

**THE UTILITY OF UNIVERSITY-INDUSTRY PARTNERSHIPS:
A CASE STUDY OF THE UNIVERSITY OF CAPE TOWN (UCT) AND SASOL**

BY

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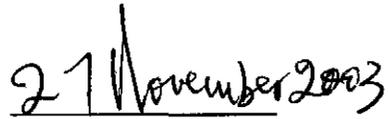
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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it any university for a degree.


Signature


Date

ABSTRACT

In South Africa few systematic studies have been done on university-industry partnerships. This research investigated the evolution of the University of Cape Town (UCT) and SASOL partnership involving heterogeneous catalysis. As part of this investigation, I analysed the driving force and sought to determine the motivations and benefits that UCT and SASOL have since accrued as a result of their partnership. I also analysed knowledge transmission or technology transfer processes such as the hiring of graduates, intellectual property etc. In light of all of these I sought to draw lessons that could be learnt from UCT-SASOL partnership for future purpose.

I followed four themes or sections in order to situate the study. These were, (a) the socio-economic context (global and knowledge economy, innovation, knowledge society etc.), the changing modes of knowledge production ("Mode 2") and the changing ways of interactions among stakeholders-industry, university and government (Triple Helix). The key argument here is that the university-industry partnership cannot be seen as an independent development, but is interrelated or partly the consequence of changes in the socio-economic, science, technology and higher education fields. (b) The driving force behind the partnership, (c) motivations, benefits, and (d) knowledge or technology transfer/transmission processes.

I used the case study research design. I conducted interviews with the UCT Chemical Engineering Department, UCT Centre for Research and Innovation and SASOL officials. I collected several documents related to the study and also visited the laboratories in which UCT-SASOL partnership research activities were happening.

Some of the findings of the study include the following. The partnership demonstrates the significant role of an individual academic, who steered transformation in terms of research activities and culture in the Chemical Engineering Department. The legacy of the individual academic's strong personality and commitment to research is evident and continues to stimulate high levels of research interest and teamwork among staff members which is characteristic of this department. A strong link is maintained between the basic disciplinary "Mode 1" teaching and research on the one hand and the multi-disciplinary "Mode 2" applied and strategic research and training on the other: This is evident in the strong emphasis on the solid undergraduate disciplinary education as a basis for a high quality multidisciplinary postgraduate education. All staff members are involved in both teaching and research. A strong link is maintained between academic, research and postgraduate activities: The department utilizes surpluses generated through industrial-oriented research to cross-subsidize the academic and postgraduate activities.

OPSOMMING

Daar is weinig sistemiese studies in Suid-Afrika reeds uitgevoer oor universiteit-industrie samewerking. Hierdie studie ondersoek die ontwikkeling van 'n vennootskap tussen die Universiteit van Kaapstad (UK) en SASOL wat heterogene katalise insluit. Ek analiseer in hierdie studie die dryfkrag van die vennootskap, en probeer die motivering en voordele bepaal wat beide die UK en SASOL toegekome het as deel van hulle vennootskap. Ek analiseer ook die oordrag van kennis of oordrag van tegnologiese prosesse soos die aanstelling van graduandi, intellektuele eiendom, ens. Ek probeer op grond hiervan lesse van die UK-SASOL vennootskap uitlig vir toekomstige doeleindes.

Ek het vier temas of afdelings gebruik om hierdie studie te vestig. Dit is, (a) die sosio-ekonomiese konteks (globale en kennis ekonomie, innovasie, kennis samelewing ens.), die veranderende modus van kennis produksie ("Modus 2") en die veranderende wyses van interaksie tussen belanghebbendes - industrie, universiteit en regering (Triple Helix). Die sleutel argument hier is dat die universiteit-industrie vennootskap nie gesien kan word as 'n onafhanklike ontwikkeling, maar dat dit verband hou met of deel is van die gevolge van die veranderinge in die sosio-ekonomiese, wetenskap, tegnologie en hoër onderwys arenas; (b) die dryfkrag agter die vennootskap; (c) motivering en voordele; en (d) die oordrag van kennis of tegnologie/oordrag van prosesse.

Ek gebruik die gevallestudie metodologie in hierdie studie. Ek het onderhoude gevoer met die UK Chemiese Ingenieurswese Departement, die UK Sentrum vir Navorsing en Innovasie, as ook die SASOL betrokkenes. Ek het die projekdokumentasie versamel en het ook die laboratoriums besoek waarin die navorsingsaktiwiteite van die UK-SASOL vennootskap plaas vind.

Die bevindinge van hierdie sluit dus die volgende in. Die vennootskap demonstreer die belangrike rol van 'n individuele akademikus wat transformasie bewerkstellig het in terme van navorsingsaktiwiteite en die kultuur in die Chemiese Ingenieurswese Departement. Die nalatenskap van die individuele akademikus se sterk persoonlikheid en toewyding tot navorsing is duidelik en stimuleer steeds hoë vlakke van belangstelling in die navorsing en spanwerk in die departement. Dit is ook een van die kenmerke van hierdie departement. Daar is 'n sterk skakel gehandhaaf tussen die basiese dissiplinêre "Modus 1" onderrig en navorsing aan die een kant, en die multidissiplinêre "Modus 2" toegepaste en strategiese navorsing en onderrig aan die ander kant. Dit is duidelik in die sterk kleim wat gelê word op die stewige voorgraadse dissiplinêre onderrig as 'n basis vir 'n hoë kwaliteit multidissiplinêre nagraadse onderrig. Alle personeel is betrokke by beide onderrig en navorsing. 'n Sterk skakel is behou tussen akademiese, navorsings- en nagraadse aktiwiteite: die departement gebruik die oorskotte van industrieverwante navorsing om akademiese en nagraadse aktiwiteite te kruis-subsideer.

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1. INTRODUCTION AND BACKGROUND

1.1. Introduction

This study investigated the evolution of the University of Cape Town (UCT) Department of Chemical Engineering or Catalysis Unit and SASOL partnership involving heterogeneous catalysis (chemical reaction process in which both the reactants and the products are in a different phase to the catalyst.) As part of the investigation I focused on how the partnership started, changed, and how the general patterns of the partnership emerged (such as funding, research types and projects etc). I analysed the driving force/s behind the partnership. I sought to determine both the motivations and benefits that could be accrued to both UCT and SASOL as a result of the partnership. Finally, I sought to determine lessons that could be learned from the UCT-SASOL partnership for the future establishment of long-term formal partnerships.

I was alerted to the UCT-SASOL partnership during the initial rounds of interviews with Deans of research of almost all South African higher education institutions, as part of the South Africa-Netherlands Programme Alternatives in Development (SANPAD) project, a joint venture between the University of the Western Cape Education Policy Unit (EPU), the University of Stellenbosch Centre for Interdisciplinary Studies (CENIS) and the University of Twente, Netherlands. This project was aimed at enhancing the contribution of higher education to South Africa's dual national development goals, which are to increase the nation's global competitiveness and to meet the basic needs of the majority through reconstruction and development. Throughout the world, higher education is experiencing rapid changes in response to shifting global socio-economic conditions. Whether or not these changes entail a new mode of higher education knowledge production has been the focus of much recent debate (Gibbons et al., 1994 cited in SANPAD proposal, 3). SANPAD can partly be understood as a response or contribution to this debate using empirically based evidence.

Some key features of the UCT-SASOL partnership include the following: It represents what Webster and Etzkowitz (1998:53) termed as a strategic long-term alliance, a pattern of the new institutional forms of collaboration. It has existed for almost twenty-one years involving the same activity (heterogeneous catalysis). Throughout its existence, it has contributed to human resource development, technology development, and infrastructure development. It has also enhanced research culture, capacity and the delivery of research results. Other contributions of the partnership include the diversification of funding, and technology transfer/ interchange. In 1996 the five-year joint Fischer-Tropsch Synthesis Project was established as one of the key outcomes of the long-standing partnership. It was a new form of partnership involving simultaneous multiple sites of research activity at the university and in the industry, and different from others in that both organisations (UCT and SASOL) collectively shared the responsibility of managing the project and were equally represented in all decision-making processes. It reflected mutual relations of trust

between management authorities and academic and industry researchers. The latter had the autonomy to run and control the direction of the research without the interference of the authorities.

The partnership demonstrates the significant role of an individual academic, who steered transformation in terms of research activities and culture in the Chemical Engineering Department. The legacy of the individual academic's strong personality and commitment to research is evident and continues to stimulate high levels of research interest and teamwork among staff members which is characteristic of this department. A strong link is maintained between the basic disciplinary "Mode 1" teaching and research on the one hand and the multi-disciplinary "Mode 2" applied and strategic research and training on the other: This is evident in the strong emphasis on the solid undergraduate disciplinary education as a basis for a high quality multidisciplinary postgraduate education. All staff members are involved in both teaching and research. A strong link is maintained between academic, research and postgraduate activities: The department utilizes surpluses generated through industrial-oriented research to cross-subsidize the academic and postgraduate activities.

1.2. Research Aims

The overall aim of the study was to investigate the evolution of the UCT-SASOL partnership in the field of heterogeneous catalysis over the past twenty-one years. In addition the study sought to:

- (a) To analyse the "drivers" or driving force behind the UCT-SASOL partnership.
- (b) To determine the UCT and SASOL perceptions about the educational, epistemological, political, strategic, financial and technological motivations and benefits that have been accrued to the partnership.
- (c) To investigate the technology/knowledge and transfer/transmission processes (including intellectual property, publications, and the training of graduates etc.)
- (d) In light of this, to determine the lessons that could be learnt from this UCT-SASOL partnership for future purposes.

1.3. Background and Rationale

Throughout the world, university-industry partnerships have become prominent on the agenda of higher education and science and technology policy making at national and institutional levels. These partnerships are increasingly being viewed as a key driver of innovation, and an integral component of national economies if they are to be globally competitive. In this regard, governments are increasingly acknowledging the importance of higher education institutions as strategic actors in national and regional economic development. Higher education institutions could potentially upgrade skills and knowledge of the labour force. They could contribute to the innovation process and products through technology transfer. As a result of financial stringency, higher education institutions themselves have become very keen on developing relations with industry and business internationally and also locally as reflected in national and institutional documents (Hernes and Martin, 2001: 9;

Martin, 2000a: 13; White Paper on Science and Technology, 1996; see also 2001 UCT Vice-Chancellor's vision).

On the one hand, higher education institutions consider their partnership with industry as a strategy to improve the relevance of their teaching and research activities and also to address resource constraint due to decline in government subsidies. On the other hand, industry is being challenged to adapt and change its research approach. Gibbons et al. (1994:86-87) argue that research in industry, even if conditions are better than in many university laboratories, is always problematic because it has to keep its objectives in harmony with the company's overall strategy. A commitment to basic research is particularly difficult to sustain. It is constrained by time limits and subject to frequent, rigorous evaluations in the light of shifting company fortunes. As research becomes more expensive, and is subjected to strategic and financial considerations its base tends to narrow. As a consequence, to remain competitive industry increasingly needs access to knowledge generated elsewhere. One avenue is to join with other firms in pre-competitiveness research. Such collaborations are still infrequent. For many reasons, the universities remain the preferred option. However, a number of prerequisites have to be met. Geographical proximity is important; it facilitates information exchanges and informal contacts necessary before any, closer, cooperation can be initiated. Close contacts and trust have to be maintained during the entire period of collaboration. Where this is done on a long-term and systematic basis, collaboration has a greater chance of success. The need for mutual accommodation is particularly clear in technology transfer.

In addition, Martin (2000b: 12 citing C. Blackman and N. Segal. 1993: 938; see also Eva María Mora Valentín (2000: 166) identified certain benefits (to universities) that are perceived from stronger collaboration with enterprises, both in developed and developing countries. These That is, (a) opportunity to attract additional funds for initial teaching and research, increasing financial autonomy of higher education institutions, especially if governmental core funding is tightly linked to specific academic purposes. (b) Co-operative research with enterprises pulling in more public funds if there are governmental project funds for collaborative research or teaching programmes. (c) Acquisition of or access to up-to-date date equipment. (d) Opportunities for staff and students to become familiar with state-of-the art industrial science and technology and management systems plus the enhancement of their familiarity with the constraints of industry. (e) Improved interaction of higher education departments and employers for the development and adaptation of technology oriented degree programmes. (f) Improved training and employment prospects for students. (g) Supplemental income from consulting, allowing academic staff to improve their salaries. (h) Enhancement of the higher education institution's image as a contributor to the economy.

Some developed countries have achieved a long-standing tradition of collaboration between universities and industry, such as North American countries for example. However, in most other OECD countries, such relations have been developed and have intensified particularly during the past

decade. Higher education institutions in the developing world are now very much encouraged by their governments to develop strategies in this domain (Martin, 2000b: 11). This is clearly reflected in South Africa's Science and Technology, Trade and Industry, Labour and Higher Education policies.

The review of international literature suggests that the study of university-industry partnership is well developed. Some studies⁰ demonstrate that it is possible for long-term formal partnerships to succeed, despite obstacles, are mostly discussed in chapter 2 and 4. However, the review of local literature indicates that the research area is underdeveloped and in fact very few systematic studies have been done in South Africa. In this regard, one is reminded of the works of Van der Walt and Kaplan (1996) "Industry-academic-government cooperation in technological innovation and human resource development", *Industry and Higher Education* 10 (6) pp. 394-401; Carstens and Mouton (2002). "Industry-Higher Education Partnerships", a literature review: CENIS and Kraak (2001) "Investigating the Network Society: Industry-Higher Education partnerships in South Africa", a research proposal: Human Science Research Council (HSRC), Pretoria and the current HSRC project entitled "Investigating the Network Society: Industry-Higher Education partnerships in South Africa". It is at this broad level that this case study sought to contribute to the development of the university-industry partnership study.

On the one hand, it could potentially enhance the understanding of university-industry partnerships, which is underdeveloped in South Africa. On the other hand, at both local and international levels, it represents a successful and complex example of the long-term strategic partnership, which remains in the same area or activity (heterogeneous catalysis). What is important is that the UCT-SASOL partnership is not merely a long-term partnership as commonly known, but reflects the recent emergence of new distinctive forms of partnership clearly evident in the 1996 five-year joint Fischer-Tropsch Synthesis project. In this project both university and industry researchers collectively ran and controlled the research process.

In addition, this long-standing UCT-SASOL partnership is in the engineering field, and not in one of the fields identified by Webster and Etkowitz (1998:53). They argue that the growth in long-term academic industrial strategic alliances has been primarily in the bioscience/biomedicine and pharmacology fields. These alliances reflect a growing corporate strategy to fund centres of academic expertise. Such coalitions normally are based on a coincidence/ converging of interests or mutual affinity between the scientific concerns of the company and the university. They are typically wide-ranging and, compared with corporate in-house R&D, unfocussed, often involving the funding of a whole new (embryonic) field of research or an entire academic department. These coalitions are established with the aim of drawing on the discovery skills and expertise of academics in the new era, which remain undeveloped within the company, as much of the first of these collaborations, the Hoechst/Massachusetts General Hospital (molecular biology) deal, exemplifies. In many cases it is cheaper and quicker to achieve the company's goals by funding academics, whose ideas feed the

firm's in-house product development concepts. This kind of funding is high risk but can yield beneficial results.

In addition, there are specific contributions that this study sought to make. Webster and Etzkowitz (1998: 51) argue to date that throughout the world there have been no systematic studies of the emergent new institutional forms of institutional collaboration, especially the long-term strategic partnerships. Yet the growth in strategic long-term alliances has a number of both methodological and theoretical implications for research. It is vital that research focuses on the structure of the collaboration itself as an inter-organizational form, a structure that raises a number of general issues independently of the fact that it combines industry and academia. This signifies that there is some value to be gained in treating the linkage between the two sectors as a combination that is worth exploring. This was evident in the analysis of the 1996 Fischer-Tropsch Synthesis project.

Borys and Jemison (1989 cited in Webster and Etzkowitz, 1998: 51) have provided an analysis of inter-corporate alliance that raises a number of points that are applicable to any collaborative structure. They argue that analysis should among other things seek: Firstly, to determine the relationships of authority and trust between the participating organizations. Secondly, to determine which parts of the organizations are to be linked together. Thirdly, to determine whether or not and, if so, how stability mechanisms operate in order to sustain the institutional relationship over time. Fourthly, to determine how the process of value creation is measured and achieved within the collaborative venture. There has unfortunately been little or no attempt by sociologists or science policy analysts to explore these dimensions of trans-institutional structures. These points may even apply to internal organizational restructuring as a result of commercialization/commercialisation of academia in as much as it requires the repositioning of what were once peripheral activities into a more central role. This study explored the first and second dimensions again through the 1996 Fischer-Tropsch Synthesis project.

Another area that this study sought to contribute to is what Webster and Etzkowitz (1998: 61) identified as the need for the analysis of the emergence of new forms of institutional collaboration, if it were deemed important to respond to the deeper theoretical and methodological issues related to the study of university-industry partnerships. Coupling this, are some generic institutional questions that cut across specific forms of linkage that needed addressing. These relate to the three ways in which commercialisation: (a) tends to steer scientists toward setting research agendas that are not merely applied but also overly accommodating to the commercial interests of their sponsors; (b) generates forms of normative conflict; and finally, (c) creates acute and/ or chronic periods of institutional instability and volatility. In particular, this study analysed the issue of research agendas as manifested in the 1996 Fischer-Tropsch Synthesis project.

1.4. Research Design and Methodology

This section is not meant to provide thorough details of research design and methodology, which is done in Chapter Three. Rather it provides very brief and general information on the research design and methodology followed. The research employed the case study design approach. According to Yin (1994:3) case studies are distinctively needed to understand complex social phenomena. In this respect the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events such as individual life cycles, organizational and managerial processes, and neighbourhood/ environmental change.

I first raised the issue of using the Catalysis Unit as a case study during a SANPAD project in 2001. At the time there was no firm research proposal but I knew what I wanted to do. When the proposal was ready I sent it to Dr. Fletcher in May 2002. Subsequently, a meeting took place between Dr. Fletcher and myself in which we discussed the proposal in detail. Dr. Fletcher indicated that he would forward his response in few days time, which duly happened. He sent me an email through his secretary indicating that he accepted my request, by so doing granting me access and permission, which entailed conditions. These conditions related to the sensitive and confidential aspects of the agreement between UCT and SASOL. Basically I was only allowed to access research data that is not considered sensitive or which could lead to commercial prejudices to SASOL. This mainly related to the 1996 Fischer-Tropsch Synthesis project.

Dr. Fletcher also agreed to facilitate my access to SASOL and the university research and innovation office. Subsequently I was able to conduct interviews with respective officials. He also agreed that I could use data that was gathered through previous meetings with him in 2001.

I conducted three interviews with Dr. Fletcher and one interview with Mr. Gibson of SASOL and Mr. Barnard of UCT Centre for Research and Innovation. All these interviews were recorded and transcribed. I further made several calls and sent several e-mails verifying some data or filling the gaps. I also collected various documents related to the case study and visited laboratories in which some of UCT-SASOL projects were being conducted. I employed a thematic approach to make sense of data, create categories and eventually locating data within the broader objectives of the study.

1.5. Structure of the Report

This study consists of five chapters.

Chapter 1 gives the overall background and rationale of the study. This includes the research aims, design and structure of the report.

Chapter 2 presents the literature review. This involves examining both the past and current developments in the university-industry partnership field that are available in local and international literature. The review is organised in terms of four themes related to the objectives of the study.

Chapter 3 discusses research design and methodology. This highlights the case study design, the case study content, and sample coverage. Thereafter the information is presented regarding the focus of the interviews, the main issues we probed and the supplementary documentary sources we used. This is followed by a brief description of the scope of the interviews and of the sampling frame. We also describe the research site for the case study, and provide an outline of the documentary sources we examined. This Chapter also contains a brief description of the data analysis techniques and the path followed to integrate the diverse responses. Lastly, I mention the methodological difficulties encountered in the conduct of the case study or limitations.

Chapter 4 presents and discusses the research findings.

Chapter 5 draws together the main points from the discussions in the previous chapters and relates them to the questions I investigated. Principally, I summarize the results and advance the recommendations. *Finally*, Appendices 1 and 2 provide information on the request for access and interview instruments.

2. CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This research investigated the evolution of the UCT-SASOL partnership with its driving force, motivations, benefits, and technology/knowledge transmission processes. Considering these objectives, this review surveys both local and international literature on university-industry partnership. Rather than being comprehensive, topics are selectively reviewed to provide a cross-section of inputs from the literature on university-industry partnerships, innovation, globalisation and sociology of science/ knowledge.

In line with the objectives of the study, the review is basically organised according to four broad themes (or sections). The first section seeks to situate university-industry partnership within the socio-economic context (global and knowledge economy, innovation, knowledge society etc.), the changing modes of knowledge production ("Mode 2") and the changing ways of interactions among stakeholders-industry, university and government (Triple Helix). The key argument here is that the university-industry partnership cannot be seen as an independent development, but is interrelated or partly the consequence of changes in the socio-economic, science, technology and higher education fields. With this in mind, the second and third sections become of great importance in analysing and understanding on the one hand, the "drivers" or driving force behind the university-industry partnership, and on the other hand the motivations, benefits and obstacles towards the formation of university-industry partnerships. Finally, I analyse issues such as hiring of graduates, university patent offices, technology transfer, intellectual property, conflict of interest, and other issues under the knowledge and technology transfer /transmission processes theme.

2.2. The socio-economic context of the university-industry partnership

2.2.1. University-industry partnership and global economy

Over the past two decades it has become a common theme in industrial policy to create science-based industries from academic research, as it was made explicit in France and Mexico and left implicit as in the case of the United States. For Etzkowitz, Webster and Healey (1998:2) such policies are constructed on the basis of a new relationship between universities and industry, involving transfer of technology as well as access to trained personnel. The perception that university-based science and technology is of use to industry has led to changes in the rules governing how universities and companies interact with each other, shifting the relationship from an eleemosynary to a business basis.

Etzkowitz, Webster and Healey (1998: 3) argue that the decline of traditional industries and the struggle to revive or replace them has politicised scientific and technological spheres, heretofore viewed as non-economic, self-organised, and best left unregulated. As a result economic development was added to the research university mission as well as the responsibility for education and training. This led to a serious concern being raised regarding the negative effect of economic issues on the conduct of research. As Etzkowitz, Webster and Healey (1998:3) argue the transfer of knowledge to industry was theoretically freely available through the literature. However in practice industry needed relationships with academic scientists to translate this knowledge into a useable form. This is one of the driving forces behind the normative change in academic science, although the relationships were initially formulated to insulate academic pressures.

It is important to mention that scientists have a long history working with industry, having made contributions towards the establishment of the early industrial research laboratories in various countries. University-industry partnerships have until recently separated academic and commercial practices, to the extent that previously limits were placed on how much time an academic could devote to outside concerns. Etzkowitz, Webster and Healey (1998:3) suggest that in the United States, the "one-fifth rule" allowing one day per week became commonplace (similar to South African universities). Even as ongoing-relationships, consulting arrangements were usually conducted apart from campus based research centres. Consulting-relationships typically involved brief visits to industrial sites or the conduct of discrete projects on university premises. The key consequence of this separation was that it left control of commercial opportunities of academic research in the hands of industry whereas control over the direction of research and choice of research topics was left to academic scientists.

University-industry partnerships have emerged as a central theme of economic renewal through various governments' initiatives. They have also emerged due to changes within universities and companies associated with the emergence of an innovation system based on lateral ties (Etzkowitz, Webster and Healey (1998:5). For Etzkowitz, Webster and Healey (1998:7) contemporary innovation is a precarious business. This is not simply because of transitional difficulties associated with the creation of a new innovation cycle. Rather, innovation, in the context of late modernity, is intrinsically more difficult to control, to be sure of, and to anticipate than in the past. This situation is likely to prevail. In the fields of science and technology, the more powerful our knowledge, the more difficult it is to control or decide what direction to take, and even more so to agree upon the most appropriate criteria to evaluate and regulate it. This pressure to differentiate and specialise is met by a strong desire to reintegrate our understanding according to new intellectual and professional boundaries. So one of the dynamics of society today is that boundaries are continually being eroded and renegotiated.

Most critically, new knowledge grows at such a pace that skills and the boundaries they define rapidly date, while there is a simultaneous tendency toward what has been called innovation overload. Accordingly, there is a continual pressure to audit and evaluate our knowledge base, to filter critical from non-critical technologies (Branscomb, 1993 cited in Etzkowitz, Webster and Healey, 1998:7), and to protect at institutional and national levels the intellectual and material capital on which future innovation depends (Etzkowitz, Webster and Healey, 1998:7). Further, as the intellectual boundaries within the knowledge base, between the sciences for example, become more permeable, traditional professional and sectional divisions (within industry) also begin to break down. A new division of labour has emerged, a more complex system of users and producers of knowledge and information, which has enabled a merged and a more complex system of users and producers of knowledge and information. This in turn has enabled the growth of new types of trans- or inter-organisational structures. Indeed, networking, cross-institutional linkage, informal and formal collaboration are all not merely possible but absolutely necessary if public and private agencies and individuals are to cope with the increasing differentiation and complexity of today's innovation system. Companies, for example, coping with the demands of the globalisation of production have sought to increase their involvement in strategic partnering at national and international levels.

According to Sheen (1998: 187) the importance of innovation as a stimulus to economic growth and wealth creation is now accepted. Within the complex and diverse process of innovation, technology and scientific knowledge are often key factors. Therefore institutions of higher education are now encouraged to engage more actively with industry. Consequently some of the money spent in public-sector research may have to demonstrate a more direct impact on wealth generation. Along with these changes there is a desire on the part of government for greater accountability of how public funds are being used. Public funding of research is increasingly being made dependent upon partnering with industry. Over the last few years, industry also has experienced major changes through a process of downsizing and restructuring. While this supposedly, has left firms "leaner and fitter", corporate restructuring has disproportionately reduced the size of the research function. The reduction of R&D capacity in many firms has led to more contracting out of research projects (see Gibbons et al. 1994).

Within the global economy, innovation is driven by the interaction of producers and users in the exchange of knowledge. Various governments remain increasingly concerned with developing and strengthening the national knowledge and economic base (OECD, 1996: 7 and Lindsey, 1985:90 cited in Carstens and Mouton: 2002: 6). This culminates in the redefinition of the relationship between government, education, industry and communities. Government has increasingly become a powerful partner with a range of other institutions, bodies and agencies in the process of governing (Van der Walt and Kaplan 1996: 396). Within this context, each partner - be it industry, higher education, or government - is no longer operating in a hierarchical system with strictly predefined roles for each. The direct involvement of government leads to the establishment of an expanded network system of

interactive roles and functions. This happens as government, industry, and higher education engage collaboratively to promote economic development, productivity and innovation (Leydesdorff & Etzkowitz 2001: 1-3, 6; Bozeman 2000: 632-3; Etzkowitz & Leydesdorff 2000: 109-10 cited in Carstens and Mouton: 2002: 7; see also Martin 2000b: 29).

According to Van der Walt and Kaplan (1996: 396), this shift, of government from the centre, to government becoming a powerful partner, is a shift from government to governance, a process of redefining and reconfiguring the state. Linked to this is an increased awareness of the importance of decentralized and regional delivery and accountability. This new role of government in the promotion of innovation is of particular relevance to the South African technological innovation programmes.

Etzkowitz and Webster (1998:35-6) argue that the US government has shown a definite interest in generating closer interaction between industry and higher education. While it has pursued this objective by putting in place appropriate intellectual property policies and free trade agreements, its efforts have focused primarily on funding policies (Bozeman, 2000: 632; Etzkowitz & Leydesdorff, 2000: 113-4). Government has increased its selectivity in the choice and direction of R&D in response to both perceived needs and opportunities for technological innovation. This has meant a growth in strategic research as well as in the expansion of mechanisms whereby the technologies it generates can be transferred to industry. Government has also encouraged industry-higher education relationships through trying to match public sector funds with industrial expenditure on R&D. Through this redirection of both existing and new funds, the government hopes that commercial sponsorship of academic R&D will grow steadily.

