and Strömsten, 2006). By including organisational resources in the analysis we will better understand the effect of interacting actors on the use of science. The idea guiding my analysis of interfaces containing organisational resources is that these resources are generally infused with certain schemes of valuation. Furthermore, because valuation schemes are connected to actors, organisational resources can be understood as reflecting certain actors, a point I discussed in the theoretical chapter (Chapter 2). In other words, organisational resources bear imprints from the actors to which they are tied (and at times these resources in fact constitute actors – a point I return to in the succeeding chapter). The exploration of mixed interfaces will thus shed light on how science is utilised, and hence how value is formed, by considering the materiality of science as well as the effect of actors.

Three mixed interfaces are examined in this chapter, each one singled out for the insight it offers into the use of PET science at Uppsala over the course of the Centre’s development. The interfaces selected highlight both the more general utilisation of PET, and use that is very specific to Uppsala. As mentioned above, including organisational resources, the interfaces to be studied in this chapter capture the effect of the main actors on science utilisation in greater detail than those of the previous chapter. Taken together, the chosen interfaces will enhance our understanding of the use of PET science in Uppsala, and how this use is affected by the materiality of science as well as different schemes of valuation.

Section 9.1.1 provides an in-depth look at the interplay between hot cells, unique knowledge and the 5-HTP tracer. The section shows how the singularity of this mixed resource combination results in a dependency of the Hospital on the PET Centre, drawing attention again to the challenges associated with the overlap of contexts in cases where schemes of valuation are not aligned. Continuing the exploration of the sharing of resources begun in the previous chapter, and with particular respect to the unique tracer considered in section 9.1.1 of this chapter, section 9.1.2 investigates the interface between radioisotopes, tracers, equipment and the needs and routines of both the Hospital and IMANET/Amersham/GE Healthcare. More specifically this section addresses what role exactly the different needs and routines have played in the employment of radioisotopes, tracers and machines. In contrast to sections 9.1.1 and 9.1.2, section 9.1.3 considers a resource interface embedded in contexts that for the most part are not overlapping, namely that between the PiB tracer, the University of Pittsburgh-Uppsala PET Centre relationship, and PET research units in Uppsala, India and the United States. Highlighting the value created when resources at the PET Centre are paired with resources outside of the Uppsala facility,
attention is thus directed at efforts made to generate value in use contexts that are chiefly separated.

9.1.1 The tracer 5-HTP, hot cell equipment and researchers’ PET chemistry expertise

Section 8.1.2 in the preceding chapter dealt with the physical interface between scanners, tracers and human subjects, mentioning Uppsala University Hospital’s purchase of a scanner as a way for the institution to seize control of its use of FDG scans. As for the use of the tracer 5-HTP, on the other hand, the Hospital still very much needs the PET Centre. We have already seen how the short half-lives of carbon-11 isotopes with which 5-HTP is tagged necessitate a tight interface between cyclotron and scanner. Nonetheless, as far as production of 5-HTP is concerned, this interface alone is not enough for use of this specific piece of science to take place. It must be complemented with an interface between 5-HTP, a special type of hot cell equipment and the unique expertise of PET researchers.

The reason for this is the special nature of the 5-HTP production process. As mentioned previously, both the skills and the apparatus required to complete the very complex synthesis of this particular tracer are so specific that only two centres in the world are able to do it, Uppsala and PET Centre Groningen in the Netherlands. Simply possessing the theoretical knowledge about the 21 enzymatic steps that must be completed in the chemical process does not suffice. This knowledge needs to be combined with a type of instrument in the hot cell, which at this point only exists in Uppsala and Groningen. Essentially built by hand by Långström, this piece of synthesis equipment is difficult to replicate. Moreover, failed attempts by researchers at centres elsewhere in the world indeed seem to indicate that there cannot be even the slightest deviations from Långström’s hand-made device if the synthesis is to work. Clearly, a PET researcher’s theoretical knowledge of how to synthesise 5-HTP becomes useful in combination with this unique piece of equipment. It is the interaction between the two which gives rise to 5-HTP, and hence creates the opportunity to use this tracer for diagnosis of small endocrine tumours.

All in all, the difficulty in successfully substituting other apparatus for Långström’s machine, coupled with the experience and skill needed to master the production process, points to the depth of the interface between the specific chemistry expertise of the researchers and the unique machine (Baraldi and Waluszewski, 2007). But the interface, presented in Figure 9.1 below, also illustrates how the uniqueness of a particular piece of scientific knowledge, embodied in both machines and scientists, restrict the diffusion of its use. With the materiality of science being so singular that relevant physical components cannot be acquired elsewhere, the users find themselves
in a position where not even money can secure enhanced access to the piece of science in question. As pointed out above, this situation can be contrasted with the case of the Hospital’s use of FDG, where the clinicians were able to separate their use context from that of business and academia, thanks, first, to the standard character of the machine they needed and were able to obtain (a regular scanner), and second, to the wide availability of the standard tracer FDG.

As far as 5-HTP is concerned, however, we have learned that there was never anything “standard” about its production and utilisation. Nonetheless, despite the inability to bring about widespread use, the deep interface between 5-HTP, Långström’s robot and the specialised knowledge of the PET researchers has generated significant academic and health-related value, highlighting the salience of PET to the Hospital in terms of both specific scientific know-how and equipment. More precisely, the particular combination of resources in question lays bare the complete reliance of the clinical and academic use contexts on the PET Centre’s tracer production capabilities, underlining specifically the considerable vulnerability of the Hospital. This vulnerability was especially pronounced when faced with the
commercial ambitions and business scheme of valuation of Amersham/GE Healthcare.

The interface analysed here is relevant to our inquiry into science use essentially due to its non-standard characteristic. It is informative of the dynamics that arise when something is both non-standard in its production (and hence more expensive to manufacture), and absolutely critical to only some of the actors involved, as opposed to all of them. Indeed, the non-standard feature of the entire interface in question is illustrative of the flexibility of schemes of valuation, i.e. their openness to other schemes of valuation. Notably, with the takeover of the PET Centre by a business actor, healthcare and academia depended on this flexibility in the business scheme of valuation to be able to utilise PET science through the interface. Although we know that the value creation for healthcare and academia from the interface did not take place without a certain degree of interference during the commercial years, the fact remained that both academic science and clinical procedures could be carried out to some extent through mobilisation of the interface. Evidently the scheme of valuation of business had enough pliancy to accommodate the needs of healthcare and academia in regard to the 5-HTP tracer, albeit undoubtedly on much stricter terms than before.

As the next section carries on the exploration of the combination of organisational and physical resources, with special attention to the production and use of 5-HTP in the clinical and academic use contexts, we continue our exploration of the interplay between schemes of valuation. It will be shown that differing schemes of valuation are not the only factor hampering value creation in overlapping use contexts. Indeed, as mentioned in the preceding chapter, the overlap of use contexts may be precarious even when two actors want to use science to create the same type of value – economic in this case.

9.1.2 The interfaces between radioisotopes, tracers, equipment and the needs and routines of the hospital and GE Healthcare

As touched upon by the previous chapter on physical interfaces, much of the complexity of using PET science has to do with the very short half-lives of the radioisotopes with which the tracer molecules are labelled. While the quick radioactive decay is the most fundamental, and very powerful, scientific principle on which PET is based, it also creates problems in terms of utilisation. As was discussed in the analysis of physical interfaces, the rapid emission of anti-matter by tracer molecules requires equipment to be set up a certain way. Moreover, as described in the empirical chapters, the (unalterable) physical properties of PET isotopes affect tracers’ tradability and hence their economic relevance. Either they cannot be shipped at all, or they can only be distributed to users in the same region. And, importantly, it also means that the tracers produced cannot be stored for later use, but must be
taken care of more or less on the spot. Naturally, fluorine-18 allows more leeway than carbon-11, but neither of the two can sit idly waiting for days in a storage room like more conventional goods.

In other words, a need for a certain type of tracer must be matched by production of the tracer in question at more or less exactly the same time as the PET scan is to be performed. But when there exists only one cyclotron at a facility, and hence a constant use context overlap, the requirement for production of the chosen radioisotope must be balanced against the needs of other actors to have their radioisotopes produced. Thus, unless the parties involved want the same tracer to be manufactured, only one actor at a time can have their required isotope and tracer made: one context of use has to wait for its turn while the other is in motion.

During the years of commercial ownership in Uppsala, the sharing of the cyclotron between business and healthcare, i.e. the turn-taking between the two use contexts, was not always peaceful. What IMANET (or Amersham/GE Healthcare) wanted to produce did not necessarily correspond to what the Hospital needed. The interests of the two actors diverged in particular around the boutique tracer 5-HTP. For the Hospital, the carbon-11 based specialty tracer was crucial for research studies in neuroendocrinology as well as for the diagnostic services offered to patients. For IMANET on the other hand, the production of 5-HTP had no economic importance, as opposed to tracers that could be used in fee-for-service studies or internal development studies. While IMANET’s focus on this type of commodified science did not mean that there were restrictions on the amount of 5-HTP produced, it did make long-term planning necessary on the part of the Hospital if it was to get its 5-HTP produced on time.

Compared with the period during which the university owned the centre, some of the staff at the department for endocrine oncology experienced the change in routines, in terms of careful scheduling and planning brought about by GE Healthcare’s ownership, as diminishing the flexibility of their use of PET. Instead of getting their tracers produced and scans performed at short notice, they now had to wait. Hence, the endocrine oncologists perceived the overlap of use contexts as seriously obstructing their utilisation of PET. For this reason, the full commercialisation of the Centre made the complex cluster of interfaces between radioisotopes, tracers, equipment, the needs and routines of Amersham/GE Healthcare and the Hospital hard to navigate.

It is noteworthy that in the bundle of resources constituting the interface just described and depicted in Figure 9.2 below, the friction between the company and the Hospital did not emerge primarily due to opposing schemes of valuation (although the differences in schemes of valuations inarguably played an important role too). As a matter of fact, within this interface both parties were, albeit to a somewhat different extent, concerned with the creation of economic value through the commodification of science.
Problems arose because, in order to create this value for themselves, the two depended on the same set of production technologies. Since these infrastructural resources could only be used by one party at a time to produce the types of tracers the two parties required, the creation of value for one of the actors impeded the creation of value for the other. Hence, the source of tension within this collection of interfaces was not only a clash of schemes of valuation, but also a clash of business-related needs.

![Diagram showing the interfaces between radioisotopes, tracers, equipment and the needs and routines of the hospital and GE Healthcare](image)

In terms of contexts of science use, the interface in question involved such an overlap not just between the use contexts of healthcare and business, but also between two separate business use contexts – that of IMANET and that of the Hospital. But what constituted good business utilisation of PET for the Hospital entailed simply break-even production for IMANET. Since the price of 5-HTP was set to just cover the cost of manufacturing the tracer, with no profit margin, the production and sale of 5-HTP had no economic value for IMANET. Naturally then, tracers that could be used in fee-for-service studies were more valuable to this actor. For the Hospital, however, the commercial value of 5-HTP was, and still is, considerable, and creating a stable, functioning interface between the PET equipment and itself as a user of this tracer, was therefore highly important. As mentioned above, for this interface timing is of the essence. The economic value of 5-HTP and the equipment is
only created for the Hospital insofar as these resources can be mobilised when the patient is actually present. The need to plan in advance, as well as the waiting time, therefore compromised the Hospital’s control of the interface, creating repercussions for both the healthcare and business aspects of the Hospital’s use.

The interface explored in this section, summarised in Figure 9.2 above, illustrates the challenge in matching the needs and routines of two organisations with diverging interests. Tension arises not least because of the two parties’ attempts to use the same physical resources to form the same type of value, economic such. Furthermore, the preoccupation with economic use of PET science on the part of the Hospital clearly shows how its scheme of valuation comprises other aspects besides those pertaining purely to medical knowledge and patient care. As pointed out earlier, schemes of valuation are not static, but can incorporate aspects of other schemes. The interfaces between the Hospital, IMANET/Amersham/GE Healthcare, isotopes, tracers and PET equipment highlight exactly this malleability. However, creation of commercial value from PET science is obviously not the only goal of the Hospital here. Naturally, the most basic interest lies in patient care, and scientific knowledge generated from clinical research studies is highly valued as well.

