Barriers and Stimulants to the Development of University-Industry Links: Perspectives from the Republic of Ireland

Volume I

(Two Volumes)

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DECLARATION

I hereby declare that this thesis has not been submitted as an exercise for a degree at this or any other university. Except where otherwise acknowledged, it is entirely my own work. The Library of Trinity College may lend or copy this thesis upon request.

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SUMMARY

AIM OF THE RESEARCH

The aim of this research is to investigate barriers and stimulants to the development of university-industry (U-I) links in the Republic of Ireland (hereafter referred to as Ireland) from the perspectives of academia, industry and key regional actors associated with innovation and U-I links (in Ireland and Scotland). The links which constitute the main focus of this research are: research and development (R&D), consultancy, teaching/training and the commercialisation of university research by academic entrepreneurs who have formed campus companies. When analysing the factors which promote and/or impede the development of links between the indigenous high-tech sector and Irish Higher Education Institutions (HEIs), the research focuses on five broad areas.

First, having established the volume of interaction, the nature of links existing between indigenous high-tech firms and HEIs is investigated. Second, characteristics of firms with HEI links are analysed. Characteristics of firms without HEI links are also investigated. Geographical analysis focuses on the importance, or not, of the spatial proximity between firms and HEIs as a factor which facilitates the development of U-I links. The third area of concern focuses on the role of HEIs in establishing links with industry. Emphasis is placed on the degree to which academics in science and technology (S&T) have established and actively engage in links with industry. In order to analyse the role of HEIs in establishing U-I links, the Industrial Liaison Office(r)s (ILOs) (which are located in all Irish HEIs) are a key focus of the research. HEI's commercialisation of their research base is analysed by an investigation of academics who have successfully commercialised their research. In particular, commercialisation is analysed through the formation of campus companies followed by an examination of the barriers and stimulants to the development of academic entrepreneurship in the university sector in Ireland. Campus companies represent crucial components of the U-I interface, and are, therefore, deemed an important part of this research. The fourth area of concern relates to the role played by Enterprise Ireland (EI) and other key innovation stakeholders in facilitating U-I links. The fifth and final area of concern is a case study of a science park. This phase of the research focuses on the propensity of science park firms to engage in links with the associated university followed by an analysis of barriers and stimulants to such interaction.

METHODOLOGY

The methodology used to collect data involved interviews and two separate questionnaire surveys. In all, 91 interviews were conducted with key actors involved in the development of U-I links, innovation and commercialisation of HEI research in both Ireland and Scotland (56 in Ireland and 35 in Scotland). This included representatives from state-sponsored development agencies, policy advisory bodies, specialist industrial research units in HEIs, business support agencies and key network actors with a regional and national focus. In Ireland, two separate categories of respondents were also identified. These were the ILOs of the HEIs and academic entrepreneurs who had formed campus companies. A case study of Ireland's only science park, the National Technological Park, Plassey, Limerick was undertaken in order to analyse the level of interaction between the park and its associated university UL. This phase of the research involved the participation of Shannon Development personnel, the park's management team, specialist industrial research units in UL and

companies located on the science park. The focus of this phase of the research was on links between the science park and UL and the barriers and stimulants associated with such collaboration.

For both questionnaire surveys, the populations of interest were all Enterprise Ireland (EI)-assisted indigenous high-tech firms and all S&T-based academics in Irish universities and Institutes of Technology (ITs). The industry questionnaire survey was posted to a total population of 1,980 EI-assisted high-tech firms and yielded a response of 34% after a follow-up re-mailing. The academic questionnaire survey was sent to a total population of 2,973 S&T-based academics in each of the universities and ITs in Ireland. In this instance, in order to ensure complete anonymity, a unique code number was not attached to each questionnaire. Hence the mail-out survey was conducted once and was not accompanied by a follow-up survey. It yielded a total response of 21%.

FINDINGS

Two of the key findings to emerge from the interviews in Ireland and Scotland were the lack of knowledge that HEIs have on the needs of industry and the low number of technologically sophisticated, research-dependent firms with the capability to absorb any form of technology transfer from HEIs.

One of the key findings to emerge from the industry questionnaire survey was that EI-assisted firms are not key benefactors of Ireland's S&T base. While firms are engaging in innovative activities, HEIs are excluded from such developments. In terms of the activities of firms, a significantly higher proportion of firms without HEI links engage in marketing, provision of services, R&D and software development. Focusing on R&D, firms without HEI links are engaging in basic research and new product development activities. Firms with HEI links are engaging in similar levels of innovative activity but are not utilising HEIs as sources of such knowledge. Instead, such firms are interacting with HEIs to complement existing in-house R&D activities and to sporadically use the teaching/training and consultancy services available in HEIs.

A significant result to emerge from the academic questionnaire survey was in relation to academics with industrial links. For this sample of respondents, the most common link with industry was via R&D. Collaborative R&D emerged as the most popular form of R&D interaction, while applied research links constituted the category with the highest level of R&D interaction. Similar to the data on the firms, basic research links did not constitute a significant form of R&D interaction between industry and academia. This is in stark contrast to the perception in the existing literature that R&D links constitute one of the most common forms of U-I interaction and are central to the promotion of industrial competitiveness. The evidence from this research indicates that basic R&D is not a key facet of U-I R&D links in Ireland. In relation to academics without links, one of the most significant findings was that 50% of this sample of respondents plan to engage in links with industry in the future. This suggests the existence of an untapped pool of academics with the willingness to engage in links with industry given that they are provided with adequate support from HEIs.

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For my parents, Mary and Alan Barry,
who have given me so much.

Knowledge he shall unwind through victories of the mind.

[W.B. Yeats, 1933, Sheperd and Goatherd (1919), 163]

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LIST OF ABBREVIATIONS

ACE	American Council on Education
AIT	Athlone Institute of Technology
AMT	Advanced Manufacturing Technology
ARGS	Applied Research Grants Scheme (now called Innovation Partnerships)
ASHE	Association for the Study of Higher Education (USA)
ASTE	The Australian Academy of Technological Sciences and Engineering
ATRP	Advanced Technology Research Programmes
AUA	Atlantic University Alliance
AURIL	Association for University Research and Industry Links
AUTM	Association of University Technology Managers
AVL	Approved Vendor List
BC-NET	Business Co-operation Network
BERD	Business Expenditure on Research and Development
BIC	Business and Innovation Centre
BIOREP	Biotechnology Projects
BIOTECH	Biotechnology Research and Development
BMW	Border, Midlands and Western Region
BRI	BioResearch Ireland
BTG	British Technology Group
BTIS	Business and Technical Information Service
BTO	Build-To-Order
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CASE	Co-operative Awards in Science and Engineering (UK)
CBI	Confederation of British Industry
CCDP	Campus Company Development Programme
CEB	County Enterprise Board
CEC	Commission of the European Communities
CEO	Continuing Education Officer
CEIA	Cork Electronics Industry Association
CET	Continuing Education and Training
CHIU	Conference of Heads of Irish Universities
CIE	Computer-Integrated Engineering
CIHE	Council for Industry and Higher Education (UK)
CIM	Computer-Integrated Manufacturing
CIMRU	Computer Integrated Manufacturing Research Unit (NUI Galway)
CIO	Committee on Industrial Organisation
CIT	Cork Institute of Technology
CKB	Central Knowledge Base (EI)
COMETT	Community Programme in Education and Training for Technology
CORD	Commercialisation of Research and Development
CORDIS	Community R&D Information Service
COSHEP	Committee of Scottish Higher Education Principals
CR	Contract Research
CRAFT	Co-operative Research Action for Technology
CRESP	Community Response for Economic and Social Progress
CSF	Community Support Framework
CSI	Centre for Supercomputing in Ireland
CSO	Central Statistics Office
CSSN	Communication Systems, Software and Networks
CURDS	Centre for Urban and Regional Development Studies (University of Newcastle upon Tyne)

CVCP	Committee of Vice-Chancellors and Principals of the Universities of the UK (now Universities UK)
DA	Development Advisor (EI)
DBIC	Dublin Business Innovation Centre
DCU	Dublin City University
DEL	Department of Employment and Learning (Northern Ireland)
DES	Department of Education and Science (UK)
DfES	Department for Education and Skills (UK)
DGXII	Directorate-General for Science, Research and Development, Commission of the European Communities
DGXIII	Directorate-General for Telecommunications, Information Market and Exploitation of Research, Commission of the European Communities
DGXV	Directorate-General for Regional Policy, Commission of the European Communities
DIT	Dublin Institute of Technology
DKIT	Dundalk Institute of Technology
DTI	Department of Trade and Industry (UK)
EACRO	European Association of Contract Research Organisations
EBIC	European Business and Innovation Centres
EBN	European Business and Innovation Centres Network
EC	European Commission (Commission of the European Communities)
EDC	European Documentation Centre
EEC	European Economic Community
EFTA	European Free Trade Association
EI	Enterprise Ireland
ELLD	Enterprise and Lifelong Learning Department (Scottish Executive)
ELP	Electronic Linkage Programme
EMS	European Monetary System
EMU	Economic and Monetary Union
EOLAS	National Science and Technology Agency
EPP	Enterprise Platform Programme
EPC	European Patent Convention
EPSRC	Engineering and Physical Sciences Research Council
ERA	European Research Area
ERC	Employment Research Centre (TCD)
ERDF	European Regional Development Fund
ERI	Edinburgh Research and Innovation
ERIC	Clearinghouse on Higher Education (USA)
ESRI	Economic and Social Research Institute
ETF	Edinburgh Technology Fund
ETTN	European Technology Transfer Network
EU	European Union
FÁS	Foras Aiseanna Saothair (Industrial Training Authority of Ireland)
FDI	Foreign Direct Investment
FMS	Flexible Manufacturing Systems
FP	EU Framework Programme
FP6	Sixth EU Framework Programme
GCA	Greater Cork Area
GDA	Greater Dublin Area
GDP	Gross Domestic Product
GERD	Government Expenditure on Research and Development
GLA	Greater London Area
GMIT	Galway-Mayo Institute of Technology
GR	Generic Research
GREI	Gruppen for Entreprenørskap og innovasjon (Norweigan University of

	Science and Technology)
GREMI	Groupe de Recherche Européen sur les Milieux Innovateurs
HDL	Hitachi Dublin Laboratory (TCD)
HE	Higher Education
HEA	Higher Education Authority
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
HE	Higher Education
HEI	Higher Education Institution
HERD	Higher Education Expenditure on Research and Development
HEROBC	Higher Education Reach Out to Business and the Community (UK)
HIE	Highlands and Islands Enterprise
HMSO	Her Majesty's Stationery Office
HPSU	High Potential Start-Up
IADT-DL	Institute of Art, Design and Technology, Dun Laoghaire
IBB	Irish Business Bureau
IBEC	Irish Business and Employers Confederation
IBG	Institute of British Geographers
ICT	Information and Communication Technologies
ICSTI	Irish Council for Science, Technology and Innovation
IDA Ireland	Industrial Development Authority of Ireland
IIASA	International Institute for Applied Systems Analysis
ILM	Industrial Liaison Manager
ILO	Industrial Liaison Office(r)
IMI	Irish Management Institute
INTECH	Institute for New Technologies
IPC	Irish Productivity Centre
IP	Intellectual Property
IPR	Intellectual Property Rights
IPX	Intellectual Property Exchange
IRDG	Industry Research and Development Group
ISME	Irish Small and Medium Enterprises Association
ISO	International Standards Organisation
IST	Information Society Technology Programme
ITB	Institute of Technology Blanchardstown
IT	Institute of Technology
IT-Carlow	Institute of Technology, Carlow
IT-Tallaght	Institute of Technology, Tallaght
IT-Tralee	Institute of Technology, Tralee
JIC	Just-In-Case
JIF	Joint Infrastructure Fund
JIT	Just-In-Time
JREI	Joint Research Equipment Initiative
LEC	Local Enterprise Company (Scotland)
LES	Licensing Executives Society
LIT	Limerick Institute of Technology
LYIT	Letterkenny Institute of Technology
MAC	National Microelectronics Applications Centre
MD	Managing Director
MERIT	Maastricht Economic Research Institute on Innovation and Technology
MIDAS-NET	Multimedia Information, Demonstration and Support Network
MIT	Massachusetts Institute of Technology
MNEs	Multinational Enterprises
MTI	Multimedia Technologies Ireland
M50 EPP	M50 Enterprise Platform Programme

NAB	National Alliance of Business (USA)
NBIA	American National Business Incubation Association
NBST	National Board for Science and Technology
NCTCC	National Cell and Tissue Culture Centre (DCU)
NCSR	The National Centre for Sensor Research (DCU)
NDP	National Development Plan
NEICO	Network for European Innovation and Co-Operation
NESC	National Economic and Social Council
NHS	National Health Service
NIC	Newly Industrialising Country
NICB	National Institute for Cellular Biotechnology
NIDL	New International Division of Labour
NIEC	National Industrial Economic Council
NIMT	National Institute for Management Technology
NLP	National Linkage Programme
NMRC	National MicroElectronics Research Centre (UCC)
NORIBIC	Northern Ireland Business and Innovation Centre
NPBC	National Pharmaceutical Biotechnology Centre (TCD)
NRA	National Recovery Administration
NSERC	Natural Sciences and Engineering Research Council of Canada
NSI	National System of Innovation
NSTB	National Science and Technology Board
NTBFs	New Technology-Based Firms
NTP	The National Technological Park
NUI	National University of Ireland
NUTEK	Swedish National Board for Industrial and Technical Development
OECD	Organisation for Economic Co-operation and Development
OST	Office of Science and Technology
PACE	Policies, Appropriability and Competitiveness for European Enterprises
PATs	Programmes in Advanced Technologies
PAXIS	Pilot Action of Excellence for Innovative Start-Ups
PC	Personal Computer
PDC	Project Development Centre (Docklands Innovation Park, Dublin)
Plc	Public Limited Company
PoC	Proof of Concept
PPARC	Particle Physics and Astronomy Research Council
PR	Public Relations
PREST	Policy Research in Engineering, Science and Technology (University of Manchester
PRTL	Programme for Research in Third Level Institutions
PSR	Public Sector Research
R&D	Research and Development
R&E	Research and Enterprise
R&TD	Research and Technological Development
RAE	Research Assessment Exercise
RCSI	Royal College of Surgeons in Ireland
RDG	Research Development Grant
RIP	Research in Progress
RSE	Royal Society of Edinburgh
RTC	Regional Technical College (now called ITs)
RTD	European Commission Research and Technological Development Programmes
RTDI	Research Technology Development and Innovation Programmes
RTI	Research Technology and Innovation Competitive Grants Scheme
SABRIs	Scottish Agriculture and Biological Research Institutes

S&T	Science and Technology
SDA	Scottish Development Agency
SE	Scottish Enterprise
SEA	Single European Act
SEC	Science Enterprise Centres
SEG	Scottish Enterprise Glasgow
SEM	Single European Market
SE-N	Scottish Enterprise-Network
SERAD	Scottish Executive Rural Affairs Department
SFA	Small Firms Association
SFI	Science Foundation Ireland
SHEFC	Scottish Higher Education Funding Council
SIE	Scottish Institute for Enterprise
SMEs	Small and Medium-sized Enterprises
SMOT	Strategic Management of Technology (Singapore)
SMT	Surface Mount Technology
SOEID	Scottish Office Education and Industry Department
SPSS	Statistical Package for the Social Sciences
SRG	Strategic Research Grants
SRIS	Scottish Research Information System
SRS	Simple Random Sample
STI	Science/Technology/Industry
STIAC	Science, Technology and Innovation Advisory Council
STRIDE	Science and Technology for Regional Innovation and Development in Europe
SUPRA	Scottish Universities Policy Research and Advice Network
TAP	Telematics Application Programme
TASBI	Trans Atlantic Small Business Initiative
TechMaPP	Technology Management and Policy Programme
TCD	Trinity College Dublin
TCS	Teaching Company Scheme
TDA	Technical Development Advisor (EI)
TERU	Training and Employment Research Unit (University of Glasgow)
TII	Technology Innovation Information
TTI	Technology Transfer Initiative
TLO	Technology Licensing Office
TOP	Temporary Entrepreneur Places
TOS	Temporal Support of Spin-offs
TRBDI	Tipperary Rural and Business Development Institute
TTL	Targeting Technology Ltd.
TVI	Technology Ventures Initiative
TVS	Technology Ventures Scotland
UCC	University College Cork/National University of Ireland, Cork
UCD	University College Dublin/National University of Ireland, Dublin
UCG	University College Galway/National University of Ireland, Galway
U-I	University-Industry
UIP	University Industry Programme
UK	United Kingdom
UKSPA	United Kingdom Science Park Association
UL	University of Limerick
USA	United States of America
UNIREG	Role of Universities in Regional Development
UNU	United Nations University
UCSD	University of California in San Diego
USO	University Spin-off Firm
VC	Venture Capital/Capitalist

WDA	Welsh Development Agency
WIT	Waterford Institute of Technology
WWW	World Wide Web
S^2	Sample Variance
$\overline{X}$	Xbar

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

> *Sometimes industry will reach into a university laboratory to extract the newest ideas almost before they are born. Instead of waiting outside the gates, agents are working the corridors. They also work the placement offices. And the university, in turn, reaches into industry.... As the university becomes tied into the world of work, the professor – at least in the natural and some of the social sciences – takes on the characteristics of an entrepreneur. Industry, with its scientists and technicians, learn an uncomfortable bit about academic freedom and the handling of intellectual personnel. The two worlds are merging physically and psychologically (Kerr, 2001, 67-68).*

In the global economy, knowledge has become the driving force of economic growth and social development and the primary source of competitiveness for industry (Organisation for Economic Co-operation and Development (OECD), 1999a). Higher education institutions (HEIs) and firms are immersed in a period of rapid and significant transformation as they struggle to respond to the economic and social demands of a knowledge-based global economy. Both have been forced to change their behaviour towards innovation. Internationally there is a widespread view that HEIs have the potential to incorporate a culture of collective learning, innovation and entrepreneurship within regional and national economies, thereby enhancing the competitiveness and sustainability of economic growth (Jones-Evans and Klofsten, 1997; Jones-Evans, D., *et al*., 1998; Cooke, *et al*., 2000; Jones-Evans, 2000; Charles, 2003; Glasson, 2003; Lindholm Dahlstrand and Jacobsson, 2003). Firms are recognising that HEIs can provide a stimulus to industrial innovation, thereby enhancing their competitive advantage (OECD, 1999a; Santoro and Chakrabarti, 2002). Alliances between HEIs and industries are said to be proliferating in a climate of declining government resources for research, increasing demands for new products and more intense global competition (Tomes and Phillips, 2003).

Since the 1970s there has been a significant increase in the scale, number and variety of links established between industry and HEIs (Vedovello, 1998). This has aroused a growing interest in governments and policy makers, from both developed and developing countries, who regard university-industry (U-I[1]) interaction as an under-utilised technological resource which has the potential to improve industrial competitiveness (Vedovello, 1997). U-I links have, thus, become widely recognised as one of the most effective engines for innovation and they constitute an important component of government policy, particularly in the field of science and technology (S&T). Such links emerge through research collaboration, provision of consultancy services, commercialisation[2] of HEI research and in the proactive role of HEIs in meeting the specific requirements of industry through links established during teaching/training. The necessity for an accurate analysis of U-I links has been recognised by policy-makers and promoting the development of U-I links is now a high priority in most OECD countries (Vedovello, 1995; OECD, 1999a). However, the pursuit of this objective is often hampered by an inadequate understanding of the factors which promote and impede the development of U-I links from the perspectives of both industry and academia. Such additions to the existing literature would seem particularly important given the framework of the salient role being attributed to technological co-operation and its perceived potential to promote industrial and economic competitiveness (Geisler, 1995).

1.2 AIMS AND OBJECTIVES

Despite the perceived social and economic benefits of U-I interaction and the potential for stimulating regional and national development, economic geographers have paid little attention to the field of U-I links. The main objective of this research is to investigate barriers and stimulants to the development of U-I links in the Republic of Ireland (hereafter referred to as Ireland). In particular, the research

[1] In the abbreviation U-I, the term 'university' refers to both universities and ITs. When the abbreviation U-I is used it refers to academia and industry links equally. The term 'academic-industry links' refers to links from the perspective of academia, while the term 'industry-academic links' refers to links from the perspective of industry.

[2] Commercialisation can be defined as the process of converting research into successfully marketed products and industrial processes (Botham, 1997).

highlights barriers and stimulants to the creation of U-I links from industry and academia perspectives.

The focus of the research is on indigenous companies. Firms are defined as indigenous if they are established and remain within the country of their origin. This research is funded by *The Enterprise Ireland Millennium Scholarship Award.* In relation to the focus of the research, Enterprise Ireland (EI) had two stipulations agreed upon prior to the acceptance of this award. The first was that the research focus on indigenous high-tech firms and not on foreign companies located in Ireland. The second was that some element of the research be conducted abroad. An analysis of the environment in which the commercialisation of university research has evolved is undertaken in Scotland (Chapter 5).

When analysing the factors which promote and/or impede the development of links between the indigenous high-tech sector and Irish HEIs, the research focuses on five broad areas:

First, having established the volume of interaction, the nature of links existing between indigenous high-tech firms and HEIs is investigated.

Second, characteristics of firms with HEI links are analysed. Characteristics of firms without HEI links are also investigated. Geographical analysis focuses on the importance, or not, of the spatial proximity between firms and HEIs as a factor which facilitates the development of U-I links.

The third area of concern focuses on the role of HEIs in establishing links with industry. Emphasis is placed on the degree to which academics in S&T have established and actively engage in links with industry. In order to analyse the role of HEIs in establishing U-I links, the Industrial Liaison Office(r)s (ILOs[3]) (which are located in all Irish HEIs) are a key focus of the research.

HEI's commercialisation of their research base is analysed by an investigation of academics who have successfully commercialised their research. In particular, commercialisation is analysed through the formation of campus companies followed by an examination of the barriers and stimulants to the development of academic entrepreneurship in the university sector in Ireland. Campus companies represent

[3] In the universities and ITs of Ireland, the term 'ILO' is increasingly being replaced by variations of the terms 'Head of Research and Innovation Services' or 'Head of Innovation and Business Development in S&T'. For the remainder of this thesis, the term 'ILO' will be used for the purpose of ensuring consistency and clarity.

crucial components of the U-I interface, and are, therefore, deemed an important part of this research.

The fourth area of concern relates to the role played by EI and other key innovation stakeholders in facilitating U-I links.

The fifth and final area of concern is a case study of a science park. This phase of the research focuses on the propensity of science park firms in the National Technological Park, Plassey, Limerick, to engage in links with the associated university, University of Limerick (UL), followed by an analysis of barriers and stimulants to such interaction.

In all, three key types of links are analysed. They are (a) collaboration through research and development (R&D[4]), (b) consultancy, and (c) teaching/training.

An analysis of U-I links can be conducted across the broad spectrum of manufacturing sectors. As already stated, one of the stipulations of accepting the scholarship was a focus on the high-tech sector. High-tech industry provides a good framework for analysis of U-I links for two main reasons. First, the nature of the high-tech sector is such that it demands access to advanced knowledge concerning new emerging technologies which are typically HEI-based. Second, few indigenous high-tech firms, particularly Small and Medium-sized Enterprises (SMEs), possess adequate financial capabilities to develop in-house R&D facilities. Consequently, there should be a need in the indigenous high-tech sector to reach out and tap into HEI-derived new technologies which may support product and process development. It is reasonable to hypothesise that high-tech companies are those with the greatest need and highest probability of having HEI links.

This research includes firms without HEI links. There are two reasons for this. One of the main objectives of this research is to identify the reasons why some indigenous high-tech firms do not engage in links with HEIs. Second, in analysing U-I links, international researchers have neglected to analyse firms without links to HEIs. Consequently, policy makers have little evidence from which to assess the

[4] For the purposes of this research, the Frascati Manual definition of R&D is used. According to this definition, R&D comprises "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D is a term covering three activities: basic research, applied research and experimental development" (OECD, 1994a, 7). R&D refers to efforts toward new knowledge, including the invention, design and development of processes and prototypes of products and services. R&D excludes: quality control, routine product testing, market research, sales promotions, sales service, research in the social sciences and psychology, and other non-technical activities or services.

barriers preventing firms from gaining access to areas of specialist expertise within HEIs which could have the potential to enhance the innovative capabilities and competitive advantage of these firms in international markets.

1.3 THESIS STRUCTURE

A review of the germane literature follows this chapter. This provides a comprehensive theoretical context for the research. The methodology is presented in Chapter 3, including an outline of the methods and research techniques employed to collect and analyse empirical data for the research. Chapter 4 reviews the literature on U-I links and provides an overview of some of the initiatives implemented in Ireland to encourage the development of U-I links. Chapter 5 analyses the initiatives implemented in Scotland to promote the commercialisation of university research there. The characteristics of both independent samples of survey firms are analysed in Chapter 6. An examination of industry-academic links is undertaken in Chapter 7. The reasons why firms without HEIs links refrain from such interaction are analysed in Chapter 8. The characteristics of both independent samples of academics are analysed in Chapter 9. Academic-industry links are analysed in Chapter 10, while the reasons academics without industrial links refrain from such collaboration are examined in Chapter 11. The concluding chapter provides a synthesis of the key research findings, it assesses the contribution of this research to the existing literature and makes a number of recommendations for further study in the field of U-I links.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

> *Companies, no less than governments and universities, have a stake in education. Universities have a stake in the competitiveness of local businesses (Porter, 1998a, 90).*

Reviewing the literature pertaining to U-I links, this chapter is divided into six sections, the first being this introduction. Historical development of U-I links is examined in the second section paying attention to America, Europe and the United Kingdom (UK). In order to understand the contemporary context of barriers and stimulants to the development of links between HEIs and industry, it is first important to understand the historical context in which such links have evolved. International perspectives on the historical development of U-I links provide a number of comparisons from which to examine the evolution of the role of HEIs in enhancing knowledge-based innovation in industry. The third section analyses the theory of U-I collaboration focusing in particular on the characteristics of firms and academics engaged in U-I links. This includes an analysis of the existing factors which contribute to and impede the development of U-I links from the perspectives of both industry and academia. Thereafter, the fourth section considers the role played by increasing technological change in encouraging high-tech firms to seek closer ties with HEIs. Attention is focused, in particular, on the formation of clusters of innovative firms in localised geographical areas and on their interactions with regional innovation systems. The fifth section focuses on the role of HEIs in creating and developing U-I links. This section analyses the role played by entrepreneurial HEIs in the knowledge economy through commercialisation of research and links established with industry in R&D, consultancy and teaching/training. The final section draws conclusions in relation to what was reviewed previously.

The intention of this approach is to provide a theoretical framework from which to explore the barriers and stimulants to the development of links between indigenous high-tech firms and Irish HEIs. Furthermore, this should provide a framework from which to analyse the degree to which the science park model has played a role in creating and sustaining U-I links in Ireland. The literature on Ireland will be dealt with in Chapter 4.