Armed with the knowledge that innovation is the key driver of economic growth, competitiveness and job creation and that the ability to generate and exploit knowledge resides in people, industry cannot afford to be a passive onlooker as far as the provision of the central factor of production, its workforce, is concerned. Enhanced competition requires significantly intensified involvement of the business community in research and education, in order to contribute to the expansion and simultaneous rationalization of the educational sector's intellectual infrastructure and financial resource base. This entails an increase in the magnitude and number of formal partnerships between private enterprises, higher education institutions and research councils. It should contribute to redirecting education and research, and to improving flexibility of the higher education sector to serve short and longer-term market needs (Van der Walt and Kaplan, 1996: 397).

University-industry partnerships could enable higher education to maintain cutting-edge innovation and knowledge production and to remain as a quality and competitive contributor to welfare enhancement through the production of people for the market place. Accordingly, Van der Walt and Kaplan (1996: 397) argue that higher education research should increasingly become market-oriented (note that this statement does not suggest a shift from longer term to short-term research, but rather

suggests an enhancement of the quality of research through exposure to competitive market forces). They also argue, knowing that most innovation takes place on the interfaces of disciplines, that modern research activity requires a trans- and multidisciplinary approach, as well as inter- and transinstitutional cooperation. This may include reorganizing disciplines and faculties within institutions into programmes and schools, rather than departments and faculties. Very substantive educational reform is thus required, since science and technical education, as traditionally given, are seen to be inadequate for the knowledge intensive economy.

According to Van der Walt and Kaplan (1996: 395; see also Kraak, 1994:17 and the White paper on Science and Technology 1996), in the past South African higher education institutions have interfaced poorly with the private sector and science councils, most of which are quasi-state organizations. In 1993 only 7.1% of R&D conducted by higher education institutions was funded by the private sector. In addition, it was found that the innovative activities of many local firms, particularly smaller enterprises, are not linked to the science councils. The demands of economic growth, especially the rapid pace of technological change, dictate that far closer collaboration is required in the form of relationships between higher education, science councils, private sector and government. This is especially important because the past divisions between pure research, applied research and application/ commercialisation have not sustained optimal levels of innovation and technological advance. For Kraak, if South Africa wishes to progress developmentally, then university-industry partnerships are a priority.

The higher education sector is essentially only a recipient of funds for R & D, with which it is required to provide talented human resources, meet local needs for knowledge generation related to scientific progress, create and sustain centres of excellence in the social and physical sciences and engineering, and participate in consortia and other joint research programmes. With some notable exceptions, the HES is poorly connected to the business sector and the government SETIs (White Paper on Science and Technology (1996))

New and relevant knowledge has become central to the role of higher education in contemporary society within the context of the ever changing global economy, innovation and the rise of the new information technologies. Despite the challenges of understanding and characterizing the complex dynamics inherent in the process of globalisation, it is unequivocally clear that the social organisation of knowledge and learning is dramatically changing. Within the economy, polity and culture, knowledge has salience as the central form of productive capital (Castells, 1996, 1998 and Carnoy, 1998 cited in Subotzky and Cele, 2002: 1). As a result a new relationship between higher education and society has emerged.

According to Subotzky and Cele (2002:6) higher education institutions have increasingly been urged to be 'responsive' and 'accountable' to the needs of society in terms of their contribution, as highly

(publicly and privately) subsidised institutions, to economic and social development. This has taken the form of the increased 'marketisation' and 'entrepreneurialisation' of higher education and the establishment of new partnerships with industry in generating needed knowledge to solve technological, and to a lesser extent, social problems and the public good (Slaughter and Leslie, 1997; Tierney, 1997; see Subotzky, 1999 in relation to the last point). Indeed, the emergence of the so-called 'entrepreneurial' university (see Clark, 1998 for the definitive dominant account of this) has become something of a universal benchmark for innovative institutions. There are also new demands for knowledge production and graduate training that are appropriate to the new knowledge society.

2.2.2. New Modes of Knowledge Production-'Mode 2 or the Gibbons thesis

2.2.2.1. Background and context of the Gibbons thesis

The seminal, influential and controversial analysis of Gibbons et al. (1994) and much less of its 2001 sequel, Nowotny et al, introduced a phrase of "New Modes of knowledge Production", or Mode 2 or Gibbons thesis, which according to Gibbons is a new distinct set of cognitive and social practices (2000: 40). It has also strongly influenced South African higher education and science and technology policies. Basically the Gibbons thesis argues that the current mode of knowledge production ("Mode 1") is undergoing dramatic changes across the research spectrum in terms of how western industrialized countries produce, organize and disseminate knowledge. These changes have implications for how national science systems and universities are managed, not only in the west, but also globally (Ravjee, 2001:1).

Gibbons (2000: 41) argues that the reasons for the emergence of Mode 2 are not 'hard' to find and are mainly related to: the massification of higher education that was experienced in the last three to four decades; the emergence of global and knowledge economy-competitiveness, innovation, information and communication technologies which facilitate the interactions of new knowledge production sites; the internal dynamics of knowledge production system etc. In his own words:

...Over the years the number of graduates grounded in the ethos of research together with some specialist skill have been too large for them to be absorbed within the disciplinary structure of academic life. Some of them have gone into government laboratories, others into industry, while others have established their own laboratories, think tanks and consultancies. As a result, the number of sites where competent research can be carried out has increased. These individuals and the organisations in which they work constitute the intellectual resources for, and social underpinnings of, Mode 2...-which is critically dependent upon the emerging computer and telecommunication technologies and will favour those who can afford them. The interactions among these sites of knowledge have set the stage for an explosion in the number of interconnections and possible configurations of knowledge and skill. The

outcome can be described as a socially distributed knowledge production system (Gibbons, 2000: 41)

The characteristics of Mode 2 include the following:

- (a) As opposed to traditional disciplinary research, where the research problem originates within orthodox disciplinary boundaries, Mode 2 knowledge production and the definition of the problem to which it is directed, arise in the context of application.
- (b) In Mode 2, knowledge is not linearly produced and then applied to a social problem; it is now increasingly produced through the process of solving the problem directly.
- (c) A defining characteristic of Mode 2 knowledge production is its transdisciplinarity. In its quintessential organisational form, it is undertaken by transient teams of researchers comprising experts of various disciplines. However, the result does not merely create inter- or multi-disciplinary outputs, which can feed back into the store of disciplinary knowledge. In Mode 2, the product is not reducible back to its disciplinary roots. Increasingly also, the organisation of Mode 2 teams are thus frequently trans-institutional, involving higher education institutions and corporations.
- (d) Mode 2 research is increasingly financed from a diverse range of sources, not only from statutory research councils but also by corporate, donor and civic sources.
- (e) The organisation and regulation of Mode 2 knowledge production is often less hierarchical and more collaborative than the traditional academic research team. As a result of the participation of a variety of social actors, Gibbons et al. claim that wider social accountability is inherent in this organisational form of knowledge production (although to the extent that much of Mode 2 knowledge production is market-driven, social accountability is undercut).
- (f) Whereas conventional disciplinary research utilizes peer-review as the criterion of scientific quality, the quality of Mode 2-knowledge production is increasingly assessed in terms of the satisfaction of multiple end-users.

In addition, Gibbons et al. have argued that Mode 2 is a socially distributed knowledge production, which according to Ravjee (2001:1) involves, on the one hand, people, institutions or countries with access to new technology and other resources. On the other hand, it will not change current levels of unequal participation in research i.e. conducting research, deciding on research agendas, funding research, using results. They have also argued that even as Mode 2 knowledge production is more globally dispersed, its economic benefits will be disproportionately reappropriated by rich countries and by those who are able to participate (Gibbons et al., 1994:166 cited in *ibid.*1).

The notion of Mode 2 has become very influential to both South African policy scholars and state policy documents i.e. Commission on Higher Education (NCHE) and the subsequent White Paper on Higher Education (Education White Paper 3, 1997) and the White Paper on Science and Technology 1996. According to Jansen (2000:156) these critical documents make it clear that a new mode of

knowledge is at play, and that higher education planning, programmes and funding should move in the direction of encouraging such innovative ways of producing knowledge. He also contends that in the section on "Research", Education White Paper 3 (DOE, 1997: 31) is explicit:

...The nature of the research enterprise has undergone radical change through: The development of multiple sites of research and knowledge production which are wholly or partially separated from higher education, including industrial laboratories, corporate research units, para-statal, statutory research councils, and NGOs, or through collaboration among these research organisations. The impact of transdisciplinary and transinstitutional research on new forms of communication - the information highway -which have accelerated and widened access to data and research findings (Cited in Jansen, 2000: 157).

The White Paper on Science and Technology (1996) is even bolder in terms of making the case for Mode 2 through its "problem-solving, multi-disciplinary, partnership approach" to innovation as a mechanism of growth and development. It states that:

Traditional ways of producing knowledge within single disciplines and institutions are being supplemented by knowledge generated within various applied contexts. This is knowledge that is collaboratively created within multidisciplinary and transdisciplinary research programmes directed to specific problems identified within social and economic systems. A national system of innovation benefits from "knowledge practitioners" being located in multiple knowledge generating sites and institutions such as higher education institutions, government and civil society research organisations, and private think tanks and laboratories...(1996:9 cited in Jansen, 2000: 157).

It is important to examine specific ways in which Mode 2 can impact both higher education institutions and industry and then engage with Mode 2 in a thorough way.

2.2.2.2. Mode 2 and Higher education

According to Gibbons et al. (1994), Mode 2 is different from both conventional disciplinary as well as applied-research. During the past two decades, Gibbons asserts, "a new economically-oriented paradigm of the function of higher education in society has gradually emerged" (Gibbons, 1998:1). A new more pragmatic and socially oriented functional view of knowledge has emerged, with the high-minded Humboldtian pursuit of knowledge for its own sake, supplanted by the perspective that universities are meant to serve society, primarily by supporting the economy and promoting the quality of life of its citizens. The traditional detached and critical function of universities has been

replaced by the need to provide the changing labour market with the power of qualified people and to produce knowledge relevant to the new informational society.

The organisational foundation of the modern university emerged from the process of the disciplinary specialization and sub-specialization of knowledge. However, as the production of Mode 2-type knowledge has increased, faculties and departments have become organisational and administrative units instead of discipline-based entities. Increasingly, the emerging form of contemporary academic organisation is the programme, research unit or, in its more mobile and quintessentially Mode 2 form, the rapidly assembled and transient research team. In order to produce Mode 2-type knowledge, Gibbons argues, partnerships, interaction and collaboration in knowledge production is vitally important (Subotzky and Cele, 2002: 7).

In the light of these developments, universities which intend to practice research at the forefront of many areas, are going to have to organize themselves ... to become more open, porous institutions, more aggressive in seeking partnerships and alliances, than they are currently (Gibbons 1998: 10). Partnerships, interaction with other knowledge producers and lifelong learning have become the new benchmarks of institutional effectiveness and innovation. This constitutes the new "dynamics of relevance" for higher education institutions.

As a result of these developments, Gibbons argues that research has become more socially distributed. This is the result of the rapid growth in access to higher education, with correspondingly high numbers of trained graduates finding their way into the labour market. With this, the capacity to produce research has been diffused more widely in both the corporate and government sectors. Research capacity is therefore no longer the exclusive preserve of academic institutions. Gibbons drives home the point that universities are now only one knowledge producing agency amongst many in an economic order where knowledge and skill are the principal commodities being traded (Gibbons, 1998:30).

The key point, for Gibbons, is that, to retain their contemporary relevance, higher education institutions will have to develop partnerships with an array of emergent off-campus research sites. New collaborative institutional arrangements are thus emerging, linking government, industry, universities and private consultancy groups in different ways. These partnerships are oriented towards solving a range of increasingly complex technical and social problems in society (Subotzky and Cele, 2002:8).

For Subotzky and Cele (2002: 9) the understanding of complexity is especially relevant in a developing country context. Given the urgency of development priorities, Gibbons' claims that certain 'impatience' towards the detachment of disciplinary science has emerged in the developing country. In contrast, the promise of the new organisation of knowledge production is that, by drawing together experts

into transdisciplinary teams, the capacity to understand complex problems is harnessed. These transdisciplinary groups are being formed to tackle problems, especially in health and medicine, environmental studies and risk analysis. Gibbons highlighted the importance of Mode 2 knowledge in the developing country context in that:

To meet both national and community needs a different organisation of knowledge production than Mode 1 is required ... [involving]: a focus on understanding complex systems, an intellectual orientation towards problem-solving, the use of computer simulation and modelling techniques, [and] the teamed involvement of broad ranges of interest and expertise. All countries possess particular complexes of natural resources, local ecologies, and distinct economic and political systems. These could become the objective of exhaustive research, the more so if local teaching programmes were oriented to providing problem-solving skills. As soon as one begins to focus on understanding complex systems, the need for different types of expertise becomes obvious - and the need for partnerships and alliances becomes imperative (Gibbons, 1998:54).

Such collaborative partnerships provide the opportunity for universities of the developing world to share resources and to enter into the distributed knowledge production system, to focus attention on the needs of their communities, to direct their efforts to the understanding of local and national complex systems, and to create "a new culture of teaching and research"? - With relevance built in." (Gibbons, 1998:55). The dilemma faced by universities of the developing world, Gibbons argues, is that they are locked into a disciplinary-based mode of knowledge production, that they are capital dependent, and oriented towards problems, which are relatively context free (Gibbons, 1998:53).

There is no doubt higher education institutions are confronted with numerous challenges, some of which are internally oriented and others are externally oriented. At the core of all of this is the need for higher education institutions to produce relevant knowledge that can address social problems and needs. In this regard, they should recognize the complex nature of the problems that require inputs of various stakeholders. This will lead to these institutions seeking partnerships with other various knowledge producers and lifelong learning stakeholders.

2.2.2.3. Mode 2 and Industry

According to Gibbons et al. (1994: 114) the growth of Mode 2 is partly an autonomous development, reflecting the inadequacies of Mode 1. However it is also one element in a much larger set of changes accompanying the spread of modernization beyond the US and Western Europe to Japan and the new industrializing countries (NICs). These changes have emerged from the larger historical development of industrial capitalism and so are interrelated. There are some however that are linked more directly to Mode 2 knowledge production. The prosperity of the advanced industrial economies relies on their

capacity to create comparative advantage, which in turn, depends upon their ability to reconfigure knowledge. Mode 2 can be observed in traditional firms as well as newer, high value, enterprises that form the core of the emerging knowledge industry.

The strategy adopted by advanced industrial nations and established firms have been to rely on technological innovation to counter imitation of existing production methods by countries with otherwise lower wages or a more favourable capital structure. This strategy has put pressure on firms on how to maintain successive productivity gains. It has led, for instance, to the development of specialist items, needed to complete the innovation process, being often contracted out. Manufacturing technologies are transferred to low wage countries and advanced industrial nations can only maintain their competitive advantage by using resources and skills, which cannot easily be imitated. This demand is met by new technologies, which in turn depend on the generation of new knowledge. In order to be internationally competitive, mature and leading edge firms must constantly keep themselves up to date in terms of knowledge and be able to access it instantly (Gibbons et al. (1994: 111).

It has been argued that one reason why the maintenance of in-house research capability has become too costly is that firms are unsure about the particular knowledge they need; often, it could have been produced almost anywhere. Another important precondition is to have access to such knowledge and expertise, being able to reconfigure it in novel ways and being able to offer it for sale (Gibbons et al., 1994: 148). Therefore, specialized knowledge for the identification and solution of problems has become in high demand. Since knowledge production is by no means a global phenomenon, it has been suggested that knowledge firms must keep access to global intelligence. The new key techno-economic paradigm is increasingly being based upon information technologies (Gibbons et al. 1994: 112).

Gibbons et al. (1994: 112) argue that parallel to the diffusion of Mode 2 knowledge production, network firms, R&D alliances, high value-added firms and new interface relations between competition and collaboration emerge. Although these new organisational arrangements and the sectors they cover vary, two broad trends underlie them. The first is a reversal of a trend towards tighter management control of more factors of production. In the past, many firms tried to absorb elements that had created uncertainties in the production process. Illustrating this reversal has been the rise of the network firm and its organisational method of operation. Horizontal structures have replaced hierarchical structures, and in general, these arrangements encourage flexibility and adaptation to unforeseen events. The second trend is that firms have ceased to try to carry out all their R&D in-house and opted for cooperation with other firms as evidenced by the rise of inter-firm alliances. They allow to cut research costs, facilitate fertilization between research areas and help to set technical standards.

Such a new contractual environment built on networks and alliances can be said to stifle competition. In contrast, we maintain that competition is stimulated on a second level. Competition no longer solely takes place on the level of making products or providing services in order to increase market shares. Rather, competition in an environment of alliances and collaboration is shifted to a second level where there is constant pressure to innovate. Competition becomes one between design configurations and the ability of firms to develop their potentiality, resourcefulness and creativity. The trend towards more collaborative patterns and new alliances is an outcome of the fact that created comparative advantage results increasingly from the creative combination of resources and resourcefulness. This means that the source of value-added elements lies in the precise form, which the collaboration of groups and the experience and skills of its members take. In this sense, competition can be said to be founded upon collaboration, since market selection is identical to group selection. In forming alliances firms make strategic key choices.

In many of these cases the mobilisation of varied skills and perspectives, in the solution of complex problems, is being built around the clustering of information and computer telecommunication technologies. The information technology paradigm increasingly replaces the previous one which is dominated by the technologies and organisation of past production consumption. A new paradigm begins to emerge when the new technologies become pervasive enough to seriously threaten existing ways of doing. Following Freeman and Parez (1988), this is exactly what is happening with regard to the four profiles of the new techno-economic paradigm i.e. its technological, knowledge production, skill and capital equipment profiles (Gibbons et al., 1994: 112-113).

Gibbons et al. (1994: 113) argue that despite the emergence of a new intellectual division of labour in the wake of the widened capacity to use research and scientific knowledge produced elsewhere, the ability to engage in research and to utilize it remains highly unevenly distributed throughout the world. An actual increase of inequalities occurs also through the differentiating effects that globalisation has on the actual ability to participate in the consumption of scientific knowledge, advanced technological products and systems. This results in many regions and countries being locked out completely. As a result, it has been argued that in general, inequalities of distribution have become more marked in the course of the process of global diffusion of knowledge production. The ability to transmit information cheaply and almost instantaneously throughout the world does not seem to lead to a more equitable distribution of scientific competence, but rather to its concentration. The growth of inequalities can be traced to the combination of two in-built tendencies: one towards standardization, the other towards diversification.

Gibbons et al. (1994: 113) related other paradoxical consequences of globalisation to the ongoing discussion about deskilling or skill enabling effects of new technologies. They argue that technology by itself does not require more or less skills, since it can be adapted to different levels of skills. It could not be overlooked, however, that a new division of labour is taking place between high

technology countries and the rest of the world. The 'industrial divide' is merely being shifted to a higher technological level. This is in full evidence when taking a closer look at the case of developing countries. As the complexities of contemporary science and technology unfold, the proposed solutions to current shortcomings of development appear all the more simple-minded. Gibbons et al. argued further that evidence is mounting that societies that were successful in building up scientific and technological competence, did so within a broader context of raising educational standards, changes of values, including a positive attitude towards science and technology. Success was also linked to focusing on long-term benefits for all, rather than expecting science to offer short-term technological fixes to complex economic and social problems or merely to aggrandize the prestige of political leaders and their grand projects (Gibbons et al., 1994:114)

The above discussion highlights one thing in particular, that is, for industries to retain a comparative advantage and competitive edge and to develop their technological capabilities, they need to be able to innovate and reconfigure knowledge in novel ways. This requires that such industries should establish alliances and constantly strive to access new knowledge available elsewhere (including from universities).

2.2.2.4. Critical responses to Gibbons

Some observers (Rip, 1998; Rip and Marais, 1999; Rip, 2000) question the accuracy of the Gibbons thesis in describing shifts towards strategic research and draw attention to explanations provided by other analysts, such as Etzkowitz and Leydesdorff (1995) and Etzkowitz, et al. (1998). Along these lines, other critics (Fuller, 1995; Weingart, 1997; Jansen, 1998) question whether or not what Gibbons et al. characterize, does indeed constitute a paradigm shift in knowledge production. While some acknowledge that the notion of Mode 2 provides a useful heuristic device, they treat with scepticism claims of a major discontinuity with conventional disciplinary knowledge.

Ravjee (2001) suggests that some South African critics (Bawa, 1997 and Mouton, 1998) do not reject the Gibbons thesis outright, but seek more empirical evidence to determine whether such changes are indeed occurring in the ways suggested, especially in the developing country context. Others (Kraak, 1997 and Subotzky, 1999) acknowledge that shifts have occurred towards applications-driven knowledge production along the lines suggested by Gibbons et al. They further regard the challenge that Mode 2 presents to the dominance of current epistemological, organisational and policy practices, related to Mode 1, as necessary and healthy in meeting the challenges and problems of developing countries. In this regard, they see Mode 2 as the means by which higher education might contribute more effectively towards reconstruction and development and poverty alleviation in South Africa (Ravjee, 2001).

A Gibbons thesis central feature - transdisciplinarity - has been described as vague and unclear, in fact Rip (1997) has argued it should in any case be modestly and simply called 'strategic research' (Rip, 1997). Another scathing and extensive critique has come from Weingart (1997: 592-8). Weingart describes the Gibbons thesis as theoretically shallow and extremely thin on empirical evidence to make the conclusion that western science has changed. He gives four points to substantiate his critique. Firstly, he argues that organisational diversity does not imply any fundamental changes in science. It merely points to the increasing salience of knowledge in socio-economic and political spheres. For him the unanswered question remains:

The question is how far the production of systematic, formal knowledge reaches into other institutional areas of society, and to what extent these are forms of knowledge processing and transfer or genuine production of knowledge. The latter is at least claimed implicitly in the thesis of increasing 'transdisciplinarity' (1997: 596 cited in Ravjee, 1999: 17).

Second, viewing transdisciplinarity as the cognitive correlate of their claims of organisational diversity, Weingart argues that the Gibbons thesis remains vague and ambiguous. On the one hand, Gibbons et al. refer to an ongoing specialization into sub-fields and their recombination independently of traditional disciplines; on the other hand, they mean a type of knowledge, which emerges in contexts of application, outside of disciplines and their criteria of evaluation (Weingart, 1997: 596 cited in Ravjee, 1999: 17-18). He finds their discussion of the blurring of disciplinary boundaries speculative, and not based on broad and methodological studies about the disciplinary boundaries. In his view the idea of disciplines as the social and cognitive frameworks for organizing knowledge is not being supplanted by transdisciplinarity:

Determining the degree of specialization is a matter of definition of disciplines and their operationalisation. The authors do not provide such a definition. The operationalisation could be sections of scholarly societies, titles of scholarly journals or denominations of university chairs. In all these cases one can be sure to encounter a correlation between growth rates of numbers of fields or specialties and general growth of the system of science as a whole (cf. Weingart et al., 1991 cited by Weingart, 1997: 597).

Thirdly, the Gibbons et al.'s claims that transdisciplinary knowledge is produced in the contexts of application are based on evidence drawn from a very narrow sector of research (technology assessment, risk research, environmental research, and sustainable development etc.), representing a small fraction of the S&T system. Viewing these fields as value laden, normative, policy oriented, and close to what is known as "strategic research", he finds in them little evidence for the presence of "persisting matrices" or the stability of "Mode 2". He argues that much of the research in these fields occurs in traditional disciplinary or multidisciplinary forms (Weingart, 1997: 595-601). Weingart asserts that the areas providing the model for Mode 2, including technology assessment, as well as

the arenas of environment, ethics committees in health, data protection in communication, are all policy areas born as a result of "scientification" (Weingart, 1997: 603 cited in Ravjee, 1999: 18).

Fourthly, Weingart does not see Gibbon's thesis, as applying to "science as a whole". He argues that it does not imply changes in how science as whole is organized. For example the Gibbons thesis does not apply to all fields of science, such as high-energy physics. For example the idea that Mode 2 will lead to revolutions in epistemology is not expanded in the Gibbons et al. text; they do not provide evidence that their observations correlate with changes in epistemology (Weingart, 1997: 608 cited in Ravjee, 1999: 18-19).

In arenas like environment and reproduction, there is the requisite technology assessment, in health there are ethics committees, in communication it is data protection. These, indeed, are new institutional arrangements, which require new types of knowledge bearing the characteristics of Mode 2. For areas of knowledge having no immediate connection to social values and subjective risk perceptions these conditions do not apply; high energy physics, astronomy, and palaeontology lie outside the concerns of citizens, groups and, at best, end up as issues in priority debates (Weingart, 1997:603 cited in Ravjee, 1999: 19)

According to Muller 1998 (cited in Ravjee, 1999: 23-24) traditional science is being challenged from two directions: the innovation economy's demand for usable knowledge, and the post-modern de-authorization of science. The shift towards transdisciplinary knowledge is undermining the epistemological bases of traditional science.

There is a commonly held view that science of a particular kind has moved to the centre of the dominant mode of production. What kind of science is the key? It has been called "strategic", "applied", "relevant", "finalized", or "Mode 2" science. Whatever it is, it is not the old curiosity-driven science that produced the disciplines and the faculties of the 18th and 19th century western universities. It is said that the horizon of pure scientific invention has reached a "steady state". Research money for such activities is in worldwide decline. One might conclude that the traditional notion of science, with its attendant disciplinary adjuncts, has been put into question by the changing global mode of production.

{Postmodernism challenges the epistemological bases of traditional science, undermining the internal authority of knowledge, displacing this authority onto various social actors or groups. Knowledge is no longer considered internally valid on its own terms. Validity, it is claimed, must now be confirmed by external stakeholders (Muller, 1998 cited in Ravjee, 1999: 23)

The relation between Mode 1 and Mode 2 remains unclear and contested. Gibbons (2000:41) dismisses the notion that the new practices are going to eliminate the old and that Mode 1 will

eventually succumb to Mode 2. It is far more likely that both will continue to co-exist. The terms of that co-existence depend as much on the response of institutions that are currently supporting Mode 1 as on the social diffusion of Mode 2. However, as Subotzky (2000: 105) argues, the general drift of Gibbons's argument assumes the increasing future dominance of Mode 2, which, in the absence of any sustained qualifications to this, suggests that Mode 2 will eventually supplant Mode 1 because the latter is not developmentally relevant. As a result of this, Subotzky contends that Gibbons assumes what Muller (1999) referred to as a replacement rather than a more sensible adjunct theory. According to Muller (cited in Subotzky, 2000: 105) this approach is problematic as it downplays the complexity of the relationship between disciplinary and applications-driven knowledge both in the acquisition of knowledge and in problem solving. For Muller, Mode 1 provides the necessary disciplinary substructure upon which quality inter- and trans-disciplinary knowledge acquisition and production can occur. Consequently, in Muller's view, related outcomes-based core competencies, in meeting developing country needs, are unwarranted and even potentially damaging if detached from the required sound Mode 1 foundation.

Herein lies the potential peril for science in developing societies. While the intention to institutionalise the organisational features of Mode 2 is noble and even progressive in meeting the dual development imperatives of developing countries, it may be counter-productive if the capacities to deliver are not there (Subotzky and Cele, 2002: 12).

Linked to this, Muller (2000) identifies the problem of unquestioningly applying the notion of Mode 2 knowledge production to the process of knowledge acquisition by creating inter-disciplinary programmes and curricula. This comes back to two key questions raised by Muller: Firstly, what is the appropriate mix of disciplinary knowledge and generic skills required by the millennial graduate? Secondly, what is the best preparation for this in terms of curriculum? For these reasons, the consideration of moving towards trans-disciplinary research and curricula, at the expense of establishing strong disciplinary Mode 1-type knowledge production and teaching should be cautiously approached in the developing countries.