In short, we see how PET science, in the form of tracers and infrastructure, in accordance with the needs of IMANET/GE Healthcare and the Hospital, is utilised to form economic, as well as scientific and healthcare-related value. It is also clear that the extent to which and how often these different types of value are created is conditioned by the overlap of the science use contexts of business, healthcare and academia. The next section explores the value generated from a resource interface which, unlike most other significant interfaces in the PET centre case, including the one just analysed, stretches across multiple, generally separated, use contexts.

9.1.3 The interface between the PiB tracer, the parent company, the University of Pittsburgh-Uppsala PET Centre relationship, and PET research units in Uppsala, India and the United States

With Amersham’s acquisition of the PET Centre in 2002, the facility became a source for the large biotechnology firm not only of scientific knowledge and material assets, but also of established relationships between the PET researchers and their collaboration partners. While the bonds between the scientists and drug companies were undoubtedly important to Amersham and GE Healthcare (this topic is treated in detail in the next chapter) a more unexpected, and, it would turn out, extremely valuable resource was the relationship between the Uppsala research team and a group of scientists at the University of Pittsburgh. As recounted in Chapter 4, two researchers at
Pittsburgh had developed a tracer molecule to be used to detect amyloid plaques – protein pieces present in the brains of people with Alzheimer’s disease. What was novel about this imaging agent, called Pittsburgh compound-B – abbreviated to PiB by the Uppsala researchers – was its capacity to spot Alzheimer’s in living patients. This characteristic of the compound set it apart from other methods where the disease could only be discovered post-mortem. Esteemed for its researchers’ skill in labelling radiotracers, Uppsala PET Centre became the location of the first clinical trials of PiB in 2002, resulting in several well-cited publications for the teams at Pittsburgh and Uppsala.

Following this study, other scientists began using the new compound as a research tool. Because Alzheimer’s disease is the most common type of dementia among the elderly, the collaboration between Pittsburgh and Uppsala soon attracted the attention of Amersham, which recognised the tremendous commercial potential of PiB. Nevertheless, successful commodification, Amersham argued, could only be achieved if the tracer molecules were labelled with the more long-lived fluorine-18 as opposed to carbon-11, which was the original radio-label for PiB. This was the start of the massive project of turning PiB into a fluorine-based substance. In this undertaking Amersham, and later GE Healthcare, involved not only Uppsala PET Centre, but also the PET Centres at Hammersmith and Turku, both of which had been testing PiB before IMANET was even formed. Research groups in the United States and India participated in the testing as well. Having made a licence agreement with the University of Pittsburgh, Amersham/GE Healthcare thus developed F-18 flutemetamol, which possessed the same properties as PiB but had a longer half-life. As mentioned in Chapter 4, F-18 flutemetamol was finally approved by the Federal Drug Administration (FDA) in the United States and European Medical Agency (EMA) in Europe in 2014, after years of clinical trials. After more than a decade of development work and clinical trials run by Amersham/GE Healthcare, what had started off as an academic invention at Pittsburgh had now become a scientific commodity – a commercial product called Vizamyl.

As pointed out in the empirical chapters, the making of Vizamyl has so far been undoubtedly the most financially rewarding project to come out of GE Healthcare’s venture with the Uppsala PET Centre. In identifying the economic potential of a substance that Amersham/GE Healthcare most likely would never have learned about had it not been for its takeover of the Uppsala PET Centre, the mother company eventually succeeded in creating major commercial value from PET science. A novel, fully commodified imaging agent, Vizamyl is so far the only concrete fulfilment of the initial objective of IMANET to produce commercial innovations in the form of new tracer molecules. The Vizamyl project stands out in other important ways too. What set the endeavour apart from other major GE Healthcare-
initiated projects involving IMANET PET Centres was its division of the work between several research units, including teams outside of IMANET. In other words, PET science was being used for development work in multiple locations. In fact, the use contexts of PET in which this work was taking place had not only been spatially dispersed over several different research units, but there had also been a clear division between academic and business use contexts. These two contexts had been separated both in time and space: the work had begun in an academic setting at Pittsburgh, and continued at other locations within a business context of which Amersham/GE Healthcare was in charge.

Encompassing a number of relevant use contexts located outside of Uppsala, the resource interface analysed here, depicted in Figure 9.3 below, differs from those studied up to this point. The fact that Amersham/GE Healthcare managed to involve not only geographically dispersed knowledge, but also geographically dispersed physical resources naturally had implications as far as use context overlap was concerned. From the engagement of a number of different PET sites in the development work followed a relative reduction in the marginalisation of the use contexts of academia and healthcare. That is, researchers’ and clinicians’ use of PET was not as squeezed out by business use as it could have been had the entire clinical testing endeavour been carried out at Uppsala. Indeed, the Vizamyl development project can be said to have been characterised by the temporal and spatial separation of different contexts of science use.
Figure 9.3 The interface between the PiB tracer, the mother company, the University of Pittsburgh-Uppsala PET Centre relationship, and PET research units in Uppsala, India and the United States

Nonetheless, it is important to stress that, although the project entailed a separation between many use contexts, the Vizamyl development work did naturally still result in context overlap at the Uppsala PET Centre. On the one hand it is true that this overlap was presumably less disruptive to the science use of academia and healthcare than would have been the case had the entire development of Vizamyl been placed in Uppsala. On the other hand, the fact remained that a context of business use of science (which the development of Vizamyl constituted) had to share space with, and dominated, the use contexts of academia and healthcare. From GE Healthcare’s perspective, however, this overlap was comparatively insignificant considering the size and scope of the overall project.

Given the mother company’s access to numerous highly skilled PET scientists within IMANET, it is noteworthy that the tracer on which Vizamyl was based did not originate in any of the PET organisations that Amersham/GE Healthcare had purchased, or in collaboration between any of these PET Centres and the mother company. Instead of the starting point being a specific piece of knowledge in Uppsala, it was rather Uppsala’s relationship to a partner that prompted the development of Vizamyl. Unexpectedly, perhaps the most significant economic contribution of the PET Centre to the mother company had thus been as a broker of knowledge.
With PiB being commercialised through licensing, this resource spilled over from an academic use context to a business use context, with one scheme of valuation giving way to another.

The spatial and temporal separation of use contexts in the overall product development effort seemed to serve the project well. With the original invention evolving in an academic space independent of wishes and interests from business actors, clashes between different schemes of valuation were not an issue affecting the endeavours of the Pittsburgh scientists. It was not until PiB was an established fact that the interplay between business and scientists, and the knowledge and physical resources connected to the latter, began. Once this interaction between business and academia started, the aim of the project had already been set by the mother company: to redesign the tracer so as to create a commercially viable product. In other words, as far as the objective of the development work was concerned, differences of opinion were a non-issue. Whatever collisions between schemes of valuation did occur were tied to the use of physical resources rather than the orientation of the development project. In the next chapter it will become clear how this situation, with its separation of science use contexts, differed from the mother company’s other commodification attempts, where PET scientists were involved from the very start.

9.1.4 Discussion on mixed interfaces
This chapter has, just like the previous one, demonstrated how the utilisation of PET science is conditioned by its materiality. But in addition, by considering the combination of physical and organisational resources, this chapter has also paid close attention to how the schemes of valuation of the main actors have affected science use. A few key points emerge from this analysis.

To begin with, we notice that the unique, non-standard character of a resource combination may translate into great value for one user, while being of no use at all for another, which creates problems in terms of resource use (consider, for example, 5-HTP, which was of great value to the Hospital but not to the mother company). Moreover, we can see how even in a situation where one actor expands its scheme of valuation to that of another (for example a switch from healthcare to business), there is no guarantee that the two actors will get along even though they are geared toward the same type of value creation (consider, for example, that Uppsala University Hospital and the mother company clashed despite the fact that they were both pursuing the creation of commercial value). As long as the actors involved do not agree on the importance of a certain resource combination, the mobilisation of these resources will please only one of the actors. As a consequence, in such a situation there is no formation of a joint use context, but instead there are two
separate use contexts, both dependent on the same set of resources to generate value. Because of the scarcity of physical resources, this inevitably leads to context overlap and discontent.

Finally, it can be noted that the only truly successful business project for the commercial owner of the PET Centre originated in a separate academic use context, spatially and temporally separated from Uppsala, and then evolved over many years in multiple, spatially separated, business use contexts. Unforeseen commercial value in the shape of a commodified scientific innovation emanated in this way from a project that had started in an academic use context without overlap with a business use context.

The findings presented in this chapter highlight the complexity of tight inter-sphere interaction. The differences in schemes of valuation as well as the limits, after all, in malleability of these schemes, have been pinpointed. Just as in the preceding chapter, the strain of the overlap of science use contexts induced by the scarcity of physical resources has been recognised as further contributing to the complexity of very tight inter-sphere interplay. Through the inquiry into purely organisational interfaces, the next chapter continues the exploration of value creation in a setting characterised by inter-sphere interaction.
Chapter 10. The combination of organisational resources: organisational interfaces

10.1 A focus on the organisational: examining the effects of interaction between dissimilar actor spheres

The analysis of physical and mixed interfaces has demonstrated how the use of science is influenced by both material and immaterial factors. We see the role played by resources such as tracers, scanners, cyclotron, hot cells, knowledge, needs and routines in creating commercial value from PET, as well as non-economic forms of value for healthcare and academia. Crucially, the investigation of physical and mixed resource combinations reveals how the materiality of science induces an overlap in the science use contexts of the different actors involved, often leading to situations where none of the users is fully satisfied with the amount of value they are able to create. The focus on materiality in the analysis of PET science hence provides insights into the consequences of the limited availability of physical scientific resources on science utilisation.

But in order to gain a more thorough understanding of why the utilisation of, and value creation derived from, PET science in Uppsala has developed how it has, we need to consider the purely organisational interfaces present in the network in which science is embedded. Thus, by directing our attention toward the interplay between organisational resources (Baraldi et al., 2011) such as knowledge, routines, relationships, strategy, management and organisational units, all of which are elements of the organisational part of the Uppsala PET network, we can home in on the mechanisms that have affected the utilisation of PET science. While the examination of interfaces containing physical resources enhanced our understanding of the effects on use of the materiality of science, the study of purely organisational interfaces is more directly connected to actors and their interactions, as discussed in Chapters 2 and 9. The point I wish to make, and one that is pertinent to this chapter and therefore worth repeating, is that organisational resources bear an imprint of the actor to which they are linked – indeed, an actor can in itself be an organisational resource. In other words, organisational resources are more or less direct manifestations of actors’ schemes of valuation.
Careful study of organisational resource combinations will therefore make us aware of the different fashions in which the actors involved have influenced the use of PET science. In so doing such investigation provides an answer to the question about the effect of the interplay of dissimilar actors on science-based value creation.

To address this question, a detailed examination of four sets of organisational interfaces now follows: 1) the Research Development Corporation of Japan and the Uppsala PET Centre; 2) the strategy of Amersham/GE Healthcare, IMANET, the pharmaceutical industry and the PET researchers’ knowledge; 3) the knowledge of Uppsala PET researchers and the knowledge of the Amersham/GE Healthcare researchers; and 4) IMANET’s management, the Uppsala PET researchers and clinical researchers at Uppsala University Hospital. I have selected these interfaces because they most acutely capture the shift in science utilisation brought about by the takeover of the Uppsala PET Centre by Amersham and GE Healthcare. More specifically, I have singled out interfaces by identifying the actors that have had the most significant impact on the operations at the Centre before and after the acquisition. I have then considered the role played by these actors either in terms of the full organisational units they constitute, or in terms of organisational resources pertaining to these organisational units, such as strategy, knowledge and management. Conjointly, the interfaces to be investigated in this chapter offer insights into vital aspects of the development of the Uppsala PET Centre as a site for academic, healthcare-related and economic use of science.