2.2 U-I INTERACTION: THE INTERNATIONAL HISTORICAL CONTEXT

> *The 19th century was steam. The 20th century was electric power. The 21st century is knowledge (Interview with Brendan Tuohy, Secretary General of the Department of Communications, Marine and Natural Resources, cited in Trani, 2002, 3).*

Internationally, the historical evolution of U-I interaction has varied considerably between countries and has led to the emergence of different practices, policies and institutional relationships which are reflected in contemporary international U-I links. Despite popular notions, U-I interaction is not a recent phenomenon; it can, in fact, be traced back to the 1800s (Rogers *et al.*, 2000b). In 1737, Germany founded the first research university - the University of Göttingen. In 1809, the University of Berlin was established by Wilhelm von Humboldt in response to the emergence of industrialisation and intense nationalism, following Germany's defeat at the hands of Napoleon (Baldwin, 1996; Noll, 1998a; Kerr, 2001). According to Kerr (2001), the University of Berlin represented the cornerstone of two great forces - science and nationalism. Emphasis was placed on philosophy, science, research, graduate instruction and on the academic freedom of professors and students. The establishment of departments and institutes specialised in subject areas were key features of the institutional infrastructure of the new university while "the professor was established as a great figure within and without the university" (Kerr, 2001, 9). The Germanic model represented an institution of higher education which had developed close ties to industry and was adopted during the course of the 20th century in Europe, the United States of America (USA), together with almost all developed countries (Conceição *et al.*, 2000).

2.2.1 Evolution of U-I interaction: the American experience

Established in 1876, John Hopkins University was the first American research university and was modelled on the University of Göttingen (Steffensen *et al.*, 1999).

Within a few years, several other US universities were founded with the mission of conducting research and providing research-based graduate-level education (Peters, 1989). These universities included Clark University (1890), Stanford University (1891) and the University of Chicago (1892). According to Baba (1988), U-I linkages in the USA flourished during periods of economic and/or technological turbulence (*e.g.* during World Wars I and II). In the USA, academic science and industrial science grew up together (Phillips, 1991). During World War II, the nature of research universities changed and some universities such as the Massachusetts Institute of Technology (MIT) were transformed into elite research institutions (Steffensen *et al.*, 1999). While a number of US research universities established a technology transfer office as early as 1925 (the University of Wisconsin at Madison), 1935 (Iowa State University) and 1940 (MIT), the majority of US research universities did not establish such a facility until after 1970 (Rogers *et al.*, 2000b).

In the USA, Etzkowitz (1999) identified two revolutions which shaped the evolution of the university. During the late 19th century, the first academic revolution was driven by the goal of discovering new knowledge. The second concentrated on the transfer of knowledge into economic activity. This became an activity of HEIs alongside their traditional roles in education and research. Patenting and marketing academic research was an American idea which originated in MIT (Etzkowitz, 1996). In the early 20th century, the resolution of a number of disputes at MIT resulted in the development of measures which provided US universities with the necessary help to facilitate U-I links and promote the successful commercial exploitation of HEI research. The MIT model became the template for present-day policies and mechanisms for successful U-I links in HEIs across the globe (Waagø *et al.*, 2001).

Since the 1940s, the USA has implemented a number of measures to encourage the growth of scientific research within HEIs. Originally published in 1945, and again in 1960, a report completed by Bush *et al.* (1960) - *Science the Endless Frontier: A Report to the President on a Programme for Postwar Scientific Research* - recommended the use of public funds to support basic research[1] within HEIs (cited in Brooks, 1986). The US scientific community was to be accorded a high degree of self-governance and intellectual autonomy. In return, the research benefits would be diffused through society and the economy. The academic

[1] Basic research refers to creative stage/initial phase of development. It is often referred to as 'blue-sky' research.

community considered collaboration with industry to represent a 'social contract' between science and society. By engaging in links with industry and, thereby, contributing to economic development, the academic community returns the benefits of basic scientific research to society in return for generous and unfettered support provided in the form of public finance (Brooks, 1986; Lee, 2000).

In the USA, the federal government provided the main source of funding for research within HEIs. This led to a HEI dependency on government to fund research projects and not on the establishment of links with potential industry partners. However, the implementation of effective technology transfer mechanisms was problematic. While the federal government sponsored HEI research and, therefore, assumed ownership of the discoveries, it lacked the capability to transfer the technologies to industry. The federal government did not have the links established with the industrial partners who would have the expertise to commercialise and market inventions[2]. Furthermore, the government was unwilling to grant licenses for the use of new innovative technologies to the private sector. Technology transfer[3] became problematic for all key partners. HEIs were unable to commercialise their research because they did not own the intellectual property (IP[4]). In addition, the federal government lacked the capability, resources and industry links to effectively engage in technology transfer. Indeed, the government prohibited industry from gaining access to patents destroying the possibility of commercialising the research.

On December 12 1980, through the implementation of the Bayh-Dole Act, the Patent and Trademarks Amendments Act of 1980, US Congress sought to redress this issue. The Bayh-Dole Act is a uniform federal patent policy allowing HEIs and small businesses to own the IP of federally funded inventions. Representing a fundamental change in patent law in the USA; it ensured that the title to inventions which were supported by government finance belonged to the small businesses, HEIs and other non-profit entities responsible for creating the invention. It also regulated technology

[2] This view was reiterated by Brooks (1986) when he stated that, while government scientists and engineers may have the capability of identifying new technical opportunities, they lack the experience and knowledge to assess market potential and user needs. Frequently, the typical government-driven technological development tends to be a technical success but a commercial failure.

[3] Technology transfer is defined as the transfer of research results from HEIs and research institutes to the commercial market place for public benefit (Irish Council for Science, Technology and Innovation (ICSTI), 2001).

[4] IP can be defined as the creation of knowledge or any form of a new innovation that can be protected by law (Archer and Steering Committee, 2002). The four main types of IP are patents for inventions, trade marks for brand identity, designs for product appearance and copyright for material.

transfer by clarifying ownership rights and responsibilities (Etzkowitz, 1999) and was a crucial factor in moving academic entrepreneurship from HEIs into the private industrial sector.

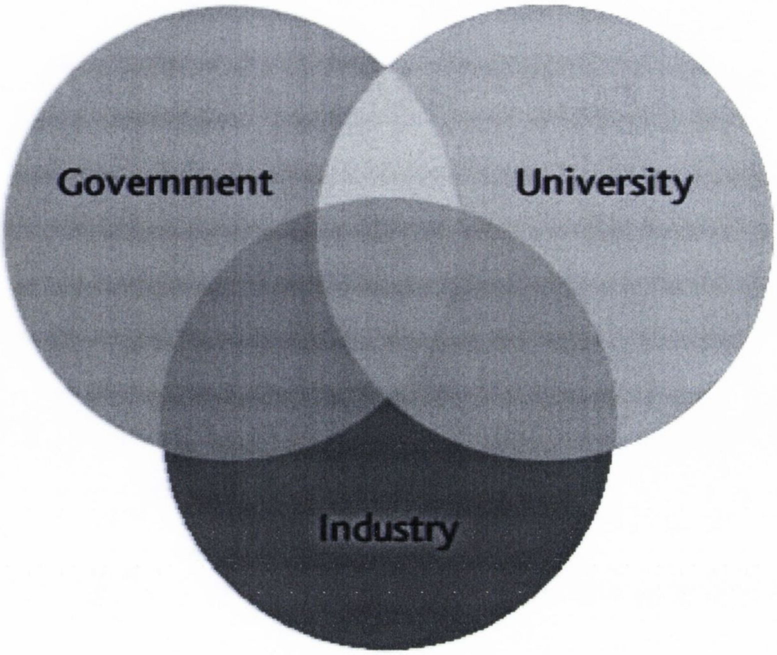
In 1980, the US government also introduced the Stevenson-Wydler Technology Innovation Act. Authorising federal laboratories to transfer technologies to industry, this legislation established centres for industrial technology in HEIs and non-profit institutions (Lee, 1996). Moreover, it facilitated the exchange of scientific and technical personnel among HEIs, industry and federal laboratories. The implementation of both the Bayh-Dole and Stevensson-Wydler Acts resulted in the establishment of more than 1,000 U-I research centres established within HEIs (Cohen *et al.*, 1994, cited in Lee, 1998). Furthermore, since the introduction of the Bayh-Dole Act, almost all US research-based HEIs have established an office of technology licensing, which seeks to facilitate the transfer of technological innovations to the private sector (Rogers *et al.*, 2000b). The Bayh-Dole Act, in particular, was crucial to the establishment of a uniform policy within HEIs on the contentious issue of ownership of academically generated IP. Finally, both forms of legislation were crucial in providing a strong incentive for increased U-I research collaboration in the USA thus paving the way for the increasing involvement of HEIs in the commercialisation of innovation and R&D.

Faced with intense global competition from Japan and Europe in the 1980s, the US high-tech sector was forced to develop corporate R&D facilities with established links to HEIs and public research institutes. Changing patterns of consumption encouraged US high-tech firms to reorganise their corporate research laboratories to better serve the "changing whims of a well-heeled and fickle market" (Gertler, 1989, 111). According to Lewis S. Edelheit, the senior vice president of General Electric Corporate R&D, "researchers have to be vital parts of the team on every major new programme in every business" (Edelheit, 1998, cited in Varma, 2000, 401). Since the 1980s, collaboration between HEIs and industry in the USA has grown significantly and HEI patenting and licensing has expanded. This has been accompanied by a dramatic increase in royalty income (Association of University Technology Managers (AUTM), 1995). Furthermore, a wide range of public R&D collaboration programmes have been initiated (Mowery, 1998). Increasingly, U-I links represent the most productive relationship possible between the public and private sectors.

One notable difference in the model of U-I interaction between the USA and Europe has been in the timing of the emergence of publicly funded R&D laboratories in the USA[5]. Established by the federal government to improve US industrial competitiveness, these centres focused on developing links with industry. State-run industrial laboratories, associated research laboratories and intellectual think tanks became commonplace after World War II, especially in the USA (HotOrigin, 2001). In comparison to Europe, the USA has a long history of state sponsored industrial research laboratories and has thus experienced a wide array of changes in the evolution of government-HEI-industry interaction, particularly industrial R&D.

[5] For details on U-I links in Canada see Hutichison *et al.* (1987); Natural Sciences and Engineering Research Council of Canada (NSERC) (1991); Lawton Smith and Atkinson (1992); Szabo (1995); Warda, (1995); Langford *et al.* (1997); and Godin and Gingras (2000).

Figure 2.1 Triple helix model of government-HEI-industry relations



Source: Etzkowitz and Leydesdorff (1999)

In the USA, the proactive role of the government in developing science, technology and innovation policies has resulted in a wide array of federal programmes providing financial incentives which help establish and maintain successful U-I links. Stimulation of U-I interaction by governments is primarily achieved through financial support of co-operative R&D (Waagø *et al.*, 2001). A number of studies have highlighted the development of a 'triple helix' model of innovation, based on integration between the institutional spheres of the US government, HEIs and industry (Etzkowitz and Leydesdorff, 1998; Leydesdorff and Etzkowitz, 1998; Benner and Standström, 2000; Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000; Etzkowitz, 2001). The triple helix model is not applicable to all countries as not all governments have established state-run, public funded R&D laboratories (Figure 2.1). However, in recent years, the focus has changed. Increasingly, free market attitudes tend to dictate the type, nature and extent of industrial R&D (HotOrigin, 2001). Furthermore, the triple helix model does not include firms which are outside the government-HEI-industry loop, firms which do not engage in links with either industry or government R&D laboratories.

2.2.2 Evolution of U-I interaction: the European experience

Interactions between industry and HEIs vary between countries as linkage mechanisms are shaped by a range of different social, economic and industrial patterns and processes of development which are specific to each country. In contrast to the USA, the link between academia and industry has been relatively weak in Europe (Prosser, 1992, cited in Caloghirou *et al.*, 2000). In analysing the historical development of U-I links in the USA, it is important to note that American HEIs and modern industrialisation emerged at the same time (Vedovello, 1995) providing an economic and social environment conducive to the development of U-I links. Vedovello (1995) argues that, in contrast to the American experience, the European university system has been marked by a predominance of elitism and a certain contempt for the commercial application of university research. According to the Council for Industry and Higher Education (CIHE) (1998), the primary purpose of European HEIs is enhancing, developing and transmitting knowledge. HEIs see themselves as national and international centres of excellence with little need to relate to or respond to the economic needs of their regions[6]. European HEIs are primarily supply-driven and are not customer focused or driven (CIHE, 1998). Moreover, the inability of a large and diverse industrial customer base to source and gain access to the appropriate services which HEIs can provide reinforces the innate conservatism and insularity of the HEI sector in Europe and serves to widen the gap between industry and academia. Consequently, one of the greatest challenges facing European economies is the comparatively limited capacity of their HEIs to encourage the development of academic entrepreneurship and convert scientific breakthroughs and technological achievements into industrial and commercial successes (Klofsten and Jones-Evans, 2000). While there are variations in the historical development of U-I links between European countries, the following sub-section focuses specifically on the historical evolution of links in the UK, as it is directly related to this research. An analysis of the historical evolution of U-I links in Ireland is included in Chapter 4.

[6] Historically, this is reflected in relatively low levels of interaction between firms and HEIs in European countries. For example, in 1977 the School of Commerce and Business Management in Bordeaux, France, was asked by the monthly *le Monde de l'Education* to conduct research on the links between firms in Aquitaine and the university (OECD, 1982). Of the 131 respondent firms, four (3%)

2.2.2.1 Evolution of U-I interaction: the UK experience

> *British higher education has undergone a more profound reorientation than any other system in the industrial world (Halsey, 1995, 302).*

According to the Centre for Urban and Regional Development Studies (CURDS) (2001) survey, measures to encourage interaction between HEIs and the business community have a long history in the UK. Academic-industry links have permeated changes in the UK system of higher education. According to a survey completed by Policy Research in Engineering, Science and Technology (PREST) (1998), this is best exemplified by the establishment of the 'redbrick' universities in the industrial heartlands of Britain in the mid and late 19th century. All founded between 1815 and 1914, London, Manchester and Birmingham, together with Leeds, represent redbrick or civic universities (Driver, 1971). Such developments were criticised by some mid-19th century British thinkers such as John Henry Newman and J. S. Mill, who were opposed to universities providing vocational training (Senker and Senker, 1997). In contrast, Herbert Spencer and T. H. Huxley argued that science and engineering subjects should become well established within the British university system. In any case, the civic universities were established to encourage academic-industry interaction through the provision of scientific and technical education in order to meet the needs of the industrial community. British industry was desperately short of well-educated and skilled personnel, and it looked to the British education/training system to provide human resources (Barnett, 1986). Therefore, the origins of British civic universities were rooted in the desire to produce a technically educated workforce (Driver, 1971). In a meeting held in Trinity College, Cambridge in 1903, Professor Forsyth stated that "in places where the movement towards universities is taking place most rapidly it is in the main on the lines of professional and industrial science and on the lines of business training; and the greatest part of the direct contribution of the new universities appears to be devoted to such aims" (cited in Sanderson, 1972, 61).

The existence of civic universities in the UK later led to the development of the polytechnic system which was designed to provide opportunities for students to pursue subjects and acquire skills relevant to advanced industrial society (Driver, 1971; Halsey, 1995). In 1966, a total of 27 technical colleges (which later rose to a

had research contracts with the university and 20 (15%) engaged in continuing training programmes with the university.

total of 30) were designated as polytechnics (Sanderson, 1972). The specific focus of polytechnics was to make direct contributions to the research and training needs of British industry in the areas of S&T. The University of Warwick was the first university to commit to the creation of links with industry in the mid 1960s. At its inception, the University of Warwick made firm statements about its determination to have a close relationship with industry by making research collaboration with companies an essential part of its programme (cited in Sanderson, 1972).

Throughout the 1970s and 1980s, the UK Government stressed the importance of improving links between HEIs and industry as a necessary measure towards enhancing innovation, production and economic growth (Bishop, 1988; Beveridge, 1991). Amongst some of the government-driven initiatives was the Teaching Company Scheme (TCS[7]), the LINK[8] and Foresight[9] programmes, and the Science and Engineering Research Council [which later became the Engineering and Physical Sciences Research Council (EPSRC)] which afforded funding through its postgraduate training programmes to provide a pool of skilled personnel to meet the needs of industry (OECD, 1984a). The main objective of each of these initiatives was to improve interaction between HEIs and industry with a long-term objective of encouraging greater R&D investment in companies, thereby enhancing the competitiveness of UK industry.

Within the UK's HEI sector, various mechanisms and initiatives were implemented to encourage collaboration and partnership with industry. Such

[7] Launched in 1975, TCS is a UK government scheme which enables companies of all types to access the knowledge base of HEIs and public and private sector research institutes through the formation of partnerships (DTI, 2000a). According to Senker and Senker (1995), the principal objectives of the TCS are to:

- Facilitate technology transfer and the diffusion of technical and management skills;
- Provide industry-based training, supervised jointly by academic and industrial staff, for graduates with an interest in pursuing commercial careers;
- Enhance the levels of academic research and training relevant to industry by creating collaborative R&D projects.

[8] Launched in 1986, the objective of the LINK Collaborative Research scheme (referred to as LINK) is to improve the competitiveness of UK industry by promoting partnerships in pre-competitive S&T between industry and the research base (PREST, 1998). Funded by the Research Councils and fourteen government departments, the scheme encourages collaboration between public and private sectors by providing industry with the opportunity to invest in further research work leading to commercially successful products, processes, systems and services.

[9] Managed by the Office of Science and Technology (OST), the Foresight Programme (originally Technology Foresight Programme) was launched in 1994 with the dual aims of forging a new working partnership between science and industry, and informing decisions on the balance and direction of publicly funded S&T (PREST, 1998). The aim of the Foresight programme is to increase the exploitation of the S&T base in the UK. The programme identifies potential commercial opportunities

initiatives were focused primarily on building partnerships in basic and applied research, promoting technological innovation and assisting in technology transfer. As a consequence, interaction between HEIs and industry became focused around a series of new developments. These included the diffusion of ILO functions throughout HEIs while a number of HEIs established commercial companies and opened HEI-based industrial innovation centres. Throughout the 1980s, UK HEIs focused their attention on developing links with industry through the development of technoparks, technology campuses, research and science parks and technology parks (Howells, 1986). Furthermore, the 1980s in particular was a significant decade in terms of academic-industry links in the UK because the right to exploit research results through IP was transferred from the British Technology Group[10] (BTG) to academic institutions in 1985 (PREST, 1998). Up to this point, BTG had monopoly control in handling all government-sponsored research results in terms of IP and technology transfer (Gering and Schmied, 1992).

In the early 1990s, the UK Government directed attention towards developing an infrastructure of technology transfer from academia to industry (Noonan, 1991, cited in Vedovello, 1995). Built on the promotion of collaborative research, this involved several regional agencies, government departments such as the Department of Trade and Industry (DTI), the Department of Education and Science (DES) [now called Department for Education and Skills (DfES)], universities and polytechnics. Yet, despite the wide range of initiatives, support mechanisms and funding structures implemented in the UK since the 19th century, the development of U-I links has some way to go before achieving a level of success considered acceptable to both academic and industry partners in the UK. Indeed, Duggan (1996) suggests only a small proportion of the three million companies in Britain have R&D facilities. Most of the HEI liaison is with the minority (3%) of larger companies who are 'academically literate'. These figures indicate that there exists a large population of firms (97%) in Britain without HEI links. Furthermore, UK funding for HEI research has become

emerging from S&T projects and it evaluates how such projects may be utilised to address the needs of the national economy in the UK in the future.

[10] Founded by the British Government in 1949, BTG focuses on sourcing, developing and commercialising new technologies by providing investment in further technical development and, thereby, adding value to the IP of the new technology. BTG aligns itself with both the universities (for acquisitions of IP) and with licensees (for licensing activities). BTG does not manufacture (so it does not compete with licensees) but it does provide early stage funding, patenting and licensing services, as well as other services such as legal and marketing advice. BTG were privatised from the state sector in 1991 and floated on the London Stock Market in 1995.

dependent on whether or not the research will make a direct contribution to the economy (Etzkowitz *et al.*, 2000). This has forced HEIs to attract industry driven funding which is focused on producing tangible outcomes to the detriment of basic research. According to Etzkowitz *et al.*, (2000), it is likely that privately funded contract research will form the primary links between industry and academia. This will add to existing tensions within academia in relation to the increasingly entrepreneurial role assumed by HEIs and in particular by universities. The challenge now facing HEIs and the UK government (as elsewhere in Europe) is to manage the interface between industry and academia through structured national schemes which meet the needs of and provide positive outcomes for both existing and potential U-I partnerships.

2.3 THEORY OF U-I COLLABORATION

There are both positive and negative implications of U-I links. Due to the wide and varied nature of U-I links as a field of academic study, the implications of such links are relative to the locational and institutional contexts in which they are set. Moreover, there is a high degree of diversity in the manner that U-I links evolve between different countries (Oyebisi, *et al.*, 1996; Wong, 1999). U-I links are multi-purpose, highly complex and diversified (OECD, 1984a). Vedovello (1997), argues that such diversity makes it difficult to undertake research in this area. Further compounded by the high economic expectation associated with U-I links, the tendency of governments and policy-makers has been to exaggerate the positive outcomes of such interactions.

Research completed tends to be analytically shallow in a number of important areas and the existing literature fails adequately to address the diversity in the nature and extent of links (Faulkner, 1992; Freel, 2000). The main problem is that much of the germane literature concentrates on the interests and experiences of the industrial partner and excludes those of the academic partner. In relation to the academic community, there has been no systematic study of the characteristics of academic researchers who have contributed to industrial innovation (Mansfield, 1995). From the perspective of academia, authors are more concerned with benchmarking levels of success between different institutions/countries and are more focused on auditing the number of spin-offs, patents and licences utilising these indices as measures of success. A recent report published by the European Commission (2001), *Benchmarking Industry-Science Relations – The Role of Framework Conditions*, provides a case in point, as does the work completed by Waagø *et al.* (2001), *The Role of the University in Economic Development: An Analysis of Six European Universities of Science and Technology*. Furthermore, policy-makers, in line with much of the existing research consensus, stipulate that U-I links are 'a good thing' with little consideration for the potential limits to effective linkage (Faulkner, 1992; Freel, 2000). Rationale for this conclusion is based on the low number of science and non-science park firms which engage in links with HEIs and on the presumed benefits that accrue from contact with HEIs for firms with HEI links (Westhead and Storey, 1995; Freel, 2000).

Many of the studies completed on U-I collaboration do not have a strong theoretical foundation (Geisler, 1995). Geisler and Rubenstein (1989) point to the lack of a theoretical foundation to explain the genesis and development of U-I links. The over-riding research design in many studies has been the small sample case study of firms with a specific focus on a university. It is perhaps difficult to apply a systematic theoretical framework which is applicable to all forms of U-I interaction in different institutional, sectoral, locational and temporal settings. Therefore, in analysing the development of U-I links, it is far more effective that the theory (or model) for hypothesising collaboration should be derived from a specific perspective. For the purpose of this research, the development of U-I links are analysed from the perspectives of the characteristics of firms/academics and the barriers and stimulants experienced by both in developing links. An analysis of the characteristics of representatives in the industrial and academic sectors will facilitate an understanding if a certain type of firm and academic is more likely to have links. By investigating perspectives on barriers/stimulants for developing collaborative partnerships, this research highlights a better understanding of the complex set of values and beliefs held by industrialists and academics which facilitate and impede the development of U-I links. The remainder of this section examines international research which has addressed these questions. This approach provides a theoretical framework from which to analyse U-I links in Ireland.

2.3.1 Characteristics of firms

One of the main indicators enabling economic geographers to analyse company innovation strategies is firm characteristics. The empirical evidence relating firms' characteristics to the development of U-I links is not very profuse (Vedovello, 1998). While a variety of indices can be used to assess the characteristics of firms, the existing literature focuses on firm size, productive sector and R&D activity (OECD, 1984a; Corsten, 1987a, 1987b; Bishop, 1988; Vedovello, 1995, 1998; Wong, 1999; Caloghirou *et al.*, 2000).

2.3.1.1 Firm size

The OECD (1984a) report categorises U-I links into four types of relationship based on firm size and sector[11]:

- Large firms intensely involved in R&D activities are the first type. These firms focus on enhancing their technology profile through links with universities, investment in in-house R&D facilities and recruiting highly qualified personnel;
- Large firms in traditional sectors are the second type. These firms provide two different attitudes to links with universities based on the pace of technological change and the level of technical sophistication in their products as required by the markets they serve. For example, there is a higher rate of interaction with universities in the more dynamic sectors such as chemistry, electrical and mechanical engineering; and fewer interactions with the less dynamic sectors such as shipbuilding, mining and automobile engineering;
- SMEs in high-tech sectors such as micro-electronics and biotechnology are the third type. These firms generally engage in R&D-intensive activities which are focused on the production of high value-added goods (and services) and, therefore, have become a policy priority for government. However, despite the relatively high-level of interaction between this population of firms and universities, the types of links established vary according to the activities they are engaged in and on the origins of firms (*i.e.* whether the firm is a spin-off from university research or a new independent start-up. The level of interaction varies in both cases.);

[11] Vedovello (1995) also provides a categorisation of the four types of relationship as specified by the OECD (1984a) report.

- SMEs in traditional industrial sectors are the fourth type. These firms require effective intermediaries (*e.g.* ILOs[12]) in order to forge links with universities. This sample of SMEs appear to be more sensitive to barriers such as an inability to source the most appropriate expertise in HEIs and limited interest of academic staff in short-term industrial problems.

While comparisons between firm size and sector provide an indication of the types of firm which engage in links with HEIs, the empirical evidence relating to firm size and establishment of links with industry indicates that it is mainly large-sized firms which engage in such interaction (Corsten, 1987a, 1987b; Bishop, 1988; Vedovello, 1995). Small firms fail to realise the benefits of U-I links.

Table 2.1 Effect of firm size on propensity for engagement in U-I links

Firm size	Number of firms that responded	Percent of firms with HEI links
SMEs		
1-19 employees	23	9.4
20-49 employees	56	20.7
50-99 employees	45	13.2
100-199 employees	36	26.4
200-499 employees	65	30.2
TOTAL	225	
SMEs and large firms		
499 employees	225	23.6
500-999 employees	43	34.9
1000-1999 employees	29	65.5
2000 employees	20	75
TOTAL	317	

Source: Corsten (1987a, 1987b)

Using the number of employees as a measure of firm size Corsten (1987a) analysed the effect of enterprise size on collaboration with universities based on a questionnaire survey completed by 317 respondent firms (from Germany, France, UK and the Netherlands). The research yielded two important results. First, SMEs (number of employees -
operation with HEIs increases with firm size (Table 2.1).

[12] ILOs are the primary interface agents between HEIs and industry. They are crucial to this research for a number of reasons. First, ILOs manage the interface between HEIs and industry. Second, they monitor a myriad of interactions between the two partners. Third, ILOs are acutely aware of barriers and stimulants to the development of U-I links from their own perspective and the perspective of HEIs.

In Scotland in 1995, System 3[13] surveyed a random sample of 500 companies in business sectors which were expected to be more likely to have academic links and a technological orientation (SE and RSE, 1996a). This survey was undertaken to assess the following: extent and nature of technology and IPR related activity in companies; extent and nature of company involvement with academics and HEIs; reasons for company involvement or lack of involvement with academics and HEIs; and attitudes of companies to technology, academics and HEIs. The survey found that the companies which were most likely to have links with HEIs were larger firms. Only one company with over 50 employees reported 'no links' with HEIs, compared to 22% of smaller companies.

Caloghirou *et al.*, (2000) analysed the effect of firm size (based on number of employees), sales, R&D intensity and share of scientists on the propensity to co-operate with HEIs. A total of 312 firms from seven European countries[14] responded to the survey. Upon initial examination, the results indicated no evidence of a relationship between size and propensity of firms to engage in links with HEIs. However, when firm size was correlated with volume of sales, significant differences emerged. It was found that large firms with average sales over €1 billion tend to co-operate more often with HEIs than SMEs. Similarly, having reviewed the results of the National R&D Survey conducted annually by the National Science and Technology Board (NSTB) of Singapore, Wong (1999) found that small firms with sales below $10 million attached less importance to HEIs as a source of technology than larger firms.