Based on the above comments, I would argue that the Gibbons thesis has been able to highlight possible changes happening within science. However, some scholars have challenged this thesis in terms of whether the changes it purports are new or not. The Gibbons thesis is also challenged in terms of its scale, that is, the extent to which it can account for everything happening in science or in only a few disciplines. There are also issues that emerged from the Gibbons thesis itself that perhaps need further elaboration. Such issues include the relations between Mode 1 and Mode 2. There are probably areas of convergence such as the increasing demand of science to become accountable, responsive and relevant to the needs and problems facing society, rather than remaining elitist, esoteric and producing knowledge for its own sake. In this regard, it is important that one thoroughly understands various roles and knowledge flows between key stakeholders involved in the partnership.

2.2.3. Models of university-industry partnership: The Triple Helix and Knowledge Flows

"Knowledge flows" and Triple Helix represent two dichotomous and contrasting models of academic-industry partnerships. The "Knowledge flows" model is based upon the separation of institutional spheres. Triple helix is based upon the integration of institutional spheres. In other words, as Etzkowitz, Webster and Healey (1998: 5) note the "knowledge flows" schema is premised upon separate academic, industrial, and governmental spheres, whereas the triple helix is based on ties among overlapping institutions. To clarify controversial issues it is often helpful to sharpen them in "ideal typical" theoretical dichotomies even though reality is, of course, more complex and occurs along a continuum (Weber, 1922 cited in Etzkowitz, Webster and Healey, 1998: 5)

Etzkowitz, Webster and Healey (1998:5) suggest that explicating these models and their underlying assumptions could clarify various aspects of university-industry relations, including conflict of interest and commitment and the appropriate role of government at the academic-industrial interface. They also suggested that knowledge flows assume that universities produce and transmit knowledge through publication, and ideally do not sell it. Linkages between the spheres and flows of knowledge across them are shaped both organizationally and ideologically. For example, many academic departments' value only publications for the sake of promotion and their members attend to the practical implications of research incidentally. Traditional academic ideology allows a narrow, yet highly effective, one-way channel from basic research to industrial innovation, the so-called linear model. This hydraulic system of knowledge flows consists of reservoirs, dams, locks, and flow gates through which knowledge, codified and tacit, is exchanged for resources across clearly delimited boundaries.

According to Etzkowitz, Webster and Healey (1998: 6) the knowledge flows model specifies institutional missions narrowly: universities are assigned functions of education and research, industry the function of production and government the function of regulation. In its traditional role, the university is the producer of trained persons to send to industry according to IRDAC in the European Union, the Government and the University Research Roundtable in the United States. The academic side of this perspective is a zero-sum game: if universities and their faculties become involved in development activities or firm-formation ventures, their basic research effort will inevitably decline. In the industrial view, the primary role of firms in innovation is to produce incremental improvements derived from experience with production and closely associated R&D. On the other hand, universities as a site of basic research are expected to be a source of discontinuous innovation.

In general, knowledge flows are recognized as a key element of university-industry partnership. Some analysts have suggested that it should be the only dimension. Yet as more intensive relations of increasing complexity emerge, often involving government, a new model, the triple helix, is required as an overlay upon knowledge flows (Etzkowitz and Leydesdorff 1997 cited in Etzkowitz, Webster and Healey, 1998: 6). In addition to linkages among institutional spheres, each sphere takes the role of

the other. Thus, universities assume entrepreneurial tasks such as marketing knowledge and creating companies even as firms take on an academic dimension, sharing knowledge among each other and training employees at ever-higher skill levels (Etzkowitz, Webster and Healey, 1998, 6).

Within the Triple Helix context, boundary crossing and hybridisation among institutional spheres not only transform and redesign functional and structural operation, but also, provide an inspiration to innovation (Leydesdorff & Etzkowitz 2001: 16 cited in Carstens and Mouton, 2002: 8). Leydesdorff and Etzkowitz (2001: 1-5; 1998:11 cited in Carstens and Mouton, 2002: 8) ascribe this injection of inspiration to the fact that in the meeting of diverse institutional traditions and manifold interests a variety of perspectives are bound to be expressed. This promotes creativity network relations, among the three institutional spheres of the Triple Helix, which are believed to provide input and sustenance to science-based innovation processes (Etzkowitz & Leydes, 2000: 109-15 cited in Carstens and Mouton, 2002: 8).

According to Carstens and Mouton (2002: 8) the Triple Helix model has not, however, been without its critics. One such critic is Marceau (1996: 252-8) who strongly maintains that the relations between government, industry and higher education are far more complex, intricate and diverse than the striking image of the Triple Helix suggests. This critic explains that the Triple Helix model is deficient on two accounts. It fails to grant adequate attention to the inherent complexity in the character and composition of each partner, which is invariably marked by diversity, variation and even internal conflict. It also fails to acknowledge each partner's entrenchment in vital linkages stretching outside the Triple Helix network. To the extent that the Triple Helix model fails to take sufficient account of either of these dimensions, it will not provide a suitable base for description or analysis of government-industry-higher education co-operation.

2.3. University-Industry Partnership: "Drivers"-Who? What? Why?

For Etzkowitz, Webster and Healey (1998: 8) higher education institutions and industry have become more alike in that both are involved in translating knowledge into marketable products, even though they still retain their distinctive missions for education and research on the one hand, and production and marketing on the other hand. Moreover the circumstances of the innovation system make the two sectors more dependent on each other. Companies seek relevant knowledge from wherever it is available: from other companies, government research laboratories and universities. Technology personnel are commonplace in larger firms and regularly attend meetings where universities, small firms, and government laboratories present their intellectual property to potential customers. Universities have experienced a similar transformation through the development of offices to seek out and market useful knowledge developed on campus. As a result of financial pressures and incentives, universities have broadened their activities from education and research for its own sake to meeting

specific research needs of industry. Although it is still a relatively small proportion of their income, universities are beginning to earn substantial sums from their technology transfer activities.

According to Martin (2000b: 12-13) without doubt, the necessity to generate supplementary income has become the most important driving force for university collaboration with industry. Many higher education systems worldwide are exposed to major pressure for quantitative expansion within a context of stagnating or diminishing public resources. Research opportunities financed by the public purse are shrinking, particularly in the developing countries, resulting in the inability to complement staff salaries and obtain research grants from industry.

Martin's 12 case studies (2000b: 36) on university-industry partnership show the growing overall privatisation of higher education. There is also an increasing movement towards the market with privatisation of public enterprises and the establishment of a modern sector of enterprises. Many of these enterprises are concerned with technological development and the improvement of quality of research and scientific work within industry itself. Some national incentives have been devised to encourage university-industry partnerships. Within this context, higher education institutions have become increasingly obliged, and also more and more willing, to supplement the core funding from government through private sources, one of which is through research contracts with enterprises.

In light of this, most institutions worldwide now have some type of interaction with local, national or multinational industry. The type of interaction and its degree of intensity depend on many internal and external factors. These include:

- (a) Research and teaching capacity both within the higher education institutions (foremost, but not exclusively, in the technological, scientific and managerial areas).
- (b) An industrial base (e.g. multinationals but also to a lesser extent small and medium-sized industry) involved in R&D activities and concerned with staff development.
- (c) The existence of governmental policies, initiatives, financial incentives, structures or programmes to stimulate collaborative R&D and teaching programmes.
- (d) A tradition of interaction between higher education and enterprise.
- (e) An entrepreneurial culture within the higher education sector.
- (f) An academic reward system and incentives for staff to collaborate in programmes with an industry innovation system (Martin, 2000b: 13).

The changing higher education and market environments are increasingly forcing universities and industries to collaborate. Companies seek relevant knowledge wherever it is available in order to maintain competitive advantage within prevailing innovation and harsh realities of global competitiveness. Universities are forced to become accountable, relevant and responsive to the needs of their respective countries by making research results more useful. They are also required to

generate supplementary income through various means such as the exploitation and commercialisation of research results.

2.4. A Framework of benefits and obstacles

2.4.1. Motivations and benefits

According to Eva María Mora Valentín (2000: 165-166), the different characteristics of universities and industry allow one to assess any kind of collaboration from the starting point of the motivations that lead to it and the potential benefits to the participants. ¹Lopez-Martinez, Medellin, Scanion, Solleiro (1994 cited in Eva María Mora Valentín, 2000:166) identify the motivations that stimulate both university and industry to initiate collaborative programmes. These authors identify three different categories of motivation for university-industry cooperation: structural, institutional and individual. Structural motivations derive from the economic, political and technological spheres, which have a wide influence over institutional and individual motivation. Institutional stimuli are variables stemming from the particular institutional characteristics of the firm and/or university involved. Finally, individual motivation refers to the personal characteristics of the individual researchers (different cultures, objectives, etc.). The results of the study show that the main (individual) motivation for university researchers to cooperate with industry relates to the accomplishment of the social function of the university. The lack of in-house capacity to carry out technological research was the most valued (structural) motivation for business executives (Eva María Mora Valentín, 2000:166).

Other authors analyse the benefits that both sectors hope to obtain from the relationship. The most complete contributions to the literature are those that link the motivations with the expected benefits. Chen (1994 cited in Eva María Mora Valentín, 2000:166) analyses the competitive benefits that direct relationships between university and industry can bring to firms. He concludes that different mechanisms of university-industry interaction have different technology transfer benefits. However, the main disadvantage of this work is that it considers only the benefits for the firms. Other studies, such as that of Wallmark (1997 cited in Eva María Mora Valentín, 2000: 166) consider whether the university should share profit from significant inventions. The author prefers the view that the university gains more from becoming an exciting place to work, and so attracting the best staff and students, than from sharing profits with inventors. Moreover, the university becomes a natural beneficiary of donations from successful alumni, increased support from industry and society, etc. Thus the benefits to the university are very different from those to firms. The university receives indirect benefits and the benefits to the firm are directly derived from the commercial exploitation of the invention (Eva María Mora Valentín, 2000: 166).

In general universities and firms have different expectations regarding their partnership. For Eva María Mora Valentín (2000: 166) firms use their academic linkages to help them to achieve their

objectives, which are principally growth in turnover and profitability. Academic institutions pursue such objectives as training students for undergraduate and postgraduate qualifications, increasing knowledge through research and disseminating new knowledge through publications. However, to these 'traditional' objectives it is necessary to add a new expectation of the university in its relationship with industry, i.e. its contribution to wealth creation.

Schmoch's (1997 cited in Eva María Mora Valentín, 2000: 166) elaborated a ranking of benefits arising from interaction between universities and industrial firms from the perspective of academic researchers. According to Schmoch's results, the perception of the academics was that the main benefits for universities were additional funds and the exchange of knowledge. Observation of scientific development, solution of technical problems and staff recruitment were the main reasons for industrial firms to keep in contact with universities.

Among the third type of study, those that link motivation with expected benefits, Bonaccorsi and Piccaluga (1994 cited in Eva María Mora Valentín, 2000: 166) developed a theoretical framework and formulated hypotheses concerning the motivations that lead firms to enter into relationships with universities (such as access to scientific frontiers, increasing the predictive power of science, delegating selected development activities and responding to a lack of resources) and their expectations regarding the performance of the relationship (knowledge generation, transmission and propagation). Again, this work ignores the academic point of view, taking only firms into account. The benefits achieved can be expected to be directly or indirectly linked to these motivations. In particular, it is possible to identify six categories of motivation behind the interaction between academia and industry: technological, epistemological, financial, educational, political and strategic (Eva María Mora Valentín, 2000: 166). This is captured in the table below.

Table 1. Benefits of and motivations for university-industry-government cooperation

Benefits	University	Industry	Government
Financial	New financial sources: salary; research and programmes; obtaining public grants.	Reducing costs; obtaining public grants; financial benefits; sharing risk.	Easier to justify for big science centres as 'hidden' benefits are obtained.
Technological	Access to the firm's equipment and materials; access to the firm's employment, scientific and technological experience.	Access to the university's resources; upgrading of competencies; spin-offs from contract work; technological advances/ radical innovations; R&D collaboration projects.	Exploitation of technological spillover.

Strategic	Scientific breakthroughs and progress; access to managerial experience.	Generating a database of potential employees (university students); creating strategic alliances, more flexibility and maintaining/improving competitive advantage.	Possibility for the emergence of new technology-based industries; strengthening of the regional innovation system; increasing economic development.
Motivations			
Educational	More practical training; industrial scientists teach at the university; contribution to knowledge diffusion; teachers/ lecturers and pupils /students have access to new subjects with influence in the firm.	Access to the new knowledge and skills in the university laboratories.	Enhancement of the national educational system.
Political	Enhancement of reputation/ institutional prestige; responsiveness to government initiatives.	Enhancement of reputation; increase in the level of national competitiveness; responsiveness to government initiatives.	Integrated science, technology and industrial policy.
Epistemological	Testing existing theories; formulating new hypotheses; increasing science's predictive power; generating new paradigms; citations/PHD theses/publications.	Access to innovative scientists; reduced uncertainty about technological trajectories; solving scientific problems.	Upgrading the skills base; improving national self-esteem and consciousness; updating the science base

Source: adapted from the model of Autio et al (E. Autio, A-P Hameri and M. Nordberg, 'A Framework of motivations for industry-big science collaboration: a case study', *Journal of Engineering and Technology Management*, Vol. 13, 996, pp. 301-314 cited in Valentín E.MM (2000) 'University-industry cooperation: a framework of benefits and obstacles', *Industry & Higher Education*, Vol. 14: 3 June, pp. 165-172,

Considerable work has been done to understand motivations and benefits that industries and higher education institutions gain as a result of partnerships. Here the focus has always been to treat motivations and benefits separately, which is not useless/without reason. However the approach that has been developed here attempts to link motivations and benefits together. This is achieved through the use of six categories, i.e. financial, strategic, technological, educational, epistemological and political.

2.4.2. Barriers/Obstacles to University-Industry Partnership

The growing willingness of both university and industry to establish partnerships is fraught with problems, which arise out of the divergence and mismatch of cultures, values, objectives and environments of the two sectors. The main objective of the firm is to carry out applied research to realize rapid benefits; universities tend to prefer basic research to enhance knowledge. For Liyanage and Mitchell (1994 cited in Eva María Mora Valentín, 2000: 166-167) each partner works towards its own benefit, which is distinct from the common objective of the cooperative programme.

According to Geisler, Furino and Kiresuk (1990 cited in Eva María Mora Valentín, 2000: 67) there are several studies that demonstrate that long-term formal links between universities and industry are completely feasible, despite the fact that obstacles may arise. On the other hand, some myths have been created around the university-industry relationship. The studies by McHenry (1990 and Geisler, 1997 cited in Eva María Mora Valentín, 2000:167) analyse the myths about university-industry cooperation. These myths are a result of the desire by industry, universities and government to apply all possible tools to improve their technological arsenal and by implication, national economic competitiveness. These myths, some positive, others negative, have tended to oversimplify the factors that contribute to the success or failure of cooperative ventures.

In this context, there are two kinds of studies. First of all, there are those that simply identify the obstacles that exist between university and industry. Secondly, there are those that, in addition, propose numerous ways of bridging the gap between the partners. While studies about obstacles to successful cooperation have been extensive, less work has been done on how the sectors might be reconciled (for details see Eva María Mora Valentín, 2000: 167-168).

Numerous studies have been conducted concerning obstacles to cooperation. For Eva María Mora Valentín (2000: 168) the obstacles in the way of successful collaboration between universities and firms can be divided into five broad categories: restrictions imposed by industry on the university; problems relating to the ownership of intellectual property; cultural differences; research term (this is fully explained below); communication related problems. It should be pointed out that the problems of one kind of collaboration cannot be extrapolated to all other cases as some obstacles appear only sporadically (depending for example on the industrial sector in which it operates, etc.).

Firstly, *Restrictions imposed by industry*. The restrictions on the university arising from collaboration manifest themselves in three different ways, that is: (a) *choice of research topics*. Industry usually limits the kind of research that the university carries out. Thus, in effect, firms force universities to focus on a certain kind of research. If universities believe that these restrictions damage knowledge generation and the educational level of their students, they should make their opposition clear (Eva María Mora Valentín (2000:168). (b) *Discussion among scientists*. Informal discussion is an important

means of intellectual exchange among scientists. In this respect, it is very important for firms to define which research results can or cannot be divulged (Eva María Mora Valentín (2000:168-9). *(c) Delays in publishing results.* When the results of the research have been obtained, the university culture encourages publication, whereas industry's preference may well be to delay publication of the results until a patent application has been filed. These delays can be very damaging to the careers of academic scientists.

Blumenthal et al. (1996: 1734-1739 cited in Collins, 2001:172) found for example, that 82% of surveyed companies that supported academic research in the life sciences required academics to keep research results confidential beyond the length of time necessary to file a patent application. Considering, by some estimates, that up to 90% of companies conducting life science research have relationships with university researchers may be especially prone to alter their research agenda and restrict disclosure.

It is therefore important that universities and firms reach an explicit agreement concerning the maximum time for which publication will be delayed (Bowie, 1994, and Brannock and Denny, 1998 cited in Eva María Mora Valentín, 2000: 169). Although the delay will vary according to the particular circumstances and the nature of the collaboration, three to six months is typical. Sometimes a more substantial delay, which can last a maximum of two years, is required while the firm obtains the patent. In any case, a joint publication makes for a successful collaboration (Bloeden and Stokes, 1994 cited in Eva María Mora Valentín, 2000: 169).

Secondly, *the appropriation of the research results.* In some cases, academics appropriate scientific results arising from collaboration and start their own business venture. This kind of impediment to cooperation arises from opportunistic behaviour on the part of individual academics (Bonaccorsi and Piccaluga, 1994 cited in Eva María Mora Valentín, 2000: 169). The degree to which an innovation may be appropriated will vary according to the tightness or weakness of the agreement under which it is developed (Chiesa and Manzini, 1998 cited in Eva María Mora Valentín, 2000: 169). In tight agreements, the firm is protected by patent or copyright and does not need to exert strong control over the project. In weaker agreements, the academic partner must be controlled in order to avoid the exploitation of critical knowledge by academic researchers and thus a loss of revenue to the firm (Eva María Mora Valentín, 2000:169). According to Ingham and Mothe, the appropriation of R&D results should be defined and protected legally through the application of intellectual property rights (1998 cited in Eva María Mora Valentín, 2000: 169).

Thirdly, *communication related problems.* As a consequence of the different values and orientation of university and industry, communication problems can arise. Some authors suggest university and industry speak different languages. According to López-Martínez et al these problems constitute a

structural barrier, bearing in mind that this study analyses three kinds of barriers to university-industry cooperation: structural, institutional and individual.

Communication can take place through personal media (face-to-face, telephonic, formal and informal meetings, etc.) and impersonal media (computer print outs, written reports etc.). However, the communication channels used for transmitting information depend on the level to which the knowledge may be codified (tacit knowledge). In fact if the knowledge cannot easily be codified (tacit knowledge), more complex communication methods are needed, such as oral transmission or repeated observation of the know-how of researchers or workers. Where knowledge can be codified more easily, it can be transmitted through written reports or similar instruments.

Collins (2001: 176) argues that the case of the University of Washington (UW) illustrates the importance of multiple channels of communication between universities and industry. Attention in recent years has focused on the role of the Technology Licensing Office (TLO) in managing and licensing intellectual property. The TLO, however, is only one part of complex set of institutions that regulate the flow of knowledge to industry and the communication of industry needs to the university. The Washington Research Foundation provides venture capital, space, and business services that enable inventors of technologies with high commercial promise to build a company. The Washington Technology Centre facilitates partnerships that match industry needs to university know-how. Together, these organisations form an effective system that promotes both formal and informal linkages between UW and the surrounding environment.

In general, communication between higher education and industry has not been very successful. While industry has shown a lack of interest in the services offered by universities, universities have in turn tended to ignore the real requirements of industry. The designation of an intermediary to improve the communication process and to solve this problem is a fundamental requirement for more successful collaboration (Eva María Mora Valentín, 2000: 169).

Fourthly, *research term*. Eva María Mora Valentín (2000:169) argues that whereas R&D managers prefer to carry out research oriented towards the short-term, practical problem-solving academics naturally adopt longer-term views. Firms usually press universities to perform short-term research, contrary to the academic inclination.

Fifthly, *Culture*. Eva María Mora Valentín (2000: 169, see also Harman, 2001: 247 and Hernes and Martin 2001: 82; Matlay 2000; Louis and Anderson, 1998: 82; Blevins and Ewer, 1988: 654; Buchbinder and Newsome, 1985: 45) argues that cultural differences may be regarded as constituting the main obstacle to university-industry links. The literature has recognized that the two different and opposite cultures give rise to numerous impediments. According to Dierdonck et al, different cultures

are the roots of the barriers to the university-industry relationships. First of all, industry and universities operate according to different ethical codes.

The behaviour of academic communities is based on ethical norms such as common ownership of the body of knowledge generated through scientific activity, freedom to publish research results, professional prestige and the quality of research and knowledge generation. In contrast, the behaviour of the industrial community centres around the privacy of knowledge obtained through research, the secrecy of research findings, profit making, business planning, and competitiveness. Industrial and academic communities are thus embedded in very different institutional environments, each with its distinct set of basic priorities. The structure of a university is rigid and bureaucratic. The structure of a firm must be flexible in order for it to survive in the market. Industrial researchers benefit from a complete remuneration and compensation system; academic researchers do not have a clear system of remuneration and compensation.

The industrialist most often thinks in terms of months, while academics carry out long-term research. However, although Meyer-Krahmer and Schmoch share the viewpoint that academic and industrial researchers belong to different organisational cultures, they attribute the considerable growth of university-industry interaction to the existence of a broad area of joint interest where institutional differences still exist, but are less important. This convergence of objectives is reflected in the interest of both in exchanging knowledge, which means that collaborative research should involve a two-way exchange of knowledge (Eva María Mora Valentín, 2000: 170).

2.5. Knowledge and Technology Transfer or Transmission Processes

2.5.1. Technology Transfer or "interchange"

There was, at the turn of the 1980s, a watershed in the history of technology transfer in the universities in the United States and in Western Europe. The transmission of knowledge from universities to industries had occurred through traditional processes: the hiring of graduates, the publication of results of university research in professional journals and consulting by university staff. In the late 1970s new transfer mechanisms multiplied during which university patent offices were created or reorganized.

New approaches to obtain value from intellectual property such as equity ownership were tried, and liaison programmes developed markedly. Industrial sponsorship of research groups, and universities rapidly became increasingly involved in regional development plans (Gibbons et al., 1994: 87; see also Etzkowitz, Webster and Healey, 1998: xiii; Blumenthal et al, 1986b cited in Louis and Anderson, 1998: 84). As a result, intellectual property, secrecy, conflict of interest, commitment and commercialisation

have become new terms in policy debates among academics, government science policy officials, administrators and laboratory directors.

University-industry partnerships are not a new phenomenon. Etzkowitz, Webster and Healey, (1998:2) argue that the transformation of science into economic goods has always existed. Certainly most technological knowledge derives from industrial practice. Indeed, these innovations have stimulated scientific progress as well, in fields such as thermodynamics and information theory. There have also been, since the advent of the Industrial Revolution, instances of the transformation of scientific ideas into industrial use, classic examples being the chemical and electrical industries. However what is new is the intensification of this process, including the shortening of the time span between discovery and utilization, and increased reliance of industry on knowledge originated in academic institutions.

As the new transfer mechanisms multiplied tensions have emerged between various stakeholders within universities. These tensions are related to the fact that some stakeholders view these developments as having a negative impact on the (a) research agenda, management and results, (b) teaching, (c) academic culture, (d) public/ social role of higher education institutions etc. Others view these developments as opening the possibility for universities to become, at least in part, financially self-supporting institutions, entities obtaining revenues through licensing agreements and other financial arrangements for the industrial use of new knowledge discovered at the universities (Etzkowitz and Stevens, 1998:238).

Technology transfer is a key factor in the economic growth, competitiveness and employment creation in the global economy. In order for companies to increase their competitiveness, win new markets and create jobs, they need to innovate: to integrate the best technologies and the most effective management practices, and it is through that technology transfer remains one of the best ways to make enterprises innovate and be internationally competitive. Most importantly, the rate of change in technology means that we need to develop faster, better, cheaper, and more robust processes for technology transfer. These are the same goals that we have for reducing time to market in new-engineered product introductions. There is an intricate mixture of human factors, business process, and technology in an enterprise's capacity to use technology transfer to innovate, compete and grow (Sackett, 2000: 288).

Gibbons et al. (1994: 87) argue that technology transfer is experiencing some changes. There was at the turn of the 1980s, a watershed in the history of technology transfer in the universities in the United States and in Western Europe. Traditionally, the transmission of knowledge from universities to industry had occurred through traditional processes: the hiring of graduates, the publication of results of university research in professional journals, and consulting by university staff. In the late 1970s new transfer mechanisms multiplied: university patent offices were created or reorganized; new approaches to obtain value from intellectual property such as equity ownership were tried, liaison

programmes developed markedly; industrial sponsorship of research groups and universities rapidly became increasingly involved in regional development plans.

They also argue that, what is happening is the transformation of the practice of technology transfer itself (there certainly is an increase in the volume of this activity). As in Mode 2 knowledge production the distinction between basic and applied research becomes blurred, the notion of technology transfer has to be reconsidered and be replaced with "technology interchange". Technology transfer can no longer be understood as an easy transmission of knowledge from the university to the receiver and usually with almost no follow up. The university should interact with various stakeholders, including business people, venture capitalists, patent attorneys, production engineers and many others in addition to the university faculty. This is in part because technology transfer now requires constant interaction and feedback from various stakeholders whose assistance is needed by the university and vice versa.

It carries similar features of innovation as described by Professor Tshipouri of the University of Athens who argues that:

Innovation is a non-linear process. Every stage, from basic research to industrial validation, interacts with the others and is equally important for economic development. As a result, the traditional distinction between the suppliers and the users of technologies is no longer relevant. In a good project the supplier of technology learns as much as the user (Sackett, 2000: 220; see also Bozeman, 2001).

Most countries see technology transfer especially between academic institutions and industry as an important mechanism by which to improve the competitiveness of large, small and medium-sized enterprises (SMEs). It is spreading very quickly through all the countries of the European Union (Galbiati, Edmondson, Tochtermann, Vercesi and Dölp (2001: 197). There are numerous initiatives that exist in various countries to promote collaboration and stronger relationships between industry and higher education institutions.

According to Gibbons et al. (1994: 86) research in industry, even if conditions are better than in many university laboratories, is always problematic because it has to keep its objectives in harmony with the company's overall strategy. A commitment to basic research is particularly difficult to sustain. It is constrained by time limits and subject to frequent, rigorous evaluations in the light of shifting company fortunes. As research becomes more expensive, and is subjected to strategic and financial considerations, its base tends to narrow. As a consequence, to remain competitive industry increasingly needs access to knowledge generated elsewhere. One avenue is to join with other firms in pre-competitiveness research. Such collaborations are still infrequent. For many reasons, the universities remain the preferred option. However, a number of prerequisites have to be met.

Geographical proximity is important; it facilitates information exchanges and informal contacts necessary before any, closer, cooperation can be initiated. Close contacts and trust have to be maintained during the entire period of collaboration. Where this is done on a long-term and systematic basis, collaboration has a greater chance of success. The need for mutual accommodation is particularly clear in technology transfer.

Different countries have different historical, economic and industrial backgrounds. The technological needs and development processes vary according to these characteristics. The latter and the industrial system existing in a specific territory should influence the development and the results of technology transfer projects. It is therefore essential to compare the economic systems and structures in which technology transfer takes place before considering individual projects (Sackett, 2000:197).