Comprised in this development is, as we know, a movement in degrees of commercialisation and commodification. While the two preceding chapters on physical and mixed interfaces laid bare the frequent overlap of different use contexts without getting into the specifics of these two processes, the examination of organisational interfaces aims to explicate in more detail how and why the contexts of utilisation changed as a result of commercialisation. Thus, recognising context overlap as a crucial characteristic of the operations at the PET centre, the investigation of organisational interfaces digs deeper into the issue of how these contexts have been shaped through processes of commercialisation and commodification.

Because the introduction of a complete business rationale translated into such a decisive change in the evolution of the PET centre, the impact of inter-sphere interplay on science use is best understood by concentrating on the combination of organisational resources actively brought together by Amersham and GE Healthcare. Specifically, we will note that the efforts of the commercial owner to create a successful business use context meant that the academic and healthcare use contexts were compromised, contributing significantly to the tension concerning the overlap of use contexts described in the two previous chapters. The focus on the commercial owner's
involvement notwithstanding, to create a sense of chronology and present a picture of same-sphere interaction prior to the acquisition, I start the exploration of organisational interfaces at a point where use contexts overlap had not yet become a sensitive issue: in the first phase of the PET centre journey.

10.1.1 The interface between the Research Development Corporation of Japan (JRDC) and the PET Centre

As recounted in the empirical chapters, the entrance of Amersham and GE Healthcare into the Uppsala PET story was preceded by a comparatively long period during which the Centre was run by the University. Amidst financial troubles and initially rather fruitless attempts to get the contract research business on its feet, the Centre was successfully building and solidifying its strong scientific reputation. A critical contributing factor to the positive scientific development was the decision of the Research Development Corporation of Japan (JRDC) to enter into a five-year scientific collaboration with the Uppsala PET Centre. Thus, two organisational resources, the JRDC and the PET Centre, were united through an agreement to jointly conduct independent PET research, i.e. to use science in an academic context.

The interface between the two organisations was strong, partly because the JRDC and the PET Centre shared a common scheme of valuation. Moreover, the value created from the interface was considerable, both from a scientific and an economic perspective. The agreement entailed several million SEK to be paid out over the course of the five-year duration of the collaboration. This meant that the PET Centre was given the means to make major investments in scientific infrastructure, allowing the researchers to use PET science in a new way. More specifically, the funding enabled the PET Centre to have a brand new pre-clinical laboratory constructed, which was a crucial addition to the facility. Furthermore, the financial infusion from the Japanese institute meant that the scientists were given the means to engage in extensive independent research projects together with Japanese scientists. In this way, the economic benefits created from the interface opened up new opportunities for the academic use of science; thanks to the Japanese funding new physical resources could be acquired and work hours could be used to conduct free research.

The economic value gained by the Uppsala PET Centre through this interface, depicted below in Fig 10.1, thus spurred the creation and mobilisation of both physical and organisational resources, such as new equipment, relationships and scientific knowledge. The influx of resources resulting from the interface between the PET Centre and the JRDC meant that the facility grew, and with this growth came the opportunity to conduct even more independent science. But sustaining a larger facility also called for
increased financial resources – and the research agreement with the JRDC had an end date. In this sense the closure of the successful collaboration, which of course led to a loosening of the interface, meant that if the scientific activity were to continue as before, major financial resources had to be secured elsewhere. As it turned out, the dissolution of the interface would soon be followed by a growing fee-for-service business yielding a much-needed economic boost. As described in the empirical chapters, this rise in contract research business culminated a few years later in the decision to let the entire centre be acquired by a commercial player, so as to ensure further expansion of the prolific research organisation.

Figure 10.1 The interface between the Research Development Corporation of Japan (JRDC) and the PET Centre

This section has highlighted how a strong and long-term organisational interface between two organisations with the same scheme of valuation created conditions favourable to the academic use of science. It did so by providing both scientific knowledge and financial support, the latter of which made possible the construction of a new laboratory as well as the pursuit of independent research projects. Apart from the production of scientific knowledge, this resource interface ultimately generated an expansion of the PET Centre, which meant that after the dispersal of the interface new sources of funding were needed so as to sustain the organisation’s new size. In some respects this interface thus marked the beginning of a development of increasing complexity in context overlap. A situation where scientists were in charge of the utilisation of physical resources, and where the extent of contract research was quite modest, eventually grew into one where a business actor was in control.

To be more precise, during the period in which the PET centre and the JRDC collaborated and up to the acquisition by Amersham, the scheduling of fee-for-service studies was handled by the same people who steered the
academic collaborative studies together with the JRDC, i.e. the leading scientists at the PET centre. Similarly, fitting healthcare-related PET scans and research studies into the calendar was done at the discretion of the PET scientists to whom the needs of the Hospital by and large were not disruptive. Whether science at a particular point in time should be used by business, academia or healthcare was hence up to the PET scientists to decide. The fact that the schemes of valuation of academia and healthcare were easily reconcilable ensured that the overlap of the different use contexts did not generally become a cause of discontent. Nevertheless, as the scheme of valuation of business became a more forceful factor in the equation as a consequence of the change in ownership, conditions quickly altered. The rest of the chapter looks into the particulars of this change of circumstances, focusing on organisational interfaces formed after the full commercialisation of the Centre had taken place.

10.1.2 Interface between Amersham/GE Healthcare’s strategy, IMANET, the pharmaceutical industry and the PET researchers’ knowledge

When we consider the years during which the PET Centre operated as Uppsala IMANET, a natural starting point for the analysis of the economic and academic utilisation of science in relation to the organisational aspects of PET is the strategy that was supposed to lay the foundations for business success. A crucial element of Amersham’s and GE Healthcare’s strategy for IMANET was the ambition to establish tight relationships with drug companies by conducting contract research for them. This fee-for-service interaction was supposed to help build up enough trust to obtain access to the drug industry’s molecular libraries. As we learned in the empirical chapters, the much-coveted resource in these libraries was the intellectual property rights for so-called failed molecules, which contained information that would potentially help PET researchers to develop new tracers. But despite the positive relationships that the PET centre had with many pharmaceutical companies from earlier collaborations, and despite Amersham’s and GE’s efforts to steer these relationships in a constructive direction, the drug industry was resistant. It showed little or no inclination to give up any of its IP rights, as these molecules could potentially be of some use in the future. As a consequence, the PET researchers never acquired the kind of information that would have been of benefit to their tracer development endeavours.

The interface between the strategy, IMANET and the drug companies, presented in Figure 10.2 below, was thus never quite formed in the critical business use context. As a result the wished-for commodification of PET science as a product – i.e. new tracers – did not materialise. Nevertheless, the
part of the strategy which was designed to create and strengthen relationships between the pharmaceutical industry and IMANET – contract research – remained in motion even though it did not produce the planned results. Hence, although the kind of relationships Amersham and GE Healthcare had hoped for, where deepened interaction would eventually yield access to molecular libraries, were not created, the fee-for-service business at least generated some revenue. In that sense an interface between a watered-down version of the strategy, IMANET, the researchers’ knowledge and drug companies existed. The implication of this weakly implemented form of the strategy was that the economic value created for IMANET from this constellation of organisational resources was limited to the income gained from conducting fee-for-service studies. Had the strategy worked fully there would possibly have been quite another picture, where access to the IP rights on failed pharmaceuticals could have furnished new tracer development, potentially generating significant economic benefits for the mother company down the line.

Figure 10.2 Interface between Amersham/GE Healthcare’s strategy, IMANET, the pharmaceutical industry and the PET researchers’ knowledge

However, while a strong interface never really emerged between the full constellation of resources investigated here, the existence of contract research implies that a robust interface between PET researchers’ knowledge and the
pharmaceutical industry was indeed in place. How do we conceive of this interface? We may recall from the empirical chapters that the Uppsala PET Centre had earned an excellent scientific standing as a result of the researchers’ deep knowledge of PET chemistry. While the depth aspect of the knowledge resource was not always as imperative in a contract research study as in an exploratory independent research project, this depth still played a significant symbolic role in that it functioned as a guarantee for academic excellence. Attracted by the scientific prowess a great academic reputation seemed to promise, pharmaceutical firms trusted the Uppsala PET scientists and had been assigning contract research work to the centre for many years. The depth aspect of the researchers’ knowledge thus had a symbolic value for the drug companies, which translated into economic value for the PET Centre and, after the acquisition in 2002, for IMANET.

This brings us to the way in which the pharmaceutical industry made use of the knowledge at the Centre. In order to evaluate the properties of pharmaceutical candidates at an early stage, drug companies used the knowledge of the PET researchers regarding how to label molecules with radionuclides and how to perform PET scans. However, the utilisation of knowledge in PET chemistry not only involved existing radiotracers. On a couple of occasions the use of PET knowledge in fact extended to the development of new tracer molecules, a few of which were patented by the pharmaceutical firm involved. Now, it is important to recognise that the potential commercial benefits from these new tracers were tied exclusively to the drug companies concerned, and not in any way to the university, during the years when Uppsala University owned the centre, or to IMANET after Amersham had taken over. The economic value from fee-for-service studies for the PET Centre and IMANET was thus always simply restricted to the fee paid by the pharmaceutical company, and never included any stakes in newly developed radiotracers. Hence, the value created through the interface between PET researchers’ knowledge and the pharmaceutical industry in no way meant that IMANET was using science for development work from which the company itself would profit on any larger scale.

While the primary purpose of the relationship to the pharmaceutical industry was to generate economic value, in fact it also played a role in value creation within the sphere of academia. An important output from a number of contract research studies was new scientific knowledge, in the form, as just mentioned, of new tracers, or new methods of radio-labelling a substance. Every now and then studies would result in publications in peer-reviewed journals, provided that the information was not classified or incomplete, and that the permission from the pharmaceutical firm to publish was granted.

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It should be noted though, that much contract research does require great skills and creativity. In the past the Uppsala PET centre had ensured that it selected fee-for-service studies that were interesting to it from a scientific point of view.
quickly enough that the findings did not lose relevance and novelty. In other words, from the interface between the PET researchers’ knowledge and the pharmaceutical industry emerged an academic value in addition to the economic value. The fact that both of these forms of value were created meant that contract research was something that at least at times was compatible with the scheme of valuation of the Uppsala scientists. Still, the situation at hand had deviated from the expectations of both the researchers and the mother company. The Uppsala PET scientists had believed science would be used to a greater extent to create new academically relevant scientific knowledge, while Amersham and GE Healthcare had predicted a stronger delivery as far as commodification was concerned.

In theory the interface between the mother company’s strategy, IMANET, the knowledge of the PET researchers and the pharmaceutical industry, shown in Figure 10.2, seemed to hold much promise. Devised to generate substantial commercial value by securing access to failed pharmaceuticals, the combination of organisational resources fell short in achieving this goal, as it never resulted in the wished-for commodification of tracer molecules developed in-house. Clearly, in drawing up this strategy, IMANET had underestimated the determination of the drug industry to ensure that certain scientific elements remained highly private. As a consequence the only commercial value to be created from PET science came from commodification of science as a service, i.e. contract research.

Although the use of science by business in terms of IMANET-controlled tracer development was never established, this failure to realise the main objective of GE’s strategy did not bring about an enhanced manoeuvring space for healthcare and independent science. Rather than increased freedom in the use of physical PET resources for the researchers, the PET facilities were employed first and foremost for contract research. In short, Amersham and GE Healthcare, acting chiefly in line with a business scheme of valuation, had power over science use. As a consequence the overlap of science use contexts became a matter over which the commercial actor alone had control.

Nevertheless, as pointed out above, the overlap of use contexts did not always have negative ramifications. The use context of academia and that of business did occasionally merge to become one in instances when contract research projects resulted in findings that could be published in scientific journals. Yet, since the control of the research results was in the hands of the drug companies commissioning the studies, the question of whether and when value for business could be transformed into value for academia was essentially up to the collaborating pharmaceutical firms to decide. Conclusively, in the interactions between the stakeholders regarding the utilisation of science, business – whether pharmaceutical firms or IMANET guided by GE’s strategy – continuously had the upper hand in relation to the researchers and their knowledge. This knowledge of the researchers is one of
the main objects of investigation in the next section, where I explore the effects of a seemingly straightforward resource combination of which the PET researchers’ knowledge forms a part.