Bishop (1988) provides a number of reasons for such findings. First, large firms have the resources to cater for student placements while small firms have little scope to implement such activities. Second, large firms have access to greater financial resources to fund links with HEIs when compared to small firms. In addition, large firms are in a position to fund basic research which attracts the interest

[13] System 3 was one of a number of bodies commissioned by Scottish Enterprise (SE) and the Royal Society of Edinburgh (RSE) to conduct research on specific aspects of the commercialisation of Scotland's science base for the purpose of compiling the *Commercialisation Enquiry: Final Research Report* (SE and RSE, 1996a). In all, the enquiry explored seven research themes. These were: review of the commercialisation process in Scotland; finance; technology and science base; corporate perspective; spin-out routes; institutional case studies; and academic attitudes and involvement. A number of research bodies were commissioned to analyse particular aspects of each theme. System 3 was one of the bodies commissioned to analyse company attitudes in relation to links with HEIs under the theme of corporate perspective.

[14] The distribution by country of the sample was as follows: Greece 88 firms; UK 73 firms; Spain 43 firms; Sweden 30 firms; Italy 30 firms; France 29 firms; and Ireland 19 firms.

of academics. Third, large firms may be more aware of the advantages of engaging in links with HEIs. Employing highly qualified personnel educated in HEIs, large firms have a pool of graduates who are aware of the capabilities of HEIs, who know how to access the appropriate expertise in HEIs and able to engage in dialogue with academics. Furthermore, large firms are more likely to have dedicated personnel focused on creating and maintaining links with HEIs. Smaller firms may lack the technological capability to absorb technology from HEIs (Wong, 1999).

Santoro and Chakrabarti (2002) correlated firm size with the types of interaction between firms and HEIs[15]. The survey found that larger firms in resource-intensive industrial sectors use knowledge transfer and research support relationships to build competencies in non-core technological areas. In contrast, the survey found that smaller firms in high-tech industrial sectors focused more on problem solving in core technology areas through technology transfer and co-operative research relationships. Evidently, large firms have the financial resources to work with HEIs on long-term leading-edge technologies not related to the firm's core technology business. Conversely, small firms gain access to HEI facilities to advance core technologies and are more concerned with survival than with creating a profile of non-core technologies.

Apart from the research completed in the 1980s and 1990s (Corsten, 1987a, 1987b; Bishop, 1988; Vedovello, 1995, 1998) and at the turn of the 21st century (Wong, 1999; Caloghirou *et al.*, 2000; Santoro and Chakrabarti, 2002), there is no substantive body of literature that provides an empirical assessment of the propensity of firms to form HEI links based on firm size. Instead the research analyses firm size, with a particular focus on SMEs (as a defined group of innovative agents), either from the perspective of links between SMEs and HEIs (Lindholm Dahlstrand, 1999) or on the sources of innovation for R&D-intensive activities of small high-tech firms (Piergiovanni *et al.*, 1997)[16].

[15] Interviews were conducted with 31 firms in the semiconductors (10 firms), metals and fabricated metals (12 firms), manufacturing (5 firms) and biotechnology (4 firms) industrial sectors.

[16] In relation to the existing literature on the innovative inputs and capabilities of SMEs, Hoffman *et al.*, (1998) highlight a series of conceptual and methodological problems associated with research completed on SMEs.

2.3.1.2 Productive sector

A firm's productive sector can influence the potential for interaction between HEIs and firms (Vedovello, 1995). Certain academic fields are more amenable to links with industry in the same way that certain industrial sectors are more amenable to links with HEIs. Evidently, a sector bias emerges reflecting the sector specific focus of much of the existing research on U-I links from the perspective of industry (Hassink and Wood, 1998; MacPherson, 1998; Giesecke, 2000).

Within the high-tech sector, as defined by the OECD (1995a) (Chapter 3, Section 3.2.2; Appendix 3.7), sub-sectors in the 'high' technology category *(i.e.* aerospace, computers, electronics and pharmaceuticals) and to some extent in the 'medium high' technology category (*i.e.* scientific instruments, electrical machinery, motor-vehicles, chemicals and non-electrical machinery) have been analysed as sector specific case studies. This is due to the high level of R&D activity in these industrial sectors which is compatible with the profile of R&D activities in HEIs. Providing a framework for sector specific analysis by researchers seeking to deduce the nature of U-I interaction in these sub-sectors, the categories of 'medium low' and 'low' technology have been largely excluded from empirical studies on U-I links.

While there is a high propensity for links between HEIs and firms in the 'high' technology category (OECD, 1995a), it does not follow that U-I links have been limited to those productive sectors (Vedovello, 1995). Research bias towards certain industrial high-tech sectors has excluded other high-tech sectors which are as likely to engage in links with HEIs. Sector specific case studies provide an in-depth analysis of the activities of firms in relation to U-I links, yet there has been no empirical evidence to suggest that specific sectors are more likely to engage in links with HEIs than others (Vedovello, 1995).

While there are certain theoretical and methodological considerations associated with research design which may necessitate a case study sector[17] focused approach, the existing literature on U-I links has been almost exclusively sector specific with the exception of Faulkner and Senker (1994, 1995) whose work focuses on three high-tech sectors (biotechnology, advanced engineering ceramics and parallel computing) and analysed firm links with public sector research (PSR) institutions and the knowledge-flows associated with such linkage. The purpose of the research was to elucidate any sector specific factors which may influence the propensity of firms[18] towards the development of links with PSR institutions. In terms of general findings, they noted that all three sectors reported new product ideas are derived primarily from internal sources. Furthermore, informal linkage plays a major role for all three sectors in links with PSR institutions. In relation to cross-sector differences, the authors noted that biotechnology had a higher propensity for links with PSR institutions compared with the case of ceramics (which has a varied propensity) and parallel computing (which had a low propensity). By way of providing a comparison with these findings from the perspective of HEIs, Meyer-Krahmer and Schmoch (1998) analysed forms of U-I interaction in three science-based fields (chemistry, information technology and biotechnology). The authors found that the science subject in German HEIs with the highest propensity for linkages with industry was biotechnology. The empirical evidence from both studies indicates a high correlation between the R&D activities of firms and HEIs in biotechnology creating a high propensity for U-I collaboration in this area.

2.3.1.3 R&D activity

There is an assumption that firms which engage in R&D activity have the potential to enhance their ability to innovate and achieve competitive advantage in international markets (Vedovello, 1998). Under this logic, the more R&D intensive firms are, the faster their economic growth with the opposite result for firms with low R&D intensity.

One source of R&D literacy is the creation of an in-house R&D department. There is a presumption that more R&D literate firms (based on access to internal R&D capability) have a greater possibility of establishing links with external sources of innovation such as HEIs, government laboratories and other firms. However, there has been no substantive evidence to suggest that firms with in-house R&D capabilities have a higher propensity to establish links with HEIs compared to firms with low levels of in-house R&D capability. In their study, Caloghirou *et al.* (2000) found that R&D intensity (computed as R&D expenditures/sales) has no significant impact on the propensity to co-operate with HEIs. They argue that there is no relationship

[17] Sector specific analyses in relation to U-I links provide an in-depth account of the development and activities of firms from the perspective of gaining access to external sources of innovation.
[18] A total of 31 firms participated in the research, 23 were based in the UK and 8 were based in the USA.

between technological intensity and frequency of co-operation with HEIs. However, in their survey of Scottish companies, System 3 found that companies with in-house R&D capabilities have greater contact with academia in every area, particularly in licensing and sponsoring research, while they noted very little contact by companies without R&D facilities (SE and RSE, 1996a).

However, from the perspective of firms with low levels of R&D intensity, an absence of in-house R&D facilities does not preclude such firms from engaging in links with HEIs, whereby their innovative capabilities could be enhanced. Increasingly, these firms tend to look for outside resources to supplement and substitute for the rather expensive in-house effort (Caloghirou *et al*., 2000). While there is no empirical evidence to suggest a correlation between R&D intensity and co-operation with HEIs, the importance of in-house R&D activity for firms undertaking links with HEIs should not be underestimated. These firms are better prepared to interact with external sources of innovation and are better equipped to evaluate/exploit new knowledge generated outside their organisational boundaries (Arora and Gambardella, 1990, cited in Vedovello, 1998). However, the degree to which R&D activity and intensity determines the propensity of firms to engage in links with HEIs is unknown (Vedovello, 1998).

2.3.2 Characteristics of academics

To date, there has been no systematic assessment of the characteristics of academic researchers who engage in links with industry (Mansfield, 1995). The one area where there has been some research completed on these characteristics relates to academic disciplines which contribute to industrial innovation (Mansfield, 1995; Lee, 1996; CURDS, 2001). This research, however, tends to audit the frequency of interaction between certain disciplines and industry and is descriptive rather than analytical.

CURDS (2001) stipulate that many HEIs are now focusing on particular sectors of their business interaction. Corroborated by Mansfield (1995), the contribution of academic research to industrial innovation is most prevalent in the drugs, instruments and information processing industries. While HEIs are targeting specific industrial sectors, it is important to emphasise that in certain academic disciplines engagement with industry occurs more frequently. Lee (1996) confirms this by stating that academic disciplines which exhibit a high propensity for links with industry are engineering and applied science (chemical engineering, electrical engineering, computer science and materials science).

In the late 1990s, CURDS (2001) initiated a survey investigating HEI interaction with industry. All 168 HEIs in the UK were requested to participate through a questionnaire survey, with 149 HEIs responding. Of this total, 48 HEIs identified biotechnology, life sciences and pharmaceuticals as one of their three most important academic disciplines in terms of links with industry. A further 52 HEIs identified various permutations of information and communication technologies (ICT), digital technologies, new media and telecommunications.

Despite some focus on the role of certain academic disciplines there has been no attention directed to other characteristics of the academic community. In particular, there has been no analysis in the literature of the following: age profile; sex; educational attainment; previous employment if any outside academia; employment history in academia; type of academic post held; and main work activities in HEIs discharged by academics. There has been no empirical evidence to assess the role that these characteristics may play in the propensity of academics to engage in links with industry. This research seeks to address this gap in the literature.

2.3.3 Barriers and stimulants to U-I links

Effective U-I links differ considerably among different industries, academic disciplines, and research areas (Mowery, 1998). A series of barriers and stimulants pervade U-I collaboration and occur at all levels of the system (PREST, 1998). Barriers and stimulants to U-I collaboration are relative to the types of links (*i.e.* R&D, consultancy, teaching/training and commercialisation of university research) that are established. The following section analyses the barriers and stimulants to U-I links from a number of different perspectives.

2.3.3.1 Barriers and stimulants from the perspective of firms

From a firm perspective, there has been no comprehensive review of the barriers and stimulants to the creation of links with HEIs. The literature on barriers and stimulants presents a bias in terms of its focus on R&D links with the exclusion of consultancy and teaching/training. Both from the perspective of firms and HEIs, the literature alludes to the barriers and stimulants in relation to the creation of R&D links (Lee, 2000; Business-Higher Education Forum, 2001).

In their survey of R&D links, the Canadian Research Management Association (1991) cite four barriers associated within the firm: (1) the cultural gap; (2) gaining management commitment for the link; (3) affordability of research; and (4) technological competence of the firm. Following the creation of an R&D link, Warda (1995) argues that industry's requirements for external outsourcing in R&D differ from the capabilities which HEIs can offer. In addition, Warda (1995) found that the most significant barrier to R&D collaboration was the culture gap between both communities. Key actors within industry stipulated that faculty culture was not geared to business collaboration and within HEIs indicated that industry had little understanding of HEI culture. These views are confirmed by the CIHE (1998), which recognises the existence of a cultural gap between HEIs and SMEs. In particular, they noted that:

- HEIs across Europe have little need to relate to their local economy;
- HEIs are primarily supply-driven rather than customer focused (Section 2.2.2);
- Internal HEI priority of basic research does not comply with industry's problem-solving R&D requirements;
- There are relatively few funding incentives encouraging HEIs to focus on the needs of industry. The prime source of HEI money is derived from state-sponsored research and the number of students on courses;
- Many academics lack exposure to the business world. Accordingly, they have limited innovative expertise and find it difficult to facilitate the time frame demands of SMEs;
- SMEs are not a homogenous group and are difficult and resource-intensive to access and cultivate;
- SMEs are focused on short-term goals, are not aware of the capabilities of HEIs and have little time or an easy mechanism of finding out;
- Many entrepreneurs are suspicious of HEIs and their graduates. They themselves do not have experience of the HEI system and feel that graduates have little to offer industry in terms of practical input.

The focus in the literature on stimulants to U-I links, is again on R&D links. The reasons which appear frequently in the literature on U-I collaboration (Lee, 2000) indicating why firms engage in R&D links with HEIs are to:

- Solve specific technical or design problems;
- Conduct 'blue sky' research in search of new technology;
- Develop new products and processes and improve product quality;
- Conduct fundamental research with no specific applications in mind;
- Conduct R&D leading to new patents;
- Access new research (via seminars and workshops);
- Maintain an ongoing relationship and network with HEIs;
- Recruit university graduates.

A number of problems exist in the literature on barriers and stimulants to U-I links from a firm perspective. First, the focus is exclusively on R&D links with no attention to the factors which contribute to and impede consultancy and teaching/training links. Each type of link elucidates specific barriers and stimulants. Second, there has been little attention focused on the relative importance of stimulants which encourage firms to initiate and maintain links with HEIs. Third, there has been no appreciation of the barriers preventing firms without HEI links from engaging in such interaction. This research seeks to add to the existing literature by addressing these issues.

2.3.3.2 Barriers and stimulants to U-I links: HEI perspectives from the UK PREST report

Much of the literature on U-I links makes reference to the barriers and stimulants from a HEI perspective (Warda, 1995; Lee, 2000). The literature on the role of HEIs as agents of technology transfer (Section 2.5), highlights both positive and negative issues which arise within HEIs in relation to links with industry. In this section, particular reference will be made to the research completed by PREST (1998). This study provides a comprehensive view and empirical evidence of the barriers and stimulants to the development of U-I links from the perspective of UK HEIs.

The PREST (1998) survey was funded by four government funding bodies in the UK. These were: the Higher Education Funding Council for England (HEFCE); PREST; the Scottish Higher Education Funding Council (SHEFC); and the Higher

Education Funding Council for Wales (HEFCW). Principal objectives of the PREST (1998) survey were to: provide a comprehensive analysis of direct and indirect interactions between all UK HEIs and industry; and provide information enabling HEIs to benchmark their individual activities in this area. Analysing three main dimensions of the relationship with industry the study focused on: collaboration through research and consultancy; commercialisation of HEI research; and industry links in the context of continuing education and training (CET). In each of these areas, the survey analysed two horizontal themes: the effect of public policies designed to support HEIs, particularly those directed at stimulation of the relationship with industry; and changes in the environment of HEIs which have had an impact upon U-I links. In analysing the commercialisation of HEI research, the survey covered IP, spin-off companies, science parks and incubator units, and company laboratories on campus. It is important to note that ILOs, continuing education officers (CEOs) and senior management (mainly vice-chancellors) were interviewed and not academics[19].

Table 2.2 Barriers to establishing research[20] and consultancy links with industry ranked by mean value[21]

Barrier	Research Mean	Consultancy Mean
Differences in objectives	2.5	1.7
Work needed by industry not interesting	1.8	2.1
Getting in touch with relevant industrial organisations	1.8	2.0
No influence on base-line funding	1.5	1.7
Insufficient equipment and facilities	1.3	1.4
No influence on academic promotions	1.2	1.8
Delay in publications	1.1	0.6
IPR issues	1.1	0.8
HEIs not seen as reliable	0.9	1.1

Source: PREST (1998)

In relation to the barriers to establishing research links with industry, the most important barrier was differences in objectives between industry and academia (Table 2.2). The second most important barrier was that the research work required by industry was not interesting for academics to undertake. In addition, HEIs noted the

[19] The PREST (1998) survey collected information for the academic years 1995-96 and 1996-97.
[20] Research in this instance refers to research contracts and income.
[21] Respondents were asked to rank their top five factors of the nine shown in Table 2.2 in order of importance. To calculate the means shown, a score of five was given to the most important factor, four to the next important factor and so on. Items outside the top five were given a score of zero.

existence of a lack of information in relation to accessing relevant industrial partners. The factor, 'no influence on base-line funding' was ranked fourth while 'insufficient equipment and facilities' was ranked fifth. What is surprising is that barriers relating directly to career aspirations of academics did not rank highly. It is significant that 'no influence on academic promotions' (ranked sixth) and 'delay in publications' (ranked seventh) were not in the top three given that these are the barriers most often cited in the literature on U-I links (Feller, 1990; Fassin, 1991; Business-Higher Education Forum, 2001). However, it must be noted that the respondents were not academics.

The barriers to establishing consultancy links were ranked somewhat differently from those for research. The factor, 'work needed by industry not interesting' was ranked at the top while 'no influence on academic promotions' rose to third in importance. Differences in objectives drops from first position for research to fourth position for consultancy. According to PREST (1998), this reflects the different expectations that HEIs have for consultancy, which are more likely to reflect industry's needs. 'No influence on base-line funding' and 'insufficient equipment' each declined in importance in comparison to their status as stimulants for research links. This reflects HEI attitudes to consultancy as an activity based on interpersonal interaction with little need for substantial input in terms of money and resources from HEIs. 'IPR issues' remain at the same level of relative insignificance while 'delay in publications' was ranked as the least significant barrier.

Table 2.3 Factors motivating research and consultancy links with industry ranked by mean value

Motive	Research Mean	Consultancy Mean
To access industrial funding	4.2	3.2
Collaboration with industry is a strategic institutional policy	2.6	2.5
To find an exploitation outlet for research capabilities	1.9	2.0
To access complementary expertise	1.6	1.3
To provide an outlet for research results	1.5	1.2
To access state-of-the-art equipment and facilities	0.9	0.6
To contribute to local economy	0.7	1.5
Government policy and/or political pressure	0.5	0.4
To contribute to UK economy	0.4	0.7

Source: PREST (1998)

In relation to motivations for establishing research links with industry, HEIs rated 'access to industrial funding' as the most important factor (Table 2.3). The second most important factor was that 'collaboration with industry is a strategic institutional policy' objective. Also significant was the fact that HEIs view links with industry as an exploitation outlet for research capabilities. Lower down in terms of importance was 'access to state-of-the-art equipment and facilities'. In addition, the survey data revealed that political pressure to develop links with industry and a desire to contribute to the local and UK economy were rated as the least significant motivation factors for research links.

In relation to stimulants for establishing consultancy links, the same top three motives for research were also recorded for consultancy. One motive which changed significantly was 'contributing to the local economy'. This factor was ranked seventh for research but was ranked fourth for consultancy. Clearly, respondents consider that consultancy links have a more important role to play in enhancing the local economy than research links.

Table 2.4 Barriers to providing CET for industry

Barrier	Number of times cited
Lack of willingness/ability to pay economic rate	26
Insufficient priority within HEI	25
Industry not perceiving CET as relevant	23
Difficulty in getting marketing information	22
Need for cultural/structural change in HEI	20
Difficulty for SMEs to release staff	8

Source: PREST (1998)

In relation to the provision of CET for industry, CEOs of HEIs were asked to identify the most common barriers. At the top of the list was a lack of willingness or ability on the part of industry to pay an economic rate for CET (Table 2.4). In particular, CEOs noted an expectation on the part of industry that such courses should be subsidised. The second most frequently cited barrier was evident within HEIs, and concerned a low level of interest for this type of activity. CEOs stated that it was the lack of career incentives for academic staff to undertake CET rather than engage in conventional teaching and research activities within HEIs which created a lack of appreciation within academia for the provision of CET for industry. A similar weighting was given to the barrier of 'industry not perceiving CET as relevant' to industrial needs. The fourth most cited barrier was an inability to access the SME community to market CET. The fifth barrier related to a need to change the internal culture/structure to be able to meet the needs of SMEs. The final barrier cited by CEOs was the difficulty for SMEs to release staff and participate in CET. SMEs very often do not have the financial or personnel resources to be able to release staff and avail of the benefits of CET.

Table 2.5 Success factors in providing CET for industry

Barrier	Number of times cited
Course content designed for industry's needs	34
Development of close and long-term links	28
High quality staff and material	12
Good marketing	11
Commitment to CET for industry	9
Credibility and reputation of the HEI	5

Source: PREST (1998)

While CEOs were asked to identify the barriers in providing CET, they were not asked to list the stimulants. Instead, they were asked to identify the top three factors for success in providing CET. They cited course content as the most important factor (Table 2.5). In particular, they noted that courses should be designed to meet the specific needs of industry. The second most cited success factor was the development and maintenance of close links between HEIs and industry. Such relationships are central to the success of CET. Of less importance were each of the remaining factors which correlate with the views expressed by CEOs in terms of the barriers to CET for industry.

While the PREST (1998) survey was comprehensive in its review of the barriers and stimulants to the creation of U-I links in research, consultancy and commericialisation, its key focus was on HEIs. It did not take into account the individual experiences of industrialists and academics. While there was a merit in analysing the institutional framework of HEIs, this approach provided only one perspective on the diversity associated with U-I interaction and failed by its omission of the key players in such collaboration.

In 2001, the CURDs report was published. This survey was commissioned by HEFCE on behalf of: the DTI; the OST; the Department for Education and Skills (DfES); SHEFC; HEFCW; and the Department for Employment and Learning (DEL), Northern Ireland. It sought to build on the research completed by PREST (1998) and reported on the role of HEIs, analysing the differing institutional missions, strategies, capacities/expertise of HEIs in developing links with industry. Focusing on the commercialisation of HEI research, it audited and benchmarked the activities of HEIs in relation to commercialisation. Since the publication of the PREST (1998) report additional government funding was placed into a range of initiatives to encourage the development of U-I links. The purpose of the CURDs (2001) report was to assess the environment for commercialisation which has evolved in UK HEIs in light of such increases in public expenditure. Highlighting significant problems with government-funded surveys it assessed the level of U-I interaction. Policy-related literature merely scratches the surface of the field of U-I links by auditing the level of interaction and providing benchmarks by which HEIs should assess themselves. The objective is that HEIs will enhance their level of participation and interaction with industry. In such literature, there is no consideration for the experiences of industrialists and academics engaging in U-I interaction.

2.3.4 Conclusion on the theory of U-I collaboration

The germane literature reviewed on U-I collaboration does not provide an all-inclusive perspective of U-I links. Rather it provides an in-depth analysis of specific areas of U-I links. Subsequently, there are a number of biases presented.

First, the literature focuses almost exclusively on U-I links from an industry perspective and, in particular, on firms with HEI links; there is little or no consideration of firms without HEI links. Moreover, the influence certain firm characteristics have on the creation of links with HEIs received little treatment. In particular, there is no assessment of the importance, or not, of the geographical proximity between firms and HEIs as a factor with the potential to facilitate the creation of U-I links. Second, the literature fails to focus on the characteristics of academics with and without industry links. Third, there is a significant bias evident in the literature in terms of sector/subject coverage. From an industry perspective there is a narrow focus on selected high-tech sectors with little or no attention paid to the activities of firms engaging in the lower spectrum of high-tech activity. This introduces a bias in sector coverage and excludes some high-tech sectors which are also likely to have links with HEIs. Similarly, from an academic perspective, the literature referring to academic links with industry focuses almost exclusively on certain subject areas (such as biotechnology and electronics) which are more likely to have links with industry and exaggerates the level of success achieved by HEIs in developing successful partnerships with the private sector. While an approach to sector/subject coverage is perfectly legitimate for the purposes of research, the tendency towards inclusiveness and exclusiveness when sector/subject selection is taking place significantly reduces the value of findings emerging from the research in terms of accurately describing U-I links or indeed as a basis for the formulation of government policy in science and innovation (Hoffman *et al.*, 1998).

2.4 INNOVATION, REGIONAL DEVELOPMENT AND HIGH-TECH FIRMS

> *He that will not apply new remedies must expect new evils. For time is the greatest innovator (Francis Bacon, Of Innovations, cited in Pitcher, 1985, 132).*

With a highly competitive and volatile global market, productive flexibility in manufacturing industry requires a continued emphasis on product and process innovation (Trigilia, 1992).

The term 'innovation' has a variety of definitions. According to the *Green Paper on Innovation* (European Commission, 1996), it is defined as the successful production, assimilation and exploitation of novelty in the economic and social spheres[22]. A later definition by the European Commission (2002) states that innovation is the marriage of knowledge and the market, using knowledge to foster economic development. The OECD (1999b) view innovation as the ability to create, distribute and exploit new knowledge and information.

While definitions of the term vary, there is little dispute that innovation has increasingly become a primary indicator of competitive advantage, performance and survival (Hazelkorn, 2002). The relationship between a nation's prosperity and ability to engage in innovation is best summed up by Umberto Colombo who states that innovation is not an option for an industrial society, it is an obligation; economies proving themselves hesitant in this climate of rapid and dramatic change lose ground internationally and this can start a perverse spiral of economic decline (cited in McBrierty and O'Neill, 1991). However, while U-I collaboration increases innovation, it is only one of many variables influencing technological innovation (Berman, 1990).

Interest in U-I links stems from the presumed role that such links play in terms of generating economic development (Hopkins DeVore, 1992). There is a widely held view that by strengthening the research capabilities of HEIs and facilitating technology transfer to industry, regional development will follow (Charles, 2003; Lindholm Dahlstrand and Jacobsson, 2003; Glasson, 2003). Some commentators

[22] According to the European Commission (1996) "innovation is the renewal and enlargement of the range of products/services and associated markets; the establishment of new methods of production,

argue that HEIs play a pivotal role in developing technological innovation, encouraging small firm growth and enhancing the industrial potential of the surrounding region (Chrisman *et al.*, 1995; Cooke *et al.*, 2000; Jones-Evans, 2000; Yang and Sun, 2001). Little doubt exists because of the variety of benefits accrued by national economies from the successful development of a deeper and more effective interaction between HEIs and industry (Hardiman, 1994). However, it would be overstating the case to argue that U-I interaction initiates economic development. According to Doutriaux (2003), HEIs are certainly important catalysts of local high-tech development, but they are generally not the drivers of such development. U-I links are not a precursor to economic development; rather, such interaction is important in terms of sustaining and facilitating development. Successful academic-industry links are crucial, therefore, in terms of providing an overall contribution to sustaining economic competitiveness.