The production of technology is far more likely to occur in some places than in others. The recent international literature on industrial clusters, networks and regional development confirms that the production of technology is rooted in the social dynamics of particular places. Technology production is one of the most geographically uneven processes operating within contemporary economies. Technology transfer flourishes in a culture in which innovation is standard practice. Under the European Fifth Framework Programme, innovation has become a structuring factor (Sackett, 2000: 290). The Innovation Programme encourages 'the expansion of technology and knowledge across Europe'. Technology transfer is seen as one of the best ways to achieve this objective. This can be pictured as a form of intervention that seeks to equalize the technology/innovation density across a region or regions. Intervention is seen to perform a useful role in promoting the dissemination of technologies. Technology-rich manufacturing nations, such as Japan and Germany, have developed extensive networks of technology transfer centres (Sackett, 2000: 290).

There are different types of technology transfer. As Sackett (2000: 290) notes, technology transfer is not just dissemination - it is proactive diffusion and exploitation through, *firstly, sectional transfer* i.e. standard solutions to problems in one sector are often innovations when applied in other sectors. The closeness of the original sector to the new application is relatively unimportant. Customisation of the technology is usually required as part of the transfer process. *Secondly, regional transfer* bearing in mind that one of the prime objectives of the European Union is social and economic cohesion. The EU has a strong commitment to support the less developed and marginal regions of Europe. A similar driver applies in many regions of the world.

Thirdly, research to enterprise transfer - the classic form of technology transfer. In the past technology transfer was seen as a simple process of moving research results from research to business and sometimes through an intermediary and with some adaptation. An inventor might have to deal with a large enterprise and this might cause problems with the balance of power. A large

laboratory might hesitate to pass its discoveries on to a small business. Cultural differences between sectors can lead to friction but also be of mutual benefit.

Sackett (2000) has identified six factors central to technology transfer. *Firstly, trust i.e.* users must reveal to an outside firm certain propriety details concerning their products or production processes. They may be unwilling to do so unless they have built a sufficient level of trust through close interaction over an extended period of time (Sackett, 2000: 291).

Secondly, geography. The disadvantages of geographical distance between technology user and producer can be reduced if the user and producer enjoy organisational proximity. Regions that might be viewed as peripheral with respect to the location of leading producers may be home to firms that are capable of using their advanced technology effectively if these firms are local branch plant operations of large, multi-location firms. Beyond organisational closeness, the literature also attributes considerable importance to cultural commonality or proximity. Increasingly, technology transfer is realized through tacit rather than explicit means. Tacit knowledge plays an increasing role in the technology development and transfer process. Technology transfer difficulties can be interpreted as poor processes for users and producers to engage in the effective sharing of tacit knowledge (Sackett, 2000: 291).

Thirdly, tacit knowledge. The tacit knowledge issue goes some way towards capturing the foundations of effective technological interaction. It is not simply the opportunity for sufficiently close contact between firms sustained over time that underlies this process. Nor is it strictly a matter of achieving cultural or linguistic commonality to facilitate the communication and sharing of technological subtleties. According to Gertler, one can anticipate profound problems when the partners involved in technology transfer are not geographically close together as they do not share either a common culture or a common business culture, or are not situated within a similar framework of broader economic institutions. Increasingly, the characteristics of the technology transfer domain are the ones identified by Gertler as presenting challenges (Sackett, 2000: 291).

Fourthly, competitive advantage. The resources of the enterprise that are unique, inimitable and valuable are central to its competitive advantage. Most enterprises do not wish to facilitate external transfer of these resources and want to develop effective inward transfer capability. Technology transfer is a vital source of innovation, and not only provides competitive edge directly but helps to sustain that advantage through a virtuous circle. The commodification of both physical and virtual resources is endemic in the global economies so the requirement is for continuous refreshment of competitive advantage. There is a relationship between the ease of exploitation of a technology and the potential enterprise business value the technology holds. In the past this could be seen as a discrete even relationship. Now it is frequently much better represented as a continuous function and

is illustrated by high product churn rates, exhibited by most of the successful enterprises operating in competitive environments (Sackett, 2000: 292).

Fifthly, comparative advantage comes increasingly from knowledge-based capabilities rather than from physical resources. All these issues are compounded when the essence of the technology to be transferred is tacit knowledge, skills and experience. These may not be readily expressed in words and communicated - 'we know more than we can tell', as Michael Polanyi puts it².

Sixthly, absorptive capability. each enterprise has a different receptivity to absorbing and exploiting the technologies available for transfer to it. The literature identifies the following factors affecting the ease of transfer as: maturity of the technology, recipients' previous experience in transferring knowledge/technology, and the number of enterprises using similar technology. The worst-case scenario in terms of ease of transfer is therefore likely to be in the university/research institute to enterprise transactions. Conversely, this also represents potentially the best source of competitive advantage. Practice in technology transfer is a key enabler. In essence, if you haven't done it, you can't do it (Sackett, 2000: 292). Organisations may use 'gatekeepers' to control the challenges represented by 'difficult to transfer' technologies with high added value potential. Gatekeepers need to possess knowledge about the technology to be absorbed and must be able to present it to the appropriate employees in the right format. They also present a formalized receptor to the innovation environment. The gatekeepers' absorptive/involvement capacity does not constitute the absorptive capacity of their enterprise units. Diversity of the knowledge base within an enterprise improves its ability to absorb innovation by providing novel linkages and associations.

Technology transfer contributes to economic growth, competitiveness and job creation. It has experienced changes. It is no longer a linear process but now requires constant interaction and feedback from various stakeholders, whose assistance is needed by the university and vice versa. In addition to traditional processes such as the hiring of graduates, the publication of results of university research in professional journals and consulting by university staff, technology transfer occurs through various mechanisms such as university patent offices being created or reorganized; new approaches to obtain value from intellectual property such as equity ownership being tried; liaison programmes being developed markedly; industrial sponsorship of research groups and universities rapidly becoming increasingly involved in regional development plans.

2.5.2. Intellectual Property Rights (IPR)

The structural problems faced by higher education institutions in developing and sustaining linkages with business and industry are similar in most countries. Yet the responses to these problems vary from one country to the other and also among institutions (Hernes and Michaela, 2000:9). According to Martin's 12 case studies report, most universities acknowledged the importance of intellectual

property and that it is high on the political agenda. It was noted further that usually there are very few higher education institutions that have long established partnerships with the private sector. Those that have such partnerships continue and remain active in this domain. This can be due to the lack or poor collaborative R&D between the university and the productive sector. It could also be due to the weak legislative framework and the lack of tradition for the protection of patentable R&D (Martin, 2000b: 159).

Martin argues that it is sometimes difficult for universities to bring inventions up to a stage where they can be filed for a patent, given the fact that this often needs considerable supplementary investment and expertise. It is only when universities can expect an important benefit from the commercialisation of IPR through royalties and licenses that they set up appropriate policies, structures and procedures in this domain (Martin, 2000b: 159-160).

In addition, better universities usually have long established partnerships with industry. They continue and remain active in this domain. Many of these universities have sought to improve their management and organisational strategies in dealing with intellectual property by establishing interface structures, science parks, intellectual property policies, patent offices or stimulating independent foundations to deal with patents and royalties (Blumenthal et al., 1986b cited in Louis and Anderson, 1998: 84).

However, the involvement of universities in intellectual property remains a major source of conflict of interest and commitment. It further represents a potential modification of the traditional view of universities as institutions supported by governmental, ecclesiastical, and lay patronage (Etzkowitz and Stevens, 1998: 238), and creates tensions around issues of research, teaching, academic culture, and the public/ social role of universities etc.

Intellectual property rights can be protected through (a) patents, (b) trade secrecy, (c) licenses and assignments, (d) copyrights (e) registered designs, and (f) trades marks. For the purpose of this discussion, I examine the first three (a, b, and c), as essential elements in the exploitation of knowledge or academic research results, which is linked to regional economic development.

Trade secrecy involves a process in which (within employment environment) employees and others are required to sign high confidentiality agreements. For instance Coca-Cola Company, its core technology (ingredients or mixture) is kept in an Atlanta laboratory, and not revealed to other multinational branches of the company. Trade secrets stemming from academic research pose a greater challenge. Companies in many fields eagerly invest large sums in the services of university researchers, asking for guarantees of secrecy in return.

...At scientific meetings, disputes over secrecy are erupting, and in some organisations, actions are being considered which could censure or expel members who use their business obligations as shields to avoid participation in the usual sharing and discussion of new advances. (Bok, 1982: 37 cited in Louis and Anderson, 1998: 83).

To say the least, this problem has not been resolved. Secrecy contradicts the academic norms of openness. It restricts communication with colleagues, some of who may also be competitors if they are linked with competing industrial interests. It greatly complicates the participation of graduate students in the research enterprise (Louis and Anderson, 1998: 83).

Patents: In order to secure a patent, an invention must be new and useful. Most importantly, such an invention should not be obvious to a person of ordinary skill in the art at the time it was made. An invention cannot be considered patentable if it was known or used by others, or described in a publication or was in public use or on sale. Patents can include machines or apparatus, articles of manufacture, compositions of matter, processes and methods. Generally, patents are considered to play an important role in technological innovation. The purpose of issuing a patent is not to reward the inventor, but to enable the investment of venture capital, without which many inventions would die on the vine. The patent also enables small companies to carve out a corner for themselves in a large field, and to grow and prosper in the midst of large, powerful competitors (Bush, 1970: 84 cited in Etzkowitz and Stevens (1998: 238). Patents enable inventors to recover costs and profits from investments in creativity, research and development through monopoly rents.

Patenting of research results with subsequent licensing arrangements is an alternative way to protect industry's interests. The temporary monopoly afforded by a patent provides an incentive to innovate (Samuelson, 1987, cited in Louis and Anderson, 1998: 83). The incidence of patent awards to university scientists or universities has been growing; many universities now contain patent offices or have stimulated independent foundations to deal with patents and royalties (Blumenthal et al., 1986b cited in Louis and Anderson, 1998: 84). In addition, many industries report that they have made patent applications based on research that has occurred in universities (Blumenthal, 1986a cited in Louis and Anderson, 1998: 84). Patents are not without complications however. Sponsoring corporations may have the option to review papers to check for patentable material, thus delaying publication (Coberly, 1985 cited in Louis and Anderson, 1998: 84). Most universities expect to hold patents based on research conducted under their auspices, but industrial sponsors may expect exclusive licenses to (or exceed) the products of research.

Business wants fair value in return for its investment and therefore wants...to use the research results without having to pay a second time...Moreover, many business people...have difficulty reconciling the role of university as public agent with its desire to take proprietary positions (Bremer, 1985: 52 cited in Louis and Anderson, 1998: 84).

Licenses and assignments - license agreement: ownership is retained but right of use is granted, usually for royalty payments. Assignment agreement includes the sale of design and all rights for a lump sum and/or royalty payments. Patent rights may be transferred by written assignment, and licenses to use the patent may be given to others by the owner at any time during the patent term. Compulsory licenses are possible if all rights are abused, e.g. failing to grant licenses on reasonable terms where this is in the public interest.

Since 1980, when the Bayh-Dole Act made it possible for universities in the USA to take ownership of inventions from federally funded research, at least 2578 new companies have been formed based on a license from an academic institution. Income from licenses and options amounted to \$725 million in 1998, up from \$611 million in 1997. Although these numbers point to an accelerating use of licensing and technology transfer by US universities, the potential impact on regional development in all but a few locations is far from clear.

Firstly, patenting and licensing activity is heavily concentrated at a handful of large research universities. In patenting, for example, the top 100 performers of academic research accounted for 89% of patents issued to universities in 1998. Generation of income from licensing was also heavily concentrated; in 1996, the top ten recipients of licensing income accounted for 63% of the total. Secondly, patenting and licensing activity is heavily concentrated in a few technologies. More than 40% of patents issued to universities in 1998 were in only three utility classes related to drugs and molecular biology. Half of total royalties were reported as being directly related to the life sciences; only about a fifth of income was related to the physical sciences and engineering. The implication is that, at least at present, formal technology transfer and licensing are most likely to be important sources of knowledge spillovers only in regions that have a top-performing Research University and significant industrial activity in the life sciences (Collins, 2001: 171).

A third area of concern is the likelihood that the benefits of knowledge appropriated through licensing of university inventions will accrue to regions other than the university's home region (see also Etzkowitz and Stevens, 1998: 230). Small start-up companies formed to commercialise a university invention are often acquired by large companies in other states or countries. Although the company may retain its local presence, future returns to the original innovation will no doubt leak out to other regions. In the worst case, the acquiring company may close down the local operation (Collins, 2001: 171). This is not to suggest that efforts be made to deter or prevent this kind of activity. It only means that policy makers need to be aware of the difficulty of appropriating knowledge locally and the likelihood that the benefits of knowledge appropriated through licensing of university inventions, will accrue to regions other than the university's home region.

Intellectual property rights are usually the most sensitive, complex and time-consuming to negotiate (Atkinson, 1985: 79 and Tolbert, 1985: 51). The growing enthusiasm for patenting and licensing,

coupled with the rise of so-called 'entrepreneur scientists', risk undercutting the more informal relationships that have governed university-industry relations in the past. Negotiating licenses with private firms is fraught with all the uncertainty and risks associated with contracts and their enforcement.

At least four parties have stakes in the agreement: faculty inventors, technology license officers, university administrators, and industry partners. Each side has its own interests. Academics seek prestige and additional funding. Licensing officers seek to maximize revenue from the contract while maintaining the freedom to license the technology to other parties. University administrators seek revenue and prestige for the university. Industry seeks exclusive rights to leading technology at the lowest cost and most flexible terms. Conflict is inevitable. Although lawsuits involving universities and firms remain relatively rare, there are concerns that the level of trust is diminishing. This could bode ill for other less formal forms of knowledge spillovers (Collins, 2001: 171).

The ownership of intellectual property is complicated and confounded with problems. Any university-industry partnership has to determine who should be granted control of ownership of intellectual property. The industry perspective (sometimes shared in certain sections of university) argues that industry should be vested with ownership of IP, simply because it provides funding. The ownership of intellectual property rights is usually used by industries as one mechanism to moderate their dependence to/on universities (Louis and Anderson, 1998: 86). For industry exclusive control of technology or information is critical to survive in the competitive industrial climate.

The university perspective (administration driven) argues that the university deserves ownership as a provider of intellectual capital, resources, time etc. Ownership of intellectual property allows the university to preserve free scientific inquiry and to secure other researcher sponsorship for future projects related to the patentable invention that are however outside the main business of the current industrial partner (Streharsky, 1993:28 cited in Carstens and Mouton, 2002:49). Failure to achieve such ownership might result in faculty investigators and their teams being prohibited from pursuing their research activities, as they are unable to secure other corporate involvement. Such limited development efforts clearly harm the higher education community by reducing opportunities to meet their mission of seeking new knowledge, of teaching young minds, and of serving the public. In essence, such limitations on the ownership of intellectual property rights directly serve to inhibit the academic institution's performance in terms of both research and innovation (OECD, 2002: 48-51 cited in Carstens and Mouton, 2002: 49).

2.5.2.1. Critique of Technology Transfer processes

According to Etzkowitz and Stevens (1998: 230) to this day, there is a division of opinion among university faculty, especially at elite universities oriented to the liberally arts and basic research, over

whether patenting or indeed any attention to the commercial implications of research is appropriate. They have argued that it was at these same universities that government funding of research was severely questioned and ultimately rejected during the 1930s.

At Columbia University, as late as 1952, a faculty member in biochemistry in the Medical School viewed government research funds as "tainted" (Personal communication from Seymour Lieberman, Nov. 29, 1995 cited in Etzkowitz and Stevens (1998:230). Since that era, government funding of research has become academic orthodoxy. Ironically, it is currently under threat of reduction and that diminution is viewed as an attack upon academia. In the face of this decline, a parallel system of generating funds from academic research through technology transfer has been created. Nevertheless, this system is still in its infancy and many question whether it can ever become a significant source of resources for academic research let alone a serious input into the economy. In addition, some critics hold that technology transfer detracts from academia by deforming the university from its traditional missions of research and education, which is their unique function (Feller, 1990 cited Etzkowitz and Stevens (1998:230). In addition where institutions are funded by public money, accountability requires that public money not be diverted for private benefit.

For Sheen (1999:199), this argument appears quite clear-cut and straightforward; but how does this apply to training, consultancy and contract research? For example many business schools, engineering faculties etc. are heavily involved in all of these activities. In part because, it is claimed, it is vital for their members to interact with the real world in order to have a grasp of the context of their expertise and, through consultancy, to practice their profession and establish credibility in the field. If their institution also benefits through additional income and normal responsibilities are not neglected, real benefits can accrue to the institution. The same argument is put forward for professional engineers who are actually required by their professional organisations to carry out a certain amount of fieldwork in order to retain their professional status. This point about learning in context is crucial for technology. Technology advances either by the application of new theory to improve control over existing processes or by using known technology in novel contexts. Teachers and researchers of technology-based subjects in universities therefore need to keep in close contact with industrial practice (Sheen, 1999: 200).

By their very nature, applied fields are more closely linked to their environments. As Ashford (1983, cited in Louis and Anderson, 1998: 84) points out, past ties with commercial organisations have made academics in engineering, medicine, and chemistry kindly disposed towards industrial goals (17, see also Smith 1984). Faculty members in applied-fields are far more likely than faculty in non-applied fields to be involved in research centres funded either by government or by private corporations. Areas such as engineering, not only have ready outlets for the results of their research, but also in fact have developed in large part in response to problems posed by external constituents:

At some institutions, in departments of engineering, physics, and biophysics, more than half the faculty is involved in some significant way in industry. And they do so not for financial gain, but because in these fields the cutting edge - or some element of the cutting edge-is, in fact, in industry. If they want to be at the cutting edge and if they want their students to be there, then they naturally work with industrial research groups (Dialogue: Disclosure of conflicts of interest 1985, 38} cited in L&A 1998, 84).

Blumenthal et al. (1987 cited in Louis and Anderson, 1998: 84-5) support this assertion, reporting that more than forty-three percent of chemists and engineers receive some research support from industry, as compared with twenty-three percent in life science fields (where the tradition of applied research is less developed). Nora and Olivas (1988 cited in Louis and Anderson, 1998: 85) in a study of a research faculty in Texas, show that those in applied fields (engineering and business) are more likely to gain additional institutional relationships between the university and private sector organisations, and less likely to believe that the institution should retain patent rights to faculty research.

According to Etzkowitz and Stevens (1998:230) for example, in 1985, the state legislature asked Iowa State University to review its management contract of a federal laboratory, suspecting that the university (and the state) was losing more than it was gaining from the relationship. The university found, on the positive side, that the laboratory was supporting the research infrastructure of several departments including physics, chemistry, and engineering. On the other hand, the intellectual property emanating from the laboratory was primarily being licensed abroad rather than contributing to local economic development.

The university began the process of founding start-up firms to develop research locally, successfully creating jobs and economic activity in Iowa from the intellectual property of the university and the federal laboratory during the past decade (Personal communication from Michael Crow, Columbia University, Nov.29, 1995). At other universities, as the technology transfer profession generates ever more glowing reports of its ability to generate returns from federally sponsored research, sceptics contend that academic attention to technology transfer is misplaced on the grounds of wasted effort that will not produce significant results.

Others argue that moving more closely to industrial research interests smacks of "short termism" and will be duplicative of industrial research laboratories. A focus on technology transfer makes the university into a barrier between university and industry. It displaces the free flow of knowledge, through publication and informal discussion, with a wasteful effort to capitalize knowledge and reap a return for the university (Etzkowitz and Stevens, 1998:230). Technology transfer efforts which focus on industrial development of PSR (public sector research, university and government laboratories) 'inventions' are misplaced and out of proportion. By far the greater contribution of PSR to innovation

lies in the less direct and intangible flow of ideas, knowledge and expert assistance (Faulkner and Senker 1995 cited in Etzkowitz and Stevens, 1998:230).

Within the university level, there is no consensus on how the ownership of intellectual property should be granted. To illustrate this, three different views can be identified. First, there is a view (mainly of administrators) that argues for the university to be granted ownership as an institution as opposed to individual faculty inventors or academic researchers. The idea is that vesting intellectual property rights with the universities rather than with academics is that the former is more likely to successfully transfer it to national industries, thereby producing a benefit to national economies.

It is often argued that while granting ownership of intellectual property rights should, in theory, increase the researcher's commitment to commercialisation, it is not necessarily the best route to follow. The advocates of this perspective go further to say, that putting all the responsibility for disclosing and protecting ownership on a single individual reduces the likelihood of patenting and subsequent licensing. In addition, the growing cost of litigation acts as a powerful disincentive for disclosing and commercialising research results when the individuals own the intellectual property.

Firms, too, may hesitate to enter agreements where there is a risk of future litigation from one or more of the co-inventors. Another problem is that the researcher who owns the intellectual property rights may take it abroad for commercialisation, thus reducing national benefits from public investment (OECD, 2002: 52 cited in Carstens and Mouton, 2002:50). Given these drawbacks, the latest OECD Report (2002: 52 cited in Carstens and Mouton, 2002:50) advises that intellectual property rights should be granted to the research organisation, but with the agreement that the participating researchers will enjoy a fair share of any resulting royalties.

The second view argues that academics and faculty associations are the rightful owners of the knowledge, which they create. This view has been criticized in that it reinforces the view of academics as self-serving and unaccountable - the very view, which is being promoted to advance agendas such as the introduction of performance indicators and the elimination of tenure. More insidiously, this position also reinforces the misconception that industry's interests are identical to the public interest (Polster, 1999).

The third view is rooted in the notion of the public role of the university. Regarding this view, the academic community should make the case that neither they nor their institutions are entitled to own the knowledge that is produced. But instead the argument should be that all knowledge produced in universities rightfully belongs to the public (Polster, 1999). Polster argues that one should make the case that the university has no business in the intellectual property business in the first place. Academics are public servants not entrepreneurs. Since academics do not fund their own research work from their own pockets, they cannot claim the products of labour as their personal property.

Further because academics do not have the legitimate claim to the knowledge produced on university time, they are likely to lose the debate about rightful ownership of intellectual property in the court of public opinion (Polster, 1999).

Polster further argues that the university's involvement in intellectual property is already eroding (and will progressively erode) in two ways its ability to reproduce itself. Academics have been prevented from drawing on and replenishing the "commons of knowledge" - that pool of freely available public knowledge is lifeblood of the liberal university. Already, many academics' ability to access and produce freely available knowledge is being inhibited as intellectual property increases the costs of research, restricts the availability of various resources needed to produce public knowledge, and alters university reward structures so that the professional benefits of public knowledge production are diminished.

For Polster, the university involvement in intellectual property is compromising the university future by reducing its ability to serve the public interest. This public interest is the main reason for the university to receive public support and a necessary condition of its continuing to receive that support. Academics involved in the production of intellectual property are less able and/or willing to share their research and knowledge with a variety of communities. They may also be unable to protect the public from harm. They may actually damage the public interest either inadvertently or knowingly, such as when they grant exclusive licenses to inventions, which inflate the price of consumer goods and/or retard scientific or economic development.

More generally, as the identification and exploitation of intellectual property become increasingly central to university operations, there are greater temptations and pressures to abandon the public interest in favour of particular interests. Although the university's involvement in intellectual property will probably not result in its physical destruction, it will very likely lead to its fundamental transformation. As opposed to an institution that produces a broad range of freely available knowledge that serves the general interest in a variety of ways, the university will increasingly resemble any other knowledge business that produces mostly private knowledge in the service of particular clients.

2.5.3. Conflict of Interest and Commitment

Issues of conflict of commitment and interest arise directly out of the growing role of universities in industry partnerships and exploitation of intellectual property. Not surprisingly, these changes imply a shift in the orientation of the academic and public research culture, from being devoted exclusively to the research and training interests of professional staff toward being open to more entrepreneurial activity. The latter raises potential conflict of interest questions and normative conflict between the expectations and standards of academia and those of private enterprise (Etzkowitz, Webster and

Healey, 1998: 13; see also Harman, 2001). Most faculty members have teaching and other responsibilities beyond their research. To the extent that work with industrial organisations impinges on these other duties and compromises the value of the non-research services that the university provides, universities may change their faculty members who have a conflict of commitment (Burke, 1985; Blevins and Ewer, 1988 cited in Louis and Anderson, 1998: 82).

Conflict of interest may be said to exist when an individual is diverted from a group's broader goal to an individual or private goal. The issue arises most clearly when an individual within organisational responsibilities seeks to gain a personal private profit through her or his position. Thus, if the pursuit of disinterested knowledge is raised as the banner of the research-university then the receipt of private profit for research pursued is ipso facto a conflict of interest (Etzkowitz, Webster and Healey, 1998:13). In academia, of course, this issue has arisen most strongly when faculty members have organized firms based on their research or have equity in commercial developments sponsored by corporations funding their work. Some of the more notable examples of both forms of cross-sectoral interest have been in the biotechnology field, as new firms were spawned during the 1980s to commercialise the new techniques and processes developed in the area (Etzkowitz, Webster and Healey, 1998: 13-14).

Consulting appears to be the primary source of difficulties: high levels of research funding from industry do not appear to have a negative effect on research productivity, but exclusive or extensive consulting is associated with lower publication rates (Blumenthal et al., 1987 cited in Louis and Anderson, 1998: 82). Ninety-five percent of all research universities regulate faculty consulting (Louis, Anderson and Swazey, 1988 cited in Louis and Anderson, 1998: 82). However, only a few universities monitor conflict of interest in any systematic way. There are some universities that have devised ways of avoiding conflict of interest and commitment (see Martin et al, 2000 and Webster and Etzkowitz, 1998: 63-66).

According to Louis and Anderson (1998: 82 citing Gluck, Blumenthal, and Stoto, 1987 and also Varrin and Kukich, 1985) one of the greatest concerns could be the possible conflict of interest in the industrially funded professors' teaching and mentoring roles. Doctoral students whose education is supported by industry funds report lower publication rates, more delays in publication, and constraints in discussing their work.

Doctoral students learn about the norms and assumptions that underlie academic work from their professors and learn about their practical application from watching scientists go about their daily tasks. However, if students encounter many faculty members who are struggling with issues of secrecy, particularism, or personal interest in their research, doctoral students will be less likely to see the traditional norms as valuable (Louis and Anderson, 1998: 82). Thus, from the university's perspective, the major problems with university-industry interaction stem from the distinctive

character of academic research and the responsibilities of academic researchers as members of the university community (Louis and Anderson, 1998: 83).

According to Etzkowitz, Webster and Healey (1998:14), those academics that embark on commercial activities can respond to this in at least two ways. On the one hand, it can be seen as an activity that must be kept separate from their more traditional roles and responsibilities, ensuring in particular that the research and development agendas of the two are discrete. On the other hand, such activity can be redefined as part of the legitimate role of academics and universities who define their tasks as contributing to innovation and economic growth as well as to the pursuit of knowledge. Since government science and technology policies appear to support this second view it is not surprising to find its ascendancy. Yet the more the need arises to restrict the dissemination of detailed information about their work.

The past decade has seen the emergence of numerous academic/government-inspired initiatives such as science parks, interdisciplinary research centres (IRCs), and start-up companies from within academia. These emerged out of different local contexts - including the university-inspired technology parks of the Netherlands to those more heavily dependent on local and national state support, such as in the United Kingdom or Canada. Moreover, the role played by each can also vary depending on local context (Webster and Etzkowitz, 1998: 57). The main aim of these initiatives is to exploit the public-sector research.

2.5.4. Science Parks

Apart from the general function of exploiting public-sector research, science parks strive to allow "intellectual osmosis" between industry and university to occur. Science parks have previously played different roles. These science parks roles included:

- (a) As a university development strategy to raise funds by selling or leasing under-utilised land, as was the case initially, for example, at Stanford and Cambridge.
- (b) As a strategy to create a technical environment for an engineering school, a source of jobs for graduates and consulting opportunities for faculty (such as Rensselaer Polytechnic Institute; Heriot Watt {Edinburgh}).
- (c) As a regional economic development strategy to attract industrial and governmental labs (e.g., Research Triangle (USA); University-Enterprise Foundations (Spain); Webster and Etzkowitz, 1998: 57).