10.1.3 The interface between the Uppsala PET researchers’ knowledge and the Amersham/GE researchers’ knowledge

The idea to access IP rights for failed molecules from drug companies was only one of the strategic tools Amersham and GE Healthcare tried to employ to create commercial value. Uniting the PET expertise at Uppsala with the knowledge of the mother company’s own researchers was the second. As recounted in the empirical chapters, the Uppsala PET Centre was renowned for its knowledge within PET chemistry, notably of methods for carbon-11 labelling. When Amersham acquired the Centre it was with the expectation that this knowledge, the Centre’s major resource as far as the mother company was concerned, would be of benefit in the development of new tracers. Amersham wanted to set up collaborations between its own researchers and the Uppsala PET researchers, an idea that the Uppsala team endorsed. Two sets of knowledge, two organisational resources, would thus be brought into contact.

However, only with difficulty could a very weak interface, depicted in Figure 10.3 below, be created between the two bodies of knowledge. On the one hand there were the Uppsala researchers, firmly connected to a scheme of valuation of academia, and possessing a deep understanding of PET chemistry, which the Amersham/GE researchers, with their training and background lacked the capacity to fully absorb. The researchers at the mother company on the other hand, accustomed to a business scheme of valuation, were skilled at identifying commercially interesting research ideas, a strength which the PET researchers in Uppsala did not enjoy to the same extent. The Uppsala team did have the intention of feeding new ideas into commercial development projects, expanding their academic scheme of valuation to include considerations of business value. Nevertheless, the actual contribution was not what the mother company had had in mind, and very little came out of the input in terms of collaborative interaction. No new tracers were developed, meaning that the interface resulted neither in the economic use the mother company had hoped for, nor any academic or healthcare-related utilisation.
All in all, combining the two capabilities from the two organisations was an excellent idea in theory, but proved much more difficult to carry out in practice. The cutting-edge feature of the PET researchers’ knowledge, which at the outset had been assumed to be able to contribute to economic value, in fact complicated the relationship with the researchers at the mother company. The depth aspect of the researchers’ scientific knowledge had undeniably served very well as a guarantee for scientific skill in relation to pharmaceutical companies, resulting in substantial contract research business. The same feature was also what had attracted Amersham’s attention in the first place. However, the vanguard characteristic of this knowledge in fact turned out to be almost a liability – or at least a feature from which very little economic use could emanate for the mother company, meaning only limited commercial value was created. Correspondingly, the business-conscious feature of the industrial researchers’ knowledge was of little value since it did not pair up well with the academic mind-set of the Uppsala team. In other words, both of these features – the depth of Uppsala’s academic knowledge and the business-consciousness of the mother company’s knowledge – were essential to the two resources and in themselves appeared valuable, but when joined together seemed to be working against each other. Because the two knowledge resources did not really fit one another, they remained only weakly interfaced throughout most of the eight years the PET Centre was owned by Amersham and GE Healthcare.

This section has demonstrated a point pertinent to any efforts where knowledge resources from different spheres are brought together with the expectation of spurring economic use of science. Namely that two organisational resources which appear to be complementary, and are hierarchically controlled within the same organisation, can resist full combination due to different barriers (for example cultural ones) which were not obvious, visible or deemed important at the outset. If we look at the
particular case of the Uppsala PET Centre, we notice that despite the
difficulty of creating a solid interface between two knowledge resources in a
business use context, the commercial owner did not give up on the idea of
using academic knowledge to create economic value. For this reason, as
detailed in the preceding section, the Uppsala scientists were not granted the
opportunity to make use of their knowledge in an academic use context when
the efforts in the business use context did not generate the desired results.
This lack of control over resource mobilisation experienced by both the PET
researchers and actors from the sphere of healthcare had a negative impact on
the organisation. In the next section I take a closer look at an interface that
sheds light on the atmosphere and attitudes during the years GE Healthcare
ran the PET centre. By so doing it affords additional insight into why the
overlap of contexts became such a contentious issue after the full
commercialisation of the Centre.

10.1.4 The interface between IMANET’s management, the
Uppsala PET researchers and clinical researchers at Uppsala
University Hospital

The takeover by Amersham, and later GE Healthcare, brought significant
changes in terms of activities, rules and day-to-day routines at the PET
Centre. Used to a great degree of autonomy and with research projects
concentrated on independent pursuits, the researchers in Uppsala adjusted to
the new order somewhat reluctantly, sceptical as they were of the new
administrative routines. Radically different from the academic way of
organising things, the new company – particularly after GE Healthcare’s
takeover – was run as the business it now formally was, with standardised
rules and routines that made the unit fit better into the larger organisational
structure of the mother company. But even though the new regime made
sense from the owner’s point of view, the researchers were frustrated.

Especially strange to the scientists was the way GE Healthcare prioritised
different activities. Careful attention to cost control made it next to
impossible to get approval for academic research projects, resulting in a
decline in activity in the academic use context of science. Meanwhile
resources would be granted for projects dealing with safety and work
environment, an aspect of the operation of great importance to GE
Healthcare, whose company-wide Environment, Health and Safety system
(EHS) required the researchers to work with these issues according to a set,
detailed plan. The researchers found it odd that such a considerable part of
the capacity of the Centre was now devoted to administrative functions, often
pertaining to safety, instead of research projects. In addition, clinical
researchers at Uppsala University Hospital found the process of getting their
clinical studies approved cumbersome. As described in the empirical account,
every request to do an experiment at the PET Centre now had to pass through a formal decision process, which involved obtaining approval from a committee with GE Healthcare representatives. These administrative hurdles diminished the academic use of science, in terms of both pre-clinical and clinical research.

In other words, the interface, represented in Figure 10.4 below, was everything but smooth and stable. One important feature of the new management, namely its rigorous attention to spending, was regarded by the scientists as an impediment to the utilisation of science, as opposed to an effective means of improving the Centre’s financial performance. Clearly, the ability of the new management to run the organisation professionally as a business was not seen as valuable by the research staff. From an academic point of view the interface between the new management, the PET scientists and the clinical scientists resulted in a reduction in academic value as a consequence of the downcaled academic use of science. On the other hand, when considering the commercial value of PET science and the PET Centre, the interface was indeed valuable. It limited the accumulation of deficit both through more thorough cost control, and by focusing on commodification of science in the shape of contract research, rather than independent science projects. In short, science was used primarily in a business context instead of an academic context.

Figure 10.4 The interface between IMANET’s management, the Uppsala PET researchers and clinical researchers at Uppsala University Hospital
The bringing together of this diverse collection of resources thus resulted in a clash between the schemes of valuation of business and academia. PET scientists and clinical researchers at the Hospital did not much appreciate the features that defined the corporate character of the management that the takeover by Amersham brought about. And, of course, the converse was equally true. For the management team, the feature that perhaps most distinctly characterised the PET researchers, namely their independence, could just barely be contained within the business organisation the management team wanted to create. What ensued was a situation where constraints and demands for alignment were imposed on a previously flexible organisation, reducing the possibilities of the organisation to engage in the kind of science utilisation it was most interested in. The consequence was a growing sense of resentment among both pre-clinical and clinical researchers.

10.1.5 Discussion of organisational interfaces

In this chapter the objective has been to shed light upon the interplay between different schemes of valuation, so as to show in detail how crucial the differences in actors’ preferences and motivations regarding the utilisation of science really are. By delineating the reasons why the use of science has taken this form, the analysis has laid bare the dynamics among the actors involved. Essentially, the study of organisational resource combinations reveals the struggle for control and influence over the overlap of science use contexts.

A few lessons can be drawn from the analysis. We have seen that when the same, or similar, schemes of valuation are brought together via the combinations of organisational resources to which they are connected, the use of science is less likely to be fraught with conflict. In contrast, when organisational resources tied to dissimilar schemes of valuation are combined, we are more likely to observe instances of negotiation, compromise, conflict and even failure.

Moreover, we can note that the combinations of purely organisational resources tied to the PET Centre are primarily characterised by fickleness, changeability and hence unpredictability in terms of outcome. This can be compared to the physical and mixed interfaces investigated in previous chapters, which in many instances in the evolution of the PET Centre have been distinguished by considerable depth and firmness due to the low substitutability of the interacting resources. Physical resources, in addition to being difficult to substitute, can be controlled, due to the fact that they do not change shape or behave erratically. For this reason deep mixed and physical resource interfaces can be expected to result in the creation of at least some value, although there is no assurance that actors with a stake in the interface will be entirely satisfied with the outcome.

In contrast, because of the intrinsic instability of most organisational resources, it is next to impossible to have full authority over an organisational
interface. As a consequence, the creation of value resulting from this type of resource interaction is more challenging to foresee. In fact, for unpredictable interfaces there is no telling if any of the expected value will be created at all.
Chapter 11. Using science in a context of intersphere interaction: a synthesis

Over the course of the past four chapters I have systematically sifted through the details of the case of the Uppsala PET Centre so as to bring clarity to the story. My approach to this task was, first, to relate the evolution of the Centre to processes of commercialisation and commodification, as well as to the schemes of valuation of the actors involved (Chapter 7); and second, to conduct a micro-level investigation of how resources have been combined within the network in which PET science is embedded, and of the outcome of these resource combinations (Chapters 8, 9 and 10). The objective of this analysis has been to enhance our understanding of the use of science in a setting where interplay is taking place between actors from disparate spheres, and where, as a consequence of this interplay, there is a movement toward and away from the commercialisation and commodification of science. More specifically, I have posed two questions concerning the use of science; I have inquired into the role played by its materiality; and I have directed attention at the effect of interaction between actors belonging to different spheres. In this chapter I intend to synthesise the analytical observations made in the past four chapters and present the findings of this thesis. I begin with the issue of materiality.

11.1 Materiality in science use

Throughout this thesis I have, both in the rendering of the empirical story and in the analysis of this account, pointed to the massive extent to which science is composed of physical objects. We have familiarised ourselves with cyclotrons, PET scanners and hot cells, not to speak of the miniscule radioactive isotopes without which tracers would not exist and PET would not be PET. Essentially, I have showed that PET science, like most scientific disciplines, in addition to existing as codifiable and tacit knowledge, is inscribed in material things. When considering science partly as an assemblage of material artefacts, by inference we can conclude that, most often, use of science involves the use of something material. What, then, happens when multiple actors from different spheres each want to use the same piece of
science – that is, share the same physical resources? How exactly does the materiality of science affect its use under such circumstances?

By scrutinising critical resource interfaces containing physical elements, the analysis in previous chapters demonstrated that the use of science in a situation characterised by inter-sphere interplay is bound up with both opportunities and limitations. In other words, when users who incorporate dissimilar schemes of valuations engage in interaction revolving around science, it is not unreasonable to assume the outcome will not be unambiguously positive. Let me elaborate on this finding by first sketching out the basic financial reality in which most organisations operate, namely that of restricted spending: when funds are limited, we can expect the quantity of material things to be limited too. We have learned throughout the study presented in this work that this was certainly the case in the PET centre journey. In such a context, the most fundamental condition for inter-sphere interaction is thus that material objects are shared between the parties involved. It is with this situation as our starting point that we can discuss the opportunities and limitations the materiality of science brings about.

The account of the evolution of the Uppsala PET Centre has revealed an array of mechanisms through which various forms of value from science have been created; by employing material artefacts such as tracers, cyclotrons, scanners and hot cell equipment, science is used to fulfil a variety of purposes. To be sure, we have learned how, over the years, the Centre has been a site not only for tracer development and clinical research, but also for clinical practice and independent research where PET is utilised as a tool, as well as for contract research and in-house commercial development work. It is within this breadth of application, and hence the wide range of mechanisms for value creation, that we find the opportunities opened up by the interaction between dissimilar actors around the same piece of science. Now, what do I mean by this? What I claim is not simply that the area of PET science, with all the material aspects that it encompasses, is one of opportunity simply due to the richness in possible forms of utilisation it offers. Rather, what I am concerned with, as far as positive connections between materiality and utilisation are affected, are the instances where value is created jointly for the actors involved – where interaction between different spheres means that the use of science is meaningful for all parties involved.