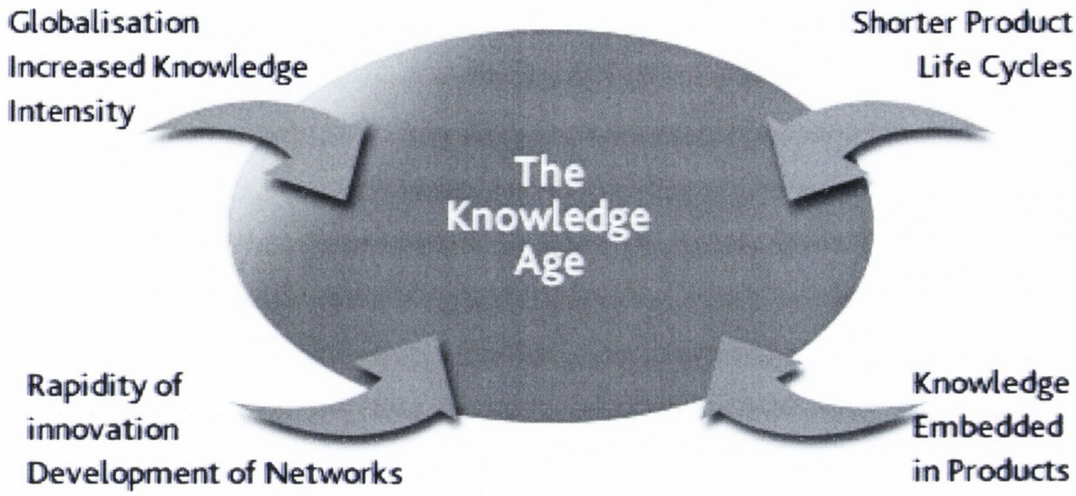
As the process of industrial restructuring has evolved, a new geography of industrial organisation has emerged. Adapting to changing quantitative and qualitative demands of volatile markets, organisational flexibility has become an essential prerequisite of industrial success. The ability to adapt and achieve dynamic efficiency within a competitive market environment emerges through a combination of intra-firm (internal) and inter-firm (external) flexibilities. Internally, firms have introduced flexible labour and new technologies. They have also implemented flexible production systems and initiated in-house R&D departments to facilitate product and process innovation. Externally, firms are becoming increasingly embedded within local economies through inter-firm co-operation and collaboration. This has occurred simultaneously with the development of networking relationships with key regional actors such as HEI-based R&D institutes. Such internal and external strategies are implemented in an effort to achieve greater flexible specialisation and thus respond to intense international competition and the emergence of increasingly differentiated markets.

Based on the requirements of flexible specialisation, firms must modify their specialised roles in order to meet the changing requirements of different markets. In particular, technological innovation has become a crucial factor in facilitating

supply and distribution; the introduction of changes in management, work organisation, and working conditions and skills of the workforce" (9).

competitive advantage in order to capture a greater share of national and international markets.

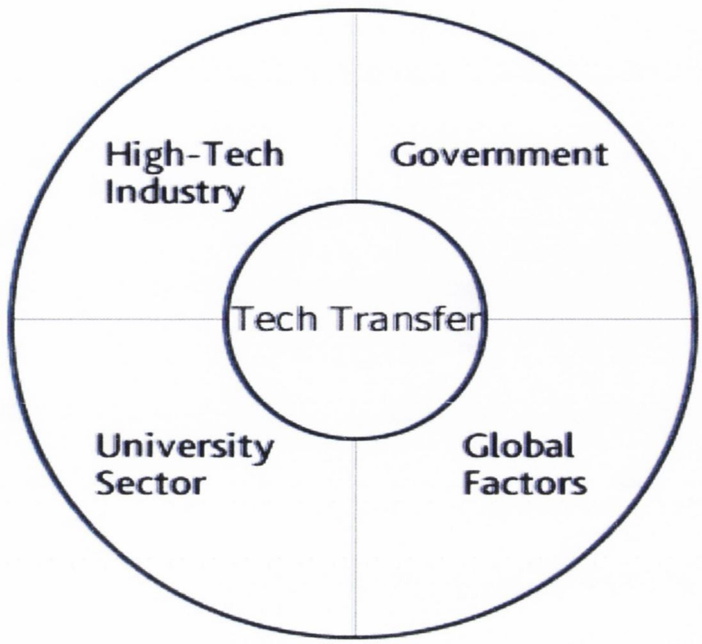
Figure 2.2 The new global competitive environment



Source: SE and RSE (1998)

Within the high-tech sector, one of the main dimensions of competitive success derives from an ability to accelerate product innovation. Increasing international competition, allied with the development of a highly volatile technological environment, has induced high-tech firms to pursue competitive strategies based on product innovation. Within the global economy, a changing consumer demand in the direction of more differentiated products and an increased desire for products of higher quality evoke an increasing need for R&D (Figure 2.2). Firms are responding to competitive pressures by adopting policies designed to manufacture a range of product configurations in order to meet the changing demands of markets. As the process of industrial restructuring has evolved into the post-fordist paradigm of industrial organisation, R&D has become an essential prerequisite for industrial success and a key spatial fix for the regional reconcentration of production. Consequently, one of the key dimensions associated with achieving competitive advantage has been an increasing commitment to and orientation towards the development of R&D networks of interaction between high-tech industry and HEIs. While a number of studies have highlighted the crucial importance of firm engagement with HEIs, international literature has failed to examine the growth for firms without HEI links. This research seeks, in part, to focus on the barriers and stimulants to firms without HEI links in Ireland.

Figure 2.3 Key stakeholders in technology transfer



According to the OECD (1994b), the growing importance of innovation in industrial strategies has brought industry closer to HEIs. International comparisons elucidate new forms of collaboration and highlight the institutional changes, mechanisms and policies which stimulate their development. Driven by global factors associated with increased competitiveness, the relevant stakeholders from HEIs, industry and government have a crucial role to play in enabling the development of the U-I interface and, thereby, enhancing technology transfer (Figure 2.3). The economy that fosters close interaction between firms, HEIs and government gains competitive advantage through quicker information diffusion and product deployment (US Council on Competitiveness, 1998, cited in OECD, 2000). Performance of a National System of Innovation (NSI)[23] depends on the intensity and effectiveness of interactions between key actors involved in the generation and diffusion of knowledge (Vedovello, 1998; OECD, 1999a, 2000). According to the OECD (1999c), innovation no longer depends solely on how firms, HEIs, research institutes and regulators perform, but increasingly, on how they co-operate. As a result, firms now recognise the importance of academic research in developing innovative activity. To maintain

[23] The NSI is the collection of all institutions and mechanisms (public and private) which interact to stimulate and support product and process innovations within the national economy (Science, Technology and Innovation Advisory Council (STIAC), 1995).

competitive advantage, firms must gain access to centres of innovation and HEIs have a crucial role to play in ensuring firms remain competitive.

2.4.1 Science parks

A fundamental component of research exploitation and diffusion as part of technology transfer has been the growth of science parks in the USA and Europe, with their distinctive local image and proactive involvement with HEIs (Mitra and Formica, 1997). Science parks represent a bricks-and-mortar-based model of technology transfer. The growth and establishment of science parks in close proximity to HEIs creates an important interface environment, one which enables the development of links between researchers and entrepreneurs and thereby facilitates new firm formation and the commercialisation of HEI research. The key focus of the science park model is to develop stronger links between industry and HEIs. Science parks represent the concentration of scientifically sophisticated research experts who generate new technologies and innovative ideas which are channelled into industry through a variety of commercial ventures resulting in the development of new companies, new processes and new products (Westhead and Storey, 1995; Cooke *et al.*, 2000; Pandya *et al.*, 2001). Science parks provide an environment promoting the necessary synergy between HEIs and firms thereby facilitating interaction between HEI-based researchers and industrial practitioners (Jacob *et al.*, 2000). The existence of a local culture favouring innovation, entrepreneurship and co-operation, coupled with formal and informal arenas for social interaction between tenant firms and HEI researchers, are among the key characteristics associated with successful science parks (Ylinenpää, 2001). According to Westhead and Storey (1995), the science park model reflects an assumption suggesting technological innovation stems from HEI-based research while also assuming that science parks provide a medium or incubator environment for the transfer of research into production. U-I collaboration and its possible effectiveness via the science park model is highly variable and is geographically, sectorally and temporally specific. Furthermore, the degree to which the associated geographical proximity has facilitated the development of U-I links is questionable and, again, varies considerably in different spatial, sectoral and temporal contexts.

In the USA during the 1980s, science parks resulted in closer links between industry and academia at all levels and led to high numbers of new HEI spin-off[24] firms (Howells, 1986). However, in Japan, close ties between industry and universities did not emerge from science park developments. According to Howells (1986), this was due to the fact that close contacts between industry and the HEI sector in Japan are maintained on an informal, personal level. Subsequently, the success of informal ties has not encouraged industry to institutionalise research contacts and, thereby, actively engage in formal links with Japan's HEIs. Recent measures implemented by the Japanese government have sought to address this trend and promote the development of formal contacts between industry and academic partners.

In the early 1990s, the work of Quintas *et al.*, (1992) reviewed the science park model linking academic institutions and industry in the UK. They suggested that the UK model did not indicate very strong links between HEIs and industry and that the science park model itself is problematic. Similarly, having reviewed the literature on science parks in the UK, Manimala (1997) concluded that science parks have very limited success in the formation of U-I partnerships. The 'HEI connection' does not provide special advantages to high-tech science park firms when their performance is compared to non-science park high-tech firms (Manimala, 1997). However, in the UK advocates of the science park mechanism maintain that geographical proximity between HEIs and firms facilitates and strengthens links between these partners (Vedovello, 1997). Indeed, one of the key research questions of this thesis will address the degree to which the science park model enhances links between HEIs and indigenous high-tech firms in Ireland. Through an in-depth analysis of a specific science park (The National Technological Park, Plassey, Limerick), this research questions and analyses the extent to which geographical proximity between science park firms and UL facilitates the promotion and strengthening of their links (Chapter 4). In addition, this research also provides an assessment of the degree to which geographical proximity facilitates the creation of HEI links for non-science park firms.

In an effort to initiate economic integration at the international level while also maintaining competitive advantage, the spatial organisation of flexible specialisation

[24] Spin-off firms are also referred to as spin-out firms. For the reminder of this thesis, the term spin-off will be used.

has become structured around a "global-local nexus" (Dicken, 1994, 102). The geography of post-fordist production is both local and global as firms pursue rapid globalisation while also retaining their local identity by embedding within regional economies. Therefore, the emergence of globalisation has generated a new economic dialectic between the local and the global (Conti, 1995). Accordingly, economic geography in an era of global competition is to some extent paradoxical (Porter, 1998a). In a global economy driven by high-speed telecommunications infrastructure, rapid transportation networks and accessible markets, it would be safe to presume that the importance of location as a source of competitive advantage would diminish. However, the opposite would appear to be the case (Porter, 1998a). Competitive advantage in the global economy lies increasingly within clusters[25] of interconnected companies and institutions – such as HEIs, government agencies, suppliers, standards-setting agencies, think tanks and vocational providers - who all provide firms with a range of specialised training, education, research and technical support services. Competitiveness depends not only on how firms utilise their intangible assets (such as skills and creativity) but also on how they extend these intangible assets by co-operating with other firms and HEIs. According to Porter (1998a), clusters affect competition in three broad ways: first, by increasing the productivity of companies based in the area; second, by manipulating the direction and pace of innovation; and third, by stimulating the formation of new businesses within clusters.

The geographical clustering of firms, their suppliers and buyers within the regional economy has become a crucial factor in terms of achieving competitive advantage (Clancy *et al.*, 1998). Consequently, the geography of such clusters has become a key strategic influence for the location of high-tech firms. The degree to which a cluster of firms has achieved competitive advantage through inter-firm networking at the regional level is a key factor influencing the location of investment. Geographical location is, therefore, crucial for industrial organisation,

[25] Based on international research, Porter's (1990) book *The Competitive Advantage of Nations* argued that competitive advantage could best be achieved if firms locate in close proximity to form industrial clusters. Spatial proximity facilitates interaction between firms and, thereby, encourages the development of networks of inter-firm synergies. The development of such networks, within and between various clusters, creates the prospect of promoting and sustaining competitive advantage within regional, national and international economic environments. The concentration of firms within clusters facilitates the establishment of inter-firm linkages and enables firms to achieve flexible specialisation. Clusters provide a crucial spatial dimension that encourages the development of networks of interaction between firms and third-level institutions and, thus, enhances the competitive advantage of firms in the global economy. Examples of famous clusters include Silicon Valley and Hollywood (Porter, 1998a).

competitiveness and innovation. Following the geographical clustering of a group of firms from a related sector, competitive advantage can be achieved through the development of a series of inter-firm linkages within the local economy. Inter-firm linkages at the regional level can contribute to competitive advantage while successful U-I interactions help to maintain such competitiveness in the long-term.

The geography of industrial activity changes as economic spaces become redefined. In Europe, technological growth is driven by the diffusion of innovation, technology transfer and knowledge transmission and is concentrated in a number of clusters which are mainly innovative high-tech SMEs (Konstadakopulos, 1998). The desire to achieve competitive advantage through innovation is a key feature fostering the development of a local culture of collective learning among regionally clustered firms thus leading to the emergence of 'learning regions' (Asheim, 1996; Morgan, 1997; Lawson and Lorenz, 1999; Asheim, 2001). The concept of 'collective learning' was first developed by the Groupe de Recherche Européen sur les Milieux Innovateurs (GREMI) or European School of Regional Economic Research and refers to the capacity of a particular regional 'innovative milieu' to generate or facilitate innovative behaviour by firms located within that milieu (Keeble *et al.*, 1998).

Located mostly in urban areas, clusters of economic activity are autonomous, locally co-ordinated and well integrated systems with a dense network of firms, HEIs/research institutes interacting with each other to develop new product and process innovations which are the foundations of competitive advantage. While the creation and development of a localised knowledge base can be structured around a range of linkage mechanisms, one of the most prevalent sources of knowledge diffusion is evident in the movement of 'knowledge carriers' between firms and between firms and HEIs. It is the movement of 'embodied expertise' and 'know-how' in the form of researchers, managers and knowledge-workers, allied with entrepreneurial spin-off activities from HEIs, research institutes and firms, that contributes to the development of a regional culture of knowledge exchange between industry and academia (Keeble and Wilkinson, 1999).

The need for firms to collaborate with HEIs is reflected in the emergence of European regional clusters of innovative high-tech firms which are located in close geographical proximity to HEIs and research institutes (Keeble and Wilkinson, 1999). Recent studies completed in a number of European regions have highlighted the strategic role played by universities in providing knowledge and resources capable of supporting the development of clusters of high-tech commercial activity (Garnsey and Lawton Smith, 1998). Examples of research on the role of HEIs in fostering the creation of clusters of innovative high-tech firms include Cambridge (Keeble *et al.*, 1999), Göteborg (Lindholm Dahlstrand, 1999), Grenoble (de Bernardy, 1999), Oxford (Lawton Smith *et al.*, 2001), Sophia-Antipolis (Longhi, 1999) and Italy (Capello, 1999). Accordingly, the diffusion of new scientific knowledge between firms and HEIs has become an important strategic factor in sustaining regional development. Technology transfer is an instrumental focus of economic development in the region. The pro-active role played by HEIs in fostering links with industry is important in re-instating the region as an autonomous production space. As a result, the development of links between industry and academia plays a pivotal role in facilitating economic development, particularly in economically peripheral and declining industrial regions.

2.5 THE ROLE OF HEIs AS AGENTS OF TECHNOLOGY TRANSFER

> *The campus has been animated by the desire to be a partner in regional economic development (Walshok, 1993, 1).*

HEIs have a general and specific place in the geography of innovation (Lawton Smith *et al.*, 2001) and their general role is derived from their traditional missions of teaching and research. A more specific contribution is focused on a 'third' mission - the commercial exploitation of academic research. During a debate on the Irish University Education Bill over a century ago, British statesman Benjamin Disraeli told the House of Commons that "a university should be a place of light, of liberty, and of learning" (cited in Skilbeck, 2001, 6). During the 19th century, Cardinal John Newman argued that universities would be the "high protecting power of all knowledge and science, of fact and principle, of inquiry and discovery, of experiment and speculation" (Martin, 1982, cited in Klofsten and Jones-Evans, 2000, 299). Strongly affected by the rapid economic expansion of the 1960s, recession in the 1970s, and the economic and technological changes of the 1980s and 1990s, HEIs are now seeking creative responses to the demands of a knowledge-based society in a competitive global market (Conceição *et al.*, 2000). The knowledge industry in modern society is no longer a minor affair run by an intellectual elite; it is a mammoth enterprise on a par with heavy industry, and just as necessary to the national economy in which it is situated (Graham, 1998, cited in Etzkowitz *et al.*, 2000).

Knowledge-based innovation has been facilitated by the ability of HEIs to identify, create and commercialise IP (Etzkowitz *et al.*, 2000). The process of technology transfer from academia to industry is facilitated through HEI-based technology transfer offices. Such offices represent the crucial interface between academia and industry in terms of establishing and maintaining research and consultancy links, creating industrial liaison programmes, ensuring the successful transfer of scientific knowledge and enabling the commercialisation of HEI research. Technology transfer strategies are implemented by ILOs within HEIs. ILOs' main focus is in the commercialisation of R&D and technologies derived from HEI-based research while also providing a fair and reasonable financial return to researchers and HEIs. These officials recognise the market potential of HEI research and establish an agreement with the firm on ownership of IP, advise on technology transfer and negotiate the financial or equity agreement between HEIs and industrial partners. IP management, including the provision of patenting and licensing expertise, is a key service provided by ILOs to support the academic community. A network of ILOs in Europe has been created for the Sixth EU Framework[26] Programme (FP6) as a measure deigned to improve networking between key players and thereby raise the profile of innovation in EU research programmes while also enhancing the development of the European Research Area (ERA) (European Commission, 2002).

The transferability of R&D, derived from HEIs and government-funded industrial research centres, into commercial practicality is proving to be a critical factor in initiating and sustaining the competitive advantage of firms in increasingly knowledge-based economies. Furthermore, the successful development of academic-industry links in research and innovation have emerged as key components of entrepreneurial HEIs which facilitates the competitive advantage of new and existing technology-based companies in international markets.

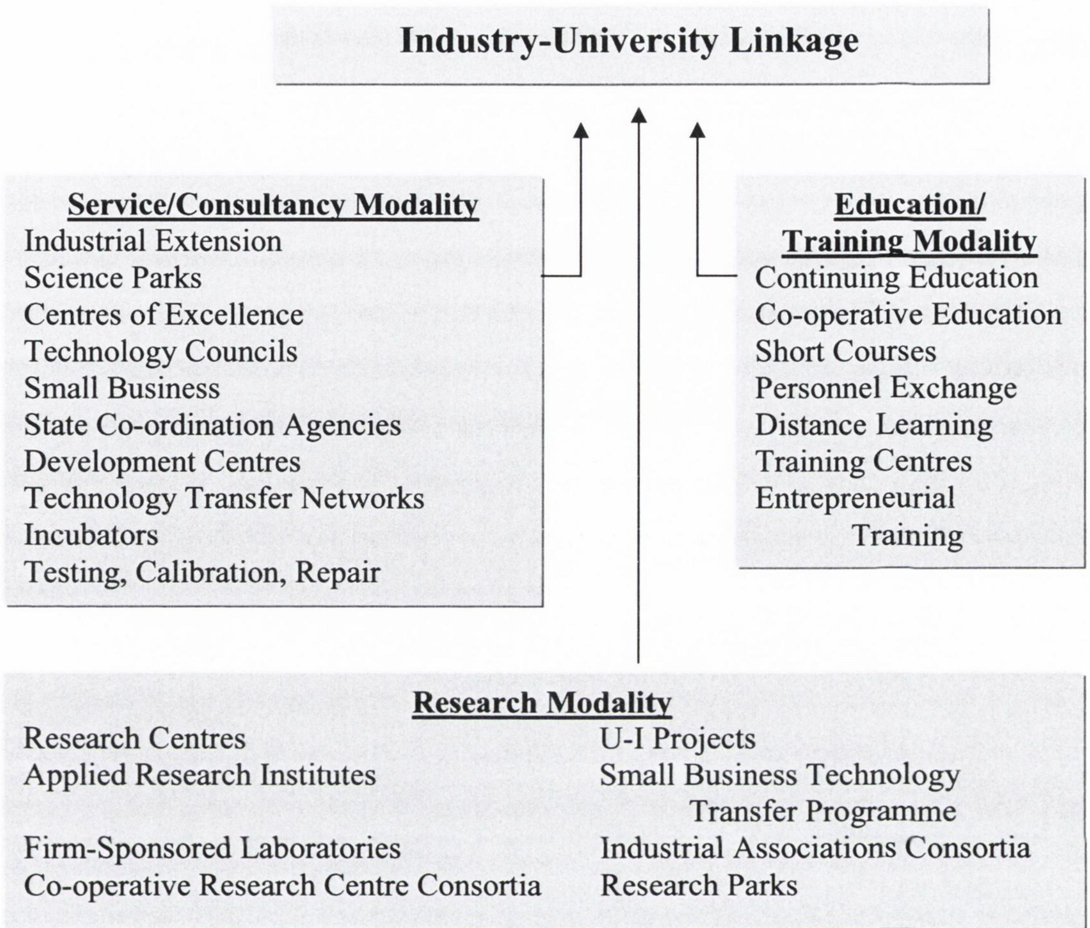
2.5.1 Entrepreneurial HEIs

Entrepreneurial HEIs encapsulate academic structures and functions that are revised through the alignment of economic development with research and through teaching as academic missions (Etzkowitz *et al.*, 2000). In the USA, the traditional HEI

[26] Formalised under the Single European Act of 1987, Framework is a multi-phase, multi-year umbrella programme that provides funds from the EU treasury to consortia of firms and/or HEIs to carry out pre-competitive research in areas of potential interest to industry (Hill, 1991). It supports R&D in such areas as telecommunications/computing, advanced materials, manufacturing technology and energy.

system was, in the past, characterised by a lack of links with industry. The system was driven by a focus on academic prestige, a reliance on government finance to fund research and by an emphasis on basic research (Smilor *et al.*, 1993). However, the traditional paradigm has evolved and restructured and is now characterised by a strong focus on the development of academic entrepreneurship through the commercialisation of HEI research. Driven by the environmental forces of a hyper-competitive global environment, a new paradigm of the 'entrepreneurial university' has emerged. According to David Blunkett, former British Education Secretary, "in the knowledge economy, entrepreneurial universities will be as important as entrepreneurial businesses" (cited in Formica, 2002, 172).

Figure 2.4 Modalities of industry-HEI linkage



Source: Konishi (2000)

As indicated previously the 'third mission' of economic development has emerged in response to the increasing importance of knowledge in NSIs and regional systems of innovation (Cooke, 1992; Gu, 1997; Gregson and Johnson 1997; OECD, 1997; Cimoli, 1998; Cimoli and Giusta, 1998; Drejer, 1999; Martin and Johnston, 1999; Gertler *et al.*, 2000). According to Smilor *et al.* (1993), entrepreneurial HEIs include teaching and research activities as central to their mission while also focusing on academic entrepreneurship as a key contributor to economic development. This paradigm emphasises more direct involvement in the commercialisation of research, a more proactive approach to local and regional development, a more problem-solving and data-driven approach to curriculum development, and a new emphasis on applying the principles of total quality management to HEI operations.

Konishi (2000) provided a summary of the main types of industry-HEI linkage (Figure 2.4). Each of the various types of U-I link can be created on a formal or informal basis.

For the purpose of this research, formal links are defined as those which involve structured agreements between academic and industry partners. These are based on collaborative programmes, contracts and services in the areas of research, consultancy and commercialisation of HEI research.

Through informal links, firms, in their attempt to implement innovation into their activities, establish contact with the pool of information, knowledge and expertise in HEIs (Vedovello, 1995). Informal links involve unstructured agreements between academic and industry partners. Such links are usually based on informal personal contact between both partners and occur on an *ad hoc* basis. Informal links comprise: personal contact; access to specialised literature and reports; access to research; attendance at seminars and conferences; access to equipment; and attendance at general education/training programmes (Vedovello, 1997).

In the USA, the UK and mainland Europe, HEIs have entered a new 'entrepreneurial' phase of U-I relationships which is focusing on developing mechanisms to increase and promote technology transfer between the public and private sector (Dill, 1995; Cooke *et al.*, 2000). These mechanisms include: the introduction or expansion of licensing and patenting offices (seeking commercial applications for HEI research); the growth of small business development centres (providing technical or managerial assistance to entrepreneurs or small businesses); the development of research and technology centres (operating or participating in facilities for the development of new technology); the provision of incubators (managing facilities in support of new technology-based businesses); and the provision of investment/endowment offices (utilising the HEI's financial resources for equity in start-up businesses) (Dill, 1995). The driving force behind the initiation and development of these mechanisms is the commercialisation of HEI research. While there is increasing evidence to suggest that HEIs are practising a range of activities that are leading to the commercial application of research findings, there is little evidence that entrepreneurship is embedded in the fabric and culture of HEIs (Hartshorn, 2002). However, before analysing the process by which commercialisation evolves, it is first important to examine its prerequisite - R&D.

2.5.2 R&D links with industry

> *We owe our continuing existence to the fact that we take ideas from research and turn them into products and processes for profit on the industrial side of the fence (Williams, 1996, cited in Bank of England, 1996, 71).*

HEI-generated R&D remains the principal source of innovation for industry (Warda, 1995) and there are a variety of different ways in which U-I R&D links[27] are constructed. R&D can be conducted collaboratively, based on the development of an academic-industry partnership. Companies may contract HEIs to conduct R&D or they may hold a license for a technology or a product developed by HEIs. Governments in western economies recognise the beneficial role that R&D plays in social and economic development and have implemented a series of publicly sponsored R&D programmes in an effort to increase the number of R&D partnerships between industry and academia. While this may have served as a key incentive for both industry and academia to engage in R&D partnerships, other stimulants also play (and continue to play) a pivotal role in the formation of links between the two.

From a firm perspective, the opportunity to access specialist knowledge and support in industrial R&D is the key stimulant which motivates companies to collaborate with HEIs. While other stimulants encourage firm engagement in such activities, it may be the case that certain companies are more likely to engage in links than others. According to Caloghirou *et al.* (2000), firm size, R&D intensity and scientific capability emerge as the crucial determinants of firms entering into this type of collaboration. This is the case not only in relation to R&D links, but with all forms of U-I interaction. To date, little is known about the characteristics of firms engaging in HEI links and this research attempts to redress this gap in the literature.

From an academic perspective, there are a series of incentives encouraging academics to engage in R&D links with industry. Principal among such incentives is the finance generated from such activities which benefits HEIs, the research director(s), his/her research team and faculty department. In a study of the benefits experienced by academics who completed industry-sponsored R&D projects, Lee (2000) found that 67% agreed that they had acquired a 'substantial' or 'considerable' amount of funds necessary to support graduate students and to purchase laboratory

[27] R&D links can be categorised into three types; (1) basic research links (*e.g.* creative stage/initial phase of research), (2) applied research links (*e.g.* prototype development) and (3) experimental research links (*e.g.* adaptation and fine-tuning of products).

equipment. The study showed that the most important factor motivating academic staff to engage in R&D links with industry was the opportunity to complement their own academic research agenda. However, within the academic environment there are certain academics more predisposed to participate in industry-commissioned R&D projects. Again, there has been little analysis completed on the characteristics of academics and the factors motivating their engagement in industry partnerships. Equally, there has been little attention in the literature given to the characteristics of academics not engaging in links with industry and there has been no analysis undertaken investigating the reasons why such academics do not choose to engage in links with industry. In a study that is focusing on the barriers and stimulants to the development of U-I links, it is important to include both the perspectives of the academic community and that of industry. In the absence of such comprehension, it would not be possible to find ways to eliminate the barriers and enhance the stimulants that may forge more positive and fruitful synergies between academics and industry in areas such as R&D.