In spite of these roles, science parks in general have had a fairly limited success as agencies for the exploitation of academic knowledge; indeed, links with academia can sometimes be fairly peripheral especially in the case of the first type outlined above (Webster and Etzkowitz, 1998: 57).

The rationale behind science parks is found in the concept of "localized knowledge spillovers" (Scott et al., 2001: 19 cited in Carstens and Mouton, 2002:23). Here it is argued that firms operating near sources of knowledge such as universities can transfer knowledge and technology and so introduce innovations at a faster rate than rival firms located elsewhere (Scott et al., 2001: 19; Hicks, 1999: 10; Bell & Sadlak, 1992: 231-4 cited in Carstens and Mouton, 2002:23).

In addition to augmented innovation productivity, the geographical agglomeration of knowledge practitioners such as found in a science park, is believed to strengthen economic development and innovation because of the personal interaction it makes possible between such practitioners. In light of the person-embodied nature of much technological knowledge and the concurrent importance of face-to-face interactions, such direct personal contact becomes imperative. This appears to be particularly true when dealing with the uncertainty inherent in the development of new technology (Salter et al., 2000: 45-9; Bonaccorsi & Piccaluga, 1994: 241 cited in Carstens and Mouton, 2002:23).

However, some analysts have suggested that science parks can act as a barrier to technology transfer and links between firms and academia because of their high-tech image, which can intimidate firms, especially SMEs. More generally however, the analysis suggests that the parks can encourage social and geographical polarization (see Massey et al., 1992, cited in Webster and Etzkowitz, 1998: 57). In response to their equivocal success many Science parks within OECD countries have recently sought to incorporate a more centralized management structure in the way they are run in order to promote closer intellectual and not just physical proximity to the neighbouring academic and industrial base in the region. This has been a key objective for parks in less-developed areas of Southern Europe, for example (see Cricelli et al., 1996 cited in *ibid.* 57).

2.5.5. International Research Centres (IRCs)

Etzkowitz, Webster and Healey, 1998: 11) argue that the second stage of organizing research activities, to create a greater volume of exploitable knowledge, can be traced back to the development of group research in the university (or the rise of research centres). The most important feature of the research centres is that their development during the latter part of the 1980s has involved a deliberate attempt to join industry and academia at a more fundamental but interdisciplinary level of research.

Where once the academic department reigned supreme, based on a single discipline, at least as in the Anglo-Saxon world, and teaching a single degree discipline, academics are increasingly grouping themselves in cross-departmental research units or centres, in order to tap into the new research markets. In the UK, the government has encouraged this development by pump-priming special interdisciplinary research centres and inter-university partnerships in specific research areas.

In the USA, Etzkowitz and Kenelgor (1998 cited in Shattock, 123: 123) have written about the collectivisation of academic science. They have also shown how a research centre could develop much closer links with external contractors than research laboratories operating within departments, even to the extent of forming its own companies, (Shattock, 2001: 123-4). They cited intensified competition in fast-moving fields and the realization that a practical or theoretical problem can best be attacked by a group of investigators drawn from several disciplines. However, "leaders" and academic entrepreneurs create centres, and their success, depends a great deal on generating external funds and industrial contracts.

Indeed, they often simulate some aspects of industrial research laboratories, buying skills (on a short term basis) not possessed in the centre, sharing valuable equipment and providing 'neutral ground' in which company collaborators can work with university staff. Such centres often offer immediate research access to companies via company subscriptions, industrial clubs and regular seminars/for external members (Shattock, 2001: 124).

Shattock (2001: 124) argues that these external and internal changes have revolutionized the organisational structures that universities formerly had in place to interface with industry. Such changes demand a new range of skills. These include: a) the ability to build networks, b) the capacity for brokerage, c) developing a wider vision about the university and the economy, d) strategic skills in identifying and marrying market niches, gaps and university research strengths, e) legal and intellectual property skills and f) skills in company formation and a broad appreciation of industrial training requirements.

Shattock (2000: 124-125) argues that where there were powerful research centres relating to industrial problems, it is likely that the specialist expertise in the research centre far outweighs in effectiveness any liaison skills that could be provided centrally by the university industrial office. Thus, as industrially funded or Mode 2 research was expanding in universities, research centres took over many of the functions that were previously located in the industrial office in the centre of the university. The situation could inevitably become much less tidy. More tension could be generated between university central authorities and academic entrepreneurs in academic departments and research centres. At the same time questions of co-ordination, adherence to the university regulations and recognition of success in terms of the allocation of institutional resources or of a financial return to the institution could become issues of great sensitivity.

2.5.6. Start- up Companies/Firms

Start-up companies/firms serve as one of the most important agencies that can act as an interface between industry and academia. When universities are involved in the translation of research results into exploitable products and formation of firms to bring products to the market, they are entering

into a domain traditionally reserved for business (Webster and Etzkowitz (1998: 58). Moreover, the capital for such firms is increasingly likely to come from the academic establishment itself being prepared to act as a venture capitalist investor. Universities may regard themselves as particularly well suited to do this role since, unlike fully commercial venture capitalists they do not need to satisfy stockholders' immediate needs for dividends and can therefore invest for the long term (Webster & Etzkowitz, 1998: 58). Such developments (as in the case of Oxford University's Oxford Molecular, or UCL Ventures Ltd. (London) are yet another indication of the way in which academia is beginning to create its own industrial sector. A key issue here is the extent to which these new firms and their parent universities manage and exploit the intellectual property rights derived from their research (Webster and Packer, (1996 cited in Webster and Etzkowitz, 1998: 59). For Collins (2001: 171-172) the potential conflict of interest and corporate influence over university research emerged as a result of the ability of academics to start companies and gain personal profit from technology transfer.

According to Collins (2001: 171-2) the ability of academics to start up companies and profit personally from technology transfer, creates a potential for conflict of interest and corporate influence over university research. Since 1970, in USA the industry funding of academic research has grown from 2.6% to 7% in 1998. Although this is still small compared to the shares from federal and other sources, some studies suggest that it has brought considerable change to the norms of academic science, giving rise to a culture more conducive to commercially relevant research. Opinions differ on whether this has been, on balance, a positive development.

On the one hand, the proportion of basic research in total academic research has remained stable over the past two decades. On the other hand, recent research suggests that growing ties with industry are forcing academics to accept restrictions on the publication of their research (this point is elaborated later). This spin-off activity is happening not only within higher education establishments but also within government and research council institutes and laboratories as the state has gradually removed the bureaucratic and legal constraints on its own institutions (Webster and Etzkowitz, 1998: 59).

2.5.7. Technology Licensing Organisations (TLOs)

According to Collins (2001: 170-171) TLOs have received a great deal of attention due to their ubiquitous presence at America's research universities today, as well as their association with a member of important innovations and well publicized start-up companies. According to a survey of the association of University Technology Managers (AUTM), which monitored and assessed licensing activities to the creation of 364 new companies and the introduction of 385 new products in the fiscal year 1998, interestingly, 79% of new companies were formed in the same state of the academic institution that licensed the technology. In terms of economic impact, 17,088 active licenses

generated \$ 33.5 billion of US economic activity, supporting 280,000 jobs - a substantial increase over the previous year's performance.

Since 1980, when the Bayh-Dole Act made it possible for universities to take ownership of inventions from federally funded research, at least 2,578 new companies have been formed based on a license from an academic institution. Income from licenses and options amounted to \$725 million in 1998, up from \$611 million in 1997. Although these numbers point to an accelerating use of licensing and technology transfer by US universities, the potential impact on regional development in all but a few locations, is far from clear.

Although TLOs manage intellectual property, negotiate licenses, and generally serve as the formal link between academic researcher and industry, local capture of knowledge spillovers depends on a host of other informal networks and supporting institutions. Private research institutes, venture capital companies, investors, business and community organizations and a pool of foot-loose but regionally based entrepreneurs able and willing to build a new firm around an academic invention - all are necessary components of a well functioning regional innovation system. Even the best-equipped universities with the most active scientists will add little to the local economic base in the absence of a regional infrastructure that enables university researchers and their industrial counterparts to communicate and be responsive to each other's needs (Collins, 2001: 171).

2.6. Conclusion

The above discussions have highlighted a number of crucial issues. University-industry partnerships do not represent a new phenomenon and has always been closely related to the socio-economic context. There were instances of the transformation of scientific fields into industrial use since the advent of the industrial revolution. As Etzkowitz, Webster and Healey (1998: 2) argue what is new is the intensification of this process, including the shortening of the time span between discovery and utilization, and the increased reliance of industry on knowledge originated in academic institutions. University-industry partnerships also contributed to the establishment of early industrial research laboratories in various countries. University-industry partnerships have emerged as a central theme of economic renewal through various governments' initiatives, and from changes within universities and companies associated with the emergence of an innovation system based on lateral ties (Etzkowitz, Webster and Healey (1998: 7).

It has been suggested that higher education institutions are experiencing changes and would need to become more open, porous and aggressive in seeking partnerships and alliances, than they are currently (Gibbons, 1998: 10). These changes are being led as much by the internal dynamics of knowledge production as by government policy or by increasing competitiveness, which has profound implications for the future shape and social function of all the institutions of science (Gibbons, 2000:

38). As a result new modes of knowledge production or a socially distributed knowledge system (Mode 2) is emerging across the board of sciences, social sciences and humanities. This is said to be different from the current Mode 1, which denotes the cognitive and social norms that must be followed in the production, legitimisation and diffusion of discipline-based knowledge. What is important to note is that the South African higher education and science and technology policies have easily adopted this and in fact encourage institutions to re-organise themselves in ways as suggested. However, there have been various criticisms levelled against this Mode 2.

Throughout the world, higher education institutions are entering into partnerships as a way of generating supplemental funding income due to diminishing and declining government subsidy on the one hand, and the increasing demand to become accountable, responsive and relevant to societal needs on the other hand.

Technology transfer has undergone tremendous changes in the past two to three decades especially in the United States and Western Europe. These include the emergence of intellectual property, secrecy, conflict of interest and commitment and commercialisation as new terms in the higher education and science and technology policy domain. This is in addition to traditional transfer mechanisms such as hiring of graduates, consulting by university staff and publication of university research results in professional journals. Technology transfer can no longer be understood merely as a linear process, but instead as a process involving constant interaction, exchange of ideas and research results between various stakeholders, hence Gibbons et al.'s proposal of the term technology interchange. It is considered very important to economic growth, competitiveness, innovation and job creation.

The involvement of university in intellectual property is seen in different ways by staff and administrators. Some staff members see opportunities such as generating supplemental funding to cover salaries, buy lab equipment, secure student's bursaries and to keep them on the cutting edge of knowledge. It is a prerequisite for staff in certain fields, such as engineering, to be involved with industry. Others have raised concerns regarding the negative effect of economic issues on the conduct of research and publication of research results. Underlying these concerns is the view that usually intellectual property agreement comes with secrecy and confidentiality aspects, which inhibits the sharing of information and the publishing of results without any delays. There is also lack of consensus as to whether ownership and control of intellectual property should be vested with individual academics or the university administration. This is despite the fact that in general the university and industry would differ as to who should retain intellectual property and thereafter the necessary steps to be followed.

There are financial, strategic, technological, educational, political and epistemological motivations and benefits that both the university and industry can gain from entering into partnerships.

3. CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

This research investigated the evolution of the UCT-SASOL partnership, including its driving force or “drivers”, perceived motivations and benefits, and technology/knowledge transfer/transmission processes. This chapter will present the research design and methods used, outline the research aims and reasons for the selection of the case study. It also presents sections on data collection methods, field practice, data capturing and analysis and finally, the limitations of the study.

3.2. Research design and methodology

The research employed the case study design approach. This case study design incorporated five elements. Before discussing these elements, allow me to explain why a case study approach was chosen. Yin (1994:3) argues that case studies are distinctively needed to understand complex social phenomena. In this respect the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events such as individual life cycles, organisational and managerial processes plus environmental change.

In particular, the study used a single case study design. This was in part because single cases are a common design for doing case studies and can be eminently justified under certain conditions. These conditions arise for instance, when the case represents a critical test of existing theory, when the case is a rare or unique event, or when the case serves a revelatory purpose (Yin, 1994:44). Further, the case study method allows for the investigation of specific issues within their real-life context where the issues to be investigated are integrally linked to the context. It also allows for a variety of evidence to be collected, including empirical data gathered through quantitative means.

In this case study, I used multiple sources of data including documents, interviews and visits to laboratories where part of the UCT-SASOL partnership research activities were taking place. Although not considered a major issue, case study research entails one limitation. That is the data collected through the case study cannot be generalized to other contexts or social phenomena.

This case study design incorporated the following elements. First, I examined the evolution of the UCT-SASOL partnership using the “project-plus approach”. In this way, I was attempting to broaden the scope of the research. Rip (2000) argues that the basic reason to have a broader scope than just a project is that the work of the scientists is not cut up in terms of nicely packaged projects. Their achievements and the products that are created cannot be understood if one looks at individual projects at a time. Scientists are resource mobilisers and credibility seekers, building life and work in their research group, lab, and institute. A project funded by an agency or an article published in a

journal is a selection from ongoing work. To understand the dynamics, one has to check the ongoing work. It could be possible to find that the actual coherence is not in one project as such, but in its combination with previous and parallel projects, in the setting in which they occur, in the research strategies and resource mobilization strategies of which the scientists are part.

Second, I analysed the "structure of collaboration" of the UCT-SASOL partnership through the 1996 five-year Fischer-Tropsch Synthesis project. The focus here was on the "structure of collaboration" itself as an inter-organisational form, a structure that raises a number of issues independently of the fact that it combines industry and academia. For example, I was able to explore various issues such as the research agenda setting, research management, conduct of research and relationships of authority and trust.

Third, I analysed the driving force behind the partnership. Fourth, I analysed the perceptions of both UCT and SASOL regarding the possible motivations and benefits to be accrued as a result of the partnership. In this way, my approach attempted to dig deeper than an immediate institutional interface between the university and industry, by extending the focus to the individual interests of both organizations. This was done within a conceptual framework that takes both academic and industry views into account: a framework that also recognizes the possibility of benefits being directly or indirectly linked to the motivations and hence it combines them. As a result, the framework was able to identify six categories, that is, financial, technological, strategic, educational, political and epistemological. I used these categories in analysing both motivations and benefits.

Fifth, I analysed the technology/knowledge transfer/transmission processes. In this regard, undergraduate and postgraduate programmes, teaching and learning, technology transfer/"interchange", intellectual property, publications etc. were explored. The UCT-SASOL partnership seems to be focusing very much on the enhancement of technological capability development within and across the two sectors. Finally, the analysis was grounded in a thorough understanding of the technological field under investigation. The analysis was located within the socio-economic context of the partnership - especially, national development, innovation and global economy. This has provided the necessary context for understanding the rationale behind the UCT-SASOL partnership. I was also able to develop some understanding of the nature and level of contribution that each organisation was making towards the partnership.

3.3. The specific objectives of the study

The objectives of the study is:

- (a) To investigate the evolution of UCT-SASOL partnership.
- (b) To analyse the "drivers" or driving force behind the UCT-SASOL partnership.

- (c) To determine the UCT and SASOL perceptions about the educational, epistemological, political, strategic, financial and technological motivations and benefits accrued to the partnership.
- (d) To investigate technology/knowledge transfer/transmission processes involved in the partnership.
- (e) To draw the lessons that could be learnt from this UCT-SASOL partnership for future purposes.

3.4. Selection of the case study

I learned about the existence of the UCT-SASOL partnership during the initial rounds of interviews, namely with the UCT Dean of Research and Head of the Catalysis Unit, which comprised the first phase of South Africa Netherlands Programme Alternatives in Development (SANPAD) project. The UCT-SASOL partnership is an interesting case study in various ways. It represents a successful and complex example of the emergent new institutional forms of collaboration, particularly the strategic long-term alliance.

It shows the significance of an individual academic (Prof. O'Connor) as an important driver of radical change and research culture in the chemical engineering department. The legacy of this individual academic's strong personality and commitment to research is evident and continues to stimulate the great levels of research interest and teamwork among staff members which is characteristic of this department.

UCT continues to keep its long-standing relationship with SASOL in the same area of activity (heterogeneous catalysis). This relationship therefore continues to stimulate and generate funding, research activities and also contributes to capacity building. A strong link is maintained between basic disciplinary "Mode 1" teaching and research on the one hand and multi-disciplinary "Mode 2" applied and strategic research and training on the other hand. This is evident in the strong emphasis on the solid undergraduate disciplinary education as a basis for a high quality multidisciplinary postgraduate education. All staff members are involved in both teaching and research. A strong link is maintained between academic research and postgraduate activities: The department utilizes surpluses generated through industrial-oriented research to cross-subsidize the academic and postgraduate activities. The 1996 five-year Fischer-Tropsch Synthesis project emerged as a consequence of the long-standing relationship between UCT and SASOL.

3.5. Data collection methods and fieldwork practice, data capturing and analysis

3.5.1. Access and Permission

I initially approached and requested Dr. Fletcher to use the Catalysis Unit as a case study. This took place during SANPAD project interviews. He suggested that a meeting would need to be arranged between the two of us to discuss my request in detail. Prior to this meeting I needed to complete and submit to him the draft research proposal. On the completion of the proposal, I sent it to him electronically through the email. He responded by suggesting the date of the meeting on 2nd July 2002.

On the 8th July 2002 I received an email from Dr. Fletcher through his secretary accepting my request. I then contacted Dr. Fletcher to clarify his acceptance. He said that it was going to be difficult for him to grant me unconditional access and permission to conduct the case study because of the sensitivity and confidential nature of the agreement with SASOL. This meant that I would not be able to access data on the actual content of the 1996 Fischer-Tropsch Synthesis project activities. However I was allowed to analyse other aspects of the project, which were not considered too sensitive such as the management structure etc. In addition, he agreed that I could look at any other aspects of his Unit. The confirmation of this permission was sent to me one week later.

Dr. Fletcher further agreed that he was going to help facilitate gaining access to both the university administrators (especially the Centre of Research, Development and Innovation) and SASOL. This was going to make things easier and reduce travelling costs in the case of SASOL. Eventually, both the university administration and SASOL granted me the permission to conduct the study under the same conditions as set out by Dr. Fletcher.

The head of the Catalysis Unit facilitated my access and meetings with the UCT Research and Innovation Centre and SASOL participants. The selection of these participants was based on their direct involvement in the UCT-SASOL partnership. These participants were involved in the negotiations, signing of agreements and general management of the UCT-SASOL partnership as a whole and the 1996 five-year joint Fischer-Tropsch Synthesis project in particular. Their involvement started in the early 1990s; excluding the present head of the Catalysis Unit who was a postgraduate student at the time that the UCT-SASOL partnership was instigated. This partly accounts for the greater focus of the case study in the last ten years of the partnership.

3.5.2. Interviews: focus and questions

I interviewed a few individuals from the UCT Chemical Engineering Department/ Catalysis Unit, the UCT Research and Innovation Centre and SASOL management using a semi-structured, open-ended question protocol. The interview protocol included questions on the historical background, the nature

and areas of collaboration and perceptions about motivations and benefits to be accrued to the partnership. It also included questions on the driving force, the relationship between various participants involved in the partnership at various levels of both UCT and SASOL and lastly, on the organisational policies with respect to partnerships and the recommendations or lessons that could be drawn.

At the outset I conducted three interviews with the head of catalysis unit, who served as the principal coordinator of the 1996 five-year Fischer-Tropsch Synthesis project. The duration of these interviews was two to three hours. I then interviewed a UCT Research and Innovation Centre official. This official was responsible for signing and managing the UCT-SASOL partnership agreement/s from the university administration side. This interview took one hour. Finally I interviewed the SASOL manager of heterogeneous catalysis. This position was equivalent to the head of Catalysis Unit at UCT in terms of the partnership. This interview lasted one and half- hours.

3.5.3. Data capturing and Analysis

I taped and transcribed all the interviews with the exception of SASOL interview which was unclear (in this case I used my detailed field notes). I analysed the interview data qualitatively. I began data analysis by reading and re-reading transcripts. The patterns that emerged from the data collected have been coded into categories and sub-categories according to various themes. Coding reduced the data, allowed codes to be displayed, and facilitated drawing conclusions from patterns.

3.5.4. Documentary analysis

Documentary information took different forms. The importance of using documents was to corroborate and augment evidence from other data sources. As Yin (1994:81) argues the usefulness of these and other types of documents must not be based on their necessary accuracy or lack of bias. In fact, documents should be carefully used and should not be accepted as literal recordings of events that have taken place.

In particular, I undertook documentary analysis on the UCT and SASOL research management, innovation and development policy and on other documents. This was done in order to inform the development of the interview schedule, the choice of the case study and to possibly investigate a mismatch between policy texts and their application in practice mainly within UCT and to lesser extent within SASOL. I solicited various documents from UCT and SASOL. These included the following: (a) UCT strategic plans, vision and mission statements; (b) Letters, memoranda and other communiqués; (c) Administrative documents - for instance research progress reports, annual reports and other internal documents; (d) Agendas, announcements, minutes of meetings, and other written reports of events. I received some of these documents during pre fieldwork and others during interviews.

3.6. Limitations

The major limitation of this research related to the 1996 joint five-year Fischer-Tropsch Synthesis Project, a confidentiality and secrecy agreement entered into by both UCT and SASOL. I could only access and investigate the less "sensitive" elements (content) of the project, which turned out to be very useful nevertheless. As a consequence I could not explore the technology transfer or interchange in detail.

Another limitation related to the lack of insights and sufficient data on the early years of the partnership. I could not gather views of those involved at the beginning of the project. Some of these people could not be traced and others could not be available. As a way of filling this gap, I solicited the views of Dr. Fletcher who was a doctoral student at the beginning of the partnership and who was being supervised by Professor O'Connor, a leader of the UCT department at the time. In as much as this took place, I was aware that Dr. Fletcher's views could not be a substitute of those directly involved, but notwithstanding served a useful purpose by providing basic information on which I reconstructed my case study.

4. CHAPTER FOUR: PRESENTATION AND DISCUSSION OF MAIN FINDINGS

4.1. Introduction

This chapter will present and analyse the main findings of the study according to the objectives (themes) of the study. That is, (a) the evolution of the UCT-SASOL partnership and the 1996 Fischer-Tropsch Synthesis project, (b) the driving force or "drivers" of the partnership, (c) the perceived motivations and benefits of the partnership, and finally the knowledge/technological transfer/transmission processes.

4.2. Evolution of the UCT-SASOL Partnership

4.2.1. Background and emerging patterns

Twenty-one years ago, the University of Cape Town appointed Prof. O'Connor as a senior lecturer who later became the head of the Chemical Engineering Department (Catalysis Unit). Challenges facing Prof. O'Connor, which were the weaknesses of his department, included the lack of research culture, activity and infrastructure and research expertise. In other words, the department was not in a position to respond to the needs of its environment, which was industry development. As Dr. Fletcher suggested UCT has to be involved with industry in one way or another in order remain at the cutting edge of research. Knowledge production and be relevant to the development needs of the country.

At the beginning, Prof. O'Connor often made brief visits to the Gold Reef Mines and industries (including SASOL) during vacations. Accompanying him was the group of final year students who were provided with an opportunity to gain industry exposure, training and networking necessary for future employment, research collaboration and sponsorship etc. One of the key objectives of Prof. O'Connor's visits to the industries was the building of trust and openness necessary for the establishment of a long-term partnership. Through these visits UCT managed to (a) establish the current partnership with SASOL, (b) develop strong a research capacity and infrastructure in various fields such as heterogeneous catalysis and (c) continue to access and generate more funding for research, teaching and postgraduate studies.

It is interesting to note that the SASOL was prepared to initiate a partnership with UCT, despite the fact that UCT did not have the same kind of expertise and competencies that existed within SASOL at the time. During the first 10 years, the main objective of the partnership was the training of students. Some of these students later became the employees of SASOL. There was also an advisory board established to look at issues such as funding, student placement, curriculum etc. Dr. Fletcher

described the advisory board as "very capable and consisting of technical representatives from many of the major corporations in South Africa".

Then SASOL became more interested in the output of skilled graduates subsequently committing itself to the long-term collaboration with UCT. In this regard SASOL asked UCT to offer a Masters programme (course work). This programme was aimed at providing SASOL employees with an opportunity to be re-trained and to improve their skills, competencies and qualifications. This in turn was going to contribute to SASOL's technological capability and innovation. Several SASOL employees have participated in the Masters programme. They usually spend four months at UCT doing course work and return to SASOL to do their theses. SASOL set and select the theses topics for its employees. The topics are selected on the basis that they are in line with what SASOL considers as its top priority demands. SASOL also allocates supervisors to work with students in conducting their theses.

Subsequently, the focus of the UCT-SASOL partnership changed to the output of research results rather than output of people. This happened at the same time that SASOL put a strong emphasis on the deliverables of research and technological results. According to Mr. Gibson "UCT is now capable of meeting these deliverable demands of SASOL. This has influenced SASOL's commitment to continue with the partnership" (interview 08 November 2002).

The partnership has impacted positively on both UCT and SASOL. SASOL continues to provide UCT with financial assistance for education (in the form of bursaries), research and service. In doing so, SASOL has helped UCT to pursue such objectives as training students for undergraduate and postgraduate qualifications, increasing knowledge through research, disseminating new knowledge through publications and adding to the economic development and wealth creation. On the other hand, UCT meets the needs of industry by continuously adapting its engineering undergraduate and postgraduate curricula, by promoting scientific and industry oriented research, disseminating research findings and transferring technology to industry.

The legacy of Prof. O'Connor continues to be reflected in the ongoing activities of the department. His enthusiasm and commitment to research has encouraged everyone in his department to start conducting research. In Dr. Fletcher words, "everyone wanted to get on the train. It just sucked everyone else in". His research approach i.e. that a researcher should visit and find out about the industry's needs so as to develop appropriate research, contributed to the radical break from the conventional academic frame in the applied engineering field and the prevailing approach to problem-solving activities. Especially, in South Africa and UCT in particular it was not common for an academic to "cross" university/industry boundaries by directly approaching industry and working there, instead of waiting for industry to commission work to be done by the university.

Prof. O'Connor's mission proved to be highly successful and laid a strong foundation for future research in the department. Subsequently, departmental research has grown into five different programme groups in which all staff members have been involved. These groups form the focus of the department's research activities. Staff members were discouraged to initiate new focus areas outside this framework. The five programmes are: catalysis group (20 years old), minerals group (20 years old), environment engineering group (10-12 years old), bioprocess engineering group (10-12 years old) and engineering education group (8 years old).

4.2.2. Types of Research undertaken

The chemical engineering department has been involved in different types of research projects. That is, first, strategic research such as the 1996 Fischer-Tropsch Synthesis project in which both UCT and SASOL collectively decided on what the project objectives and research methods should be and constantly engaging each other on the research results. The research was undertaken both at UCT and SASOL laboratories involving constant feedback and consultation. Secondly, the department conducted contract research in which the industry identified the problem and then requested UCT to do some tests on its premises. UCT would suggest materials, source them, run and deliver the collective results, which would then effectively be 'bought' by the company.

In smaller contracts companies usually ask: will you run a bunch of tests on these things for us? Which means we would often suggest the materials, we would source them, we would run the collective results, we would deliver those results to them, and they would essentially buy it? Based on our other experiences and skills we have in the house, we would do that. There isn't a lot of it, say, intellectual thinking going on. They need it, they don't have the expertise to do it and not very sure how they should run the experiments, and that's why they come to us (Interview with Dr. Fletcher 2002 August 2002)

According to Sheen (1998: 199) contract research offers no opportunity for new insights. By far the greater proportion of work done, when companies require external expertise, is not novel. Nor are the academics the best people to conduct work requiring routine problem solving but high input and process skills, or to give a low cost service. It is for this type of service that the contract research organisations are in business (1998: 199). Nevertheless, at UCT contract research seems to have a positive effect in that it is used to sponsor academic research and services.