The resource analysis revealed two main forms of mutually beneficial utilisation: that of contract research and that of activities related to clinical use.

Constituting a mechanism through which value, in fortunate cases, can be created for both business and academic science, contract research represents one area of use harbouring important opportunities. We have learned that, while the objective of contract research is obviously to solve a particular issue specified by the commissioning company, this kind of commercial project
could also be of scientific interest to the researchers assigned to the task. In such cases, the fact that scientific material resources in the shape of PET equipment are being used with the primary goal of producing a commodity – science as a service – does not rule out the creation of scientific value. Although the engagement in fee-for-service assignments precludes any simultaneous use of machines and tracers for independent research pursuits, the commercial research topic and the circumstances around the project may be such that scientifically valuable knowledge can be generated through publication in scientific journals. Clearly, on this type of occasion the use of science occurring through the interaction between dissimilar actors results in the creation of value that is simultaneously of both economic and scientific significance.

The other important source of opportunity linked to the materiality of science and its utilisation by multiple, diverse actors, can be found in clinical use. The detailed account of the collaboration between PET researchers and medical researchers showed how scientific and healthcare-related values were created simultaneously as PET researchers and clinicians used physical PET resources jointly. While diagnosis and monitoring of patients were carried out first and foremost as part of the medical care of the sick, these procedures simultaneously provided the space for scientific exploration. Thus, utilising material PET infrastructure within the setting of actual clinical practice not only meant that the needs of the patients were accommodated, but also that clinical research could be conducted at the same time. Sometimes, as in the case of 5-HTP, this clinical research was carried out alongside pre-clinical science projects. In other words, the fact that machines and tracers were used in the context of medical care, as opposed to exclusively for pre-clinical research, often resulted in benefits for both healthcare and academia.

By analysing resource combinations within the network in which Uppsala PET science is embedded, this thesis has thus shown that the materiality of science relates to inter-sphere interaction in a manner that occasionally may create opportunities for joint value creation. Nevertheless, the past few chapters also explicated how this materiality is associated with serious limitations. The unavoidable fact of the matter is that a situation such as the one the Uppsala PET Centre encountered for many years, where the same resources are required irrespective of the purpose for which PET is employed, is one of great complications. Crucially, from the investigation of the Uppsala PET Centre, we can conclude that, although there are positive aspects to the way materiality of science affects use within a context characterised by inter-sphere interplay, there are also critical difficulties tied to the fact that the same set of resources are used. While joint, simultaneous value creation did indeed occur at Uppsala, the journey of the PET centre also revealed the prevalence of situations in which one form of use pushed out another. This has urged me to discuss science use not only in terms of
materiality but also as a function of scarcity. As for life in general, in the world of science too, material resources that are expensive do not exist in vast numbers. Indeed, in instances where materiality is associated with substantial costs in a context of restricted spending, we can expect material things to be in limited supply. However, this limitation is not perceived as scarcity until the parties involved in its use or consumption begin to feel a dire need for more than is available. While in the case of the PET centre, neither researchers nor managers started to call out for purchases of additional cyclotrons and hot cells, in all actuality such a move – acquisition of more pieces of equipment – would have lessened much of the contention around the use of PET science. But naturally, because the creation of additional sets of PET infrastructure at Uppsala would have made no economic sense whatsoever, the actors most often found themselves in a situation where they needed to take turns in their employment of physical scientific resources. As a result, more often than not, the creation of one value through a particular form of use generally hindered the concurrent generation of other types of value.

The study of the Uppsala PET Centre has hence detailed how, to a large degree, science is bound up in materiality, and how the way in which this materiality relates to science use in a context of inter-sphere interplay entails both possibilities and limitations. More specifically, this thesis has demonstrated that the scarcity associated with the materiality of science, in a setting where multiple actors want to use science in their preferred way and following their preferred schedule, makes the utilisation of this entity a complex occurrence. At the heart of this complexity is the act of sharing. In a situation of diverse motivations and material limitations, sharing presents a true challenge. In the language of this thesis, the success of sharing becomes partially a matter of reconciling dissimilar schemes of valuation. I now turn my attention to precisely this aspect of science use – that of the actor – as I move on to discuss the findings made in relation to the second research question of this thesis.

11.2 Divergent schemes of valuation and the sharing of science

In this thesis I have argued that the use of science in a context of inter-sphere interaction is a function not only of materiality, but also of the preferences, norms and needs of the actual users of science. In the account of the transformation of the Uppsala PET centre, I have dealt with these elements as a whole by compounding them into the construct of schemes of valuation. In my attempt to relate science utilisation to the involved actors, this is the concept I have employed to discuss the repercussions of the materiality – and
hence scarcity – of science in relation to the different stakeholders. The chronicling of the events relating to the centre has made evident just how divergent the involved schemes of valuation have been, and, crucially, how they have affected the utilisation of science. A fundamental observation has been that, although the interests and objectives of an actor occasionally change in such a way that they in effect become attuned with those of other actors, they generally wish to make use of science in a way that accords with their scheme of valuation. As a consequence, in a setting comprising actors with different schemes of valuation, we can expect a diverse collection of preferences concerning how science ought to best be put to use.

In the analysis of the empirical material I discussed this varied utilisation of science in terms of use contexts; I maintained that academia, healthcare and business, when free to use science in accordance with their schemes of valuation, essentially operate within their own specific contexts of science use. As a result, the interaction between institutionally disparate actors, who harbour their own particular objectives in regard to science utilisation, means that science is used in many different ways. In other words, because disparate actor spheres wish to utilise science to accomplish different things, a piece of science being put to use within multiple contexts of use will have a broader, more varied range of application. Indeed, in the case of the Uppsala PET Centre, we saw PET science being employed in independent research and clinical practice, as well as within contract research and in-house commercial development projects. Nevertheless, although this breadth in utility resulting from the different-sphere involvement in science use is inherently positive, the findings of this thesis simultaneously point to the stress such interaction may cause – a fact I addressed in the preceding section.

To be more specific, the PET centre study has shown that, with increasing numbers of use contexts, the struggle to secure access to scientific resources at Uppsala University intensified. I discussed this struggle in terms of overlap, or spatial overlap, of use contexts, by which I aimed to describe a situation where the same physical space, and the resources it spans, are utilised by multiple actors for different purposes at different points in time. The most fundamental premise of this description was the acknowledgement of the basic, real-life effects of the materiality of science that I discussed earlier in this chapter: the use of science by one actor rules out the simultaneous use of the same piece of science by another actor, thereby rendering idle the use context of the other actor. As concluded at the very end of the last section, the use of science by different actor spheres therefore eventually boils down to an issue of sharing, of reaching an agreement on whose context of science utilisation should be favoured at a certain point in time. The analysis of organisational resource interfaces was informative regarding the difficulty of achieving a situation in which all parties were content with this type of sharing, clearly illustrated not least by the resource interface between the
IANET management, the PET researchers and clinical researchers. In a sense this interface encapsulated the everyday coexistence between the different actors, containing as it did all the rules, routines and decision-making that, first, reduced the PET researchers’ engagement in scientific activity while escalating their administrative duties, as well as, second, curbing the chances for clinicians to have their research projects approved. But whereas this interface served as an illuminating example of the dissatisfaction with how the overlap of use contexts was handled, the analysis of organisational interfaces also provided a significant example of the uncertainty associated with dissimilar actors collaborating within the same context of science use. More precisely, the combination of the knowledge of Uppsala PET researchers with that of the mother company’s researchers highlighted the challenge intrinsic to involving one actor in a use context that is fundamentally different from the one this actor calls home.

When taking the stance that it is in the use of science that value is created, the ramification of context overlap is largely a situation in which one type of value creation takes precedence over another. It is for this reason that the evolution of the PET Centre, which in many ways has been marked by the interaction between disparate actor spheres, can be understood as a story about claiming, taking and relinquishing the space within which scientific resources are contained. Essentially, the way science has been shared over the years, with dissimilar actors tackling the limitations associated with the materiality of science, is revelatory of the distribution of power. The journey of the PET Centre has showed that the degree to which each specific actor has been granted the opportunity to use science, and thus to create value in a way that has aligned with their particular scheme of valuation, has depended on who has been in charge of the PET Centre. Whoever has owned the Centre has eventually had the most sway in drawing up the rules for the sharing of resources. As straightforward and unsurprising as this manner of things appears, it is important to remember that when the decision to commercialise the PET Centre was taken in the early 2000s, the belief of the PET researchers, as well as – at least officially – of the University administration, was that sufficient room would be made for the researchers’ scientific interests, as well as for the needs of clinicians.

Still, perhaps the most remarkable aspect of the link between ownership and influence over the use of physical scientific resources is that the acquisition of the PET centre by a commercial actor never in actuality (if indeed formally) transferred all of this power to the new owner, not even after the University holding company UUAB had sold off its 25% stake in the venture. Because as just pointed out above, even though the actor owning the Centre had the most leverage in regard to science use, this actor still to some degree had to accommodate the needs of the other actors. The use patterns of the owner may have dominated, and marginalised other types of use, but
the fact of the matter remains that all three contexts of use coexisted – definitely not in peace for much of the time, and surely not in equal proportions, but nor was any one context completely obliterated. This existence of, and dynamics between, the three overlapping contexts of science use explains both why the process of commercialisation has unfolded how it did, and the reasons for the shifts in commodification of the Centre’s scientific output. The next section concentrates on this relationship, elaborating on the particular connection between the overlap of use contexts and the movements of commercialisation and commodification, which in a sense can be said to have been the processes defining the course of the PET centre journey.

11.3 Science use in relation to commercialisation and commodification

I began the analysis of this thesis with a chapter (Chapter 7) in which I defined a commercial organisation as one whose objective it is to make a profit, as opposed to aiming to be merely self-sustaining, or even accepting constant deficits. Normally, in a fully commercial organisation one would expect any exchange of goods and services with external parties to be an exchange of commodities: items with a price that exceed the cost of production. In other words, one would assume that there was a one-to-one correspondence between the commercial character of the organisation and the commodity status of its exchanged output, i.e. between the level of commercialisation and the level of commodification. One of the peculiar aspects of the evolution of the PET Centre, however, is the fact that such a distinct symmetry between the two processes was never established. The empirical story and the resource analysis of the previous chapters revealed that, while the progression of commercialisation certainly correlated with an increase in commodification of the Centre’s scientific output, the extent of this commodification during the commercial years was not at the level the commercial owner had wished.

This state of affairs can be traced to the existence of overlap between disparate use contexts. Throughout this thesis I have argued that because the PET centre journey involved the interplay between actors with dissimilar schemes of valuation, these actors generally wanted to make use of science within their own specific contexts. Furthermore, as concluded earlier in this chapter, because of the scarcity of material scientific resources, these contexts by necessity had to spatially overlap. The analysis of resource interfaces dissected this overlap and pointed to its consequential effect on use, and thus on value creation, both in terms of how much value was created, and what kind of value. The conclusion was that when resources must be shared,
nobody – not even the owner – is granted the benefit of uninterrupted utilisation of science. As a consequence, the eight-year long era of commercial ownership did not result in complete commodification of the PET centre’s scientific output. Despite the commercial rationale, some independent, non-commercial academic research was still being conducted, and the Hospital still could not pay more than cost price for clinical services, as opposed to a price that would have generated profit for IMANET.