2.5.3 Commercialisation of HEI research

> *We must take into account that research is produced by individuals, that organisations provide the means to do research, and that the results of research are 'traded' on many different 'markets' (Commissioner Busquin[28], European Commission, April, 2000)[29].*

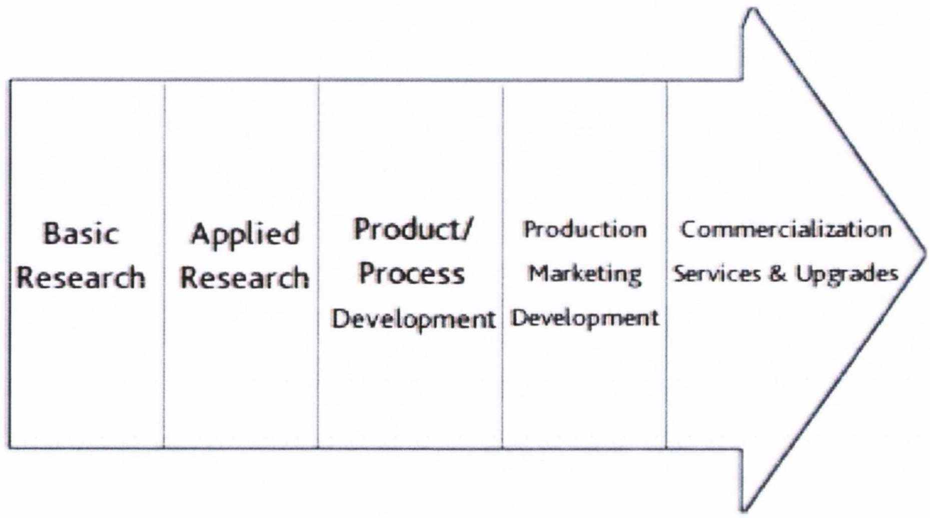
The comercialisation of HEI research through the creation of spin-off companies or through the sale of inventions, patents[30] or the licensing of IP to existing entrepreneurial ventures represents a key vehicle of technology transfer for entrepreneurial HEIs.

[28] Phillipe Busquin is the European Commission's Commisioner for Research.

[29] Commissioner Busquin made this statement in a debate "Towards a European Research Area" (04.04.2000). The source of this quotation, contributions to the debate and commentary from the Commission can be found at http://www.europa.eu.int/comm/research/area/comments2.html.

[30] According to the Patents Office in Ireland (Government of Ireland, 1999), a patent is a form of 'industrial property' that confers upon its holder, for a limited period, the right to exclude others from exploiting (making, using, selling, importing) the patented invention except with the consent of the patentee. Patents have territorial rights. A patent granted in Ireland gives no right in other countries. If protection of an invention is required in several countries, patent applications must usually be made separately in each individual country. However, in Europe, one application to the European Patent Office in Munich can result in the grant of patents effective in eighteen countries, including Ireland (Government of Ireland, 1999). The 1992 Irish Patents Act extended the term of Irish patents from sixteen to 20 years and brought Irish patent law into line with European Patent Convention (EPC) (EI, 2000). Under the terms of the EPC, which came into force in 1977, Ireland became one of the designated states that can be covered by a European Patent.

Figure 2.5 Basic research to product commercialisation



Source: Lin (2000)

It is important to note that the commercialisation of HEI research represents the end stage in a long line of research activities, product development plans and marketing strategies within HEIs (Figure 2.5).

In recent years, with the exception of the HEI sector in Ireland[31] that has received significant increases in the level of state funding to support HEI research, the reduction of publicly funded/non-commissioned[32] research has forced HEIs in many countries to secure alternative sources of funding. Increasingly, industry is the main source of funding and the outcomes generated by joint U-I R&D projects lead to increased productivity of R&D and technology-based innovation. For example, in the

[31] In Ireland, through the *National Development Plan, 2000-2006* (Government of Ireland, 2000), the Irish Government has allocated a total spend of €2.47 billion (IR£1.95 billion) to be dedicated to research in S&T, €711 million (IR£560 million) from a Technology Foresight Ireland Fund to support computer and biotechnology research and a further €698 million (IR£550 million) for the Higher Education Authority (HEA). This money is primarily invested in university research. The single currency, the euro, came into being on 1 January 1999. At that time the value of the Irish pound [along with the currencies of other EU member states participating in Economic and Monetary Union (EMU)] was permanently fixed against the euro (IR£1 Irish pound = €1.2 euros/€1 euro = IR£0.7 Irish pound). This rate was used throughout the thesis.

[32] Commissioned research is funded by industry. Non-commissioned research is funded by the state with no presupposed outputs.

field of S&T, restraints on public-sector finance have encouraged HEIs to seek partnerships with industry.

Figure 2.6 Internal and external factors that effect technology transfer

Source: Designed by author and interviewee number ten in Scotland, while discussing regional innovation systems.

The decline in the volume of government-sponsored research programmes, industrial restructuring, advances in communication technology and intensified international competition have forced the need to strengthen the relationship between HEIs and industry and create closer synergies in an attempt to provide mutually beneficial results (Konishi, 2000). Successful application and commercialisation of HEI research provides industry with a differentiated range of highly specialised, value-added products that can be redesigned according to the precise specifications of international markets. Consequently, the role and scope of modern HEIs have changed in response to a variety of external stimuli (Figure 2.6).

Transfer of technological innovations from HEIs to industry through the formation of spin-off companies represents one of the most important mechanisms for technology transfer (Steffensen *et al.*, 1999). A spin-off[33] is typically founded around

[33] According to the OECD (2000), spin-offs are: (1) firms founded by public research sector employees – including staff, professors and postdoctoral fellows and students; (2) start-ups that have licensed

a core technological innovation initially developed by an academic or a team of researchers. HEIs possess a concentration of a large crucial mass of scientifically sophisticated individuals who have the expertise to generate new technologies and innovative technological knowledge that can lead to the formation of new ventures (Jones-Evans, 2000). If HEI-generated technologies are to reach the market place, it is the responsibility of each HEI to encourage a culture of commercialisation and entrepreneurship within their academic community[34], and, thereby, provide support for academic entrepreneurs.

Although there are various definitions of 'entrepreneur', an 'academic entrepreneur' is first and foremost a researcher who engages in a novel research project with the original aim of producing new knowledge and publishing research findings. However, having conducted the research the academic entrepreneur may recognise that the research has potential commercial application. Following such a realisation, the academic entrepreneur focuses on the acquisition, deployment and management of innovative resources within the academic environment of HEIs for the purpose of converting this new knowledge or technology into commercial practicality. Academic entrepreneurship, therefore, involves the creation of an environment which actively supports knowledge exploitation and facilitates the stimulation of entrepreneurial behaviour in the academic community, as well as the exploitation of knowledge (and technology) (van der Sijde, 2002). According to Wirsing *et al.* (2002), having developed a technology-based business idea, academic entrepreneurs encounter a number of obstacles. These include: the lack of knowledge in business management and negotiation skills; the unknown market potential of products and services; the lack of a supporting network of business contacts; and high financial risks.

If HEIs are to implement academic entrepreneurship it is not enough for them to provide the necessary resources for inventing new technologies. HEIs must also provide a business support structure, personnel with commercial experience and appropriate mentoring skills enabling academic entrepreneurs to set up their own companies. While such support may not be crucial in ensuring the success of the

public sector technologies; and (3) firms in which a public institution makes an equity investment or which is directly established by a public research institution.

[34] In the Netherlands, the University of Twente runs two programmes called TOP 'Temporary Entrepreneur Places' and TOS 'Temporal Support of Spin-offs' (Kobus, 1992). Both of these

venture in international markets, it enables a venture to leave the academic environment and enter the global market place. Consquently, HEIs play a crucial role in facilitating the growth of small firms in high-technology sectors (Jones-Evans, 2000).

After leaving the HEI, the venture's success is dictated by a number of factors. These include the ability of the firm to market its products in international markets and acquire/implement relatively sophisticated management structures promoting the development of the firm. Furthermore, the venture must form international inter-firm linkages/strategic alliances and engage in the diversification of its product and process capabilities while also facing sophisticated global competition. While the creation of spin-offs is an example of technology transfer from HEIs to SMEs, HEIs also play a crucial role in the transfer of knowledge and expertise through the provision of consultancy services to existing local entrepreneurial ventures (Jones-Evans, 2000).

2.5.4 Consultancy links with industry

The diffusion of scientific and technical knowledge through consultancy by academics for external customers represents one of the most cost-effective and rapid methods of technology transfer between HEIs and industry (Stankiewicz, 1986). Consultancy typically involves relationships between academics (or a team of academics) and a customer (usually from industry) over a specified period of time. Academics provide technical assistance, information and advice based on specialist knowledge. The role of academics as consultants includes the provision of expert advice on particular projects undertaken by firms, providing assistance with production matters, business plans and the introduction of new technologies and providing assistance with technical/analytical problems experienced by firms. One of the areas in which academic consultants make a significant contribution is in industrial R&D (Geisler and Rubenstein, 1989).

Consultancy constitutes the most effective two-way channel of communication between HEIs and industry. Academic scientists and engineers engaging in consultancy become aware of industry needs and can, therefore, identify ways in which HEIs can meet the requirements of industry. Distance from the commercial world creates space for academics to devise more approaches to problem solving for

programmes are focused on providing support for the creation and development of knowledge-based spin-off companies that can enhance the technology and industrial potential of the region.

industry. Academics can also provide firms with knowledge about accessing alternative sources of expertise within HEIs and, therefore, provide firms with opportunities to create and/or expand their links with HEIs. Accordingly, consultancy can assist firms in deciding whether or not to initiate and/or develop research partnerships with HEIs (AURIL/CBI, 1997).

Within the academic community there are certain barriers which may prevent academics from engaging in consultancy links with industry. Very often academics cite a lack of time as a barrier to their engagement in consultancy activities. Primarily, this is due to the time commitments associated with teaching, research and administrative responsibilities. Second, if a mistake is made or poor consultancy advice is provided, the liability for the indemnity may rest with the HEI. As a result, the reputation of the HEI is at stake. Third, the nature of the consultancy services required by industry are often considered to be routine by the academic community who would rather focus their services in areas of original scholarly research. Consequently, consultancy may not further the prospects of promotion in an academic's career. Fourth, the consultancy requirements of industry are often short-term and sporadic with little opportunity for the development of long-term objectives. Fifth, the rate of tax on pay from earnings accrued from provision of consultancy services may be considered to be too high. In light of the high tax returns associated with money earned from activities over and above the normal pay salary of an academic, consultancy services are often provided by academics privately in their own time on an informal basis. Such activities are not formally registered or administered by ILOs of HEIs and, therefore, it is difficult to quantify the level of private consultancy practiced by individual academics. In light of each of these negative outcomes, academics are often reluctant to engage in consultancy activities. On an individual level, the main factor encouraging the academic community to provide consultancy services for industry is the financial gain accrued from such activities.

2.5.5 Teaching and training links with industry

> *We seek co-operative research relationships with industry not simply to generate royalty revenue and stimulate economic growth, but to create relationships with industry that will help faculty in pursuing their own research and in training graduate students*

(Atkinson (Richard C. Atkinson is the President of the University of California), 1999, 47).

HEIs have been viewed naively as 'engines' of innovation providing new knowledge and ideas which are translated into commercial entities thereby enhancing regional economic growth (Florida, 1999). This has generated a range of mechanistic national and regional policies seeking to convert new ideas to commercial practicality and transfer them to the private sector. While there is nothing wrong with a practical, policy-driven approach seeking to encourage the flow of new knowledge into the commercialisation cycle, this view fails to incorporate the larger economic picture. According to Florida (1999), HEIs are far more important as the nation's primary knowledge source. Equipped with intellectual or entrepreneurial talents, knowledge workers are the most crucial resource to any economy. Knowledge workers are the new production resource upon which companies base their ability to achieve competitive advantage.

This has been demonstrated most often in the high-tech sector where U-I connection, in terms of access to skills and expertise, is viewed as a necessary infrastructure. The high-tech sector demands access to a large pool of highly skilled 'knowledge workers'. Advanced knowledge is required about newly emerging technologies which will interact with HEIs and research-based institutes with a view to maintaining competitive advantage. The increased need to access global markets encourages indigenous high-tech firms, particularly High Potential Start-Ups (HPSUs[35]) and SMEs, to internationalise production and technology systems at an early stage in their development. In order to gain international competitiveness within the global markets of North America, South-East Asia and Europe, it is essential for high-tech firms to establish production, marketing and R&D agreements with other corporate enterprises located within each of these markets (Morris, 1992). Within the global economy, high-tech firms engage in inter-firm synergies or linkages involving strategic alliances, joint R&D ventures, subcontracting specialised labour, services and manufacturing tasks, and the co-operative marketing and distribution of products within national and international markets. Subsequently, high-tech firms require sophisticated management structures and, hence, need to interact with HEIs to access a supply of managerial talent equipped with technology-based entrepreneurship skills. As a result, the demand for managerial competence increases to the extent that it is a vital resource in knowledge-intensive industries (Murray, 1991). HEIs are now a crucial part of a nation's industrial infrastructure especially in terms of their ability to generate high quality research and training which is applicable to industry. Consequently, the role of HEIs in the production of R&D and in training and educating R&D/managerial personnel in the fields of science, technology and entrepreneurship, remains a crucial factor in maintaining a highly competitive indigenous high-tech sector.

2.5.6 The entrepreneurial HEI: friend or foe?

HEIs are currently undergoing a 'second revolution' incorporating economic development as part of their mission (Etzkowitz, 1998). The growth of a commercial ethos within academia is an outcome of changes internal to HEIs. Such changes include: (1) the development of internal capacities to administer services to industry; (2) a cultural change in the academic community's perception of the commercialisation of HEI research; and (3) a shift in the motivation of academic staff to engage in partnerships with industry. The emergence of entrepreneurial HEIs has generated a debate in relation to the specific function and role of HEIs in terms of their service to society. As commercial exploitation of HEI research becomes a key factor in the generation of economic wealth, the traditional educational function of HEIs as disseminators of knowledge has been altered. In an increasingly knowledge-based society, HEIs now articulate a number of roles encompassing teaching, research and translation of scientific research into economic development through technology transfer (Etzkowitz *et al.*, 2000; Lazzeroni and Piccaluga, 2003). Along with their key missions of teaching and research, entrepreneurial HEIs represent an interdisciplinary, interactive environment equipped with a culture of academic entrepreneurship. Focused on effective technology transfer by fostering the creation of new businesses on campus, entrepreneurial HEIs also enhance the competitive advantage of existing enterprise entities both within and outside HEIs.

While HEIs are a key vehicle for technology transfer, a debate has emerged on the growing influence of the private sector on HEIs as entrepreneurial agents (Feldman, 2001). Some critics emphasise the need for entrepreneurial universities to avoid a decrease in the quality of and freedom to pursue long-term basic research while stimulating economic development (Lee, 1996; Etzkowitz, 2000; Lazzeroni and

[35] See Appendix 2.1 for a definition of a HPSU.

Piccaluga, 2003). According to Rosenberg and Nelson (1994), some academics despair at greater involvement with industry, fearing that it will corrupt academic research and teaching, divert attention away from basic research and destroy the culture of open communication between university scientists on campus. Critics of technology transfer claim that HEIs are being reduced to nothing more than new 'industrial' service units frequented by and serving the research requirements of customers. They argue that the role of HEIs in society has shifted to an increasingly instrumentalist position, from a more idealistic position focused on the creation of knowledge (Readings, 1996, cited in Charles, 2003; Lee, 1998). Furthermore, there is a perception in society, often fuelled by the media, that the autonomy and authority of academic governance is being eroded by the commercial ethos and profit-orientated priorities being adopted by HEIs (Campbell, 1997; Charles, 2003). Academia's tilt towards the industrial research culture has increased while unfettered curiosity-driven research has declined (Krimsky *et al.*, 1991; Brooks, 1993). The private sector is said to be manipulating HEI research agendas. In particular, critics point to the loss of public confidence in what was once perceived to be the traditional role of academic scientists as independent critics of government policies and industrial activities in their respective fields of expertise. In 1966, the former President of Cornell University expressed concern for the future of HEIs, questioning the degree to which the autonomy and integrity of HEIs would be compromised through its growing involvement in state, regional and national planning (Perkins, 1996, cited in Skilbeck, 2001). In recent years, critics of entrepreneurial HEIs argue that the 'privatisation' of academic and public research has had an adverse effect on the academic independence/autonomy of many scientists. Feller (1990) argued that the 'privatisation of research' may actually slow the rate at which technological innovation is disseminated into the public sphere of society. The existing routes through which academic research flows to the market are likely to become blocked as HEIs limit existing flows of innovation in order to direct faculty findings to specific firms. The diffusion of new knowledge is postponed due to temporary delays in the publication of faculty findings in order to provide corporate sponsors with sufficient time to file patent applications.

According to Fassin (1991), HEIs have evolved from a 'public' model to a more 'commercial' model which has lead to conflicts of interests for academics and thereby endangered the objectivity and neutrality of HEIs in society. Critics of the 'commercial' model stipulate the following: laboratories will focus on applied research rather than on basic research; HEIs will pursue financially profitable projects instead of following long-term objectives; industry's influence on research strategy will increase and HEIs will lose autonomy and independence (Fassin, 1991). Moreover, the model places a greater emphasis on the development of the applied sciences and tends to exclude any considerations to develop most human sciences. Much of the important debate is diluted by the territorial and elitist perspectives focusing on preserving fundamental 'blue sky' research capabilities at the expense of other considerations of higher education value, such as the development of the economically active learning organisation (Mitra and Formica, 1997).

Critics of the 'commercial' model argue that the distribution of wealth generated by HEIs is not evenly distributed within HEIs. While HEIs may differ in terms of their governance of resources and research funding, the allocation of revenues from research royalties/licensing are generally distributed at the discretion of the HEI itself. The capital accumulated from the commercialisation of HEI research is often redirected into science faculty departments where the research originated, and not into the departments of social sciences and humanities. Traditionally, research conducted in social sciences and humanities provided crucial perspectives on the social, cultural and economic dynamics, together with changes in society.

If universities have become key accumulation agents, the issue of the degree to which an equable distribution of funds generated from the commercialisation of scientific research arises. The key question faced by universities is how such finances can be democratically governed and fairly distributed across all departments and be inclusive of those which are not engaged in commercialisation (*i.e.* social sciences and humanities) (Feldman, 2001). Evidently, there is a danger that universities will concentrate funding and resources in science and business faculties, while excluding social sciences/humanities. According to critics of the entrepreneurial model, HEIs need to assert the primacy of crucial thought articulated by the humanities over the practical expediency provided by the applied sciences (Cosgrove, 2002).

While the debate as to the specific function and role of HEIs in society continues to unravel (Krimsky *et al.*, 1991; Pelikan, 1992; Feldman, 2001), it is incumbent upon HEIs to continue focusing on the traditional academic missions of teaching and research[36]. HEIs should continue to focus on the generation and diffusion of knowledge through mission-orientated research and education that serves the public interest (OECD, 2000). However, HEI departments, as centres of research excellence, must also respond to the specific research requirements of industry but should not become outsourced research departments for the private sector. HEIs have a crucial role to play in strengthening industrial competitiveness by promoting the efficient identification, management, development and commercialisation of a research base with market potential. According to the OECD (2002), evaluation of researchers from HEIs and public research institutes should be reformed to provide more recognition of their contribution to the commercialisation of research. One of the aims of HEIs is to conduct research which meets the needs of society, is informed by learning, teaching and professional practice, while also being integrated with measures to promote economic and regional development via innovative partnerships and commercialisation (Hazelkorn, 2002).

At a joint German-OECD conference on *Benchmarking Industry-Science Relationships*, (Berlin, October, 2000) speakers were united in highlighting a number of ways in which HEIs could encourage the development of academic entrepreneurship without sacrificing the traditional missions of HEIs (OECD, 2002). The first recommendation was to change the culture within HEIs by highlighting benefits to the academic community of forging relations with industry. Such benefits would include the acquisition of new sources of funding, new opportunities to attract graduates to HEIs and the potential to explore new areas of research in some fields. The second recommendation for HEIs was to focus equally on both basic and applied research. The third recommendation was to produce comprehensively educated students with a well-rounded education and a range of skills providing them with the flexibility to cross disciplinary boundaries. The fourth recommendation encouraged HEIs to work with, rather than against, the academic community in promoting the development of academic entrepreneurship. The key issue in this recommendation was to provide incentives for academics with an interest in pursuing entrepreneurial activities on campus. At the same time, HEIs should accept and respect the fact that other members of the academic community do not choose to include entrepreneurship as a feature of the development of their academic careers.

[36] The term 'research' in this instance refers to traditional 'blue sky' research conducted by the HEI sector.

Much of the literature on U-I collaboration has been dominated by the possible negative effects of technology transfer and the emerging entrepreneurial model of research and innovation on the essential values and functions of academic work (Dill, 1995). While many of these concerns are legitimate, the reality is that technology transfer will continue to be a key function of HEIs as long as it is financially supported by public and private investment. The increasing focus of HEIs as creators/disseminators of 'entrepreneurial science' will generate further debate and changes both in academia and in public and private sectors in the coming years (Waagø *et al.*, 2001). The speed and success of the change will depend on a number of factors which are relative to individual HEIs. In particular, it will depend on the quality and priorities of HEI research, the nurturing of a culture of academic entrepreneurship within HEIs, the implementation of government initiatives designed to facilitate such change and the local industrial structure/level of economic development in the surrounding region. While the debate continues, one of the public service missions of entrepreneurial HEIs is to support regional economies through the leverage and dissemination of academic resources and new technologies to enhance economic and social development. Increasingly, therefore, HEIs will have a global focus allied with a regional responsibility (Hazelkorn, 2002).

2.5.7 Conclusion on the role of HEIs as agents of technology transfer

> *The true criterion of a university's success is the culture it propagates and the public spirit it creates (Pádraig H. Pearse, 1903, cited in McBrierty, 1993, 8).*

The functions and societal expectations of HEIs have broadened considerably following the realisation of their potential economic value for a commercially viable research base. Volatile international markets allied with increased turnover of technological innovations have encouraged the development of partnerships between HEIs and industry. A new industrial research culture of dependence with a mission-orientated approach is replacing the traditional culture of independence with a result orientated approach (Varma, 2000). HEIs are adopting a more outgoing, market-led commercial attitude which supports economic development (Cooke *et al.*, 2000). HEIs now combine academic and commercial expertise. Many HEIs now have industrial innovation centres and incubator facilities that promote the development of campus companies and spin-off firms. HEIs are playing a vital role in fostering and developing an entrepreneurial spirit in the academic community, through their creation and diffusion of technology-based scientific knowledge to both public and private sectors. The role of HEIs in implementing technology transfer is facilitated through the provision of consultancy services, contract research, teaching and training programmes in the formation of spin-off companies and also through the establishment and development of links with industry via science parks. Academic-industry links, in research and consultancy, in commercialisation of HEI research and in teaching and training, enhances a firm's competitive advantage, encourages the growth of small entrepreneurial businesses, revitalises economies and promotes regional development. Increasingly, firms are realising the strategic role played by research expertise in creating and sustaining competitive advantage. Consequently, the frequent and intermittent need to access sources of new scientific and technological knowledge has resulted in an increasing focus on collaboration between industry and academic institutions (Jones-Evans *et al.*, 1999).

2.6 CONCLUSION

Four bodies of literature address U-I interaction: the S&T policy research literature, the innovation literature, the literature on the role of HEIs as agents of technology transfer, and that on the science-industry relation (Faulkner and Senker, 1994). In analysing this body of research, a number of problems were noted.

The S&T policy-related literature audits the number of interactions between HEIs and industry and is descriptive rather than analytical. It focuses more on the institutional perspective of HEIs and provides inadequate depth of the reasons why firms choose to link with HEIs. Much attention is devoted to exposing the positive outcomes of U-I collaboration in terms of economic development and there is little or no consideration for the negative aspects and outcomes of such interaction. In particular, it focuses on the alleged potentially beneficial effects of U-I links on economic and regional development. To date, there has been no substantive evidence in the literature to suggest that U-I links create and sustain economic development. There is also little appreciation for the factors which promote and impede this potentially beneficial stimulant for economic growth.

Innovation literature focuses almost exclusively on U-I links from the perspective of firms with little attention on the role of HEIs. It also concentrates on the positive benefits accrued by firms engaging in R&D links with HEIs.

Literature on the role of HEIs as agents of technology transfer focuses on the development and characteristics of entrepreneurial HEIs focusing in particular on the internal conflicts faced by HEIs in engaging in links with industry. This body of work is the most extensive in terms of its theoretical contribution to the development of U-I links. However, assumptions are made about aspects of the U-I interface and are not inclusive of the industrial perspective, lacking a substantive empirical base.

Science-industry literature focuses on the cognitive characteristics of U-I links from the perspective of industry or academia, but not both simultaneously. In failing to recognise the crucial role played by both partners this body of literature provides a biased perspective on U-I links.

Despite the potential to do so, as already noted, economic geographers have not paid much attention to the field of U-I links. This is significant given the obvious associations of U-I interaction with regional innovation systems, firm growth and potential for HEIs to implement social and economic development in the regions in which they are located. In particular, economic geographers have not analysed the role geographical proximity plays between firms and HEIs in terms of developing U-I links.

Overall, it was found that the literature lacks empirically based research which is inclusive of the perspectives of both industry (inclusive of a broad spectrum of high-tech sub-sectors) and academia (inclusive of a broad spectrum of academic S&T subjects) in the development of U-I links and in the factors responsible for encouraging and inhibiting such interaction. This research seeks to address this gap in the literature. In doing so, it provides a geographical perspective to the study of U-I links through an analysis of the role that geographical proximity between firms and Irish HEIs plays in facilitating the development of U-I links. Furthermore, this study provides a new perspective on regional development in Ireland and the role played by Irish HEIs in enhancing economic and social development in the regions in which they are located. It is within this framework that this research attempts to highlight the mechanisms necessary to enhance the capacity of HEIs in terms of supporting the growth of indigenous high-tech enterprise and regional economic development through collaboration and partnership with industry.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Industrial geography is an empirically grounded subject which has traditionally employed a variety of research designs (Hayter, 1997, 12).

A fundamental element in the design of social science research is the collection, analysis and interpretation of empirical data. In human geography, as in the social sciences, two main types of research methodology exist: quantitative and qualitative. Quantitative research is associated with quantitative explanations which test for hypotheses or generalisations (Hayter, 1997). Typically, quantitative research involves the use of formal, standardised questionnaires to obtain a highly structured and consistent database, collected from a representative sample of respondents. Qualitative research, however, is focused on obtaining qualitative information on the underlying meanings and processes which shape behaviour. This typically incorporates the use of less formal, less standardised and more interactive interviews which generate qualitative information (Sayer and Morgan, 1985; Healey, 1991). Effectively, both approaches are complementary, with one being primarily explanatory and the other primarily descriptive (Sayer and Morgan, 1985). Both quantitative and qualitative approaches were used in undertaking this research thesis. Questionnaire surveys comprised the main data gathering tool for this research, but in addition interviews were also used. While questionnaire surveys have mainly quantitative questions, they may also include qualitative questions. In contrast while interviews largely generate qualitative data, quantitative data can be generated from certain questions asked and particularly from those asked in a standardised interview. Accordingly, data collection methods will play an important role in influencing the type of data acquired.

The primary purpose of this chapter is to discuss the methodology employed during this research. With this in mind, the chapter will focus on the design and administration of two separate questionnaire surveys (one for firms and the other for academics). In addition, it will discuss the implementation of interviews as a data collection tool. Finally, the chapter summarises the processing and analysis of data collected from both the quantitative and qualitative research methodologies.

3.2 THE QUESTIONNAIRE SURVEY

The questionnaire survey is one of the principal methods used to gather primary data in social science research. The main purpose of a questionnaire survey is to query (something) in order to collect data for the analysis of some aspect of a group, theme or particular area of research. The content of a questionnaire needs to be firmly rooted in the research objectives or hypothesis under investigation (Parfitt, 1997). Such a research strategy provides researchers with a scientific instrument enabling the systematic collection and measurement of data (Oppenheim, 1992). The majority of questionnaires can be categorised into four types: the standardised, formal interview; the postal questionnaire; the group-administered questionnaire and; the telephone survey.