In the third type of research, UCT plays the dominant role in the applied research and research capacity building activities. In particular, postgraduate research is by and large in the area of applied-research and aligned to industry. Dr. Fletcher said that his department is supposed to be training and "brewing" postgraduate students for future applied industry research. The university has received philanthropic donations and student bursaries to develop human capital and research infrastructure.

In collaboration with an unnamed company, Dr. Fletcher said his department identified the problem and relevance of the project. The company did not lay down any stringent guidelines; everything was left to UCT. Again, the long-term association with SASOL is an example of this. SASOL has, for many years, provided donations to build human capacity and equipment.

According to the Catalysis Unit 2001 Annual Report (5), the process of research consolidation over the past several years would appear to have reached its full practical extent for the immediate future. Although, by its very nature, research direction is constantly under review as a result of an ever-changing flux of new discoveries, ideas and industrial imperatives, it is necessary for many reasons that the unit concentrates its activities within a certain core focus. As things currently stand, that focus consists of research and development in three areas, viz.

- (a) Shape selective materials and processes. This is based on long established activities in the field of acid catalysis by clays, zeolites, and other micro-porous materials, and is now focused on the application of these materials in the general field of phenols and derivatives.
- (b) Fischer-Tropsch synthesis now firmly established over the years relates to a key South African technology position and is an area in which the Unit can and should take a leading position with time.
- (c) Novel systems in that the subject of catalysis by gold has developed out of a general activity in novel systems, including oxidation catalysis. Given the limited capacity of the Unit as well as domestic interest, the novel catalysis by gold currently dominates this research focus. The earlier activity in oxidation catalysis continues on a smaller scale, however, it is expected that with the anticipated association of an additional academic at the University of Stellenbosch, oxidation catalysis will re-establish itself as a substantive activity, parallel with gold catalysis.

It is clear that the Catalysis Unit is engaged in different types of research projects with the industry. At this point I would like to closely examine one of the key projects of the UCT-SASOL partnership, i.e. the 1996 five-year joint Fischer-Tropsch Synthesis project.

4.2.3. The 1996 UCT/SASOL Fischer-Tropsch Synthesis Project

4.2.3.1. Background and purpose

As a consequence of their long-standing partnership, UCT and SASOL established the five-year Fischer-Tropsch synthesis project in 1996. Fischer-Tropsch Synthesis fulfils an important technological role to both UCT and SASOL. It is firmly established and related to a key South African technology. Over the years, SASOL set its primary focus on innovating new or improved products and processes, especially in the fields of Fischer-Tropsch gasification and allied petrochemical process technology. To this extent SASOL has proved that the group's Fischer-Tropsch technology can be used effectively to convert natural gas to high-quality liquid fuels and petrochemicals (SASOL Facts, 2000). The 2001

Catalysis Unit Report states that UCT can and should with time take a leading position regarding Fischer-Tropsch synthesis.

The overall aim of the 1996 Fischer-Tropsch synthesis project was to innovate and improve the products and processes of SASOL. In this regard, UCT was expected to generate innovative 'ideas', which were supposed to be used by SASOL in product development. Underlying this was the interactive process that involved constant exchange of research results and ideas between UCT and SASOL. Dr. Fletcher stressed that SASOL has the capacity to conduct its own research and do what UCT was asked to do. Instead SASOL opted that UCT take this role. First of all, UCT has over the years "developed huge expertise and remains the only substantive training centre in the heterogeneous catalysis" (Dr. Fletcher interview 2001 February 21).

In the past UCT used to import expertise from as far as Germany in order to develop its capability in heterogeneous catalysis. It has also succeeded to attract foreign experts to join its research team. Secondly, SASOL "probably wanted to add strength on its thinking and knowledge base, and therefore sought outside and independent expertise in the form of the UCT department" (ibid.), a point which was echoed by Mr. Gibson (2002).

Both UCT and SASOL view the 1996 Fischer-Tropsch Synthesis project as crucial in enhancing their existing partnership, and building further capacity. Throughout the project UCT remained circumspect about not becoming what Dr. Fletcher termed as "merely an extension of SASOL research". In this regard, it kept its focus on its specific task of generating 'ideas'. Dr. Fletcher argued that SASOL has never prescribed to UCT what research to undertake. Instead, SASOL would sometimes suggest what "should be tried out". SASOL was continuously "looking for something different". At times SASOL would ask UCT to comment on certain ideas. If these were found useful and promising, then both parties would come together and develop proposals that could further explore those ideas. This was the procedure that had been followed throughout the project.

What they want us to do is come up with ideas for improving a product and they want us to demonstrate that by doing experimental showing, improved performance. We would not develop the improved product. They would take it and work it out themselves. They want to know what are the ideas, let's try the ideas, see what we have got, whether it is promising, it's the proper relationship. They are using us to do what supposedly we can do right and not asking us to do what they can do themselves (Interview with Dr. Fletcher 2001 February 21).

In the first phase, which has been running a year, we had to demonstrate that our own equipment could do the same as theirs. At the moment, that we can take theirs and get the same performance, and that we can reproduce the synthesis. We have already filled in the forms moving into the next year and they are saying right up front. Tell us what we think they

should list in the contract. They are open to it. But they are not telling us what research to do. They are actually asking us, what do we think should be tried out? One should probably get nervous about these things but we are not working as an extension of their research, they are looking for something different, asking us to think about these things, to come up with suggestions, how do you make it better, and then they'll listen to these, they may have tried some of these things themselves in the past. So it's a good idea, collectively we will come together with a proposal. We will then go and do it, give quarterly feedback, or invoice them in advance (interview with Dr. Fletcher 2001 February 21)

This project entails some unique features as compared to most university-industry partnership projects. Without being repetitive, both UCT and SASOL were willing to share, run and manage the project collectively without losing their identities as two distinct organizations. In addition the project has some interesting analytical dimensions, which are worth exploring, such as the following.

4.2.3.2. Relationships of Authority and Trust

It seems that the 1996 Fischer-Tropsch Synthesis project was established upon existing strong relations of trust between UCT and SASOL authorities on the one hand, and between these authorities and academic scientists and industry researchers on the other hand. This is clearly reflected in the management structure and decision-making processes of the project in relation to research activities. Central to the management structure was the intricate combination of hierarchical and participative elements. Built on this structure was the devolution of decision-making powers to lower levels in which academic scientists and industry researchers were represented and actively involved. In ensuring the smooth running of the project, the steering committee, comprising representatives from both organisations played an overall coordinating function. The principal idea was that should the research discover any findings, these would be forwarded to this committee to make final decisions. The senior representatives such as the Dean of Chemical Engineering faculty were rarely consulted.

4.2.3.3. Research Agenda Setting

Webster and Etzkowitz (1998: 62) suggest a number of questions that can be used to generate answers in order to deepen analysis and understanding of the issue of a research agenda setting in the context of a long-term alliance such as the UCT-SASOL partnership. These questions include: (a) what managerial autonomy does the research team involved in collaboration have in deciding their own programmes and in allocating resources to facilitate them? Clearly, agenda setting would depend on a sponsor's capacity to control and direct academic research. (b) What is the cultural and organisational link between the in-house corporate R&D and the academic centre's own research? (c) How much interchange of personnel, findings, technologies, and materials occurs? The analysis of the 1996 Fischer-Tropsch Synthesis project could only help to address these questions.

In terms of the first question, the 1996 Fischer-Tropsch Synthesis project clearly indicates that the research teams have the management autonomy to make decisions about the direction of the research activities and have been able to define problems and experiments. Research teams were able to basically run the project without the interference of the senior authority. This occurred through the steering committee, which served as an engine of the project. In terms of the second question, the evidence available might be limited to give the full picture. However, based again on the same 1996 project, the project was "co-managed" and "co-developed" meaning that there was close and constant interaction between UCT and SASOL. The management structure consisted of various representative committees involving both organisations. In terms of the third question, the research teams shared materials, laboratory facilities, findings etc.

To some extent the project can be characterized as an example of a non-linear "technology flow," rather than the older forms of "technology transfer" associated with the traditional consulting and contract research arrangements. That is to say, new organisational forms break down traditional boundaries between the two sectors in which the construction of research programmes displays an interactive, feedback, or spiral process (Webster and Etzkowitz, 1998: 52).

4.2.3.4. Project management structure

A fairly complicated project management structure had evolved in order to accommodate the aim of joint participation and decision-making. The project was co-managed and co-developed by both UCT and SASOL. They were equally represented and participated in all decision-making processes. This involved generating ideas and proposals collectively, and agreeing on the subsequent research development steps.

It's not even co-managed; it is intentionally co-development. At the functional level, their guys and our guys are effectively working on it together. Collectively deciding what should be done and what the results mean. They get the raw data, they look at it, and it's a total participatory thing. It's not a question of we do the work. It's a joint research team. In principle we could even run some of the experiments here. So far it's all over there. If something interesting comes out it all happens there. What happens next is that their guys pickup and take it there, and tune it up. And leave us to get onto the next idea type of thing. In the end that's how we would use their and our lab. In essence their technical people and our technical people agree jointly to the experiments, they get done, everybody gets the data, argues about what the stuff means, etc. Because of the pressure of day-to-day business, we do it. The plan is that the steering committee must meet at least 3 times a year. The technical guys need to meet face-to-face we have telephone conferences. We really are trying to work as a team. You are sitting a thousand miles away from each other and you

have got to make effort to keep the team functioning. Even the social stuff (Dr. Fletcher interview 2001 February 21)

To this end, an interesting communication media strategy had evolved. First, there was no fixed venue for meetings. Second, meetings involved face-to-face and telephone conferences, which often occurred. The research members who were dealing with technical aspects of research were supposed to meet face-to-face. The purpose of using various forms of meetings was to promote "team work". One could understand this communication media strategy as an attempt to facilitate the free flow and exchange of ideas, and make interaction between academic scientists and SASOL researchers much easier.

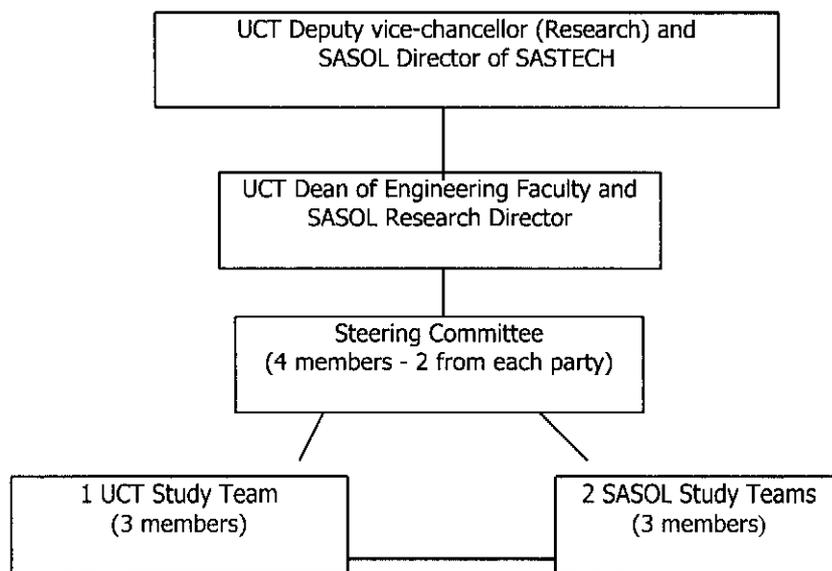


Figure 1 shows the 1996 UCT-SASOL Fischer-Tropsch Synthesis project management and decision-making.

The management structure appeared to be the intricate combination of hierarchical and participative elements. But as shown in Figure 1 above, the main activities and decisions were taken at the lower levels. At the lowest level, there were separate Study Teams on both sides; each comprising three members who focused primarily on actual research activities. Research findings, as they arose, were then submitted to the next level, the Steering Committee. This committee was responsible for the overall functioning of the project. It consisted of four members, two from each partner and held meetings four times a year. It was the "engine" of the project, where research progress was reviewed and crucial administrative decisions were made. The aim was to reach decisions by "unanimous consent". In instances where this was not attained, the matter was referred to the senior representatives of the management teams, which, in the case of UCT, was the Dean. Should the matter still remain unresolved, it was then referred to the highest level, which comprises the UCT Deputy vice-chancellor of Research and the Director of SASTECH (SASOL). Dr. Fletcher indicated that,

in practice, the Steering Committee managed to resolve all matters, and nothing was referred to the higher structures.

We have a budget; if we don't spend it they keep the money. We take the profit always; they know what the profit is; it is specified. If we didn't have to buy equipment, or employ someone and they only come on board halfway through the year, obviously they don't take the money. They know exactly what is going on. In the same token if during the year something comes up and we need something, like last year we ran out of space. But you know what research is like you never know what is going to happen. It's a good system, the money is on the table, and there is no suspicion. If at the end of the year they want the entire account, every nut and bolt, they can have it. That helps. Because once the sum of money gets substantial, then people get nervous. It's a long relationship. What we spend, we spend, if we need more we have to motivate before we spend it. This works well. It's a good approach especially when people don't know each other so well. The account is totally transparent (Interview with Dr. Fletcher 2001 February 21)

The above discussion has shown new interesting organizational forms embedded in the 1996 Fischer-Tropsch Synthesis project such as co-development and a collective decision-making research process. Academic and industry researchers were autonomous to the extent that they could decide on the direction, control and running of the project. Both organizations showed great level of trust and respect for each other and also senior authorities (both sides) entrusted lower level staff members with powers to run the project without interference.

4.2.3.5. Modes of Knowledge Production

The main research actors involved in the 1996 Fischer-Tropsch Synthesis project were UCT and SASOL. The UCT group consisted of five academics with different disciplinary backgrounds. These were: Prof. O'Connor - Dean of the Faculty of Engineering (a chemist by training); Dr. Jack Fletcher (a chemical engineer); Dr. Eric van Steen (a chemical engineer); Prof. Mark Dry (a retired chemist who worked at SASOL for many years); and Dr. Klaus Moller (a chemical engineer).

I followed a two-pronged approach in analysing this issue of knowledge production. That is, (a) a specific focus on the 1996 Fischer-Tropsch project in relation to the kind, function and purpose of knowledge produced and (b) the perceived tension between basic and applied research and even strategic and "Mode 2". First, it was clear that the 1996 Fischer-Tropsch Synthesis project was neither pure basic research nor "Mode 2" based on its characteristics. Instead it appears to be strategic research, which refers to basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognized current or future practical problems (Irvine and Marvin (1984: 4). It appears that, in terms of its role in the project, the

university has received a fairly free mandate to explore various innovations related to the process of catalysis. While this appears to constitute primarily applied research, the highly collaborative project management structure and close interactions among the university-industry partners suggest something more of an applications-driven mode of knowledge production, associated with Gibbons' Mode 2. As indicated, while the aim of the project was not directly product development (at least from the UCT side), it was expected to generate innovative "ideas to improve the product" and to apply such ideas in product development in order to enhance SASOL's long-term competitiveness locally and internationally. The research appeared to be more multi-disciplinary than trans-disciplinary in nature.

So then the fact is that all issues out there, industrial in life, developments are not about chemical engineering or electrical engineering or chemistry or physics, they are about making more quality environments. That's not taught at the university. That's a problem, which involves all kinds of things, developing corn, growing corn, harvesting corn, guys doing grinding and the mixing and the baking and the cooking. So there is a whole range of different disciplines, which come into that problem. That's how all problems typically are. So that's when the multi-disciplinary approach has to happen naturally. If you try to package that into pieces, as maybe was the approach you don't make progress fast enough. You cannot first do the basics and then pass it on to this guy and then he passes it on to the next guy. It's too slow a process. Probably you could find that in the industry twenty years ago that's what happened. The guy who does some conceptual designs and then it went to the next step. And it probably took three or four years to get a car from start to the production platform. Whereas today they do it in short times because the concept guy, the engineers, the users, they are all in the first meeting. You throw all the stuff into melting pot. That's a multi-disciplinary thing. It's a natural thing once you are doing it (Interview with Dr. Fletcher 2001 February 21)

In the 1996 Fischer-Tropsch Synthesis project knowledge produced appears to have a dual function: instrumentally, to improve SASOL's products and competitiveness thus benefiting the company, the country's economy and ultimately the consumers, as well as scientifically to add to the existing knowledge base. In meeting the first function, the university was going to benefit in that the knowledge produced was to become a commodity, which could enhance the university's commercial interests and second stream income generation.

There seems to be some form of assumed and indirect social accountability in Dr. Fletcher's comments of "making more quality environment". The 1996 project work was of a highly technical nature. It required high commercial confidentiality, which excluded the participation of various social agents (even students) in the knowledge and product enhancement process. As a result, knowledge remained highly codified, scientific and expert-driven.

In the second function, most scholars including (Louis & Anderson, 1998:80; Feller 1990; Etzkowitz and Stevens, 1998:230) have argued that maintaining an appropriate balance between basic research and commercial objectives is an area of tension (Smith, 1984 cited in Louis & Anderson, 1998: 80), as is the related question of research direction. To the extent that external institutions seek to direct academic research based on their own interests, faculty members become subject to controls inconsistent with their professional roles and the purpose of their work (Blevins and Ewer, 1988 cited in Louis & Anderson, 1998: 80).

I have discussed issues around the research agenda setting and to some extent the purpose of the work above. In this case study basic and applied research were substituted by use of "scholarly work" and "industry type research" by participants. Balancing "scholarly work" and "industry type research" is creating difficulties, but Dr. Fletcher insisted that his department is able to strike the necessary balance. However it appears as if the department is aligning itself more towards the applied side than the basic side. Conducting engineering research is always expensive, especially in the light of diminishing state funds; only industry would be able to provide funding. Engineering like all other applied fields is more disposed towards applied and industry oriented research, in order to remain on the cutting edge of knowledge and technology and to be relevant to the particular country's reconstruction and economic competitiveness needs.

Training real people to go out and do pretty mundane stuff better, so the country gets wealthier, everyone lives a better life. That's all we are about. It's what the whole engineering discipline is there for. It's about making the country better. (2001 February 21).

And look there are things, which is a key intermediate for a whole range of things. It's around that, which we should go and look for opportunities, which are relevant to this country. Task number one should be to go into the South African industry, and see what is going on there, look at the general opportunities there and you work on things, not necessarily identified by them. We are going to start a new student on a project now and we have our own totally crazy idea of how we might make it. There is no such process out there, or in South Africa. But it's all about female chemistry, which is very relevant in this country. Within that you automatically set constraints because you say let's do it this way, it's very interesting. The question is what is the demand for the product realistically, what are the alternate routes, which are out there, does it really make sense? We always put those constraints on because it's what happens in the real world. You raise this issue of scholarship and the ... balance between scholarly work and industrial type research and then we do contract type. We do both, at least being in the context of the South African industry and South African opportunities. It doesn't mean we don't do academic research, we do but we don't really handle those things. For the simple reason no one pays for it, because once you are in the applied field like engineering, it's expensive to do the work. There is only a limited

slice of state funds. If you are in basic things like chemistry, where you don't have to spend to do simple experiments, then you can do much more academic, scholarly activity. It's appropriate. With engineering it's always expensive, and there are not state or university funds. You getting it from industry and they don't always prescribe what you do, but they like to see that its semi-relevant (Interview with Dr. Fletcher 2002 August 20).

4.2.3.6. Fragmenting the Collegial

This research further confirms that by their very nature, applied fields are more closely linked to their environments. As Ashford (1983, cited in Louis and Anderson, 1998: 84) points out, past ties with commercial organisations have made academics in engineering, medicine, and chemistry "kindly disposed towards industrial goals" (17, see also Smith 1984). Faculty in applied fields are far more likely than faculty in non-applied fields to be involved in research centres funded either by government or by private corporations. Areas such as engineering not only have ready outlets for the results of their research, but also in fact developed in large part in response to problems posed by external constituents:

At some institutions, in departments of engineering, physics, and biophysics, more than half the faculty is involved in some significant way in industry. And they do so not for financial gain, but because in these fields the cutting edge-or some element of the cutting edge-is, in fact, in industry. If they want to be at the cutting edge and if they want their students to be there, then they naturally work with industrial research groups (Dialogue: Disclosure of conflicts of interest 1985, 38 cited in Louis and Anderson, 1998: 84).

4.2.4. Diversified Funding

The Chemical engineering department receives industrial funding through long-term research projects, academic research and postgraduates. The money generated through contract research is used to "cross-subsidize" academic research and services. In general SASOL provides UCT with different forms of funding ranging from unspecified and general (philanthropic) to goal oriented and specific projects and bursaries.

We do it all the time. We make a profit off the industrial work. I would almost put three categories, that is, long-term research, academic research, then there is maybe where you use post-graduates, then you have other postgraduate projects which I would call industrially aligned research. In other words, we don't get money specifically for the results, there is no embargo on the funds, it's a home study, we choose. But we choose it in the context of South African Industrial issues and opportunities. Although it is relevant (Interview with Dr. Fletcher 2001 February 21)

It's a pragmatic approach. The problem is people say we are going to start making money out of research and our target is 50 million a year and royalties and therefore we have to have ownership of everything, we have to patent everything. You should look for royalty income and you should look to get maximum value of course, and industry would expect it but you need to do it within a reasonable boundary (Interview with Dr. Fletcher 2001 February 21)

In addition to that we do contract research. On the contract research they gain experience. We unashamedly try and make the most profit that we can. That money supports the other two varieties. On this applied research we sometimes differ, typically Anglo Gold now where I had the money coming through a city group, or the guys in the city. But we ourselves decided that the project is relevant and is part of the training and they are happy. They don't tell us exactly what to do. Also in that area, like with SASOL we get a donation every year, which has been for many years. Which we use as we see fit. We can even use it for academic research. And then of course we get something, which they want; the numbers and they want it by a certain date. But the profit of all those stuff goes into the remainder of the activities (Interview with Dr. Fletcher 2001 February 21)

Based on the above comments, it seems that UCT's approach to industry is partially profit-motive driven. UCT establishes relations with industry in order to remain relevant and to be aware of existing opportunities to do research. UCT seems to be convinced that it provides necessary experience and expertise to the industry through research. UCT always attempts to strike a balance between scholarly work and industrial oriented research. UCT seems to be always cautious about not allowing the industry to define, shape research questions, and the research process. The evidence seems to suggest that the involvement of the department in contract research entails a positive impact on other activities of the department. It was mentioned earlier that, contract research cross-subsidizes academic research and service activities. This case reminds one of the Iowa State University case (see also Sheen 1998: 199).

4.2.5. Departmental culture (Chemical Engineering-UCT)

The departmental culture appears to provide enabling conditions for a flexible and less hierarchical leadership to create a highly collaborative and participative environment in which staff members support each other. This is made possible by the fact that the department operates like a "family unit". There seems to be a sense of belonging and commitment to the shared goals. The head of department is not appointed on the basis of seniority or experience, but instead the position rotates. This rotation of leadership has led staff members to support anyone heading the department. By lending the support individual staff members are securing and guaranteeing themselves similar support for the future. Staff members work as team, even though their research activities are

independent. Every staff member is involved in both teaching and research. The department usually holds regular meetings each week on Friday morning. In Dr. Fletcher's words this is "holy time" during which staff members discuss various issues, including undergraduate and postgraduate teaching, management and other administrative matters of the department. This "holy time" serves as an important function as an informal discussion forum for scientists. As Eva María Mora Valentín (2000: 168-9) notes informal discussion is an important means of intellectual exchange among scientists. In this respect, it is very important for firms to define which research results can or cannot be divulged (2000:168-9)

4.2.6. Reputation or "brand name" of the department

According to Dr. Fletcher three factors have contributed in building his departmental reputation. Firstly, the chemical engineering department is "one of the few places" that has managed to maintain a long-standing relationship with the same company (SASOL) involving the same activity (heterogeneous catalysis). Secondly the department offers a quality undergraduate programme, which is attractive to most companies. This programme is rooted in strong and solid disciplinary fundamentals. Thirdly, the department has quality and high rate of outputs in terms of postgraduate programme and research activities. In fact, the department has the largest postgraduate programme in its field in the country and its postgraduate students are highly sought after by industry.

We are trying to raise money now, not years down the road. The amount of money is not important as long as it helps us attract world-class academics; academics from overseas to come and spend time here. Part of the answer was that over the last twenty years it is one of the few places, where the relationship and the activity are still there. All the others you put money in for about five years and it falls apart because the guy picks up and moves or goes somewhere else. That is something to overcome. Resources are tight, we are not doing it because it is slightly nice, academic, it's very much a ... decision and if things don't stay the course then the business doesn't work. There are plenty exceptions, you cannot always solve things in research, you can make mistakes. But if you do not manage it well, to let it fall apart, to let things come and go, keep pouring money in, it's a bit of a hit and miss on the success. We have been fortunate, but it is ingrained in the way we operate that the thing must be able to survive otherwise everyone suffers. The reputation of the organisation is first. There are a lot of other issues. There is no doubt that the twenty-year history helps us (Interview with Dr. Fletcher 2002 August 20)

It's very important, then you have to say there is the mineral activity, process control, environmental, etc. and everyone has come to a stage where we have to build relationships. We now definitely have an advantage of twenty years of success. The fact that I can go to someone I don't know out there, I mean chemical engineering at UCT that helps a lot. That

answers a lot of questions immediately. Now the track record is a huge advantage. If you have delivered goods consistently in the past, there is an automatic kind of, they will find somebody you have worked with in the past and ask do you know who this is at UCT, and he will say, no he is a great guy. That opens a lot of doors for you (Interview with Dr. Fletcher 2001 February 21)

4.3. "Drivers" or Driving Force

When asked to comment on the driving force behind the partnership, from the UCT perspective Dr. Fletcher indicated that in the first instance Prof. O'Connor pioneered and facilitated the establishment of the partnership.

This department research activity really kicked off because of an individual. Its growth, the size and the success of it kind of bootstrapped the whole process. Everyone is now very much involved and there is a strong feeling you cannot do good teaching if you do not have a strong research basis. So that is how it is going and I would still say if you want to get something started, you need a young academic or whatever, to get out there and get involved (Interview with Dr. Fletcher 2001 February 21)

Secondly, the Catalysis Unit brand name and reputation has attracted considerable work over time. It has successfully delivered on its commissioned work, and has thereby managed to sustain long relationships with certain companies, such as SASOL for the past few decades.

But now having a 20 or at least a 15 -year substantial track record, with industry and it is the same company in so many ways and it is much easier to kick off something. Now you say that I am in chemical engineering at UCT and I want to do research and there is a lot of credibility at our place that it will get done (Interview with Dr. Fletcher 2001 February 21)

Thirdly, the need to generate funding.

So you have to go and do the selling yourself. But having said that, the South African industry has got a very open ear and if you can convince them of what you want, they will give you some money and you can make good of that money and do a good thing and keep things stable (Interview with Dr. Fletcher 2002 August 20)

To do engineering research is expensive - you cannot get that kind of money from the university/state, so in a sense it has always been industry research (Interview with Dr. Fletcher 2002 August 20)

Finally, the unbundling of both local and international companies such as Gold Fields and Anglo-American led to the outsourcing of major non-core functions, including research. For Dr. Fletcher these big companies "have an open ear and invite universities to undertake outsourced research". Universities are considered to be "less risky" and have been proven to be "more efficient" in doing industry-related research. Related to this, some companies lack the capacity to conduct the sort of research necessary for their technological development and innovation.

Universities are expected to be inventing and finding new things. That is what industry is doing, especially in the first world. In South Africa, you have to recognise that we don't have that depth of research capacity. The country is too small to carry huge research departments. That is why people come to universities in this country [and ask them] to do what in the developed world would happen inside industrial companies (2002 August 20).