While the use of science taking place within the business context was naturally one in which the output of the Centre was treated as commodities (e.g. contract research) or soon-to-be commodities (e.g. commercial tracers under development), the situation was, as just hinted at above, different in the use contexts of academia and healthcare. Within the academic context of use the primary interest was the production of scientific knowledge, rather than the sale of science as a commodity or development efforts geared toward the creation of commodities. For the commercial actor during the commercial years, granting academia temporary access to physical PET resources for the purpose of free research therefore meant a momentary abandonment of something very valuable – time at the machines – and hence a lost opportunity to engage in the commercial use of science. Similarly, the healthcare context of science use also entailed a disruption of the commercial activities at the Centre, in that this use rested upon the purchase of semi-commodities (clinical services) as opposed to the purchase of products or services further up the commodity continuum (Kopytoff, 1986). The fact that the business context of science overlapped in this way with the use contexts of academia and healthcare thus meant that the scientific output of PET (for example tracers and PET scans) was not consistently treated as commodities even during the fully commercial period.

The degree of commodification is thus in essence contingent on two factors. On the one hand we know that whoever controls the materiality of science has the greater control of how science is put to use, i.e. the extent to which scientific output is regarded as commodities or used to produce commodities. Yet, on the other hand, as the case of the Uppsala PET Centre has shown, when non-commercial actors are regularly given the opportunity, however circumscribed, to utilise science in accordance with their particular schemes of valuation, the commercial actor faces a recurring situation in which the organisation, though commercial in the way it is run and in terms of the economic expectations set for it, reasserts its non-commercial roots.

Conversely, the process of de-commercialisation is just as revelatory of the effects of use context overlap as the process of commercialisation. With ownership returning to the public sphere and the re-adoption of a non-commercial mode of operation, the use of physical scientific resources for direct sale as commodities and for production of commodities still continued for a few years after the commercial actor had sold the organisation. Not only
did the previous owner continue making use of the facility for its commercial projects, the now non-commercial centre also carried on, albeit to a reduced extent, the contract research business. This meant that although the de-commercialisation of the PET centre involved a weakening of the position of business in the three part overlap of use contexts, there was still very much an overlap. As a consequence a slight commercial character to the centre remained. Hence, irrespective of the scheme of valuation of the owner, commercial considerations and creation of commodities, mainly in the form of contract research studies, always constituted an aspect of the Centre’s operations to a certain extent.

All in all, the practical ramifications of context overlap in terms of how science is used can be described as an oscillation in the degree to which scientific output is treated as commodities or used to create commodities. This oscillating movement was explicated in detail in the resource analysis: during the commercial years, a fee-for-service study could be sold as a full commodity one day, while the machines could be used on the next day to produce a clinical service – a semi-commodity – and the day after that employed to carry out an experiment as part of an academic research project. In other words, the implication of sharing material science has been a constant negotiation of the extent to which science should be treated as a commodity.

As a matter of fact, in both of the major organisational transformations the Uppsala PET Centre has undergone – that of commercialisation and that of de-commercialisation – ambitions concerning commodification were central. Around the time discussions about commercialisation began, there was an interest among the Centre’s leading figures in being able to expand the volume of both independent research and the contract research business; put differently, the aspiration was, among other things, to increase the degree of commodification of the scientific output. The subsequent dissolution of the fully commercial form of the PET centre less than a decade later was likewise fuelled by wishes concerning commodification. But this time the University, together with the Hospital, wanted less commodification, while the commercial owner desired more. More, it would turn out, than it was possible to achieve in a place where overlapping use contexts each claimed a space.

11.4 Summing up the key findings

This chapter has aimed to present the key points of the present work as they evolved from the analysis of the empirical material. The object of my study has been the Uppsala PET Centre, which throughout its journey of commercialisation and de-commercialisation has been the locus of science use. We have seen how varied expectations and hopes for the economic

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performance of the Centre have been over the course of its development. The organisation has migrated between two extreme points, one of which has been distinguished by a fully commercial rationale with profit in focus, whereas for the other, operation in the red has been tolerated. The material aspects of science have meant that scarcity and deep interfaces between physical resources have affected the possibility to make use of science, unhampered and uninterrupted. The constraints on science use have also been a consequence of the insistence of actors with dissimilar schemes of valuation, and hence different science use contexts, on engaging in science use. The restraints on science use result in an overlap in science use contexts, making sharing and turn taking necessary. By handling context overlap in this fashion all three actors are able to use science to some degree, and thus generate value for themselves. The relative proportion of each form of value created is contingent on the degree of commercialisation of the PET Centre: when the Centre was semi-commercial a lesser share of commercial value was created compared to the fully commercial phase, and so on. But regardless of the degree of commercialisation of the organisation, it is impossible to attain complete commodification of all scientific output from the Centre: as long as all three actors are granted the right to create the kind of value they prefer, the generation of commodities will always make up only a portion of the output. This comprehensive finding of the PET centre story is depicted in Figure 11.1 below.
In a case such as that of the Uppsala PET Centre, where non-commercial actors wanted to partake in science use alongside a business actor, the existence of this use context overlap has thus had major implications for the degree to which science can be commodified. With multiple disparate actors voicing legitimate concerns regarding their ability to create their preferred form of value from science, it becomes clear that the issue of what counts as “useful” in relation to science ought to be approached with caution. The next, conclusive chapter, in which answers to my research questions are presented, connects the findings of the PET Centre case to the ongoing conversation about the use, role and economic potential of university science.
Chapter 12. The challenge of creating science-based value through inter-sphere interaction

This chapter discusses the findings of my study on the Uppsala PET Centre journey in four steps. First, I link the results to my research questions. Second, I consider how my findings contribute to the literature. Third, I relate the key findings to current discourses in research and innovation policy, discussing how the implications of this study may be useful for policymakers, universities and industry. Lastly, I suggest possible avenues for further research on the commingling of academia and business.

12.1 Research questions revisited

The overarching purpose of this thesis has been to achieve a better understanding of science-centred interplay in which the parties belong to dissimilar spheres. Focusing on a journey of commercialisation and de-commercialisation involving a university, a company and a hospital, I have sought to grasp how their intermixing has affected the use of science. To this end, the phenomenon of science-based inter-sphere interaction has been approached from two angles: materiality and actors. Each highlights an aspect of this form of interplay. This twofold focus is reflected in the two thesis research questions, addressed below.

1. How does the materiality of science affect its use by the spheres of academia, business and healthcare?

The PET Centre case has demonstrated that physical infrastructure is crucial to PET science, and how the importance of these physical resources has affected interaction between academia, industry and healthcare.

1) The materiality of science has fundamentally restricted the *flexibility* of science use, owing to two factors: (a) scarcity of physical scientific resources; and (b) deep interfaces between these resources, where the depth makes the specific combinations of physical resources tightly attached and hence inflexible.
2) These two factors combined result in *constraints* on science use, where the simultaneous use of science by actors in different spheres becomes severely restricted. Figure 12.1 below shows a graphic representation.

![Materiality of science](image)

Figure 12.1 Science use in relation to the materiality of science.

3) Despite these serious constraints on simultaneous science use, the actors in each sphere insist on maintaining their own use of science.

4) The consequence of (a) the severely limited scope for different actor spheres to use science simultaneously, and (b) the actors’ persistent attempts to use science despite the restricted availability of physical resources, is that use context overlap arises. In this situation, multiple actors use science in the same space, mobilising the same scientific resources contained therein. Figure 12.2 provides a graphic representation.
To grasp the consequences of a) this use context overlap in a situation of interaction between different spheres and b) of combining organisational (as opposed to physical) resources tied to the different spheres in a single use context, one must consider the dissimilarity of the interacting actors’ schemes of valuation. This is done in the second research question:

2. **How does interaction between the spheres of academia, business and healthcare affect value creation from science?**

The disparateness of the main actor spheres involved in the PET Centre has been discussed in terms of schemes of valuation. These schemes have been found to have a profound impact on the way science is used, in terms of both the part they play in use context overlap and how they affect the combination of organisational resources. The points below sum up the answer to the second research question.

1) The dissimilarity of the schemes of valuation reflects the respective actors’ conflicting wishes concerning the use of science at the PET Centre, resulting in the development of three clearly divergent contexts of science use. This co-existence of different use contexts

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27 To be clear, if the various users had not been tied to dissimilar schemes of valuation, the constraints resulting from the materiality of science would still have precluded simultaneous use by different actors. However, if the actors belong to the same sphere, and the use context is thus the same, the restrictions on use do not have the same grave effects on the extent of value created. In concrete terms, this means that academics’ sharing of resources hinders value creation less than sharing them with parties belonging to disparate spheres, such as business.
would have posed no problem without the constraints imposed by the materiality of science, since it is these constraints that result in the overlap of the various use contexts.

2) Overlapping science use contexts mean that no single actor can generate the desired types and extent of science-based value. Yet, in using physical scientific resources, the actors can still expect to create some value since the materiality of these resources enables them to be controlled during use. Nevertheless, owing to use context overlap, the types and extent of value created may be unsatisfactory for particular actors when their schemes of valuation are not prioritised in value creation.

Specific actors’ dissatisfaction with the extent of value created and obtained cause struggles to control physical scientific resources. These struggles may result in (a) sharing and turn-taking in the use of science to manage context overlap and/or (b) efforts to separate use contexts to accommodate user needs better. See Figure 12.3, for a graphic representation of points (a) and (b), below.

![Figure 12.3 Effects of dissimilar schemes of valuation on science use.](image)

3) The dissimilarity of valuation schemes also affects the use, and thus value, of organisational resource combinations. When organisational resources are marked by disparate schemes of valuation and made to combine in a use context that is thus alien to one or more of these organisational resources, the outcomes of these combinations are impossible to anticipate and control.

Science-based economic value creation from organisational resource interfaces is therefore highly unpredictable in a situation of inter-sphere interaction. Figure 12.4 shows a graphic representation, including a comparison with the outcomes of physical resource combinations as discussed in (2).
By pinpointing the mechanisms of science-focused interaction between three disparate actors, these findings contribute to our understanding of science use in mixed-sphere interplay. They do so in terms both of repercussions on the use of, and hence value creation from, science and of the dynamics of inter-sphere relationships. The findings are relevant to both Science and Technology Studies, and to research on university–industry interaction. The following section discusses my contribution to these literatures.

12.2 Theoretical contributions

12.2.1 Science and Technology Studies
With its focus on the effect of physical and organisational factors on science use and science-based value creation, this thesis adds to the field of Science and Technology Studies (STS). In STS, a central topic concerns production of scientific facts and technological artefacts. The idea of building networks (see
for example Latour, 1987) and systems (Hughes, 1987, 1993) has been strongly influential. While, in line with the STS perspective, my study concerns the impact of social aspects of life on material objects and vice versa, its focus is not on the traditional STS matter of construction. Rather, the present work brings to the fore issues of disturbance and redefinition of the network in which science is embedded.

By concentrating specifically on the relationship between science use and mingling of multiple disparate schemes of valuation, I have highlighted interferences of an established network, originally designed to produce novel, academically relevant scientific knowledge. I have shown that the antagonism among such different valuation schemes concerns not the question of how best to link the physical aspects of the network, but that of what the primary purpose of the network is. The PET Centre case demonstrated that, for each of the actor spheres involved, the main purpose of the network was distinctive. For one, the primary purpose of the PET scientific network was to produce new, academically relevant knowledge. For the other two spheres, it was healthcare and production of science-based commodities respectively. The implication of this disagreement regarding purpose is that, while the network is largely left materially intact, use of the network is repeatedly disrupted as first one and then another actor sphere enters the network and takes over in a sharing and turn-taking system. For example, as the PET Centre case illustrates, researchers adhering to an academic scheme of valuation scheme had (for varying lengths of time) to stop using resources in the network to give way to business and healthcare, and vice versa.

If a network in which science is embedded is disturbed by an actor tied to the same scheme of valuation as the user currently in charge of the network, the network’s purpose in terms of use does not change. For instance, when a group of pre-clinical researchers must take turns with a group of clinical researchers, the network’s main purpose remains production of new scientific knowledge. On the other hand, when a business actor takes charge of the network, its purpose changes: the focus shifts to producing science-based commodities and generating profit. With sharing and turn-taking between actors in dissimilar spheres, the network’s purpose is repeatedly redefined.