The standardised, formal interview uses a set questionnaire. The group-administered questionnaire is distributed to a group of assembled respondents while the researcher is present to oversee the completion of the questionnaire, offer help and advice (in a nondirective way) and check finished questionnaires for completeness (Oppenheim, 1992). The questionnaire may be presented to the respondent by an interviewer who explains the purpose of the inquiry and leaves the respondent to fill in the questionnaire. It is then collected at a later date. Alternatively, the questionnaire may be posted to the respondent who then completes the questionnaire and returns it to the researcher by post.

The postal questionnaire was deemed the most appropriate research instrument for the collection of data by the firms' research directors and by academics within HEIs. While being aware of the limitations associated with postal research, the advantages of this data collection technique outweigh the disadvantages in the context of this study. One of the main strengths of postal surveys is that respondents can complete the questionnaire survey at their own pace thereby encouraging a more considered reply to each question (Healey, 1991). Furthermore, the postal questionnaire provides a standard format from which a large body of information can be recorded from a population or a random sample of a population. In many cases, a population or a random sample of a population may be considered too large to conduct an individual interview with each member of the population or sample. Consequently, the postal questionnaire is used as a method of acquiring information from a large group of potential respondents.

3.2.1 Questionnaire survey design

The purpose of a questionnaire survey design is to translate the research objectives into a specific set of questions that are clear, concise and easily understood by respondents. In order to effectively communicate the research objectives to respondents, careful design, layout and presentation are crucial to the success of questionnaire surveys (Dixon and Leach, 1978). Questionnaires should be simple in structure and questions should be organised in a logical sequence and divided into well structured sections. In particular, in designing a questionnaire, it is crucial for the researcher to consider the respondent *i.e.* it is important to 'think of your respondent'.

According to Dillman (2000), questionnaire design must strive to achieve two objectives: (1) to reduce non-response and (2) to reduce or avoid measurement error. A well-designed questionnaire includes a cover letter describing the survey significance and the importance of responding. In the administration of a postal questionnaire survey, the cover letter is important; it is the first item that the respondent will see and read upon opening the envelope. In the context of this research the cover letters (Appendix 3.1; 3.2) attached to both the industry and academic questionnaires respectively were designed according to the specifications of Dillman (2000).

The length of the questionnaire should not be excessive. In particular, completion of the postal questionnaire should not exceed 30 minutes; otherwise a fatigue bias can generate poor data quality (Parfitt, 1997). Accordingly, the questionnaire should be designed in a manner that minimises fatigue, boredom and non-response. Technical or vague terms should be avoided and unambiguously phrased questions using terminology familiar to the respondents should be employed (de Chernatony, 1988). In particular, attention should be focused on the diction of questions. The phrasing of questions should not bias the respondent to provide particular answers, since this would ultimately affect the quality and analysis of the information received. Harvey (1987) asserts that a questionnaire should be constructed in a way which appeals to the respondents and should direct itself to arousing, rather than assuming, the interest of respondents.

Fundamental to the design of a questionnaire is the structure of the questions asked and the format of the response categories accompanying the question (Frankfort-Nachmias and Nachmias, 1992). Two types of question structure can be distinguished: open-ended and closed questions.

Open or free-response questions allow particular issues to be raised but do not provide any format or specified choice of possible replies for the respondent. Instead, open-ended questions allow respondents total freedom to formulate their own answers using their own words. Open-ended questions do not force the respondent to adapt to preconceived answers: having understood the intent of the question, respondents can express their thoughts freely, spontaneously and in their own language (Frankfort-Nachmias and Nachmias, 1992).

A closed question is one in which the respondent is offered a choice of pre-coded answers and asked to select the one which reflects their views most closely by merely ticking a box. Essentially, there are four types of closed question. The first requires a simple 'Yes' or 'No' answer and is the most common form. The second type can be presented in the form of a rating scale where the respondent is asked to numerically rate their preference towards a set of characteristics or attitudes, *e.g.* from 1 to 5. The third type requires the response of a simple fact, such as the number employed or the year of start-up of a firm. The fourth requires the respondent to tick the relevant box(es) from a range of response categories. It can be difficult to develop a closed question of this nature, as the researcher must ensure that all potentially important response alternatives are included.

In both the industry (Appendix 3.3; 3.4) and academic questionnaire surveys (Appendix 3.5; 3.6), the majority of questions were closed questions. In both questionnaire surveys the closed questions required a simple 'Yes' or 'No' answer, or else respondents were asked to tick the appropriate box(es). A number of questions employed a rating scale from 1-5. In each question employing a rating scale, respondents were presented with a number of factors from which they were required to assess the importance or otherwise of each factor on a scale of 1-5. Closed questions are quick and easy to answer and lend themselves to greater quantification than open-ended questions.

In both the industry and academic questionnaire surveys, the majority of closed questions had the category of 'Other' included. This was included to provide respondents with an alternative response category in which they were given the freedom to give their own response. The response of 'Other' arose so infrequently in the answers that it did not merit inclusion in the relevant tables of results.

In section A of questionnaire 1 of the industry survey, 22 questions were closed questions and 6 were open-ended questions. Many of the questions were divided into five parts. The first three parts of the question were generally closed questions requiring a simple 'Yes' or 'No' answer, a tick in the appropriate box(es) and answers to rating scale questions. The fourth and fifth parts of the questions involved open-ended questions where the respondent was asked to state an opinion, for example, in relation to the positive and negative outcomes experienced by firms in relation to links established with HEIs. Similarly in section A of questionnaire 2 of the industry survey, 6 questions were closed questions and only 1 was an open-ended question (question 8) in which respondents were asked to assess the reasons why the firm does not engage in links with HEIs (Appendix 3.4). While answers to open-ended questions are more difficult to analyse than closed questions, they provide qualitative, empirical data on the nature of industry-academic links and academic-industry links. In addition, the answers to the open-ended questions used in the industry questionnaire survey provided a greater understanding of the quantitative data generated from closed questions.

In the academic questionnaire survey, all of the questions were closed questions. Respondents were required to provide 'Yes' or 'No' answers, tick the appropriate box(es) and provide answers to the rating scale questions. Open-ended questions were not used in the academic questionnaire survey for two reasons. In the industry questionnaire which was administered first, while respondents did not have a problem completing the closed questions, some did not complete the open-ended questions. Second, closed questions are quick and easy to complete and, therefore, are more likely to encourage the respondent to complete the questionnaire.

The survey population should consist of all of the units (firms and academics) to which the researcher desires to generalise survey results (Dillman, 2000). In populations that are large, it is time consuming and expensive to collect data from each individual and therefore a sample is selected. The sample frame is a list from which a sample of subjects is drawn. This sample is drawn in order to represent the survey population and is then studied in order to make inferences regarding the entire survey population (Hussey and Hussey, 1997; Levy and Lemeshow, 1999). It is crucial that the sample should be 'representative' of the population that is of interest. Samples that are truly representative of their parent populations are deemed unbiased (Kranzler and Moursund, 1999). To ensure that a sample is representative, members for the sample must be chosen at random from the parent population (Rowntree, 1981). It is important to select a simple random sample (SRS) (Blalock, 1979, 554-557) as all statistical tests of significance assume a random sample[1].

The first and most crucial stage of the survey is to select a sample. In selecting a sample, it is important to have a well-defined population of subjects. In the context of this research, before administering the pilot survey of the industry questionnaire to the high-tech firms and deciding on a population of firms from which to select a sample, it was first important to define the term 'high-tech'. Such a definition dictates the size of the total population of firms and the size of the individual sub-sectors within the industry.

3.2.2 Definition of 'high-tech' industry

Providing an appropriate definition of the term 'high-tech' is problematic (Malecki, 1997). Researchers in the past have tended to use the OECD classification of R&D intensity (Appendix 3.7). However, within this classification, it is only the category 'high technology', that is really high-tech, spending more than 4% of turnover on intra-mural R&D expenditures. While this is still the most commonly used classification of R&D-intensity, there are a number of problems related to it. First, from a conceptual point of view, this classification is too focused on a linear model of innovation, which views innovation as a set of development stages originating in research. Innovation, however, is also a social, non-linear process based on

[1] In statistics, the methods that are used for inference depend on the sample being random. For example, Xbar ($\overline{X}$) is a statistic that is the average of a random sample. Since each of the possible values of X are equally likely to be selected at random, $\overline{X}$ can be considered to be a random variable whose distribution is known (sampling distribution of the statistic). The sampling distribution of a statistic is the distribution of values taken by the statistic in all possible samples of the same size from the same population (Moore and McCabe, 1999). Since the distribution of the statistic is known, when a researcher analyses a particular value (having collected data) he/she can infer something about the population. The shape of the sampling distribution depends on the collection of 'random' data. Thus, inference about the population relies on the sample being taken at random.

interactive learning which emphasises the importance of co-operation between firms and external actors (such as universities and public research institutes) in NSIs and regional systems of innovation (Asheim, 1998). Second, from a practical point of view, the definitions of R&D in the OECD's Frascati Manual, which structures R&D data collection in OECD economies, excludes a wide range of activities that involve the creation or use of new knowledge in innovation.

In contrast to the OECD approach, modern innovation theory, where innovation is considered to be based on interactive learning, views knowledge creation in a more diffuse way. Firstly, innovation rests not on discovery but on learning. According to Gregersen and Johnson (1997), innovation can be defined as the introduction into the economy of new knowledge or new combinations of old knowledge. Learning, therefore, does not necessarily imply discovery of new technical or scientific principles and can equally be based on activities that adapt existing forms of knowledge. This in turn implies that activities such as design and trial production (which is a form of engineering experimentation) can be knowledge-generating activities. Hence, learning leads to new knowledge, thus enabling entrepreneurs to use this knowledge to form innovative ideas and projects that can be transported into the economy in the form of innovations (Gregersen and Johnson, 1997). Secondly, a key emphasis in modern innovation analysis is on the external environment of firms. Firms interact with other institutions in a range of ways; these include, for example, the purchase of intermediate or capital goods embodying knowledge. Thirdly, in a vertical disintegrated globalising learning economy, where the adequate focus is on local and global production sytems with suppliers and subcontractors, the use of intra-mural R&D-expenditures becomes even more irrelevant.

According to Porter (1998b), the distinction between high-tech and low-tech has little relevance, particularly in relation to achieving productivity and competitive advantage. The mere presence of 'high-tech' activity in an industrial sector does not guarantee prosperity if firms are unproductive. What is becoming more and more relevant is the distributed knowledge base of firms, where a value-chain or value system perspective is applied when the knowledge intensity of a product or the knowledge base of a firm is evaluated. For example, food and beverages ranks at the bottom of the low-tech branches, yet this sector is becoming more and more knowledge-intensive due to the incorporation of bio-technology and food engineering in the production of functional food, fish and farming. However, the most knowledge-intensive parts are located relatively early in the value-chain and are not registered as intra-mural R&D expenditures according to the OECD classification because the knowledge base is distributed. Increasingly, researchers are focusing on the knowledge-intensive industries, the subsequent emergence of a new type of knowledge-driven economy and the resultant implications of the distributed knowledge base for regional innovation systems (Asheim and Isaksen, 2002).

Initially, the use of the OECD classification was considered as a primary indicator and parameter of high-tech sub-sectors from which to select a random sample of firms. However, in light of the issues and problems associated with this classification, the researcher decided instead to use the population of high-tech firms as outlined by EI. However, there are a number of problems with EI's classification of 'high-tech' industry. First, EI were unable to provide a definition of what they consider to be 'high-tech' industry. In practice, EI classifies firms as being high-tech if they came under the remit of six sub-sectors[2]. Using EI's list of high-tech firms poses the question of accuracy whether all firms may indeed be assumed to be high-tech or not. To counteract this to some extent, one of the questions in section B of the industry questionnaire survey asked if firms considered that they engage in high-tech activities (questionnaire 1, question 22, see Appendix 3.3; questionnaire 2, question 19, see Appendix 3.4). However, due to time restrictions and the absence of an alternative 'defined' population of high-tech indigenous companies, it was decided to use the population of EI-assisted high-tech client companies.

The EI Central Knowledge Base (CKB) is a database comprising the largest and most comprehensive list of indigenous high-tech firms located in Ireland. It categorises firms into six sub-sectors which EI consider to fall under the remit of high-tech industry (Appendix 3.8). This database provides a profile and geography of the total population of EI-assisted indigenous high-tech firms in Ireland. However, one significant problem with this database concerns the size of the total population of firms. If a firm ceases production, there is a time difference between firm closure and

[2] The sub-sectors are:
- digital media/e-commerce;
- electronics and precision components;
- engineering;
- financial/healthcare services;
- healthcare pharmaceuticals;

when that becomes known in EI. This difference can be anything up to three months and is indicative of firms not being closely monitored by EI. Therefore, the list of firms in EI's CKB is not a definitive list of all EI-assisted companies in existence at any one time. This introduced a non-response error which occurs when an individual chosen for the sample cannot be contacted or does not co-operate (Moore and McCabe, 1999; Dillman, 2000). In the absence of an alternative database, the EI CKB was used for the purpose of this research. Prior to the pilot survey of the industry questionnaire, the researcher received this list from EI in October 2001.

Within the list, substantial variation exist in terms of firm size, location, date of start-up and the high-tech sectors to which the firms belong. The industry questionnaire was posted to the total population of 1,980 EI-assisted companies and respondents were considered to represent a random sample within the specific population.

3.3 PILOT SURVEY OF THE INDUSTRY QUESTIONNAIRE

The pilot survey was conducted using a purposive sample. This is a sampling technique in which the researcher purposely chooses the subjects/objects or cases, on the basis of background knowledge, which are deemed relevant to the research topic (Shaw and Wheeler, 1994)[3]. The purposive sample was selected to ensure that the industry questionnaire survey included and was sampled by as wide a spread of the different types of firm as possible. Due to the high degree of variation in firm size and location in the total population of 1,980 firms from the six high-tech sectors, it was necessary to select firms on the basis of size and location.

Table 3.1 Sample distribution of three pilot firms from one high-tech-sector

Firm size	Rural location	Urban location	Known industry cluster/science park or presence of a HEI
Small-sized firm			*X*
Medium-sized firm		*X*	
Large-sized firm	*X*		

X = Firm selected to participate in the pilot survey of the questionnaire

Within each of the six high-tech sectors a total of three firms were selected on the basis of firm size; one small firm, one medium and one large. In terms of

- information/communication/telecommunications services.

[3] Purposive sampling is often used for focus groups, pretest and pilot studies. It is not valid, however, to conduct statistical tests on a purposive sample, as explained earlier, due to the reasons associated with the importance of selecting a random sample.

selecting the firms by location, three spatial contexts were used: rural, urban and in a known industry cluster/science park or close to a HEI in an urban centre (Table 3.1). In each high-tech sector, the location of the firm varied according to firm size. A unique identification number was given to each firm.

On 22 October 2001, a telephone survey of each of the eighteen firms selected for participation in the pilot survey was conducted in order to obtain the name of the current research director and to find out the size of the firm. The research director was chosen as the respondent for the industry questionnaire as he/she is the key decision-maker in relation to the research activities of the firm. Furthermore, the research director is the individual in the firm most likely to have an in-depth knowledge of the existence or otherwise of links with HEIs.

A brief, personalised pre-notice letter was sent to the research directors in each of the eighteen firms that were selected for the pilot survey (Appendix 3.9). For maximum effect, this letter was designed according to the specifications of Dillman (2000). The purpose of the pre-notice letter was to provide a positive and timely notice requesting the recipient to complete the questionnaire survey. Research has consistently shown that a pre-notice letter posted a few days or a week prior to the date of the actual questionnaire survey improves the response rate to postal surveys (Dillman, 2000). The pre-notice letter for the pilot survey was mailed on 25 October 2001 (Appendix 3.9).

On 1 November 2001, the questionnaires were mailed to the research director in each of the eighteen firms selected for the pilot study. Each questionnaire was accompanied by two letters and a self-addressed business reply envelope with a unique licence number which the researcher had previously organised with An Post. One letter was sent from the Policy and Planning Department of EI (on EI letterhead notepaper) and it confirmed the credentials and purpose of the researcher (Appendix 3.10). The other letter was the cover letter from the researcher (Appendix 3.11). It outlined briefly the objectives of the research, confirmed the support provided by EI and emphasised the confidentiality of all information received. In order to ensure such confidentiality, each firm was allocated a reference number and the name of the firm was not attached to its corresponding questionnaire. Of the pilot firms only one firm did not participate as it had gone into liquidation.

3.4 INDUSTRY QUESTIONNAIRE SURVEY

The pilot survey resulted in one substantial change to the industry questionnaire. Originally, it was comprised of three sections. Section 1 was to be completed only by firms with links to HEIs; section 2 was to be completed only by firms without links to HEIs; and section 3 was to be completed by all firms. Respondents to the pilot survey did not appear to have problems with the content of the questionnaire. However, respondents seemed to dislike the length of the questionnaire and some seemed confused as to which section was relevant to their firm. To address these issues, it was decided to change the structure and layout of the questionnaire and, thereby, reduce the length of the questionnaire by dividing the original questionnaire into two smaller separate questionnaires.

Questionnaire 1 was to be answered by firms with HEI links and questionnaire 2 was to be answered by firms without HEI links[4]. Both questionnaires were divided into two sections. Section A of questionnaire 1 focused on the firm's experience of its established links with the third-level educational sector. Questions pertaining to the barriers and stimulants to the development of three main links with the HEI sector were included in section A. These links are (a) R&D, (b) consultancy and (c) teaching/training. Section A of questionnaire 2 addressed the issues surrounding the firm's reasons not to engage in links with HEIs. The questions asked in Section B of both questionnaires were the same. Section B was designed to gather information on the general activities of the firm. In particular, it sought data on employment, year of start-up, origin of the firm, factors that influenced the choice of location, geographical proximity to the nearest university and IT, sectoral information, R&D and innovation activities of the firm and, finally, on the barriers and stimulants to establishing U-I links in Ireland. It was crucial that Section B of both questionnaires asked the same questions to enable assessment of the characteristics of all firms in relation to the establishment or otherwise of links with HEIs in Ireland. In particular, the data gathered from Section B of both questionnaires enabled the researcher to compare and contrast the characteristics of the firms that had established links with those that had not established links with HEIs. To date, there has been no research completed comparing firms with HEI links and those without.

[4] Hereafter the term 'industry questionnaire survey' is used to denote both questionnaires 1 and 2.

It is important to note that one question in Section B (question 16 on questionnaire 1 and question 13 on questionnaire 2) asked the respondent to indicate whether the firm is a foreign-owned or Irish-owned company. The purpose of this question was to include the returned questionnaires that indicated that the firms are Irish-owned and to exclude questionnaires that indicate that the firms are foreign-owned.

The focus of the research was on indigenous companies. As already indicated (Chapter 1), one of the terms of accepting *The Enterprise Ireland Millennium Scholarship Award* was that the industrial research would focus on indigenous firms. In any case, due to time constraints it was not feasible to conduct separate industry questionnaire surveys for indigenous and foreign industry. Furthermore, indigenous companies have a higher tendency to integrate R&D activities into their activity profile and, therefore, are more likely to have developed in-house R&D facilities and have links with Irish HEIs than their industrial counterparts in the foreign sector. Foreign companies tend to source their R&D from their parent companies, and, therefore are more likely to have links with HEIs abroad. Due to the fact that Irish firms are mainly stand-alone units, it is also easier to track the level of interaction between the firm and HEIs. In contrast, the transnational nature of multinational companies makes it difficult to assess the level of interaction with HEIs for the subsidiary, its sister companies located in Ireland and its parent company located abroad. Furthermore, it can be difficult to assess which foreign subsidiary is engaging in HEI links.

3.4.1 Industry survey design

In terms of the design of the questionnaire there should be minimum page turning. In order to reduce the number of times the respondent would have to turn over the pages, it was decided to produce both questionnaires in a booklet format. Both questionnaires were collated and printed professionally by a printer and produced in a booklet format. While the printing of the questionnaire survey was expensive, it proved to be crucial in terms of delivering a professional image of the survey to the respondents. Both questionnaires were in separate colours to create clarity and enable each respondent to select the appropriate questionnaire for their firm.

3.4.2 Administration of the industry questionnaire survey

The industry questionnaire was administered to all EI-assisted high-tech firms in Ireland for two reasons. First, EI has designed and implemented a range of initiatives and programmes specifically focused on developing and maintaining U-I links in Ireland. In light of this, it was deemed appropriate for the research to focus specifically on all EI-assisted high-tech firms in order to assess the effectiveness or otherwise of the initiatives implemented by EI in the area of U-I links. Second, it was difficult to acquire a full and complete list of non-EI assisted firms. In Ireland while the majority of indigenous firms receive EI assistance, a small proportion do not. In light of this, the researcher contacted Forfás[5] and received a list of client companies of Údarás na Gaeltachta[6]. A letter was also sent to each of the 34 County Enterprise Boards (CEBs)[7] (Appendix 3.12) requesting a list of client firms that were non-EI assisted (Appendix 3.13). A total of fourteen CEBs returned lists of their client companies. One CEB stated that it was unable to provide a list of its client companies due to restrictions imposed upon them by the Data Protection Acts. Two CEBs would not provide their list of client firms as they had previously assured confidentiality to their client base by making a commitment of not releasing firm names and addresses. A total of four CEBs stated that they have a policy of not providing the names and contact details of their client companies for research purposes. The remaining thirteen CEBs did not respond in any form. It was decided not to include non-EI assisted firms as it was not possible to acquire a complete and definitive list of this population of firms.

[5] Forfás was established in 1994, as part of the Irish Government's drive to restructure the development agencies for industry and S&T in order to meet the challenges of an increasingly competitive international market environment. Based in Dublin, Forfás encourages and promotes the development of enterprise, trade, science, technology and innovation in Ireland by supporting the industrial development agencies EI and the Industrial Development Authority of Ireland (IDA). It is the body through which powers are delegated to EI for the promotion of indigenous industry and to IDA Ireland for the promotion of foreign direct investment (FDI).

[6] The Údarás na Gaeltachta Act of 1979 established Údarás na Gaeltachta, the Irish Government Authority with responsibility for the economic, cultural and social development of the Gaeltacht areas and for promoting the Irish language. The headquarters of Údarás na Gaeltachta is located in Galway.

[7] Established in 1999, there are 34 CEBs, one designated for each local Authority in Ireland. The role of the CEBs is to develop indigenous enterprise and stimulate economic activity at the local level, through the provision of financial and technical assistance, as well as providing a range of non-financial business support services to indigenous entrepreneurial ventures. The aim of the CEBs is to encourage the development of small and start-up business enterprises with a maximum of ten employees.

Figure 3.1 Regions of Ireland

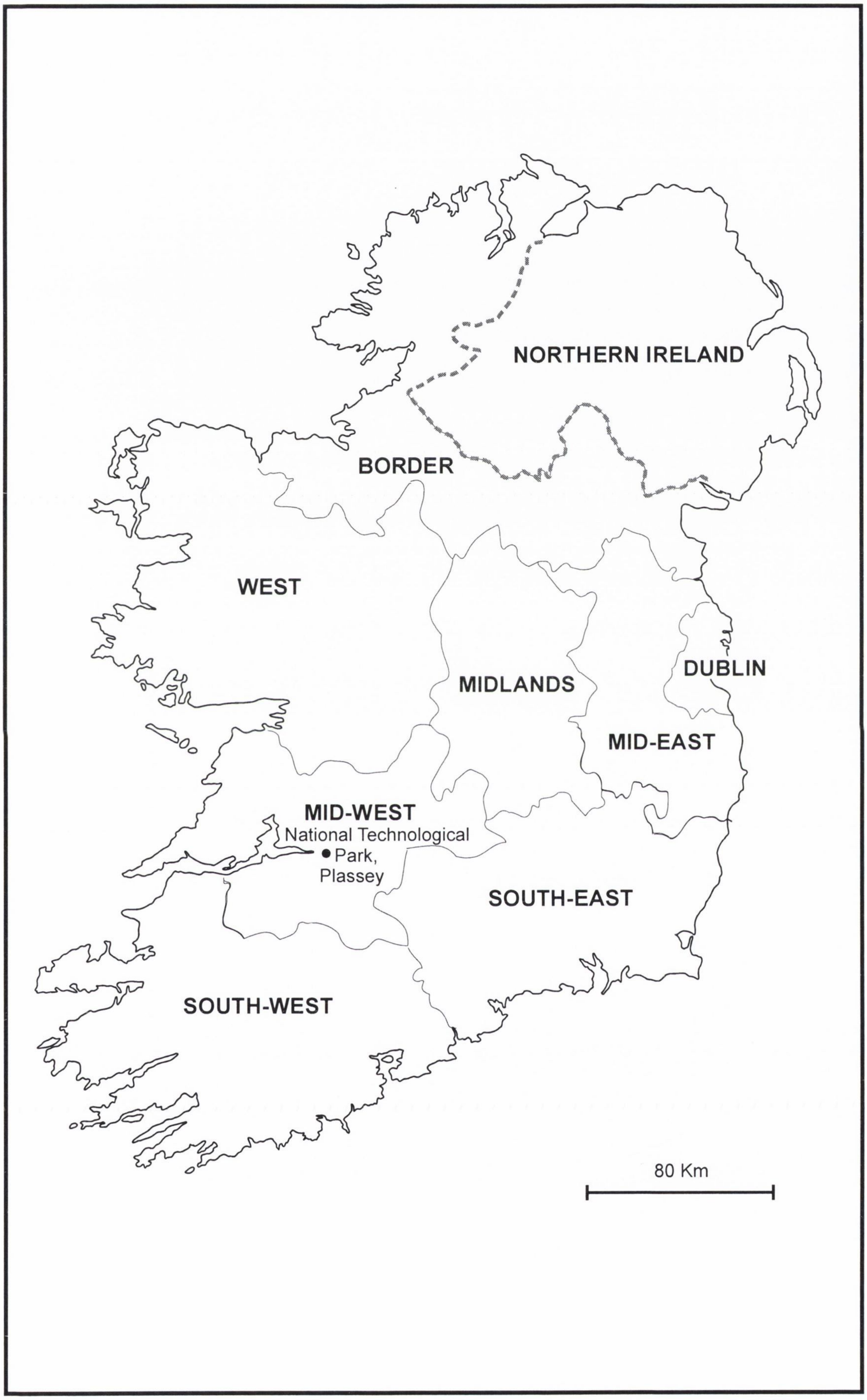
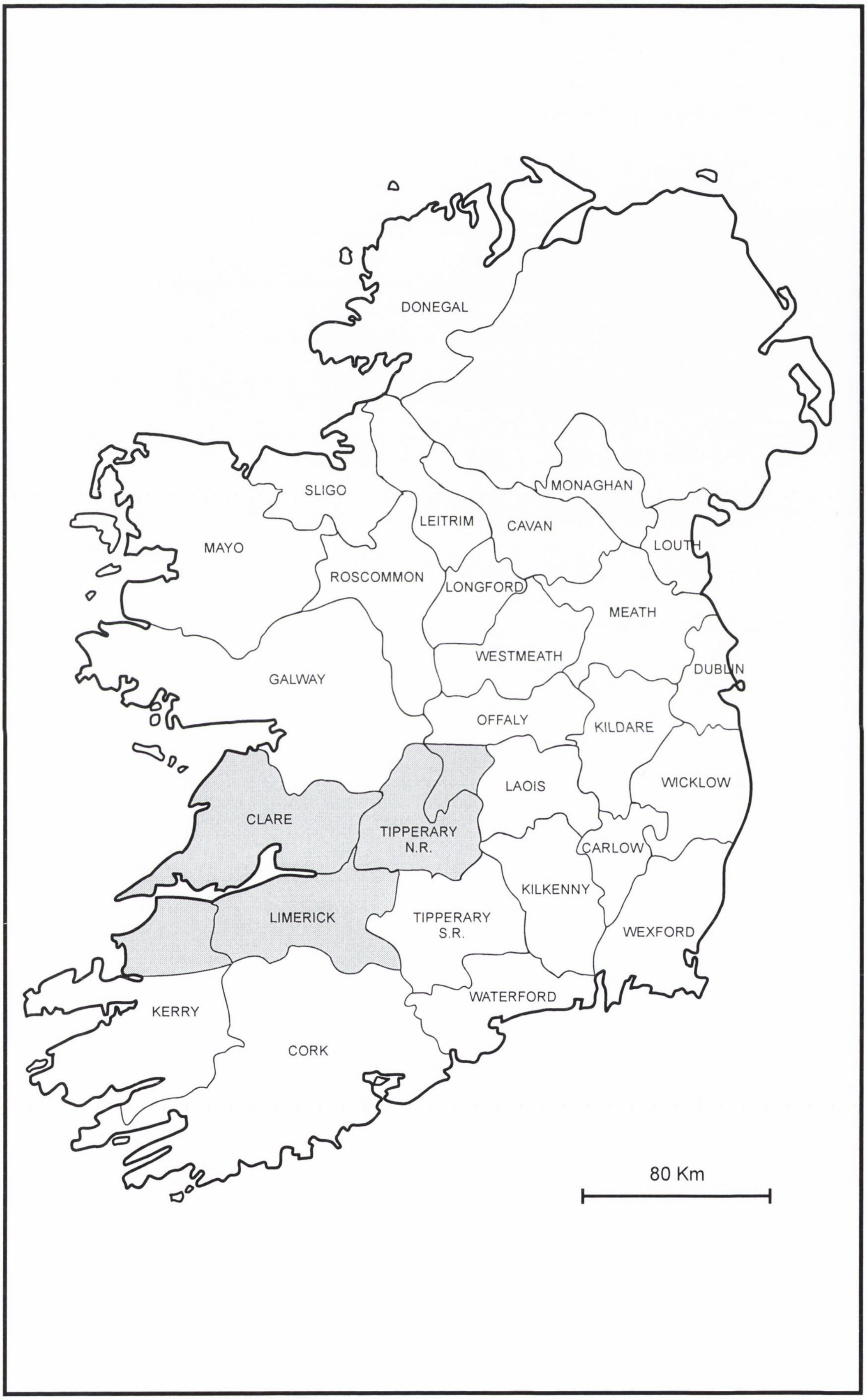


Figure 3.2 Shannon Region



The database of EI-assisted indigenous high-tech firms was deemed a sufficient database and became the focus of the population of firms for this research. Consequently, the EI classification of high-tech sectors was used (Appendix 3.8). Firms located on the National Technological Park, Plassey (which is managed by Shannon Development) in the Mid-West Region were also included in the study (Figure 3.1). These companies are supported by Shannon Development, the regional development company in the Shannon Region.