From the SASOL perspective, Mr. Gibson highlighted three things as driving the partnership. First, the Management of Catalyst Unit or Chemical Engineering Department has always seen the relationship with industry as crucial and has also seen the need to deliver on what the industry needs in terms of skilled manpower production and technology development. Second, UCT has always been willing to work with SASOL whose primary focus is in applied research and delivery of research results. Recently, the partnership has focused on technological deliverables, and UCT has proved that it could deliver. Third, in order for SASOL to excel in its core technology, it needs the university to strengthen what SASOL has in terms of existing competencies.

4.4. Motivations, Benefits and Obstacles

4.4.1. Motivations and benefits

This analysis is located within the framework developed in Chapter 2. The analysis is underlined by the idea of linking of motivations to the expected benefits. Eva María Mora Valentín (2000: 166) suggests that the benefits achieved can be expected to be directly or indirectly linked to the motivations. There are six categories used to analyse motivations and benefits as discussed below. These are financial, technological, strategic, educational, political and epistemological.

Table. 2. ³Benefits and Motivations for UCT and SASOL Partnership

Benefits and Motivations	University of Cape Town (UCT)	SASOL
Financial	Received funding from SASOL that could be used to pay salaries, conduct research, and develop infrastructure, service, student bursaries and scholarships. This is against the background of declining government subsidy and demands for greater accountability.	Commissioning university to do research involves some cost reduction and sharing risk.
Technological	<p>(a) Working and conducting industry-oriented research assist UCT academic scientists to remain at the cutting edge of knowledge and technology development so that it can be able to respond to the needs of the country ("development"). In other words, gaining access to the current scientific and technological developments contributes towards UCT remaining responsive and relevant. Obviously the 1996 Fischer-Tropsch project provided such opportunity for academic scientists and industry researchers to exchange ideas, knowledge and technological experience in a collectively shared way.</p> <p>(b) UCT academic scientists are able to access SASOL laboratory equipment and materials. This was evident in the 1996 project.</p>	<p>(a) SASOL wants to retain competitive edge and strengthen its comparative advantage. As Mr. Gibson said that in order for SASOL to excel in its core technology, it needs the university, to strengthen existing competencies. This finding confirms what Louis and Anderson (1998: 79) and Blumenthal et al. (1986) argued that from the standpoint of industry, access to researchers at the cutting edge of knowledge provides valuable advantages for commercial development. This access is viewed as the most beneficial of university research sponsorship by firms engaged in biotechnology (Blumenthal et al. 1986a cited in Louis and Anderson, 1998: 79).</p> <p>(b) Has continuous access to the UCT high-level expertise, such as competent and experienced academic scientists.</p> <p>(c) The 1996 Fischer-Tropsch is one of R&D collaboration between the organizations.</p> <p>(d) The enrolment of SASOL staff at UCT allows for re-training and upgrading of skills and competencies both critical to SASOL.</p>

<p>Strategic</p>	<p>(a) The long-term strategic partnership with SASOL has opened UCT access to SASOL funding, research support and activities, R&D activities and other funding agencies or institutions.</p> <p>(b) "The Catalysis unit is the huge asset, and leading training centre in South Africa". It has contributed to the development and growth of heterogeneous catalysis, which is critical to SASOL. In particular, UCT has done well in developing its Fischer-Tropsch Synthesis techno-logical capability, a key to South African technology and to SASOL in particular.</p> <p>(c) The 1996 Fischer-Tropsch Synthesis project seemed to have provided an opportunity for academic scientists to gain management experience. The overall management and coordination of the project involving committees representing both university and industry rested with the academic scientists.</p> <p>(d) Keeping the partnership for twenty-one years. It has increased credibility and reputation for the UCT department necessary for future funding and research opportunities.</p> <p>(e) UCT believes that working and conducting industry-oriented research help them to remain on the cutting edge of knowledge production and be relevant to the needs of the country.</p>	<p>(a) UCT has produced a number of graduates some of whom become SASOL employees after completion. During their studies, students find opportunity to conduct their theses or practical work at SASOL under the supervision of SASOL staff. As a result SASOL finds an opportunity to know its potential future employees.</p> <p>(b) Keeping the partnership for twenty- one years has improved SASOL's confidence and trust that UCT is capable of delivering, hence more collaboration projects.</p> <p>(c) The Catalysis Unit is unique or the only leading plant and training centre in South Africa in the area of heterogeneous catalysis, which is critical to SASOL.</p> <p>(d) The existence of trust, confidence and mutual respect between the organisations has lead to the consolidation of the partnership and perhaps to some changes in the nature and form of research projects pursued such as the 1996 Fischer-Tropsch Synthesis project. In the context of highly competitive global economy, it is even more imperative to have a trustworthy partner so as to avoid any unnecessary disclosure of information to the competitor. All industries need to keep their comparative advantage a secret within itself.</p> <p>(e) SASOL approached UCT because the management of The Catalyst Unit or chemical engineering department "has always seen the relationship with industry as crucial</p>
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		<p>and also the need to deliver on what the industry needs in terms of skilled manpower production and technology development” (Interview with Mr. Gibbons 2002 November 08).</p> <p>(f) UCT’s willingness to collaborate with SASOL in its focus areas, by means of applied research and delivery of research results. The partnership is currently focusing on technology deliverables.</p>
Educational	<p>(f) UCT graduates find jobs at SASOL after completion. As Mr. Gibson put it “UCT produces skilled graduates who do not need more time to settle before delivering on productivity”.</p> <p>(g) UCT students usually conduct their practical and theses work at SASOL.</p> <p>(h) UCT provides an opportunity for SASOL employees to be re-trained and improve their skills, competencies and qualifications. These employees access UCT knowledge base laboratories and impart their skills to the fellow students and academic staff.</p> <p>(i) UCT staff have been involved in knowledge diffusion through interacting with SASOL researchers, findings, personnel and telephonically etc.</p>	<p>(g) SASOL employs UCT graduates - including highly skilled post-graduates with PhDs that allow access to new knowledge and skills etc. Most UCT graduates adapt easier and quicker. This facilitates and enhances productivity.</p> <p>(h) SASOL employees who are registered at UCT usually conduct their theses at SASOL. The research topics are chosen in line with SASOL needs and under the guidance of experts.</p> <p>(i) Consistent access to academic staff with necessary experience and competence.</p> <p>(j) SASOL sponsors post-doctoral students from overseas, and that could benefit host institutions. It also offers scholarships for students to study abroad.</p>
Political	<p>(j) Partnering with the industry helps to enhance UCT’s reputation with government, which is committed to strengthening university-industry links - see White Paper on Science and Technology 1996, Integrated Manufacturing Strategy, 2002 R&D Strategy etc.</p>	<p>(k) SASOL has described its association with UCT to be in line with the recent “Proud South African campaign”, a government sponsored campaign. Therefore, SASOL described itself as a proud South African company committed to the transfer of skills and knowledge.</p>

		(l) Partnering with the university enhances the industry's reputation to government and supports its initiatives aimed at strengthening university-industry partnerships; White Paper on Science and Technology 1996; Integrated manufacturing Strategy, 2002 R&D Strategy etc.
Epistemological	(k) The 2001 Catalysis unit report indicated that the department produced six Journals, one chapter in a book, four Ph.D. theses, eight MSc. theses and nine published conference proceedings. Part of this is related to the ongoing research partnership between UCT and SASOL. (l) UCT provides additional and independent thinking, ideas and scientific solving approaches	(m) It has access to UCT academic scientists with concentrated great expertise in the field of heterogeneous catalysis at the Catalysis Unit.

Source: adapted from the model of Aution et al (E. Aution, A-P Hameri and M. Nordberg, 'A Framework of motivations for industry-big science collaboration: a case study', *Journal of Engineering and Technology Management*, Vol. 13, 1996, pp. 301-314 cited in Valentín E.M.M (2000) 'University-industry cooperation: a framework of benefits and obstacles', *Industry & Higher Education*, Vol. 14: 3 June, pp. 165-172,

4.4.2. Obstacles to the UCT-SASOL Partnership

This analysis is located within the framework developed in Chapter 2, in analysing obstacles whether stated during interviews or gathered through documentation. Firstly, *Restrictions imposed by industry*. The evidence drawn out of the 1996 Fischer-Tropsch synthesis project indicates that UCT and SASOL collectively identified and agreed on the choice of research topics for the 1996 Fischer-Tropsch Synthesis project. On the *discussion among scientists*, the department has formally set aside weekly meetings to allow staff to exchange views on wide-ranging issues. However, it appears that the 1996 Fischer-Tropsch Synthesis project confidentiality agreement could impact on the extent and nature of what academic scientists involved in the project could share with others. In this regard, it is possible that academic scientists could only share views on what might be deemed to have less prejudicial consequences to SASOL patenting.

Secondly, *appropriation of the research results*. There is no evidence in this respect, since nothing novel had been discovered in the 1996 Fischer-Tropsch Synthesis project. Thirdly, *communication related problems*. It appears that UCT and SASOL managed to avert some of the communication

related problems during their 1996 Fischer-Tropsch synthesis project. This case could be classified as an example of a successful collaboration regarding communication etc. Fourthly, *research term*. Eva María Mora Valentín (2000) argues that whereas R&D managers prefer to carry out research oriented towards short-term practical problem-solving academics naturally adopt longer-term views. Firms usually press universities to perform short-term research, contrary to the academic inclination (169). This case study has found that part of what UCT does is short-term practical problem-solving mainly requested by companies. However there are also research projects such as the 1996 Fischer-Tropsch Synthesis project established to deal with long-term practical problem solving.

Fifth, *Culture*. The case study findings support the view of certain authors (Eva María Mora Valentín 2000; see also Harman, 2001: 247 and Hernes and Martin 2001: 82; Matlay 2000; Louis and Anderson, 1998: 82; Blevins and Ewer, 1988: 654; Buchbinder and Newsome, 1985: 45; Dierdonck) who have suggested that cultural differences might be regarded as constituting the main obstacle to university-industry links. This was evident when UCT and SASOL advanced different approaches on intellectual property rights during the negotiations of the 1996 Fischer-Tropsch Synthesis project. These approaches were to a greater extent informed by differences in cultural backgrounds. Obviously at the end a compromise was reached.

It is clear that the UCT-SASOL partnership has yielded numerous benefits, which provides sufficient motivation for its continuity. These benefits range across human resource development (training of UCT students, and SASOL staff members), technology transfer or interchange, technology development and research capacity development etc. At the same time the partnership has experienced some obstacles. Fortunately, most of these obstacles were overcome so that the partnership still succeeds and continues.

4.5. Knowledge and Technology Transfer/Transmission Processes

4.5.1. Teaching and learning programmes

Interestingly, from the perspective of this study, the department maintains a close relationship between teaching and research. The department insists that all staff members should teach as well as be involved in research. Dr. Fletcher said that his department views research as underpinning good teaching and vice versa. The department's ongoing contacts with industry provide knowledge of relevant cutting edge developments and the opportunity to continually update the curriculum. The department emphasised basic disciplinary material and skills.

In order to teach well, you have to do research. The fact that we have a very active and confident research activity means that we are in touch with industry we know what is going on. The fact that we teach fundamental stuff, basic stuff, regularly every year keeps you on

your toes when you are doing research. These things are now at your fingertips, the fundamentals are there (Interview with Dr. Fletcher, 20 August 2002).

The department believes that it is important to have a solid undergraduate programme that produces many graduates. This is crucial for both postgraduate and research programmes to succeed and not fall apart. The undergraduate programme has significantly contributed to the department's brand reputation and through its quality undergraduate students

The department continually reviews its curriculum - from design to methods. This is in line with department's constant question of what type of an engineer it wants to produce. To that extent Dr. Fletcher argues that "at the undergraduate level, the engineer should be trained to be stronger technically" - that is, students should attain proficiency in the basic engineering disciplines. In the case of chemical engineering, undergraduate studies should therefore produce an engineer who "can work in plants and do design generally" in industry. An in-depth and strong discipline based education is "an essential prerequisite if you want to do something in the technical field". This should constitute 80% of the curriculum. Therefore few options and specialization are offered at the undergraduate level.

The Chemical Engineering Department is emphasising the teaching of the "fundamentals" as opposed to teaching "various applications". According to Dr. Fletcher (2002) it is not important to know everything, but that students should rather understand the basic tools or basic principles in order to become "rock solid" with them and to be able to use these in different scenarios. The idea is to produce people who are "equipped for what ever is out there". Dr. Fletcher argues that his department always tries to keep a balance between the fundamentals and what students should learn to apply in different contexts.

At the postgraduate level, discipline based education is less emphasised and instead, research in context, in which various disciplines combine and interact is much more important. Dr. Fletcher said that, for instance, in catalysis, "you need physicists; you need applied mathematicians; you need engineers; you need material scientists". This field requires a "multi-disciplinary understanding". Unlike the undergraduate programme, the postgraduate programme trains people in "research, technology and specialized information". The postgraduate programme is industry-oriented. Dr. Fletcher insisted that the success of the postgraduate programme depends on the quality of the sound grasp of fundamentals at the undergraduate level.

Catalysis is a good example, you need physicists, and you need applied mathematics. So it's an incredibly multi-disciplinary thing to have any measure of understanding of it. You are into that whether you like it or not (Interview with Dr. Fletcher, 21 February 2001).

It appears as if industry plays an important role in shaping and influencing the curriculum design and content of the department. The professional statutory body, the Engineering Council of South Africa, in which companies and organisations like SASOL, AECI and the CSIR are represented, set the requirements and criteria for certification of all degrees offered in the department. In this regard the industry is therefore not only involved in utilizing the "end product" of the educational process but also in the process itself. In the first instance, it is in the industry's interest to hire graduates who possess both generic knowledge and aptitudes - job-relevant know-how and particular skills - so the industry feels somehow obliged contribute to the curriculum.

Generally, individual firms sometimes exercise indirect influence by providing opportunities for practical training (internships, co-operative education placements, practice, and the like) which, in many professional and applied fields, is required as part of the academic programme. While such industry placements provide students with the opportunity to apply theoretical knowledge to practical problems, for companies this means ongoing contact with faculty and opportunities for feedback concerning the relevance of the academic curriculum.

In addition, the department has developed entrepreneurship oriented training programmes for students interested in developing business ideas. Dr. Fletcher described this move as "innovation thinking" which emphasises the "real world and experience-based learning". The introduction of such programmes followed the realization that students are increasingly less likely to find employment with large companies such as Anglo-American and Gold Fields due to unbundling, outsourcing and other restructuring processes. Therefore the intention is that graduate engineers should be equipped to start their own businesses and create employment. The question has arisen whether the department has the capacity to teach entrepreneurship. Accordingly, it was resolved that the UCT Graduate School of Business would teach and provide contacts to final-year students.

In a good team you have those generalists and you have the specialists. That's just the nature of problems. We believe that well they are engineers so they need to be able to communicate well, they should understand about law, they should understand a bit about industrial law and employment law and about businesses and managing businesses and finance. Well if they are going to do all this stuff when am I going to teach the guy the engineering part. So it's a continual battle and one keeps going over, the pendulum swings back and forth, but we have a very capable industrial advisory group in this department with a technical representative from many of the major corporations in this country. Whenever we come up with content and things, they'll say no its fine, do research. The big thing is innovation. And we teach innovation. They are engineers, they are not going to go out and work for the Anglo-American and the Goldfields of the world, because those companies are splitting up and outsourcing. So he must start his own business. That's the whole idea of being an engineer, to create employment. So the question is should we be teaching

entrepreneurship, could you teach it, what should you teach? And in fact we are doing it, we have the business school come and teach our final year students, giving lectures on entrepreneurship, what is it about, how does it work, where do you get contacts and support. Because we recognize that a lot of our graduates will not go into big companies. So all these things are relevant because you don't go and work in a disciplinary company anymore. Especially if you start your own business. And there is more need to go and be entrepreneurs. Then it doesn't have to be whiz electronic specialist; there are companies like that. The feeling still is they want all this, they want good communication skills, they want understanding of law, business and entrepreneurship and people relations. Because you have to do these things in life. But they are all saying not at the expense of a thorough engineering ground. So you have to balance it. There is a feeling that people have to be more rounded. Fit into a group but not at the expense of the others. And that is a tricky thing. In many ways we promulgate that by saying, even in chemical engineering lets not teach a lot of content. Let's teach principles. Teach them quite a bit of concepts of these processes. Whereas in the past one tendered to say let the person really understand this by taking those concepts and applying them to process A, and another one which is B and C. There are different ways of separations, liquid extraction, etc. In a sense you took the fundamentals and showed them how to apply it to the different processes. It was a good teaching approach, it was practical and the same fundamentals are applicable in many situations (Interview with Dr. Fletcher 2001 February 21)

The Chemical Engineering Department seems to be clear that its undergraduate programme should remain solid and disciplinary based. It is important to empower students with necessary fundamental skills so that they could be able to work competently under different contexts/conditions. At the postgraduate level, the department seems to be convinced that students must be equipped with multidisciplinary skills so that they could deal effectively with "problems" defined as complex and multidisciplinary. The industry plays an important role in influencing the curricula in line with "market needs". This happens in different ways, sometimes in formal ways like participating in the advisory board, and in other instances through internships, funding etc.

4.5.2. Research Capacity and technology transfer

This analysis is premised on the notion of technology with two dimensions, that is, tacit and codified. In this regard, first of all, UCT consciously employ young staff and attracted a few retirees some of whom have worked in SASOL before. An example is Prof. Dry. The mixture of the young and old blood is meant to provide an opportunity to transfer skills, knowledge and expertise. In addition, through their vast experience and widely connected networks, the older staff members are supposed to mentor and expand access opportunities for young staff in terms of securing funding and establishing research networks etc. Secondly, the department enrolls 95 postgraduates, 65 of whom are full time

and the remainder part time students. One Ph.D. and four full-time MSc. students and ten part-time students are working on the SASOL sponsored projects except in the 1996 Fischer-Tropsch Synthesis project.

Historically, the most prized output of the Catalysis Research Unit has been its graduates with MSc and Ph.D. degrees in catalysis and, in this regard, the Unit has reached a milestone whereby the total number of such higher degrees awarded through the Unit exceeded 50 for the first time. Indeed, by the end of 2001 the University had awarded 57 higher degrees as a result of studies conducted in the Catalysis Research Unit since the first one in 1982. In recent years the number of degrees awarded has increased substantially from one or two per annum in the early years to eleven in 2001. With the number of students studying for higher degrees in catalysis expected to remain stable over the medium term, it is conceivable that at the time of its 25th anniversary in 2006, the Unit may be in a position to celebrate its 100th graduate.

Thirdly, SASOL usually sends its staff to do UCT Masters degree course-work, at least for three months, and their theses back at SASOL. Most of these staff members are well experienced; they could impart their skills and expertise to other fellow students and even academics during course-work. While at the same time drawing from the university academics the latest technology skills, knowledge useful for their SASOL work. I need to emphasise also that UCT send some of its postgraduate students, even though not sponsored by SASOL, to do their practical and thesis work at SASOL. SASOL experts would be allocated to supervise these students. Fourthly, in 2001 the Unit successfully "experimented" with the employment of two technikon NDip (Chemical Engineering) candidates for the 1-year in-service training requirement of the diploma course. These students participated in the research activities and were given an opportunity to make presentations to companies as a way of networking and exposure. It was suggested that the Catalysis Unit would continue to seek out capable candidates to do internship, as an effective way to cover short-term technical personnel needs.

4.5.3. Intellectual Property Rights

Innovation and commercialisation constituted top priorities in the UCT Vice-Chancellor's 2001 vision. In terms of this vision, innovation and commercialisation processes are supposed to facilitate UCT to grow and develop its ability to "profit from research", and to establish " a strong link between intellectual work and commercial and social benefit" (UCT Department of Research Development document, 2002). UCT has identified the establishment of UCT Innovation Ltd. and UCT Ventures Inc. as key drivers for the commercialisation process. UCT Innovation Ltd. has been earmarked to deal with patents, licensing, marketing, business plans, incubator and entrepreneurship. Whereas UCT Venture Inc. has been earmarked to deal with venture capital, and spin-off or start-up ventures. In addition, both these initiatives/companies were expected to serve as 'strategic partners' for the

university. In fact the UCT Innovation Ltd is an officially registered company now, although it is still non-functional. Whereas the UCT Venture Inc. has not yet been formally established.

When asked to comment on the issue of intellectual property rights, the interviewees held different views, which was more evident in the case of the 1996 Fischer-Tropsch project. Mr. Barnard indicated that since the university is providing infrastructural support, time, space and other resources to the faculty, it is entitled to all intellectual property rights. This is the similar line of argument that the university initially advanced during 1996 Fischer-Tropsch Synthesis project negotiations with SASOL. Obviously this view changed at the end of the negotiations to accommodate SASOL. Subsequently the university has developed an approach informed by the view that any decisions on intellectual property should be based on individual cases.

According to Mr. Gibson if SASOL has funded the particular project, then it should be entitled to all intellectual property rights. This view is being consistently maintained in all SASOL negotiations including the 1996 Fischer-Tropsch Synthesis. In this regard, Dr. Fletcher did not see anything untoward when SASOL demanded to retain all intellectual property rights since they funded the 1996 Fischer-Tropsch project. This was as long as SASOL agreed to reward the university when the IP became commercially exploitable. Mr. Gibson contended that there was no mechanism existing to determine the price for the reward in the absence of the secured patent. Even if the patent was available, one needed to know its impact on the overall performance of the company.

Dr. Fletcher (2002) argued that, during most negotiations with industry, university officials seem to focus on maximizing income through such industrial contracts. This is based on the assumption that academics develop an innovation, which the university would want to patent, license to the company concerned and earn royalties. The idea is that in ten years' time half the budget would be based on royalties. Dr. Fletcher's view is that while this remains a grand idea, it is "a bit misguided". Universities are "right in making demands for publication and ownership". However he warned that this attitude needs to be balanced and should not "chase away the clients".

The 1996 Fischer-Tropsch Synthesis negotiations concluded that SASOL was going to retain all intellectual property developed during the project. UCT was going to retain a non-exclusive royalty-free, a non-transferable license to use all such subject matter for research, teaching and publication purposes. However, this was contingent on SASOL's approval. In the case of SASOL abandoning the intellectual property, UCT had the right to take ownership of the IPR at its own expense.

Dr. Fletcher raised the view that SASOL does not know how to handle intellectual property issues related to its partnership with UCT. But Mr. Gibson dismissed this view by arguing that SASOL has "a capable intellectual property office and its position on intellectual property is consistent throughout all partnerships between the company and universities" (2002 November 08). There was a consensus

between Dr. Fletcher and Mr. Barnard about the point that UCT lacks the necessary capacity (legal expertise) to handle contracts with industry. Although the Research and Innovation centre was improving its dealings with industry from what it used to be in the past.

4.5.4. Publications

Publication of results is often described as the traditional process of technology transfer/knowledge transmission processes. At the same time it often becomes a highly contested issue between university faculty, university administrators and industry. This is so because the university and industry operate according to different "ethical codes". The behaviour of academic communities is based on ethical norms such as common ownership of the body of knowledge generated through scientific activity, freedom to publish research results, professional prestige and the quality of research and knowledge generation. In contrast, the behaviour of the industrial community centres around the privacy of knowledge obtained through research, the secrecy of research findings, profit making, business planning, and competitiveness (Eva María Mora Valentín (2000: 169).

In some instances, these differences have been used to explain the decline of scientific publication outputs. According to Blumenthal et al. the university consulting appears to be the primary source of difficulties. This means that, high levels of research funding from industry do not appear to have a negative effect on research productivity, but exclusive or extensive consulting is associated with lower publication rates (Blumenthal et al. 1987 cited in Louis and Anderson, 1998: 240). Moderate consulting does not appear to interfere with scholarly productivity, but is associated with a reduced commitment to teaching (Boyer and Lewis 1985 cited in Louis and Anderson, 1998: 240). This is contrary to my findings, which indicate that the department has done well both in terms of productivity and publications. Dr. Fletcher indicated that the Unit is able to "strike a good balance and remains the highest within the Engineering faculty in terms of contract research and publication output". This was further corroborated in the Unit's 2001 Annual Report. The Report indicated that the Catalysis Unit had produced six journal articles, one chapter in a book, four Ph.D. theses, eight MSc. theses and nine published conference proceedings. Considering the impact that consulting could have on teaching and learning, the department subsequently employed a full time person. This person's sole responsibility is to enhance and improve the teaching and learning and ensure that the department does not neglect these critical functions.

Analysing the aspect of the 1996 Fischer-Tropsch Synthesis project agreement on publication was interesting. First, it appears that both UCT and SASOL recognized that not all research results lead to patenting. As a result the agreement was developed in such way that it embedded this recognition, which would allow for UCT to publish as many results as possible subject to SASOL approval. The agreement made a 30-day provision for SASOL to review the UCT proposed manuscript intended for use of publication. SASOL could only refuse UCT if the manuscript carried commercial prejudice. UCT

had an option of either to remove the prejudicial information, and re-submit the amended manuscript to SASOL on the same conditions as mentioned before. Or subject to the provisions of Clause 6.1 (which deals with confidentiality), delaying use or publication for a period not exceeding 30 months, allowing for the possibility of prior securing of intellectual property rights. Further analysis is needed to probe the submission, amendment and feedback processes of the manuscript. What gets cut out or added? Why? Or whether academics engage themselves in some "doctoring" of their conclusions as a way of circumventing industry objections? What impact does this have?

There are some other aspects that come in. A lot of universities sometimes see industrial contracts and say we can skim off some money. There is always this thing that we are going to cash in big time. Our academics are going to come up with this thing, we are going to patent it, license the company and the university is going to take its royalties and in 10 years time half our budget will be royalties. It's a bit misguided that vision but it is not something to not go after. The scale needs to be more readable. The problem of this grand idea of making a lot of money is that now they get into a contract and say we have to own it, we have to have the right to publish this. If you don't push that these guys will say forget it. We have had huge battles over the last couple of years. I appreciate the universities' principles that we should publish the university names. Some of the universities in South Africa took on military contracts, they still do. But in those days it was secret. The guy has got his degree but no one has ever read his thesis. There is a bit of a history here but the fact of the matter is to absolutely insist that we must own this and publish this because that is what we are. The spirit is right but it is the 80/20 percentages. Trying to squeeze out the last 20 percent, all you are going to do is chase away the clients and all you get is a few extra publications (Interview with Dr. Fletcher 2001 February 21)

But it's a mix. We have tried to keep it clean, because the university doesn't like us. The university gets very unhappy that the contract allows the company to put a prohibition on publications. They don't like signing those contracts. As much as we tell them we have been silent for twenty years, we have never been told that we can't publish it; we often have to tell them. It works, every time you get a new guy running the Directorate of development down the road and he wants to get all clean and official, like a textbook. It's quite an activity (Interview with Dr. Fletcher 2001 February 21)

Mr. Barnard indicated that in terms of UCT policy, academic scientists and students should publish their research results within two-years. Regarding industry-oriented research, UCT take decisions based on the individual cases.

There is no doubt that the issue of publications will generally remain thorny between universities and industries because of different backgrounds. However, the Chemical Engineering Department seems

to be doing well in keeping the balance between high publications (as compared to other departments) on the one hand, and conducting industry-oriented research on the other hand.

4.6. Conclusion

This chapter has discussed various interesting findings. The continuing existence and success of the partnership is derived from the fact that it has existed for twenty-one years. Throughout this period, both organizations have developed confidence, mutual respect and trust for each other, the effect of which has been increasing innovative collaboration projects such as the 1996 joint five-year Fischer-Tropsch Synthesis project. This project was the shared and collective responsibility of both organizations. There was equal representation in all committees and decision-making processes. The management structure was less hierarchical and participatory with academic scientists and industry researchers playing a greater role in the control and direction of research. Researchers were able to take crucial decisions without the interference of the authorities. They were able to communicate effectively and exchange ideas, research results etc. Initially the partnership focused on the supply of an educated workforce. Subsequently postgraduate output and technological deliverables constituted a broad mandate of the partnership. Part of this was the establishment of the masters' degree programme that allowed SASOL staff members to upgrade their skills, knowledge and expertise.