Thus, the PET Centre’s evolution illustrates that the fragility of a knowledge-producing network lies not solely in how easily it may fall apart (because of a broken machine, for example), as for example Actor Network Theory recognises. The history of the Centre shows that an additional reason for such a network’s vulnerability is the speed at which it can be disturbed and the purpose of its use redefined. Clearly, in a world where the marriage of science and business is sought, this flexibility of an established, effective science-producing network is attractive. But, whether for better or for worse, inviting players from disparate spheres into a carefully crafted network causes disturbance and redefinition of its purpose. If the PET case gives any
indication, the network is flexible only in a superficial sense. It can serve many different types of user spheres, but as soon as each sphere persists in its needs and presses for its rights to use the network, limitations on the network’s flexibility become apparent.

12.2.2 University–industry collaboration

The PET Centre case is also relevant to theories on academia–business linkages. As mentioned in the introduction, much literature on university–industry interaction either implicitly or explicitly labels this form of interplay as intrinsically positive (albeit complex). Nonetheless, the findings of the present work challenge this outlook. The story of the PET Centre has made us aware of both the very practical challenges that arise when physical scientific resources are shared and the unpredictability of interfaces between organisational resources tied to disparate valuation schemes. Through these results, the work at hand has highlighted the difficulties this form of interaction may entail.

While in society today we undoubtedly see growing entanglement between academia, business and the state described, for instance, by the Triple Helix model (Etzkowitz and Leydesdorff, 2002), there is no reason to assume that such intertwining is automatically favourable. Research using the frameworks of the Triple Helix and, in particular, Innovation Systems would benefit from adopting a perspective with no *a priori* assumptions on the positive effects of this type of intermingling. This study of the PET Centre, where the initial variables seemed unusually advantageous, underscores the advisability of avoiding uncritical assumptions about the merits of science–business interaction. As this thesis has shown, avoiding such suppositions can prompt formulation of new sets of research problems and hence new insights into university–industry interaction.

In the PET Centre study, the combined focus on the materiality of science and the dissimilarity of the actors involved has shed light on the phenomena of commercialisation and commodification. I have shown that these phenomena do not necessarily exist in pure form at all times, but instead take place on a continuum, along which the level of both commercialisation and commodification shifts (Kopytoff, 1986). In the case of the PET Centre the process of commercialisation proved to move back and forth over time. As for commodification it was demonstrated how, similarly, a single item of scientific output (such as a molecule or a scan) had varying degrees of “commodity-hood” (Appadurai, 1986) at different points in time. However, I also showed how the degree of “commodity-hood” varied among various products and services even within a single period. During the fully commercial phase at the PET Centre, for example, some services were deliberately sold at cost price, while others were sold at a price that generated
profit. Essentially, what these findings highlight is the fact that the degree of commodification of scientific output does not necessarily exist in a one-to-one ratio with an organisation’s degree of commercialisation. This observation is pertinent to the research field of university–industry interaction, since it points to the difficulty of anticipating and exerting full control of the level of commodification within commercial academia–business endeavours.

Furthermore, by directing attention toward the materiality of science, the study of the PET Centre has also indicated that the need for physical scientific resources may play a critical part in university–industry interaction. Regarding the PET Centre, the wishes associated with the physical research infrastructure partly explained both commercialisation and de-commercialisation motives. This study has clearly demonstrated that considering the role of science’s material aspects can be a fruitful approach to understanding both the drivers of and the obstacles to interaction between academia and business.

The sections below discuss how the contributions of the PET Centre study described in this and the above section can inform the schemes and actions of policymakers, universities and industry.

12.3 Practical implications for policy, universities and industry

At the very beginning of this thesis a few general, basic questions were posed: what do we want science to be, what does it mean for science to be useful and what kinds of benefit are we striving for? What I have attempted to do in the work at hand is not to present any definitive answers to these questions but, rather, point to the diversity of opinions and the wide range of needs and areas of use. These aspects should form essential parts of any ongoing societal debate and be seriously considered in policymaking, as well as in formulation of strategies and goals in both academia and industry. Implications of the PET Centre study’s findings for these institutions are discussed below.

12.3.1 Implications for research policy

The investigation of the PET Centre journey has demonstrated how intricate and complicated the intermixing of academia and business can be. In light of these findings, policy guidance on university–industry interaction appears to generally underestimate the complexity of such interplay. As when any social actors are combined, events are set in motion and their repercussions are unforeseeable. All interaction contains an uncontrollable element, and the
interplay between science and business is no exception. This has become amply evident in this study, as well as in other works examining science–industry relations (see Mirowski, 2011).

Policymakers could usefully take this point to heart in their calculations, predictions and policy creation. Boundary-crossing activities revolving around science may have extraordinary results, but risks are high and failure far more common than unequivocal success (see Hagen, 2002). One policy implication of this thesis is that while institutions can be made to overlap to form “hybrid organisations” (Etzkowitz and Leydesdorff, 2002; Etzkowitz, Manoel Carvalho de Mello and Almeida, 2005) in the way described and prescribed by the Triple Helix, for example, the overlap on the individual level is highly uncertain. As shown in my study, people are fundamentally not as flexible and easily redirected as policymakers may wish.

The findings of this study are also relevant to policy because they call into question the basic premise of innovation policy recommendations: the notion that introducing science into the commercial sphere enhances its usefulness. As this thesis shows, not even commercialisation of an established innovation like PET necessarily boosts utility. Rather, reduced access to scientific resources compromised PET’s usefulness to academia and healthcare alike. If Vizamyl, the new commercial tracer, had not finally (after the Centre’s de-commercialisation) emerged from the interaction, the outcome would have been utilisation that was unsatisfactory for all parties involved. The issue of utility is sensitive, since the choice of favouring one actor’s activities over another’s means that some portion of utility, in whatever form it may be, is inevitably lost. How to handle this issue is debated by politicians and academics alike, and policymakers are faced with the complicated task of prioritisation.

In these efforts, policymakers could take note of two things. First, serious consideration should be given to science’s usefulness within spheres that are not (or are only to a minor degree) governed by market logic. In this thesis, academia and healthcare constitute two such spheres. Even when a strictly economic rationale is applied (as policymakers tend to do), there is a clear case for taking seriously science’s usefulness to both healthcare and academia. For academia, the use of science brings economic growth further down the line through the output of new graduates. Importantly, in the case of healthcare, the usefulness of science is ultimately manifested in a healthier population. This, in turn, sustains or boosts economic productivity. Such economic gains are real, although they may be less readily quantifiable than direct revenues through commercial spin-offs.

A second point for policymakers to consider is the circumstances in which the only commercial innovation to come out of the PET Centre journey evolved. While scientists and clinicians struggled to make use of PET science in the ways most meaningful to them, the development of Vizamyl meant
that the PET venture ultimately became useful at least to the commercial stakeholder. An interesting point for policymakers to consider is that this utility stemmed not from tight interplay between different spheres, but from a division of labour between academia and industry. As the outcome of university research, the original invention on which Vizamyl was based had evolved in a use context without business involvement. When a company decided to develop the product further to suit the commercial market, it did so with a clear choice of direction and of the academic collaborators’ prospective role in the development of the new product. The innovation process involved not only temporal and spatial separation between the academic and business contexts of science use but also (once the company embarked on its product development) multiple, spatially separated business contexts.

All in all, this reduced overlapping of different use contexts seems to have facilitated innovation. There are a few possible reasons for this. First, there was no struggle to combine, in a business context, two knowledge resources tied to different schemes of valuation (those of academia and business) to achieve an original invention. Instead, this invention was taken from an academic use context where there had been no stress or pressure for commercial achievement. Second, dispersing product testing between several academic research units meant a smaller portion of business use for each unit and thus reduced constraints on science use due to resource scarcity. The development of Vizamyl thus illustrates the possible benefits of more loosely bound collaborations. What, then, should policymakers make of this? One study alone cannot answer that question, but in policy formulation the idea that excessively close interaction may be disruptive to commercial innovation is surely worth considering.

12.3.2 Implications for universities

Perhaps the most fundamental decision universities need to make concerns the extent to which they want and can afford to engage in independent research, and what shape and form their interactions with industry should take. While contract research can and does provide academic scientists with interesting research problems and, frequently, the chance to publish the results in peer-reviewed journals, industry interaction may also require scientists to relinquish their ambitions to carry out cutting-edge research. The PET Centre story is an extreme case, but it highlights aspects of university–industry interaction that are pertinent to all universities deliberating their approach to inter-sphere interaction. More precisely, the PET Centre story tells of one potential drawback of gearing science too closely to industry’s needs: production of new academic knowledge may suffer. Undeniably, in Uppsala, commercialisation came at a high price in terms of free science.
This is also where the issue of materiality comes in. Collaboration with industry not only means that the researchers’ knowledge is concentrated in topics that may not be at the scientific cutting edge. In addition, as demonstrated in the PET Centre study, material scientific resources are tied up because of the interaction, reducing access to these resources in purely academic research endeavours. This specific issue of sharing material artefacts, a crucial effect of university–industry interaction, should be considered by universities wishing to expand or deepen their collaboration with enterprise. Observations based on the PET Centre alone are insufficient as a basis for the universities to draw up specific guidelines on these matters. However, based on the findings of this study, some more general observations may be made. If universities aspire to ensure that academic, entirely non-commercial knowledge makes up a certain proportion of all knowledge produced, they need to continuously and carefully monitor use of research infrastructure, to gauge the extent to which these resources are employed for university–industry interaction.

Related to this concern is the question of when, and under what circumstances, industry should be invited to share the burden of financing. As we have seen, commercialisation of the PET Centre was in a very real sense triggered by the current and future need for costly infrastructure. Faced with situations where researchers request new equipment, universities need to be cautious in considering whether and, if so, how such wishes can be granted without jeopardising independent science. Questions of this kind have no obvious answers: while industry funding has potential negative effects, it also offers undeniable opportunities.

12.3.3 Implications for industry

Industry’s appreciation of universities is understandable: they contain material infrastructure, skilled hands and creative minds. Nonetheless, the PET Centre case indicates that while academic researchers’ knowledge is often tremendously useful, it is also, in some ways, less ideal than envisioned as a resource for industry. A point that is pertinent to business is that researchers’ knowledge may be of limited flexibility. As noted in this thesis, academic scientists’ ingenuity cannot be assumed to be automatically accompanied by an ability to propose new ideas for inventions of direct commercial value. One of the most salient findings of the work at hand concerns precisely this point: despite close inter-sphere interaction, certain actors’ schemes of valuation may remain largely unchanged. There is always the risk of some academics’ valuation schemes being more or less impervious to external demands, as at the Centre. This observation underscores the need to approach joint innovation undertakings with realistic expectations, and should be considered by industrial partners in their strategy formulation.
Further, the case of the PET Centre also highlights the consequences of tightening up command of an organisation where an academic scheme of valuation remains strong. GE Healthcare’s attempts to increase its control of the Uppsala PET Centre and the use of PET science shows how such measures can be almost counterproductive to the workings of an academic organisation.

Both the concern regarding the relative lack of flexibility of academic knowledge when faced with loosely formulated commercial tasks, and that of the risk of imposing too heavy regulations and rules, are manifestations of one of the main findings of this thesis. Namely that organisational resource combinations, when involving resources connected to disparate schemes of valuation, have a very uncertain outcome.

12.4 Study limitations and issues for future research

My study of the Uppsala PET Centre is at once narrow and expansive. It is narrow just as all single-case studies are: no comparisons are made. On the other hand, the PET Centre study is broad in that it encompasses the whole (rather than select aspects) of a science–business venture. The study’s limitations relate to the narrowness and breadth alike.