It is important to note that while Shannon Development and EI are two separate development agencies, both have responsibility for the indigenous industrial sector. EI has responsibility for indigenous client firms at the national level while Shannon Development, under delegated powers from EI, has responsibility for its indigenous client base in the Shannon Region. This region comprises Limerick City and the counties of Clare, Limerick, North Tipperary, West and South-West Offaly and North Kerry (Figure 3.2). Shannon Development provides the same suite of programmes and services in the Shannon Region as EI provides for its client company base at the national level.

The Shannon Development companies that are non-science park firms were not included in the research. This group comprises a total of 665 companies (which in 2001 employed 14,229 employees). A list of the Shannon Development companies that are non-science park firms was taken from Shannon Development's Irish Companies Database of the Shannon Region. While this list specified the products and services provided by each firm, it did not specify which firms were high-tech or identify the manufacturing sector to which each firm belonged. In addition, due to the problems associated with providing an appropriate definition of the term high-tech, as discussed in section 3.2.2, it was difficult to categorise individual firms as high-tech or not high-tech. For example, a firm that produces wood products may not appear high-tech but may have a high level of product and process innovation integrated into its manufacturing systems. The Shannon Development non-science park firms, therefore, were not categorised into high-tech sub-sectors in the same way that EI-assisted firms were categorised in the EI classification.

In order to ensure continuity in the selection of a population of firms for the purposes of this research, it was decided to focus on all EI-assisted high-tech firms at the national level. However, the science park firms located on the National Technological Park, Plassey were also included in this research as these firms are categorised as a population of indigenous high-tech firms that are supported by Shannon Development under delegated powers from EI.

Table 3.2 Responses from EI-assisted high-technology firms

Industry	Total number of firms	Number of completed surveys returned	Percent of total number of firms
Digital Media/E-Commerce	226	64	28
Electronics and Precision Components	360	189	52
Engineering	351	95	27
Financial/Healthcare Services	274	84	30
Healthcare Pharmaceuticals	667	203	30
Information/Communication/ Telecommunications Services	102	37	36
TOTAL	1,980	672	34

Source: Industry questionnaire survey (2002)

The list of EI-assisted firms was derived from the EI database of both active and non-active high-tech clients[8]. This list comprised a total of 1,980 EI-assisted firms located in Ireland and classified into distinctive high-tech categories defined by EI. The classification of high-tech firms, as defined by EI, is divided into six sub-sectors (Section 3.2.2, Footnote 2, 69) and the number of firms in each sub-sector dictated the overall size of the indigenous high-tech base for the implementation of the industry questionnaire survey (Table 3.2). The list of firms was acquired from the CKB[9] of EI in January 2002. This database comprises the name, address and contact details of each of the client firms of EI. The database of firms was stored in Microsoft EXCEL and each of the firms was assigned an identification number between 1 and 1,980. Amongst the respondents, there was a high response from electronics firms. There is no reason to suggest that this sample was biased in any way. It is, however, an unusually high response rate (52%).

In relation to administering the industry questionnaire to campus companies, the researcher contacted the Campus Companies Programme[10] Manager in EI and

[8] The terms 'active' and 'non-active' are used by EI to denote whether or not firms from their client base interact with EI on a regular basis.

[9] While the CKB list is the population of EI-assisted indigenous high-tech companies, international mergers, acquisitions and take-over bids can quickly alter the nationality of a company, particularly in the high-tech sector.

[10] Run by EI, the Campus Companies Programme is designed to assist academics/entrepreneurs interested in commercialising R&D on the HEI campus. The Campus Companies Programme encourages the growth of new companies in third-level campuses and supports the development of existing companies in the HEIs. The Campus Companies Programme is not to be confused with the Campus Company Development Programme (CCDP), which is a joint initiative between EI and the

requested a list of all EI-assisted campus companies in the universities and ITs of Ireland. EI were unable to provide such a list as many campus companies and potential spin-off opportunities are extremely sensitive about their ventures becoming public knowledge in both academic and industry circles. Many of these companies insist upon guaranteed anonymity and confidentiality as a condition of their participation in the Campus Companies Programme run by EI. Consequently, not all EI-assisted campus companies are listed in the EI CKB of high-tech companies. While ILOs of HEIs have lists of campus companies in their own institutions, these lists are not categorised into EI-assisted or non-assisted[11]. It is important to note that not all campus companies are EI-assisted. As it was not possible to secure a definitive list of EI-assisted campus companies in universities and ITs, it was deemed necessary to conduct an interview with a number of EI-assisted campus companies selected from a number of universities and ITs in Ireland. Under current government legislation in Ireland, ITs are not permitted to take equity in companies formed on campus. Consequently, while a number of ITs have companies that were formed on campus and are on the Enterprise Platform Programme (EPP[12]), they do not have an

University Industry Programme (UIP) in UCD. The objective of the CCDP is to assist academic entrepreneurs in the establishment and development of knowledge-intensive enterprises. Drawing on the expertise and facilities through EI and the UIP, the focus of the CCDP is to develop entrepreneurial business ideas through a series of workshops, lectures, intensive counselling, mentoring and the completion of a number of business assignments over the nine-month duration of the programme. Established in 1996, the CCDP was initially a joint initiative of the UIP and the Dublin Business Innovation Centre (DBIC). Since 2000, the CCDP has been organised jointly by the UIP and EI.

[11] In Ireland, it is important to note that it is not necessary for a potential HEI spin-off venture to go through EI in order to spin out of the HEI. However, these firms are required by European IP law to go through their respective HEI in order to spin-off, except in the case of software. Software companies do not in most cases have IP. In many software companies there is copyright on the software, and consequently, there is no IP. Some software companies go through the ILO of the HEI but most do not as it would mean that if a company were to make a complete break from college they would have to give the HEI an equity stake in the company. If there is IP the HEI owns the IP.

[12] In the *National Development Plan, 2000-2006* (Government of Ireland, 2000), provision for Research, Technological Development and Innovation (RTDI) in the HEIs includes an allocation of €38.1 million for the technological sector and is administered through three programmes. These are the Postgraduate R&D Skills Programme, the Core Research Strengths Enhancement Programme and the EPP. Under the EPP, €12.4 million is being provided (on a competitive basis in 2000 and 2003) to facilitate the provision of systematic enterprise development training programmes in each of the fourteen ITs. The EPP is a programme approved by EI. In particular, it targets graduate entrpreneurs or teams of such individuals with innovative technology-oriented ideas. Under the programme, an IT or a group of ITs working on a collaborative basis have a target of ten companies to take on each year. The programme is designed to provide comprehensive support in the form of training, office accommodation, incubation facilities, mentoring, business support services and some financial support to graduate entrepreneurs who wish to start their own companies. The level of financial support depends on the background of the company. EI identify HPSUs within the companies that the approved ITs take on and offer them a substantial increase in the funding they receive. The scheme is funded by the National Development Plan (NDP) and administered through the Council of Directors of the ITs. Each of the approved ITs or groups of collaborative ITs have developed training programmes

equity stakeholding in the companies. ITs which did not have a company located on campus at the time of this phase of the research were: Athlone Institute of Technology (AIT), Institute of Technology Carlow (IT-Carlow), Dublin Institute of Technology (DIT), Dundalk Institute of Technology (DKIT), the Cork Institute of Technology (CIT) and Waterford Institute of Technology (WIT).

The commercialisation of university research was investigated through three interviews with campus companies in three HEIs. In all, fourteen campus companies were targeted to participate in the research, but only three companies agreed to do so. The remaining companies were unable to participate due to lack of time. In order to ensure continuity in the focus of the research on the target population of all EI-assisted high-tech firms, it was important to focus specifically on EI-assisted campus companies. Interviews with the campus companies enabled assessment of how the commercialisation process unfolds through the formation of innovative ventures on campus. In relation to spin-off companies from universities and ITs, interviews were not conducted with these ventures because EI-assisted spin-off companies are present in the EI population of client companies and are, therefore, included on the CKB list.

The industry questionnaire was posted on 18 February 2002[13]. It was due to be distributed earlier but was delayed because it was felt that the Christmas period and the requirement for firms to make various tax returns in January and the first half of February might have had negative effects on the response rate. Both questionnaires and two cover letters (Appendix 3.1; 3.14) were sent to the research director in each of the 1,980 EI-assisted high-tech firms located in Ireland[14].

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to assist graduate entrepreneurs and aims to provide them with the appropriate skills required to establish and run their companies. A number of ITs and groups of ITs working in collaboration have been approved and currently receive funding. An example in Dublin of a group of ITs working on a collaborative basis under this programme is the M50 EPP. This is a collaborative programme run by IT Tallaght, Institute of Technology Blanchardstown (ITB) and DCU. In 2002, there were thirteen companies on the programme and all were located in IT Tallaght. The M50 corridor is the link between these three HEIs. If the M50 collaborative partners are successful in the second round of the EPP competition in 2003, it is hoped that the M50 EPP will include the fourth HEI located on the M50, namely; the Institute of Art, Design and Technology, Dun Laoghaire (IADT-DL). An example of a collaborative initiative by a group of ITs under the EPP located outside Dublin is the EPP-South East Region. This programme is based on a collaboration between WIT, IT-Carlow and Tipperary Rural and Business Development Institute (TRBDI).

[13] Attached to the back of each envelope was the address label of the sender. The purpose of this was to ensure that if a firm closed, the envelope would be returned to the researcher.

[14] Prior to posting the industry questionnaire, the researcher analysed the list of EI-assisted firms in order to deduce whether or not parent companies had subsidiary firms located in Ireland. If two or more firms had the same name, one of the companies was telephoned in order to find out if the firms were subsidiaries of a parent company in order to ascertain which of the firms was the head office. One company, for example, had a head office with 21 subsidiaries located all over Ireland. In such cases, the questionnaire was posted only to the head office and not to any of the subsidiaries. The

By 2 April 2002, a total of 379 EI-assisted firms had returned completed questionnaires. Of these, 97 firms completed questionnaire 1 (indicating they had links with the HEI sector) while 282 firms completed questionnaire 2 (indicating the absence of HEI links). By 2 April 2002, 81[15] firms had returned questionnaires that were not completed, stating that the firm had either gone into liquidation or was currently in the process of closing its operation. In a number of cases, firms telephoned or e-mailed the researcher and indicated that they had ceased production and were currently in receivership. It seems likely that there were other firms in similar situations that did not return the questionnaires or indicate to the researcher that they had ceased their operations. Furthermore, five firms returned uncompleted questionnaires stating that company policy was not to complete questionnaire surveys.

A total of 465 firms responded to the initial questionnaire. A follow-up re-mailing was made on 2 April 2002 to the 1,515 firms that had not responded in any form. This yielded a further 207 responses.

Table 3.3 Responses to the industry questionnaire survey

Responses	Percent of total number	Number of firms
Firms which participated	34	672
Firms which ceased production	8	154
Refused to participate due to company policy	0.5	10
Refused to participate due to pressure of work	0	1
Non-response	57.5	1,143
TOTAL	100	1,980

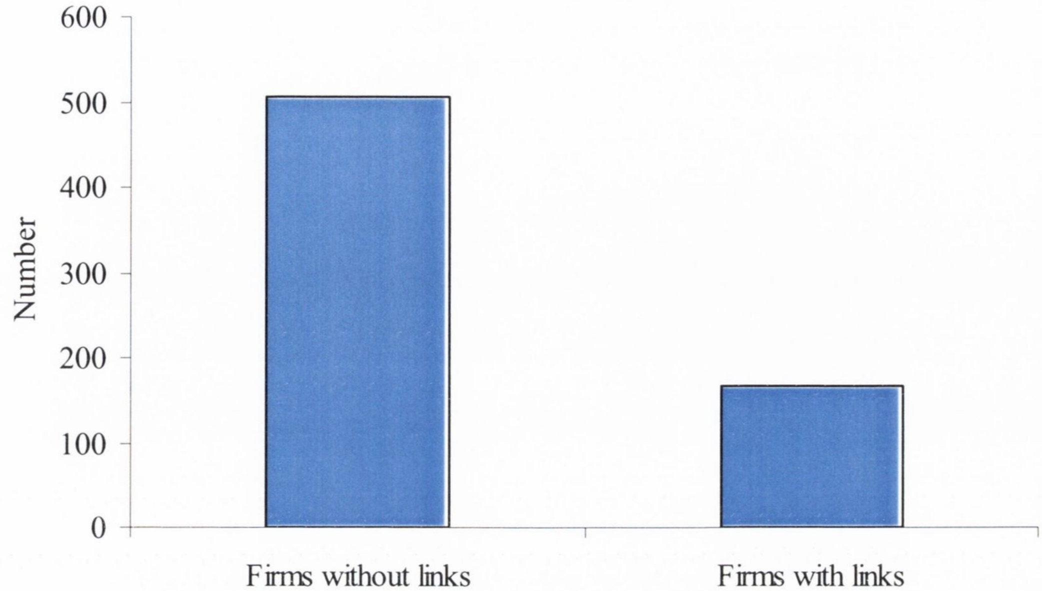
Source: Industry questionnaire survey (2002)

Inclusive of both the initial and follow-up surveys, a total of 672 firms returned completed questionnaires (Table 3.3). The response rate of 34% is considered to be exceptionally high for a postal survey and is reflective of a well-designed and administered questionnaire survey.

purpose of this was to ensure that there would not be any overlap in the information provided by one or more subsidiaries with the same parent company. Furthermore, the inclusion of the subsidiaries would inflate the number of firms in each sub-sector and would bias the statistical results.

[15] According to the annual report from EI (EI, 2003b), 105 EI supported companies went out of business in 2002.

Figure 3.3 Number of responses from the two independent samples of firms



Source: Industry questionnaire survey (2002)

Of these, 167 firms returned questionnaire 1 and 505 returned questionnaire 2[16] (Figure 3.3). The target population for the industry questionnaire survey was 1,980 EI-assisted firms. Of this total, 672 firms returned completed questionnaires, a response rate of 34% for the industry questionnaire survey. A further 154 firms returned questionnaires that were not completed either stating the firm had ceased production or was currently in liquidation. If the 154 firms that ceased production are taken out of the total population, the response rate rises to 37%. Furthermore, ten firms returned uncompleted questionnaires stating that company policy was not to complete questionnaire surveys. Due to pressure of work, one firm stated that it was unable to complete the questionnaire.

3.4.3 Administration of the industry questionnaire survey to science park firms

The industry questionnaire was administered to each of the indigenous high-tech firms under the remit of Shannon Development that are located on the National Technological Park, Plassey. While these firms are supported by Shannon Development, they are a sub-population of EI-assisted firms and, therefore, constitute an integral part of the focus of this research. For the purposes of the research, they

[16] A total of 167 firms returned questionnaire 1 indicating that they have links with HEIs, providing a response rate of 25% of the number of respondents from the total number of 672 firms that returned completed questionnaires. In all, 505 firms returned questionnaire 2 indicating that they do not have

represent a concentration of indigenous high-tech firms in the context of a science park located in Ireland. Investigation of the activities of the firms in relation to their links or lack of links with UL and other third-level educational institutions facilitated comparisons between the micro scale of the science park firms and the macro scale of the target population of EI-assisted firms for the industry questionnaire survey. Furthermore, an analysis of the science park firms and their relationship with UL facilitates a comparison with the patterns of activity emerging at the national level with non-science park EI-assisted high-tech firms.

A list of all indigenous high-tech firms located on the National Technological Park, Plassey was acquired from the manager of the park on 11 February 2002. Prior to posting the questionnaires on 18 February 2002, the researcher had telephoned each of the 66 indigenous firms located on the park in order to acquire the name of its research director[17]. Accompanying the postal questionnaires were two letters. The first letter was from the researcher outlining the objectives of the research (Appendix 3.15) while the second was from the manager of the park (on notepaper with the letterhead of the company National Technological Park, Plassey Ltd.) confirming the credentials and purpose of the researcher (Appendix 3.16). This letter confirmed the support provided by the park's management team and encouraged the firms to participate in the research. Such support, provided by EI and National Technological Park Plassey Ltd. was crucial in terms of ensuring a high response rate to the industry questionnaire survey. The questionnaire was sent to each of the indigenous high-tech science park firms and a follow-up re-mailing was undertaken for those firms who did not respond to the initial survey.

Of a total of 66 firms, eighteen returned completed questionnaires representing a response rate of 27%. In all, twelve science park firms returned questionnaire 1 and six firms returned questionnaire 2. The fact that six firms returned questionnaire 2, indicating that they did not have links with HEIs, is surprising considering the hypothesis that geographical proximity between HEIs and science park firms facilitates the development of links between these partners (Vedovello, 1997). During the period in which the questionnaire was administered to the science park firms, a

links with HEIs. This number represents 75% of the total number of 672 firms that returned completed questionnaires.

[17] At the time of the research, there were twelve multinational companies located on the park. As the focus of the research was on EI/Shannon Development-assisted companies, the multinationals were not included in either the industry questionnaire survey or in the interviews with science park firms.

total of eight firms ceased occupancy of the park (either through liquidation or relocation)[18]. If this number of firms is removed from the original population of firms, the response rate increases to 31%. Unfortunately, the number of firms was too low to generate any statistical analysis that would be of value to this study.

In order to acquire qualitative data, semi-structured interviews were conducted subsequently with three firms. It proved difficult to persuade firms to participate in this phase of the research. Due to this reluctance, it was decided to secure access through the management team of the science park. Shannon Development secured research access to seven of the 66 firms located on the science park. Of this number, three firms participated in the research.

It was also necessary to include the perspectives of the academic community in UL in relation to the establishment of links with science-park firms. While the academics were already targeted in the academic questionnaire survey, an element of research bias would have been introduced if certain academics were targeted based on their links with science park firms. Instead, university representatives in the Programmes in Advanced Technologies (PATs[19]) Centres in UL were targeted. UL houses four Centres associated with three of the PATs: AMT Ireland; Materials Ireland; and PEI Technologies. Each of the directors from each PAT was approached and asked to participate or nominate a representative who would be available for an interview. AMT Ireland and Materials Ireland participated in the research.

[18] For example, *Dell Computer EMF* moved out of the park and centralised their operation in Raheen, while *Felxtronics International* also moved out of the park during the period in which the industry questionnaire survey was administered to the science park firms.

[19] The PATs represent partnerships between EI, industry and the HEIs. In the late 1980s, the government recognised that technology transfer between HEIs and industry was non-existent. To address this issue, the PATs were set up. The initial purpose of the PATs was to fund research in order to develop leading edge technologies. The remit for the PATs has since changed and the focus now is to provide technology transfer services through commercialisation while also providing an advisory service for industry on technology. Instead of conducting contract research for industry, the PATs assess R&D and commercialise it either with an existing company which is interested in developing it or by starting a HPSU. Seven PATs are located in more than 30 centres in the HEIs. These are:

- AMT Ireland (Advanced Manufacturing Technologies);
- BioResearch Ireland (Biotechnology);
- Materials Ireland;
- PEI Technologies (Power Electronics);
- Optronics Ireland (Optoelectronics);
- Software Ireland;
- Teltec Ireland (Telecommunications).

Table 3.4 Key actors interviewed in UL and the National Technological Park, Plassey, Limerick

Campus Industry Programme Manager, Shannon Development, Park House, National Technological Park, Plassey
Centre Manager, Technology Transfer Initiative, Foundation Building, UL
Director – Knowledge Enterprise, Shannon Development, Shannon, Co. Clare
Director, Materials Ireland Research Centre, UL, National Technological Park, Plassey
Executive with New Enterprise Development, The Innovation Centre, National Technological Park, Plassey
General Manager, AMT Ireland, UL, National Technological Park, Plassey
Industry Manager, Shannon Development, Shannon, Co. Clare
Marketing Executive, Shannon Development, Park House, National Technological Park, Plassey
Planning and Research Manager, Shannon Development, Shannon, Co. Clare
University Industry Programme Manager, Shannon Development, Park House, National Technological Park, Plassey

Interviews were also conducted with personnel from National Technological Park Plassey Ltd. and the park's Innovation Centre which have responsibility for the management and development of the science park. In Shannon Development, personnel attached to the park were interviewed as well as personnel based in Shannon, with associated links with the science park. In all, thirteen interviews were conducted in UL and the science park and included the science park firms, science park management and representatives from UL, Shannon Development and the PATs (Table 3.4; Appendix 3.17).

3.5 PILOT SURVEY OF THE ACADEMIC QUESTIONNAIRE

Despite the fact that there is increasing evidence of academic institutions taking a proactive approach in collaborating with industry, very little is known about the role of the academic community in developing such links. Much of the previous research on technology transfer from academia to industry has concentrated on discussing these processes from only the viewpoint of industry (Jones-Evans, 1998). Within the international literature on technology transfer, there has been very little detailed examination of the proactive role that HEIs (at an institutional or individual level) can play in developing links with industry. In particular, very few studies have examined the role of academics in developing links with industry in the areas of R&D, consultancy and teaching/training. Furthermore, very little is known about the barriers and stimulants experienced by academics who seek to establish links with industry. Previous research has focused almost exclusively on the experiences of industry and has neglected to include those of the academic community. If governments are to implement policy measures designed to encourage the development of more effective links between academia and industry, it is important to understand the barriers and stimulants experienced by both partners in their respective endeavours to engage in positive and fruitful relations with each other. As such, this research forms one of the first detailed studies of the barriers and stimulants experienced by both the academic community and industry in relation to their respective experiences of developing links with each other. In the context of Ireland, it was not possible to interview each of the academics who have links with industry. Instead, it was more feasible to design a questionnaire survey and administer it to the total population of academics from S&T-based disciplines in the universities and ITs. The academic questionnaire aims to assess and analyse the:

- Factors which encourage academics to establish links with industry;
- Factors which encourage academics to establish links in one or more of the areas of R&D, consultancy and teaching/training;
- Barriers which make it difficult for academics to establish links in one or more of the areas of R&D, consultancy and teaching/training;
- Types of links established in the areas of R&D, consultancy and teaching/training;
- Number and nature of links established by academics which are formal and informal;
- Positive and negative outcomes for academics as a result of their links with industry;
- Problems making it difficult for academics to maintain existing relationships with industry;
- Role which HEIs should undertake to encourage the development of more successful relationships with industry;
- Role which EI should undertake to encourage the development of more successful relationships with industry;
- General barriers and stimulants to the development of links with industry;
- Demographic and employment characteristics of academic respondents.

Section A of the questionnaire was designed to acquire information on the types of links academics have established with industry. Information on the barriers and stimulants to the development of links experienced by the academic community is also provided by the questions asked in this section. Section B is designed to acquire general information on the demographic and employment characteristics of academics who have links with industry. Initially, academics who do not have established links with industry were excluded from the research. Establishing links with industry is not a crucial feature in the career path for academics pursuing promotion within academia. Furthermore, not all of the specialist research areas of academics are conducive to the development of entrepreneurial ventures or the establishment of links with industry. Many academics, therefore, do not include entrepreneurial activities as features of the development of their academic careers; instead they focus their attention on teaching and research. As a result, this population was deemed an irrelevant source of enquiry for this research.

3.5.1 Description of the sampling procedure for the pilot survey

Before administering the pilot study of the questionnaire, it was important to select a sample of academics from the total population. For the purposes of conducting the pilot survey, a sample of academics was selected only from universities[20] and not ITs. During the summer months (June to September) academics from ITs are not required by contract to be present at the IT in a similar fashion to second-level teachers.

Table 3.5 Universities in Ireland

Dublin City University (DCU)
Trinity College Dublin (TCD)
University College Cork (UCC)
UCD
UL
National University of Ireland, Galway (NUI Galway)
National University of Ireland, Maynooth (NUI Maynooth)

Due to the fact that the pilot survey was conducted in July 2002, it was felt that the inclusion of academics from ITs would have a negative impact on the response rate. In all, there are seven universities (Table 3.5).

[20] The Royal College of Surgeons in Ireland (RCSI) was not included in the research as it focuses mainly on one subject, namely medicine. By selecting a sample of academics from the RCSI, an element of bias towards academics in the health sciences would have been introduced. All of the other HEIs were included as they each have a common range of S&T-based departments.