The partnership has diversified UCT funding. SASOL has made philanthropic donations that helped to build the research infrastructure, pay salaries, student bursaries and internships. It continuously supports contract research. This contract research supports academic research and service. In as much as SASOL provided funding to UCT, it also gained through reduction of costs and sharing of risk. The partnership has contributed by improving and maintaining the competitive advantage of SASOL (the 1996 project) on the one hand, and the growth and development of UCT's technological capability, especially the heterogeneous catalysis, on the other hand.

The partnership contributes to capacity building in that UCT students sometimes visit and spend time at SASOL as interns, and this offers them practical training, exposure and the possibility of employment. Knowledge diffusion takes place through student supervision and staff exchanges and visits. The partnership offers an opportunity for both UCT and SASOL to access resources namely equipment and materials as well as expertise and scientific breakthroughs and technological advances. It can also be viewed as response to the growing demand to strengthen ties between the two sectors.

There are numerous drivers of the partnership including Prof. O'Connor and the need to generate supplementary income etc. UCT offers attractive and quality undergraduate (solid and disciplinary-based) and postgraduate (multidisciplinary) programmes, which result in many companies hunting down students for employment and building the reputation of the department. The partnership also

battles with the tension between conducting basic research and publishing on the one hand and industry oriented-research and remaining relevant and responsive to the development needs, on the other hand. University administrators, academic scientists and industry always contest the control and the ownership of intellectual property. This has also been the case with UCT and SASOL. The partnership managed to deal with some of the obstacles that threatened to destroy it. An example of this is the negotiation agreement of the 1996 Fischer-Tropsch Synthesis project. Some of these findings are further discussed in the next chapter 5.

5. CHAPTER 5: SUMMARY AND CONCLUSIONS

5.1. Introduction

This chapter is divided into three sections. The first section summarises the key findings, which is done under the four objectives (themes) of the study. The second section draws together the key lessons and puts forward several recommendations to improve the university-industry partnership. Finally the chapter identifies issues for further research.

5.2. Summary of Key Issues

This study investigated the evolution of the UCT-SASOL partnership, which included the analysis of the driving force, perceived motivations and benefits, and knowledge/technological transfer/transmission processes characterizing the partnership. The results show that:

5.2.1. Evolution of the UCT-SASOL partnership

5.2.1.1. Emergent new institutional forms of collaboration

This case study contributes to several other studies⁴ that demonstrate that long-term formal links between universities and industry are completely feasible, despite possible obstacles. The UCT-SASOL partnership was established twenty-one years ago and has continued ever since with the same field of study (heterogeneous catalysis). This has led to numerous research projects (such as the 1996 Fischer-Tropsch Synthesis project), human resource development (training of staff and students), technology development and diversification of the funding base (UCT in particular).

Both organisations have developed a great deal of trust, confidence and respect for each other. SASOL continuously provides funding to UCT. This is in part because UCT has proved that it could deliver on SASOL demands. Whether SASOL funded UCT because it was cheaper and quicker to achieve its goals by funding academics as Webster and Etzkowitz (1998: 53) suggest, is not clear. I would agree with them though that this case resembles others in that it might have been based on a convergence of interests or mutual affinity between the scientific concerns of the company and the university (Webster and Etzkowitz, 1998: 53).

The UCT-SASOL partnership (especially the 1996 project) confirms the conclusions of Garnsey and Wright, (1990 cited in Webster and Etzkowitz (1998: 53) that the development of strategic alliances allows mobile "innovation teams" to cross the institutional boundaries of industry and academia, providing a much more flexible and effective innovative environment for the large corporation (Webster and Etzkowitz (1998: 53). Indeed the attractiveness of this type of coalition to industry no

doubt reflects the growing need for new, flexible organizational structures within which innovation can occur (Webster and Etzkowitz (1998: 53-4).

They also argue that it is possible to link the growth of these alliances to the shift in the character of the manufacturing industry. That is, from large-scale, less research-intensive mass production in which modern corporations orchestrate their productive activities in a more flexible, decentralized way, relying on new technologies while contracting out specialized functions to others such as "discovery labs" in academia. Flexibility is required in order to remain competitive in a global economy where there are no safe havens, even for long-established large companies (ibid. 53-4).

5.2.1.2. Consulting relationships

Etzkowitz, Webster and Healey (1998: 3) suggest that consulting-relationships typically involved brief visits to industrial sites or the conduct of discrete projects on university premises. This has been happening ever since the advent of industrial revolution. At that time there was a clear separation between academia and industry. A consequence of this separation was that it left control of commercial opportunities of academic research in the hands of industry whereas control over the direction of research and choice of research topics was left to academic scientists. Therefore there is nothing atypical and strange about Prof. O'Connor's brief visits to the Gold Reef Mines and industries (including SASOL) during vacations. However UCT engineering academics were not involved especially in consulting relationships when visiting the industry sites. Perhaps in that sense one can say Prof. O'Connor's consulting relationships were important and indeed laid the necessary basis for future long-term research collaboration (such as with SASOL), and for funding opportunities and technology transfer or interchange.

The mere fact that UCT initiated the partnership with SASOL was in itself not surprising. Considering that universities are frequently the initiators of cooperative ventures with industry rather than vice versa (Olswang and Lee 1984 cited in Louis and Anderson, 1998: 79).

5.2.1.3. Shift in leadership approach

The evidence seems to suggest that the leadership of UCT's Chemical Engineering Department has over time evolved into what Webster and Etzkowitz (1998: 48) term academic entrepreneurship. The traditional perception of the entrepreneur would be someone who undertakes fundraising activities to support research (Vollmer, 1962 cited in Webster and Etzkowitz, 1998: 48). Again traditionally, the organizer and fund seeker for a research group does not affect the channels through which research results are distributed except to increase the flow through them, for example through more papers presented at conferences, additional submissions to journals, and so on. Perhaps too, the entrepreneur shapes the production of academic research by introducing a division of labour into the

academic research unit over and above the traditional division of labour among researchers at different sites.

What is interesting about the more recent forms of academic entrepreneurialism is the role the academic plays as the organizer of start-up companies based on academic research, sometimes though not always in partnership with a large private-sector company, Webster and Etzkowitz (1998: 49). There is an element of continuity with the prior traditional role here in as much as organizing a research group requires skills and power similar to those of a research manager in a firm. The research team is like a quasi-firm with the principal investigator directing the research overall and taking responsibility for personnel management, strategic direction, and fundraising. However the key factor for the new academic entrepreneur is the need to take decisions about R&D that are informed by the profit motive. What is the effect of the introduction of the profit motive on shaping the research direction in academia? Krinsky (1991 cited in Webster and Etzkowitz (1998: 49) has postulated from his data on collaborative ties (such as professors' memberships on scientific advisory boards and roles in forming firms) that such effects exist but has not been properly documented. If such a relationship were found to exist, proponents and opponents of collaboration would interpret it quite differently: the former as a useful redirection of effort and the latter as a loss of academic autonomy.

5.2.1.4. Industry primary interest

This research seems to confirm Louis and Anderson's (1998: 86) analysis regarding industry's primary interest in universities. Louis and Anderson argue that the industry's primary interest in universities has traditionally focused on their supply of an educated workforce. This fact explains industry's support of higher education through such mechanisms as philanthropic donations, internships for students, and participation in disciplinary advisory boards. Increasingly in recent years, industry's funding of graduate study has supplemented more traditional forms of support. Moreover, the increase in the commercial value of university research has broadened industry's interest in faculty work, potentially increasing both university-industry interaction and interdependence.

Responding to this interdependence, my analysis agrees with Louis and Anderson that on the industry's side, one mechanism by which organisations seek to moderate their dependence is by obtaining ownership of research results (see the 1996 Fischer-Tropsch project). On the university side, the Louis and Anderson study and this case raise different interesting points. They argue that on the university's side, strategic mechanisms for tempering industry's influence include maintaining diversity in external funding sources and approaching university-industry linkages with enough caution that overall industry support remains a relatively small proportion of funding for academic research (1998: 86). This is true because in the USA industry support (proportionately) much less university research and in fact much more comes from the federal government. In this case study data, though

limited, seems to suggest that UCT would like to see more funding from industry. As Dr. Fletcher argues "engineering research is always expensive and there are no state or university funds. You are always getting it from industry and they don't always prescribe what you do, but they like to see that it's semi-relevant" (Interview with Dr. Fletcher 2001 February 21).

5.2.1.5. Diversified Funding and Contract Research

This study shows that to some extent the approach of the Chemical Engineering department is partially cost-recovery driven. To conduct engineering research and maintain laboratory equipment in a good state is expensive within the context of diminishing state resources and subsidy. The department views its involvement in industry-oriented research as allowing it to know about industry needs, which is necessary to develop appropriate research questions and topics. It also allows the department to do relevant research and be responsive to the country's development needs. There is always an attempt to keep a balance between scholarly work and industrial oriented research. The department is always cautious about not allowing the industry to define and shape research questions and the research process.

Contract research has positive impact on other activities of the department. Basically it cross-subsidizes academic research and service activities. This brings to mind the Iowa State University case (see also Sheen, 1998: 199).

SASOL' s funding to UCT ranged from research specific to non-specific projects to philanthropic donations including student bursaries. The department has managed to use this funding to pay salaries, buy laboratory equipment and materials and generally to maintain the laboratory in good condition.

5.2.1.6. Culture and Reputation of the Department

The leadership of the department is flexible and less hierarchical. The head of department is elected on a rotational basis, which makes all staff members potential heads of department. This also serves to ensure that staff supports whoever is in charge. The department is a highly collaborative and participative environment in which staff members support each other. Basically it operates like a "family unit" where there is a sense of belonging and commitment to the shared goals. All staff members are expected to teach and research. Teamwork is strongly encouraged even in research. There are research programmes within which staff members are expected to develop their niche areas. Staff members find time to discuss various issues such as teaching, research and administration always on a Friday.

The department has developed its reputation by being one of few places that has been involved in a partnership with the same company for twenty-one years. This has led to both organizations developing confidence, mutual trust and respect for each other. The department offers a quality undergraduate programme, which is attractive to most companies. This programme is rooted in strong and solid disciplinary fundamentals. Thirdly, the department has quality and high rate of outputs in terms of the postgraduate programme and research activities. In fact, the department has the largest postgraduate programme in its field in the country and its postgraduate students are highly sought after by industry.

5.2.1.7. The 1996 Fischer-Tropsch Synthesis Project

There are many interesting things about this project. Firstly, it was established as a five-year joint venture between UCT and SASOL. Its overall aim was the enhancement of SASOL's products and processes (technology). In addition it was going to consolidate and improve the technological capability position of UCT in Fischer-Tropsch synthesis, which SASOL has proved can be used effectively to convert natural gas into high-quality liquid fuels and petrochemicals. SASOL considered collaborating with UCT because of its huge concentrated expertise and experience and the fact that it remains the only substantive training centre in the area of heterogeneous catalysis.

Secondly, the project was jointly shared and the collective responsibility of both UCT and SASOL. In this regard the project management structure promoted equal representation and participation in all committees and decision-making. There was clear delineation of roles and functions of various committees, at the same time powers were devolved to committees at lower levels so that they could make crucial decisions without interference from the authorities. Lower committees were important because it is where academic scientists and industry researchers were represented.

Thirdly, academic scientists and industry researchers were autonomous and influenced the control and direction of research, and the choice of research design etc. There was a constant exchange of ideas, research results between the academic scientists and industry researchers. Fourthly, the project is an example of strategic research. Fifthly, the project evolved effective communication strategy that minimized communication problems usually associated with university-industry partnerships. Sixthly, the project managed to resolve tensions around intellectual property in the manner that to a greater extent accommodated the interests of both organizations.

5.2.2. Drivers or the Driving Force behind the UCT-SASOL Partnership

A few drivers of the UCT-SASOL partnership have been identified here. First, it is Prof. O'Connor who pioneered the establishment of the partnership and his legacy is still evident in the Chemical Engineering Department. Second, the strength of the partnership lies in the fact that there is strong

mutual trust, confidence and respect existing between the two organizations. This has contributed in ensuring the success and sustainability of the partnership. Third, UCT has proven that it can deliver on its commissioned work, produce research results and sustain collaboration with SASOL for twenty-one years. Thus leading to SASOL to committing itself towards a long-term partnership with UCT.

Fourth, the partnership enables UCT to generate supplementary income in the climate of diminishing public resources and the expensive nature of the laboratory equipment etc. Fifth, the leadership of the UCT Chemical Engineering Department is continuously viewing its relationship with SASOL as crucial. As a result the department has ensured that it always delivers in terms of the industry needs such as skilled manpower production and technology development. Sixth, UCT has always been willing to work with SASOL whose primary focus is applied research and delivery of research results. Finally, SASOL require UCT to add and strengthen its existing competencies for SASOL to excel in its core technology.

It is interesting to note that perhaps only the first and fourth drivers are widely reported in the literature. The rest seems to be new and could represent an important source of learning about successful long-term term partnerships.

5.2.3. Motivations, Benefits and Obstacles to the University-Industry Partnership

Motivations and benefits of the UCT-SASOL partnership are clearly summed up and interlinked in chapter 4 according to six categories i.e. financial, technological, strategic, educational, political and epistemological. Without being too repetitive, the results show the following. On the university side, first of all, UCT managed to receive funding for salaries, research, teaching and learning programs, and student bursaries through the partnership.

Second, UCT graduates find employment at SASOL. UCT academic scientists and students have access to SASOL equipment and materials and scientific and technological experience. SASOL is well established in the heterogeneous catalysis and has helped UCT to develop this technology. Third, academic scientists gained access to industry managerial experience, which was evident in the jointly managed and developed 1996 Fischer-Tropsch Synthesis project. There were also expectations that this project would lead to scientific breakthroughs and progress.

Fourth, UCT students sometimes visit and spend time at SASOL as interns, and this offers them with practical training, exposure and the possibility of employment. Knowledge diffusion flows through student supervision and staff exchanges and visits. Fifth, the university improves its reputation as the institution that is responsive to government initiatives especially those encouraging strong cooperation with the industry. Sixth, the department keeps high publication and postgraduate output records as

compared to other departments in the faculty. There is an extent to which its research results contribute to testing existing theories, formulating new hypotheses and generating new paradigms.

On the industry side, firstly, the partnership contributes in reducing costs and sharing risk. There is always a sense in which public funds subsidize the industry projects. Secondly, SASOL has managed to access the university's resources (laboratory equipment and materials, academics and students), and managed to upgrade its competencies such as sending of staff to do Masters degrees and employing university graduates, hosting academics etc). There have been few R&D collaboration projects such as the 1996 Fischer-Tropsch Synthesis project. There is always a possibility for projects to lead to technological advances or radical innovations. Thirdly, it has access to the database of potential employees (students), and has developed a long-term strategic alliance with UCT. The 1996 Fischer-Tropsch Synthesis project was meant to maintain or improve the competitive advantage of SASOL. Fifthly, it has access to the new knowledge in the university laboratory. Sixth, it has increased its reputation and contributed to national competitiveness. It has shown to be responsive and relevant to government initiatives such as to strengthen ties with university etc. Seven, it has access to innovative scientists and the catalysis unit which is the only centre of its kind in the country specializing in heterogeneous catalysis.

When compared to other studies, this case study contradicts the results found in the study conducted by ⁵Lopez-Martinez, Medellin, Scanion, and Solleiro (1994 cited in Eva María Mora Valentín, 2000:166). They found that the lack of in-house capacity to carry out technological research was the most valued (structural) motivation for business executives. SASOL has a strong local in-house capacity and in fact assisted the UCT department to establish and develop its capacity in the area of heterogeneous catalysis. UCT has demonstrated that it can deliver quality research and technological results that SASOL would need in time. It is always willing to collaborate in areas of high priority to SASOL. At the same time this case study confirms the results of the ⁶Lopez-Martinez, Medellin, Scanion, Solleiro study that showed that the main (individual) motivation for university researchers to cooperate with industry relate to the accomplishment of the social function of the university (Eva María Mora Valentín, 2000: 166). It also supports Schmoch's results that found that academics perceived generating additional funds and knowledge exchange as the main benefits for university' involvement with industry. Observation of scientific development, solution of technical problems and staff recruitment were the main reasons for industrial firms to keep in contact with universities (Eva María Mora Valentín, 2000: 166).

This study shows that the UCT-SASOL partnership managed to find mechanisms to deal with various obstacles related to cultural differences, restrictions imposed by industry (such as research topics, discussion among scientists, delays in publishing results), appropriation of the research results and communication-related problems. However, some of these mechanisms need to be further developed. For example, the relationship between conducting industry-oriented research as a way to supplement

income, remain on the cutting edge of knowledge, and remain relevant on the one hand, and the persistent need to conduct basic research and publish on the other hand, remains a contentious issue that calls for constant negotiations. The control and ownership of intellectual property right is another problem especially in the absence of clear guidelines as to where this should be vested, be it at the institutional level, the individual level or the industry level.

5.2.4. Knowledge and Technology Transfer/Transmission Processes

5.2.4.1. Teaching and learning programmes

This research has found the following points worth noting regarding teaching and learning. First, "Mode 1" and "Mode 2" linkage is evident in the strong emphasis on the solid undergraduate education as a basis for good postgraduate education, which was said to be multidisciplinary and needless of strong disciplinary orientation. Second, the department maintains a close relationship between teaching and research. The department insists that all staff members should teach as well as be involved in research. Third, the department's ongoing contact with industry provides knowledge of relevant cutting edge developments and the opportunity to continually update the curriculum. The department emphasised basic disciplinary material and skills.

Fourth, there is an advisory board consisting of key companies such as SASOL. The industry in general plays a critical role in the curriculum review and certification of degrees. In this regard the industry is therefore not only involved in utilizing the "end product" of the educational process but also in the process itself. In the first instance, it is in the industry's interest to hire graduates who possess both generic knowledge and aptitudes - job-relevant know-how and particular skills which lead the industry to feel somehow obliged to contribute to the curriculum. Fifth, the department introduced the entrepreneurship oriented training programmes in order to prepare students to become employers rather than employees in the context of global competitiveness and unbundling, outsourcing and restructuring of big companies such as Anglo-American and Gold Fields.

5.2.4.2. Research Capacity Building or Technology Transfer

It appears that the Chemical Engineering department is committed to research capacity building or transfer of technology, skills and knowledge. This is clearly evident in the employment of mainly young staff members whose lack of experience, networking, and industry-exposure is complemented through the appointment of the old and experienced members. This blending of new and old members provides an opportunity to transfer skills, knowledge and expertise, to learn to network and to expand access to funding opportunities. The department runs an internship programme, which in the past has provided the opportunity for technikon students to gain research skills, exposure and

better networking opportunities. This internship is also used, as an effective way to address short-term technical personnel needs.

5.2.4.3. Intellectual Property Rights

It is important to understand UCT view on intellectual property in relation to its broader research and innovation policy. In particular the university has committed itself to improve innovation and commercialisation of research results as a way of maximizing financial returns. To that extent it established the UCT Innovation Ltd. and is currently attempting to establish UCT Ventures Inc. This stands in sharp contrast to the traditional academic ethos and values such as making knowledge freely available in the public domain through publications. Whereas engaging in the commercialisation of research results requires secrecy and confidentiality in order to secure intellectual property such as patenting. This seems to suggest the emergence of a quasi-academic-corporate strategies culture, which has the potential to transform some of university's make up and redraw boundaries with industry.

There is always tension in terms of whether intellectual property should be owned and controlled by the university administration or academic scientists or industry. At the same time the view of the university does not necessarily represent the academic scientist, as it was the case with the 1996 Fischer-Tropsch Synthesis project. As I said in the previous chapter 4, the university initially argued to retain all intellectual property, although this changed later. The academic scientist did not necessarily agree with this demand and in fact did not see anything untoward to SASOL retaining all intellectual property. At the end consensus agreement was reached that managed to balance the interests of both organizations. On the one hand the university's demand to have research results published within two years was accepted subject to SASOL's approval. On the other hand, SASOL's demand to retain all intellectual property was accepted by UCT provided it was going to receive rewards flowing from any subsequent commercial benefits. Currently UCT deals with intellectual property issues case by case. It must also be pointed out that it remains a challenge for academics to balance the need to publish and do industry-oriented research. This balance seems to be maintained by the UCT Chemical Engineering Department, which remains top in terms of publications as compared to other departments in the Engineering Faculty.

5.3. Recommendations

- (a) Mutual trust, respect and confidence that SASOL and UCT accorded each other became one of the cornerstones of the partnership to succeed and continue for twenty-one years. This was primarily due to the ability and willingness of UCT to deliver quality research results in time. Perhaps this is one lesson that others can draw from in the future.
- (b) For any partnership to succeed, each sector will need to be prepared to deal with the effect of what Borys and Jemison called the "boundary permeability" which is bound to happen in

any developing strategic partnership. This is important to deal with potential obstacles, which arise mainly due to the diverse nature of the university and industry.

- (c) Both university and industry should develop mechanisms to better manage the partnership. This includes developing consistent and accommodative policies in order to ensure that interests of both sectors are addressed. Essentially much more has to be done in the area of dealing effectively with intellectual property etc.
- (d) Universities' research administration should constantly negotiate with academic researchers especially those involved in industry-oriented research around issues of basic research, publications, and teaching and learning. In other words the university should develop mechanisms to ensure that there is balance between "scholarly work" and industry-related work".
- (e) The university and industry agreements sometimes show great deal of consensus regarding various aspects. At other times they lack clarity on certain crucial aspects. For example the 1996 Fischer-Tropsch Synthesis project agreement remains unclear what happened to the issue of publication processes especially the re/submission, amendment and feedback. One needs to know what was cut out or added to the manuscript? Why? Or whether academics engage themselves in some "doctoring" of their conclusions as a way of circumventing industry objections? What impact does this have?
- (f) The university needs to maintain its research capacity building policy especially to appoint young staff members and to improve on staff exchanges with industry. This should not only be confined to the industry employees enrolling for the degree to upgrade their skills and competencies, but it should also involve academics spending months in the industry and the vice versa.

5.4. Conclusion (areas for further studies)

- (a) I would like to recommend that further study should be undertaken to analyse the knowledge flows and scientific and technological inputs (SITs) that each organization (UCT and SASOL) make. This sort of analysis is necessary in that in terms of STIs, a major contribution in this area will be appreciated if it could develop yardsticks that could classify and measure the STIs necessary to inform any analysis on any specific form of collaboration (Webster and Etkowitz, 1998: 50). Regarding knowledge flows; work has been done in this area. For example, Senker, Faulkner and Velho (1998) did a comparative study on the "Science and Technology Knowledge Flows Between Industrial and Academic Research". This study examined companies' interaction with and use of university and government laboratories in three fields of advanced technology - the new biotechnology, advanced engineering ceramics and parallel computing. One major limitation of this study is that it conceptualises knowledge flows as a linear process, focusing only on what the university contributes or what the industry gains from interacting with the university. This is done rather than the two-way

approach with the industry being analysed in terms of knowledge contribution and what the university is gaining by interacting with industry in terms of knowledge flows etc. That leaves room to develop an analysis that could entail both perspectives, hence my recommendation.

- (b) Linked to the above, I recommend that more work be done in order to better understand the "interactive" or the "non-linear" model of technology transfer or knowledge flows or what Gibbons et al. referred to as "knowledge or technology interchange".

6. Bibliography and End Notes

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Meeting with Dr. Fletcher (Catalysis Unit-UCT) 02 July 2002

Interviews with Dr. Fletcher (Catalysis Unit-UCT) 20 August 2002

Interview with Mr. Barnard (Center for Research, Development and Innovation-UCT) 27 August 2002.

Interviews with Mr. Gibson 08 November 2002 (SASOL)

Interview with Dr. Fletcher (Catalysis Unit-UCT) 21 February 2001

The University of Cape Town and SASOL Cooperation Agreement received on the 3rd July 2000

⁰ E. Geisier, A. Furino and T.J. Kiresuk, 'Factors in the success or failure of industry-university cooperative research centres', *interfaces*, Vol. 20, No 6, 1990, pp-99-109 and also see Gibbons et al. 1994: 86)

¹ R.E. Lopez-Martinez, E. Medellin, A.P Scanion and J.L. Solleiro. Motivations and Obstacles to University-Industry Cooperation (UIC): A Mexican Case. *R&D Management*, Vol. 24, NO1, 1994, 17-31.

² Michael Polanyi, *The Tacit Dimension*, Peter Smith, 1983

³ Grant Hartman. (2001: 254) *the University-Industry Research Partnerships in Australia: Extent, benefits and risks: HERDSA*, reports on the extent to which science and technology academics in three major Australian research universities are involved in research partnerships with industry and the nature of such partnerships, using the data from a social survey. In terms of positive aspects of industry research funding, respondents perceived the most important benefits to be provision of additional resources, an increased rate in the application of the outcomes of basic research to industry problems, involvement of less red tape than government funding, and enhancement of the career opportunities for students. Overall, industry-supported academics gave higher value than their colleagues not supported to these various benefits.

⁴ E. Geisier, A. Furino and T.J. Kiresuk, 'Factors in the success or failure of industry-university cooperative research centres', *interfaces*, Vol. 20, No 6, 1990, pp-99-109 and also see Gibbons et al. 1994: 86)

⁵ R.E. Lopez-Martinez, E. Medellin, A.P Scanion and J.L. Solleiro. Motivations and Obstacles to University-Industry Cooperation (UIC): A Mexican Case. *R&D Management*, Vol. 24, NO1, 1994, 17-31.

⁶ R.E. Lopez-Martinez, E. Medellin, A.P Scanion and J.L. Solleiro. Motivations and Obstacles to University-Industry Cooperation (UIC): A Mexican Case. *R&D Management*, Vol. 24, NO1, 1994, 17-31.

Gabriel Cele - Re: Masters Thesis

From: sfick <sfick@chemeng.uct.ac.za>
To: <gcele@uwc.ac.za>
Date: 7/23/02 1:39 PM
Subject: Re: Masters Thesis

Dear Gabriel

I refer to your e-mail sent to Prof Jack Fletcher on July, 08th 2002.

Prof Fletcher requested me to inform you that it will be in order for you to conduct a case study of his linkage with SASOL.

Please do not hesitate to contact me should there be any queries.

Kind regards

Susan Fick
PA to Prof Jack Fletcher

APPENDIX 2

Interview Schedule¹

1. Please describe the evolution of the UCT-SASOL partnership.
2. What are the areas and forms of collaboration?
3. How have these forms changed over time?
4. What "drives" UCT-SASOL Partnership?
5. What are the main motivations and benefits of UCT-SASOL partnership?
6. Describe technology transfer or knowledge transmission mechanisms involved in the UCT-SASOL partnership?
7. How is intellectual property being managed and controlled in the UCT-SASOL partnership?
8. How is university's involvement in industry research balanced with the need to publish?
9. What managerial autonomy does the research team involved in collaboration have in deciding their own programs and in allocating resources to facilitate them?
10. What is the relationship between any spinoff (or start-up) companies and the research base in academia that they depend on for new STIs; does the company tail wag the research dog?
11. What is the cultural and organizational link between the in-house corporate R&D and the academic center's own research; how much interchange of personnel, findings, technologies, and materials occurs?
12. When no institutional mechanisms are available to discuss and adjudicate issues concerning academic-industry relations or conflict of interest charges, what happens?
13. What conflict has arisen between administrators and faculty? Some scientists who have generated intellectual property wish to control its disposition, including its commercialization, and view administrative efforts to exploit it as an unwarranted interference, even regarding it as a breach of academic autonomy and freedom.
14. How have administrators handled different corporate philosophies toward collaboration?
15. What are the different consequences for the university in negotiating with domestic, multinational, and foreign corporations for research support, collaboration, and exchange?
16. Do administrators articulate the sort of inter-organisational concerns regarding such matters as collaborative boundaries, breadth of purpose, and the "permeability" of new collaborative structures?

¹ some of the questions were adapted from Etzkowitz and Webster, 1998