A single-case design inevitably entails limitations regarding both comparability and the issue of how prevalent the observed phenomena are. Moving beyond such studies, an interesting research focus would be to compare university–industry interaction in a variety of fields where the material research infrastructure is not as expensive, complex or massive as in PET science. Comparisons between different national contexts would present another avenue for further research. In relation to the topic of commercialised PET science, a comparison of the Uppsala PET Centre and its counterpart in London (formerly known as the PET Centre at Hammersmith) might be an interesting subject of study. Apart from highlighting whether and how the two centres differ, such research could concentrate on the reasons for these differences. Questions could concern the following aspects: variation in research focus (pre-clinical versus clinical); relative influence and strength of schemes of valuation; effects of various forms of funding, perhaps specific to the different national contexts; and the tradition of university–industry collaboration in the two countries. This kind of study could indicate potential effects of institutional factors on academics’ schemes of valuation.

Regarding the single case’s breadth of scope, it has affected my ability to treat each commercialisation mechanism in detail. Instead of choosing one specific mechanism as my focal point, I opted to concentrate most on the actors’ valuation schemes and the infrastructure needed for all sorts of
science utilisation. This focus, however, precluded a more thorough examination of the practice of each type of inter-sphere interaction. A suggestion for future research would be to study these different types of collaboration in greater detail. Our comprehension of the inner workings of fee-for-service research and its financial and scientific impact, for instance, would greatly benefit from such investigation.

Moreover, while some time was spent on investigating the development of Vizamyl and efforts to create science-based innovations from joint research projects involving Uppsala PET researchers and those at Amersham and GE Healthcare, these interactions were not studied in detail, at a micro-level. Just as our understanding of the workings of contract research could benefit from micro-level studies, so could our comprehension of collaborative university–industry projects aimed at commercial innovation. What makes such endeavours succeed or fail? In what ways is industry helped? And what aspects of such projects are most enjoyable, meaningful and/or challenging for academic scientists?

12.5 Sensible expectations: a new path?

Pavitt writes (1991):

“[E]conomists and social scientists will benefit enormously if they drop the conceptualisations of science and technology as activities producing easily transmissible and applicable ‘information’, and recognise them instead as search processes and skills embodied in individuals and institutions. In this context, they would more easily appreciate the importance of basic research as both training and a cumulative body of research” (p.118).

Though directed at researchers studying science-based value creation, this message is also relevant to policymakers, university management and industry in their formulation of forecasts and plans. If we adopt a conception of science and technology along the lines proposed by Pavitt, expectations of the short-term economic and social effects of university–industry interaction must change. As demonstrated in the work at hand, this form of interaction is a complicated affair, encapsulating opportunities and unforeseeable challenges alike. Despite the attraction between the spheres of academia and business, where front-line scientific knowledge and financial resources are the main forces bringing the two together, neither agreement nor valuable results can be assumed.

As long as the flexibility of academic scientific knowledge is overemphasised, the processes of its commercialisation are misconstrued and researchers’ physical-resource needs are not seriously considered, universities risk being unfairly perceived as underachieving in their value-creation task. As
an antidote to wishful thinking and unreasonable assumptions, we should continue to critically and carefully examine the practice and results of university–industry interaction. This is necessary if we are to improve our evaluation of the potential of such interaction for both obstructing and promoting achievement.
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Correspondence 1989
Floor plans 1988, 1989
Appendix A: Interviews

PET case interviews

1. B. Långström (PET scientist and former Director of the Uppsala PET Centre), 2010-02-05, Uppsala, Sweden
2. B. Långström (PET scientist and former Director of the Uppsala PET Centre), 2011-01-12, Uppsala, Sweden
3. L. Jonsson (CEO of UUAB), 2010-03-30, Uppsala, Sweden
4. B. Sundqvist (former Chancellor of Uppsala University), 2010-11-17, Uppsala, Sweden
5. U. Pettersson (former Vice-Chancellor, Uppsala University), 2010-12-09 (telephone interview)
6. G. Antoni (PET scientist, Uppsala PET Centre), 2010-11-22, Uppsala, Sweden
7. G. Antoni (PET scientist, Uppsala PET Centre), 2010-12-06, Uppsala, Sweden
8. G. Antoni (PET scientist, Uppsala PET Centre), 2011-01-28, Uppsala, Sweden
9. G. Antoni (PET scientist, Uppsala PET Centre), 2011-03-25 (follow-up telephone interview), as well as follow-up questions via e-mail.
10. A. Browning (Project Manager at UUAB), 2010-11-30, Uppsala, Sweden
11. M. Andersson (Senior Legal Advisor, Uppsala University), 2010-12-14, Uppsala, Sweden
12. E. Hemmingsson (former Director of Uppsala University Hospital), 2011-09-02, Uppsala, Sweden
13. M. O. Karlsson (former Deputy Opposition Leader and former Chair of the County Council Executive Committee, Uppsala läns landsting), 2011-02-15, Uppsala, Sweden
14. K. Öberg (Medical doctor, Professor of Endocrine Oncology, Uppsala university hospital), 2011-02-17, Uppsala, Sweden
15. K. Öberg (Medical doctor, Professor of Endocrine Oncology, Uppsala University Hospital), 2013-02-27, as well as follow-up questions via e-mail, Uppsala, Sweden,
16. A. Grundström (former Head of Human Resources and Controller, Uppsala PET Centre pre-commercialisation), 2011-02-19, Uppsala, Sweden
17. B. Skogseid (Medical doctor, Professor of Endocrine Tumor Biology, Uppsala University), 2011-02-22, Uppsala, Sweden
18. B. Skogseid (medical doctor, professor of Endocrine Tumor Biology, Uppsala University), 2013-02-25 (telephone interview)
19. U. Haglund (former Assistant Dean on the Faculty of Medicin, Uppsala University, and former chair person on the PET Centre board pre-commercialisation), 2011-05-06, Uppsala, Sweden
20. M. H:son Holmdahl (former Chancellor of Uppsala University), 2011-05-07, Uppsala
21. G. Beijer (former CEO of Uppsala IMANET), 2011-05-17, Uppsala, Sweden
22. E. Telne (former Assisting Director of Uppsala University Hospital), 2011-05-19, Uppsala, Sweden
23. P. Ehrenheim (former Head of the Separation Division at Amersham and GE Healthcare, former CEO and president of Life Sciences at GE Medical Systems), 2011-08-24, Uppsala, Sweden
24. J. Jeans (former manager at Amersham and GE Healthcare Life Sciences, former Deputy Chief Executive of the Medical Research Council), 2011-11-10, London, UK
25. L. Thurfjell (former Director Diagnostic Software at GE Healthcare, former Managing Director at Uppsala IMANET), 2011-11-15, Uppsala, Sweden
26. C. Archer (R&D positions at Amersham and GE Healthcare, former head of Hammersmith IMANET), 2011-12-05, London, UK, as well as follow-up questions via e-mail.
27. G. Lee (former Business Developer at Amersham ) 2011-12-05, London, UK
28. S. Peake (former Vice President of IMANET) 2011-12-07, London, UK
29. B. Clarke (former Head of Amersham Health R&D) 2012-06-08, Milwaukee, USA
30. R. Dannals (Professor of Radiology and Radiological Science) 2012-06-11, Baltimore, USA
31. S. Luthra (Head of Chemistry and Radiopharmaceuticals for GE Healthcare), 2012-10-18, London, UK

UU Innovation/ UUAB interviews
32. L. Jonsson (CEO at UUAB), 2009-09-30, Uppsala
33. M. Santurio (former Project Manager at UU Innovation), 2009-10-05,
34. M. Santurio (former Project Manager at UU Innovation), 2009-10-13, Uppsala
35. L. Jonsson, L-E. Larsson (Senior Advisor at UUAB), meeting 2009-10-13, Uppsala
Pre-studies

Solibro case
38. M. Edoff (Professor in Solid State Electronics, spec. solar cells) 2010-03-01, Uppsala

“Algae battery” case
39. A. Mihryan (Associate Professor within Nanotechnology and Functional Materials), 2010-02-19, Uppsala

Bioarctic case
40. L. Lannfelt (Medical doctor, Professor of Geriatrics, co-founder of Bioarctic), 2010-03-17, Uppsala
41. L. Lannfelt (Medical doctor, Professor of Geriatrics, co-founder of Bioarctic), 2010-03-24, Stockholm

Rolling Optics case
42. F. Nikolajeff (Associate Professor within micro systems technology), 2010-02-08, Uppsala
43. A. Lundvall (Material Scientist Researcher, Uppsala University and Co-founder Rolling Optics), 2010-02-17, Stockholm

ÅMA case
44. A. Olsson (Project Manager Ångström Materials Academy), 2009-11-02, Uppsala
45. A. Olsson (Project Manager Ångström Materials Academy), 2010-12-11, Uppsala
46. Ångström Materials Academy AIMday observation
Appendix B: Interview guides for each interlocutor category

Interview guide

PET Centre
What is you background within PET science?
How long have you worked at the PET Centre, and what is/was your role?
Did your way of working change as a result of the commercialisation of the PET Centre, and if so, how?
Did your way of working change as a result of the return of the Centre to public ownership, and if so, how?
What kind of interactions has the PET Centre had with other organisations over the years (within business, healthcare etc.)?
If you did research, was your research affected by the commercialisation and subsequent de-commercialisation of the PET Centre, and if so, how?

University
When and why did thoughts about starting a PET Centre begin to evolve?
Who were involved in the decision to establish the Uppsala PET Centre, and what were the discussions you/they had regarding the founding of the Centre?
What was the financial situation of the PET Centre like?
How did the idea of commercialisation come about?
Who were involved in the decision to commercialise, and what were the discussions you/they had regarding the commercialisation of the Centre?

Uppsala University Hospital
When did you start utilising the capabilities at the PET Centre, and how have you utilized these capabilities over the years?
Who have you worked with at the PET Centre, and what did your interaction look like?
Did your way of working within clinical practice/clinical research change as a result of the commercialisation of the PET Centre, and if so, how?
Did your way of working within clinical practice/clinical research change as a result of the return of the Centre to public ownership, and if so, how?

Business
What were Amersham’s reasons for purchasing the Uppsala PET Centre?
What was your role within IMANET, and what was/is your connection to PET science?
Who did you work with in IMANET, and what did your interaction look like?
What were the biggest challenges within IMANET, and how did you respond to them?
What was the atmosphere at the PET Centre like in your opinion?
Did you continue working for GE after you left IMANET/after IMANET’s dissolution, and if so, did you continue your interactions with the Uppsala PET Centre? If so, what were these interactions?

Sample questions posed to specific interlocutors

PET Centre
Were there conflicts within the Centre, for example between management and staff (before and after the commercialisation), and if so, what was the nature of these conflicts?
What was particularly challenging in your work at the Centre in terms of for instance economic considerations or interaction within the organization?
Can you give examples of different collaborations you had with the pharmaceutical industry?
Under what circumstances can you publish results obtained within a contract research study?
What is the procedure for a contract research study in terms of preparations, discussion and execution of project etc.?

University
What were your initial thoughts on founding a PET centre at the University?
Which were the points most difficult to agree on in the negotiations concerning the commercialisation of the Centre, and later, in the negotiations concerning the de-commercialisation of the Centre?
What was the reasoning behind the particular funding structure of the PET Centre?
Was there scepticism in relation to the PET Centre expressed during the years the University owned the Centre, and if so, what were the reasons for this scepticism?

Uppsala University Hospital
What was it like to discuss e.g. pricing of services with Amersham and GE Healthcare?
What were the most difficult questions to reach agreement on in the discussions on pricing with Amersham and GE Healthcare?
Can did you describe the steps involved when you wanted to make use of PET in your work as a doctor and as a clinical researcher?
When the hospital had its own PET scanner, what, if any, were the dependencies of the hospital on the PET Centre?

Business
How did you experience the negotiations between Amersham, Uppsala University and the county council?
What was Amersham’s/GE Healthcare’s strategy in regard to Uppsala PET Centre and IMANET? Did this strategy change, and if so, how?
What was the reasoning behind Amersham’s/GE Healthcare’s strategy?
Why did GE Healthcare decide to purchase Amersham?
What was the business plan for Uppsala PET Centre?
Did GE Healthcare give you any directions as to how to manage Uppsala IMANET, and if so, what were they?


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