Table 3.6 Classification of academic departments used in the pilot survey

Chemical and Physical Sciences:
- Biochemistry
- Chemistry
- Microbiology
- Physics
- Geology

Engineering:
- Electrical Engineering
- Civil Engineering
- Mechanical Engineering

Health and Life Sciences:
- Nursing and Midwifery

Information Technology:
- Computer Science

It was decided to send one questionnaire to each of ten departments in each of the seven universities. The departments were categorised according to the classification in Table 3.6. These departments were selected due to the fact that they are S&T-orientated and, therefore, are more likely to have links with the high-tech sector, which constitutes the focus of this research. The total number of academic staff (both full-time and part-time) in each specified department in the universities was 1,228. This figure was calculated by adding the total number of academic staff (full-time and part-time) outlined in each of the university web pages of each of the relevant departments. From this total population, using random number tables[21], a sample of 70 academics was selected to participate in the pilot questionnaire survey.

The researcher accessed the website of each of the specified departments and recorded the name of each staff member. Depending on the total number of academic staff members listed in each department, the researcher assigned a number from 1 to *N* to each individual. Using the computer to select random numbers for each individual department from 1 to *N*, one academic from each department in each university was selected.

A brief, personalised pre-notice letter was sent to the ten chosen academics in each of the seven universities on 8 July 2002 (Appendix 3.18). On 15 July 2002, the questionnaires were mailed to the chosen academics. The questionnaire was accompanied by two letters and a self-addressed reply envelope. One letter was sent from the Policy and Planning Department of EI (on EI letterhead notepaper) and it

[21] A mathematical random number table represents an equation or mathematical procedure that produces sequences of random digits (Burt and Barber, 1996).

confirmed the credentials and purpose of the researcher (Appendix 3.19). The other letter was the cover letter from the researcher (Appendix 3.20). In order to ensure confidentiality, each academic was allocated a reference number and the name of the academic was not attached to their corresponding questionnaire.

Of the 70 respondents, a total of 32 (46%) returned completed questionnaires. Furthermore, a total of 25 (36%) returned uncompleted questionnaires stating that they did not have links with industry. The remaining 13 (18%) academics did not respond.

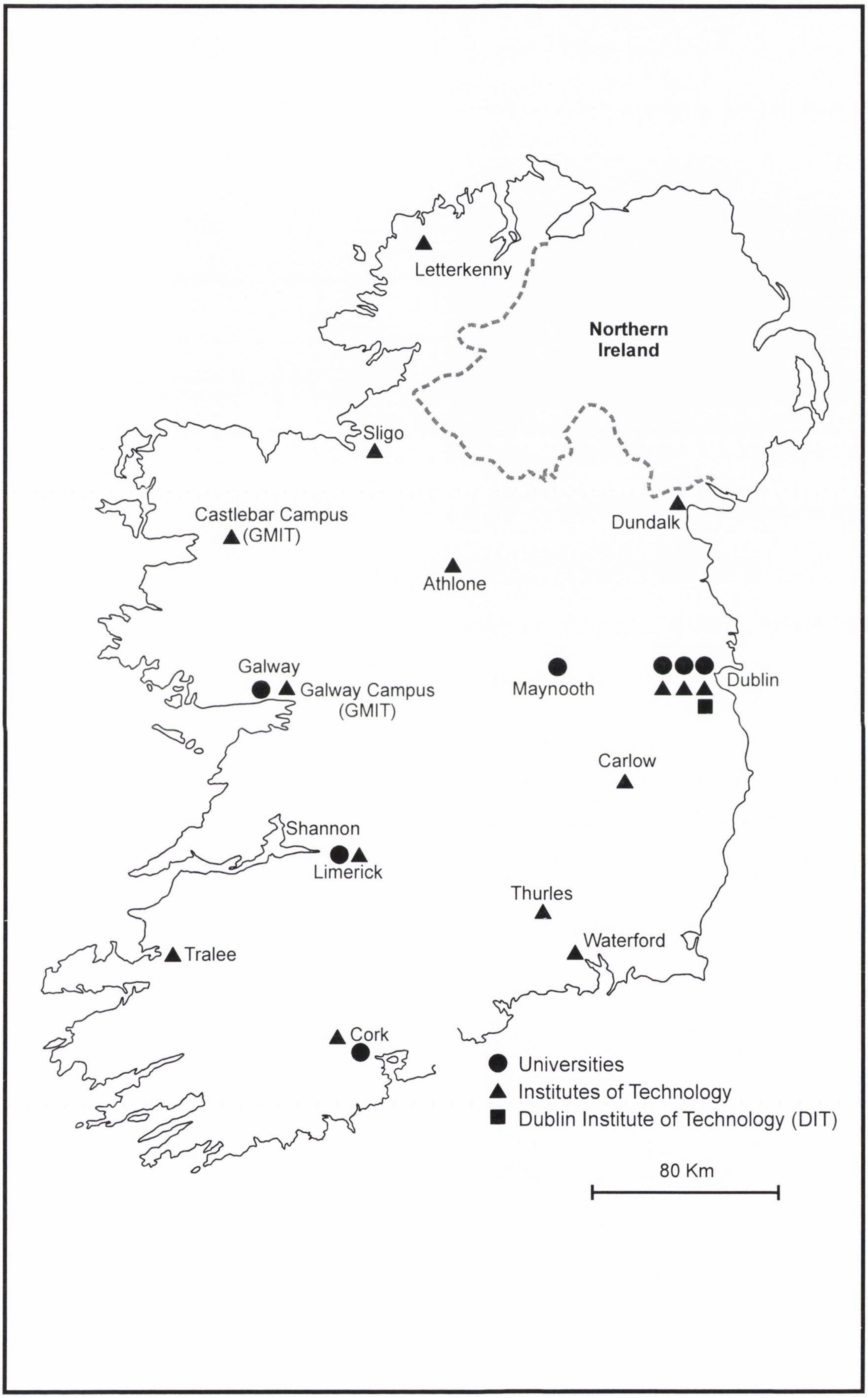
3.6 ACADEMIC QUESTIONNAIRE SURVEY

The pilot survey resulted in one change to the academic questionnaire. The pilot survey had comprised one questionnaire with two sections. Respondents did not have problems with the content or completion of the questionnaire. However, a large proportion of the respondents without links to industry sent back their questionnaires stating this to be the case. At this point it was realised that not designing a questionnaire for academics without links to industry meant that a very important section of the academic population was being excluded. For example, it is highly likely that the barriers discussed in the academic questionnaire aimed at the respondents who have links with industry are the very factors that may have prevented many academics from engaging in links with industry. At this point the researcher designed a questionnaire survey for those academics without links to industry.

3.6.1 Academic survey design

Questionnaire 1 (Appendix 3.5) was to be answered by academics with links to industry and questionnaire 2 (Appendix 3.6) was to be answered by academics without links to industry. In both of the academic questionnaires, all of the questions were closed questions and both were in separate colours to create clarity. Both questionnaires were divided into two sections. Section A of questionnaire 1 focused on the type of links established and the academic's experience in establishing these links. Section A of questionnaire 2 addressed the issues surrounding the academic's reasons for not engaging in links with industry. The questions asked in Section B of both questionnaires were the same. Section B was designed to gather information on the demographic and employment characteristics of academics. It was crucial that

Figure 3.4 HEIs in Ireland



Section B of both questionnaires asked the same questions to enable assessment and comparison of the characteristics of all academics in relation to whether or not they had established links with industry. To date, there has been no research completed in which academics with industry links have been compared with those who do not have such links.

3.6.2 Administration of the academic questionnaire survey

On November 4 2002, the academic questionnaire was posted to 2,973 full-time and part-time academic staff from S&T-based disciplines in each of the Irish universities and ITs (Figure 3.4). The questionnaires were accompanied by two cover letters, one from EI (Appendix 3.21) and another from the researcher (Appendix 3.2). The names of the target population of respondents were taken from the web pages of each of the specified departments in each university and IT.

In the case of four ITs the names of academic staff were not included in each of their respective websites. In each case, contact was made with the administrative officer in each of the relevant departments to procure the names of each academic. In all, each of the seven universities, the DIT and each of the fourteen ITs were included in the survey.

Table 3.7 Classification of academic departments used in the survey

Chemical and Physical Sciences:
- Biochemistry
- Chemistry
- Microbiology
- Physics

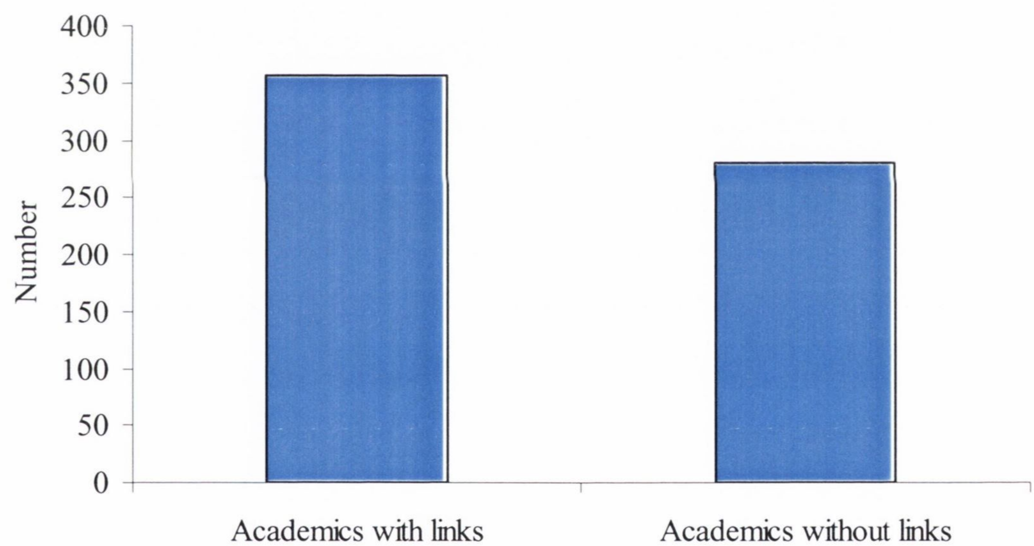
Engineering:
- Electrical Engineering
- Civil Engineering
- Mechanical Engineering

Information Technology:
- Computer Science

The questionnaires were sent to all academics in each of the departments outlined in Table 3.7. The departments of Geology and Nursing Studies[22] were not included in the survey as these departments are not found in all ITs. Two anomalies emerged despite the fact that the same types of departments were targeted in both universities and ITs. First, in the TRBDI, the ICT department (with a total of 20 academic staff members) was the only department relevant to this research. Second, in IADT-DL, the School of S&T (with a total of 37 academic staff members) was the only department relevant to this research. The remaining departments in the TRBDI and IADT-DL did not come under the specified classification of departments outlined.

As already mentioned, the target population was 2,973 for the academic questionnaire survey. In all, the names of 1,036 academics in the universities, 327 academics in DIT and 1,610 academics in ITs were inputted into an excel database. The name and postal address of each academic was recorded. A unique code number was not attached to each name. During the pilot survey, it became apparent that the issue of complete confidentiality was necessary to secure the participation of the academic community. In light of this and in order to ensure a high response rate, it was decided not to attach a code number to the questionnaires.

Figure 3.5 Number of responses from the two independent samples of academics



Source: Academic questionnaire survey (2002)

A total of 636 academics returned completed questionnaires yielding a response rate of 21% for the academic questionnaire survey. Of these, 356 academics returned questionnaire 1 and 280 returned questionnaire 2 (Figure 3.5).

3.7 QUANTITATIVE DATA ANALYSIS

Before data from completed questionnaires was entered into the Statistical Package for the Social Sciences (SPSS) 11.0 for Windows (SPSS Inc., 2001), the response to

[22] The academics in the departments of Geology and Nursing Studies in each of the universities

each question was categorised according to the type of variable *i.e.* whether ordinal, nominal or continuous. In the case of an ordinal variable, the measurement is one of a number of named items, the collection of which has a natural order *e.g.* agree, neither or disagree. In the case of a nominal variable, different categories with different 'names' are assigned a value. The measurement is based on values attached to the set of 'names' which do not have a natural order *e.g.* country of birth; male or female. A continuous variable is a measure of quantities which take values on a continuous scale *e.g.* height.

In order to facilitate data entry into SPSS, a unique identifier code was attached to each individual variable[23]. In the case of ordinal data, the responses were coded 1, 2, 3, 4 or 5 and in some cases the data was also coded as nominal data in order to obtain proportions. In the case of nominal data, the responses were coded as 0 or 1. For continuous variables, the values were inputted.

For the industry survey, the data was coded into three data files: section A of questionnaire 1, section A of questionnaire 2 and section B of both questionnaires. Section A of questionnaire 1 had 126 variables, 83 of which were nominal and 43 were ordinal; section A of questionnaire 2 had 36 variables, 29 of which were nominal and seven were ordinal; section B contained 80 variables, 67 of which were nominal, nine were ordinal and four were continuous. It is important to note that an extra nominal variable was included in this dataset to categorise the respondents into those with links and those without links to HEIs. This brought the total number of variables to 81.

In the academic survey, the information was coded into three data files as before. Section A of questionnaire 1 had 165 variables, 101 of which were nominal and 64 were ordinal; section A of questionnaire 2 had 47 variables, 40 of which were nominal and seven were ordinal. Section B contained 44 variables, 38 of which were nominal, five of which were ordinal and one continuous. Similar to section B of the industry questionnaire survey, an extra nominal variable was included in this dataset to categorise the respondents into those with and without links to industry. This brought the total number of variables to 45. To summarise, six data sets were created, three from each survey.

comprised a total of 192 in July 2002.

[23] A variable refers to a characteristic that changes or varies over time and/or for different individuals or objects under study (Mendenhall *et al.*, 1999).

3.7.1 Statistical analysis

The data was subjected to a variety of different types of analysis and these are now discussed in turn.

3.7.1.1 Descriptive Statistics

In the case of continuous variables, the mean and standard deviation were found. For nominal data, only the proportions were calculated (which equal the mean). In the case of the ordinal data relating to the rating scale (1-5), the mean and standard deviations were calculated. Bar graphs were also constructed in the case of ordinal data.

3.7.1.2 T-Test

In the case of section B of both the industry and academic questionnaire surveys the independent-samples t-test difference of means test was undertaken to compare the mean scores of both independent samples (*i.e.* those with and without links). This test is used to compare the mean of any two independent sample populations and highlights whether a statistically significant difference exists between the mean values of the two independent samples (Pallant, 2001, 177-180). The t-test produces a 'prob-value'; which is the risk which must be taken to suggest that a significant difference exists between the two sample means: the lower the 'prob-value' the more certain one is that a significant difference exists. For this study, and as is usual in research of this type, all tests that returned a 'prob-value' of .10 and less were considered statistically significant.

Before the 'prob-value' for any t-test is consulted the outcome of an equality of variance test must be consulted. This test determines whether or not equal variances may be assumed in both sample populations. In effect, it tests whether the range of the data is significantly different in both independent sample populations. In the case of continuous data, Levene's test for equality of variances was first undertaken. If the 'prob-value' emerging was greater than .10, equal variances were assumed. If the 'prob-value' was less then .10 equal variances were not assumed. In each t-test, the appropriate 'prob-value' was taken depending on whether equal variances were assumed or equal variances were not assumed.

In the case of independent samples t-tests concerning the difference of two proportions, it can be shown that the 'prob-values' associated with 'equal variances not assumed' are the appropriate 'prob-values' that need to be consulted (Barber, 1988; Burt and Barber, 1996; SPSS Inc., 1999). Thus, the 'prob-values' associated with 'equal variances not assumed' are quoted in the tables that follow.

3.8 INTERVIEWS

Similar to other methods of data collection, interviews have both merits and demerits. In terms of advantages, semi-structured interviews provide a flexible and adaptive method of accessing information. Furthermore, this method of data collection provides the interviewer with a unique opportunity to access what lies behind the implementation of various actions or outcomes.

The main disadvantages of the interview process are that they can be tainted by potential biases. In addition, the quality of the data received depends very much on the quality of interaction between the interviewer and the interviewee. Furthermore, the quality of the data gathered also depends on the clarity of the interviewer and on their prior knowledge of the topic being researched.

In selecting potential respondents, the interviewer must be aware of the context/background of individuals being interviewed. This may have an affect on whether or not interviewees agree to be interviewed, the nature of the interview itself and the power relations that may emerge between the interviewer and interviewee. For example, interviewing shoppers at random in a shopping mall on a Saturday afternoon is very different to interviewing corporate managers with busy work schedules. The researcher, therefore, must consider the context/background of the interviewee. This may dictate the approach an interviewer takes in order to secure access to an interviewee and implement the interview itself. For the purpose of this research, the population of potential respondents for the interviews were elites who were considered to be experts in their respective fields of professional experience.

In an interview, the interviewer organises the interview around a set of questions that (s)he wishes to address. The interview technique may be categorised into standardised and non-standardised (Healey and Rawlinson, 1993). In standardised interviews, each respondent in the survey is asked an identical set of questions in a fixed order. In contrast, a non-standardised interview is much less structured and the questions vary from interview to interview.

In Ireland and Scotland, the key actors involved in the development of U-I links constitute a large population of potential respondents from state-sponsored development agencies, policy-advisory bodies, specialist industrial research units in HEIs, business support agencies and key network actors with a regional and national focus. As a result, it was not feasible to design a questionnaire that would be relevant to each individual respondent. Furthermore, in terms of acquiring detailed information on each of the separate initiatives and programmes associated with the development of U-I links, the interview technique proved to be the most effective method of collecting such information. Both standardised and non-standardised interview techniques were used during the course of this research.

Table 3.8 Key actors in innovation interviewed in Ireland

EI interview respondents:
Business Development Executive, Bioresearch Ireland, EI, Dublin
Campus Companies Programme Manager, EI, Dublin
Divisional Manager, Science and Innovation, EI, Dublin
General Manager, National Pharmaceutical Biotechnology Centre (NPBC), Bioresearch Ireland, TCD, Dublin
Manager of Regional/North-South Innovation Initiatives and Research Training, EI, Dublin
Manager, Regional and North-South Initiatives, EI, Dublin
Manager, Regional Technology and Innovation, EI, Limerick
Programme Manager - Institutes of Technology, Science and Innovation, EI, Dublin
Programme Manager - Universities, Science and Innovation, EI, Dublin
Senior Research Scientist, National Cell and Tissue Culture Centre (NCTCC), Bioresearch Ireland, DCU, Dublin
Technical Operations Manager, AMT and Materials Ireland, EI, Dublin
Computer Integrated Manufacturing Research Unit (CIMRU), NUI Galway, Galway
DBIC, The Tower, TCD Enterprise Centre, Dublin
Dean of Research, TCD/Nutriton Unit, Department of Clinical Medicine, TCD
Department of Business Administration, UCD, Dublin
Department of Management, NUI Galway
Development Office, IADT-DL, Kill Avenue, Dun Laoghaire, Co. Dublin
Élan Corporation plc, Biotech Building, TCD
Growcorp, Dublin
IBEC, Dublin
ISME, Dublin
NMRC, Cork
Project Development Centre, Docklands Innovation Park, Dublin
Provost of TCD/Former Dean of Research, TCD/Department of Physics, TCD, Dublin
School of Business Studies, TCD, Dublin
TecNet, Cork
The ILOs in the HEIs of:
AIT
CIT
DIT
DKIT
IT Carlow
IT Tallaght
IT Tralee
TCD
UCD
WIT
Trinity College Enterprise Centre, Dublin

A series of interviews were conducted with a wide variety of key actors involved in innovation and in the establishment of U-I links in Ireland. These actors included: ILOs of HEIs; EI-assisted campus companies in universities and ITs; specialist research units in HEIs such as the NMRC in UCC with established links with industry; support services for the indigenous sector such as the Irish Business and Employers Confederation (IBEC), Irish Small and Medium Enterprises Association (ISME[24]) and DBIC; the EI-administered PATs located in a number of universities; EI personnel involved in the implementation of initiatives designed to promote the development of U-I links; EI personnel involved in the creation and implementation of science technology and innovation policies; Shannon Development personnel; and a range of other key actors in Irish innovation. In all, a total of 56 interviews were conducted in Ireland (Table 3.8; Appendix 3.17).

A standardised set of questions were asked to all ILOs (Appendix 3.24) who agreed to be interviewed and another set to each of the campus companies interviewed. Interviews with ILOs were designed to seek detailed information on the interactions between their respective HEIs and industry. Each ILO who agreed to be interviewed took a great deal of time to provide valuable information, despite their heavy work schedules. Interviews with campus companies were designed to assess the barriers and/or stimulants experienced by the academic entrepreneur in commercialising their idea or research through the formation of a campus company. As explained in section 3.4.2, it was not possible to conduct the industry questionnaire survey with EI-assisted campus companies in universities and ITs.

Apart from the ILOs and campus companies, all other interviews were non-standardised interviews in which the questions were tailored to each individual interviewee. For example, if an EI person with responsibility for the implementation of an EI programme relevant to the creation of U-I links agreed to be interviewed, the questions were designed around acquiring information on that particular programme. In general, the questions were open-ended which enabled respondents to answer with freedom. One of the limitations of these interviews was that some of the interviewees tended to focus on providing descriptive accounts of the programmes or activities that

[24] ISME was originally part of the Small Firms Association (SFA) and was under the remit of IBEC. In the early 1990s, some member firms of the SFA felt that the needs of the indigenous manufacturing SME base were not being addressed. In response to this, in 1993, ISME was formed as an independent organisation with the specific aim to represent the interests of and provide a wide range of support services to its client base of indigenous owner-managed SME manufacturing companies. In particular, ISME makes representations on behalf of its client companies to the government, state-sponsored development agencies, financial institutions and other bodies associated with industry in Ireland. Based in the centre of Dublin, ISME has a Chief Executive, a Chairperson and a staff of five personnel. ISME is a self-funded organisation, funded by its own client companies who pay an annual fee of €255. ISME estimate the population of indigenous SMEs in Ireland to be in the region of 10,000 firms. In all, of this population, 1,700 are ISME firms, while 1,300 are SFA firms. ISME appeal more to

they themselves were involved with and were reluctant to give their opinions on their own programmes, especially in relation to the barriers and stimulants to the development of U-I links and on the environment in which U-I links have evolved in Ireland. This was also the case in some of the interviews in Scotland and would appear to be symptomatic of interviewing high-profile elites who belong to a small network of key actors in science and innovation. In the case of this research in both Ireland and Scotland, some interview respondents were reluctant to communicate their opinions in case these would become public knowledge either within their own organisation or within the milieu of their professional peer networks. However, the majority of interviewees did provide opinions. Taken as a whole, the interviews generated a wealth of background information on the programmes and activities associated with U-I links in both Ireland and Scotland.

3.8.1 Interviewing elites

Within organisations such as firms, HEIs, or government departments, an elite is an individual with authority, representing decision-making powers and specialist knowledge of some form. When studying elites, the researcher is dependent on the co-operation and generosity of time of a relatively small number of people with the capacity to mobilise specialist knowledge (Cormode and Hughes, 1999). Providing a definition of an elite is problematic (Hughes and Cormode, 1998). In the literature, there are varying definitions and broad generalisations of the term. In particular, it has been used loosely as shorthand for those actors who are perceived to be more powerful or more privileged than some undefined other group (Woods, 1998). By definition, elites "are less accessible and are more conscious of their own importance" (Richards, 1996, 200). One of the reasons it is difficult to provide a definition of the term elite is that this group has been relatively unstudied. According to Hunter (1995), this is largely due to the fact that elites are powerful and can more readily resist the intrusive inquisition of social science researchers. According to Woods (1998), elites represent a cluster of individual actors bound by strong social, professional or political ties. Within each of these settings, elites interact with each other to form 'elite networks' (Parry, 1998). Research access to such networks has been problematic for the social science researcher.

manufacturing industry, while SFA appeal more to service sector companies. Not all members of ISME are EI-assisted.

Having sourced a sample of elites to be interviewed, difficulties in obtaining access to this sample remains a crucial issue for the researcher. Very often elites have busy work schedules and access to them is often difficult. Access can also be inhibited due to the personality of the elite. Arrogance, self-centeredness, insecurity and an inflated feeling of self-importance can be the key personality traits steering elites from agreeing to participate in interviews with social science researchers (Ward and Jones, 1999). An element of bias can be introduced into the research based on the personality types of the elites who agree to be interviewed.

In this research, gaining access to various groups of elites was fundamental in order to acquire qualitative data on various aspects of the research. Interviewing elites proved to be very important in terms of acquiring information that would otherwise have been difficult to access. A key part of gaining access to interview elites involved networking at various events organised by EI, universities and ITs. Furthermore, the title of the *Enterprise Ireland Millennium Scholar* was particularly effective in terms of securing interviews with policy advisors, representatives from the business community and key actors in innovation in Ireland and Scotland. The research was immediately associated with EI and, therefore, high-profile respondents were more willing to participate in the research and be interviewed. According to McDowell (1998), while this is not a strategy commonly discussed in the literature on social science research methods, the context/background of the researcher and his or her informants is a factor that may facilitate access to the subjects of the research.

In 1992 and 1993, McDowell (1998) interviewed a sample of 75 employees in three merchant banks in the City of London. The purpose of the research was to examine the recruitment procedures and culture within merchant banks with the intent of investigating the reasons for the continuance of discrimination on the basis of class and gender. Having experienced considerable difficulty in gaining research access to the banks, McDowell had to conduct her interviews in the banks that would co-operate. Access was secured through the use of college connections to target members of the elite on boards of the banks that were the focus of her research. McDowell did not suggest that employment by an elite educational institution is a prerequisite for conducting research on elite groups. Such connections did, however, represent a viable opportunity to gain access to the particular organisations that were the target of the research. Furthermore, she did stress that there are many different ways of utilising a range of networks in order to secure access to organisations that are the focus of the research.

For the purposes of this research, attending national and international conferences proved to be very productive in terms of acquiring names of potential interviewees and arranging interviews with relevant people in both Ireland and Scotland. Such interaction provided the researcher with a unique opportunity to become known in academic and government circles which later facilitated access to relevant elite networks in science and innovation in Ireland and Scotland. Indeed, it also facilitated access to key people who were advisors to the Irish and Scottish Parliaments. The practice of 'cold-calling' a high-profile potential interviewee rarely produces a positive reaction in terms of organising an interview. Instead, it is important for the researcher to lay the groundwork by networking and becoming known in academic, business and government circles.

In order to acquire qualitative data on various aspects of this research, the researcher had to gain access to a number of broad categories of elites. In Ireland, five categories of elites were identified. These included ILOs within HEIs, campus companies, EI and Shannon Development personnel, the research directors of science park firms in the National Technological Park, Plassey and key actors in innovation, technology transfer and entrepreneurship in Ireland (Appendix 3.17). It is important to note that an element of bias was introduced into the selection of elites. The sample of elites interviewed was not a representative sample generated by random sampling from the total population. As discussed in section 3.2.1, research bias emerges when not every individual in the total population has an equal chance of being included in the survey. Due to a number of reasons, such bias was unavoidable. In relation to ILOs, potential bias arose due to non-response. The researcher had no control over who agreed to be interviewed. Each ILO was contacted by letter (Appendix 3.22), e-mail and telephone. Unfortunately, of the total population of 22 ILOs, only eleven agreed to be interviewed.

In relation to campus companies, there was bias in the selection of companies to be interviewed in a number of ways. First, it is important to note that campus companies do not represent a ubiquitous group. The first common feature of each of these companies is that they were founded on a college campus. The second area of commonality relates to funding. In Ireland, campus companies are either EI-assisted or not in their initial phase of development. As EI-assisted high-tech companies are the target population for this research, the researcher required that a campus company be either initially funded or currently funded by EI and that the associated HEI has an equity stake in the company. At the time of the research, government legislation did not permit the ITs to take equity in campus companies, so they were excluded from the research. In terms of selecting a campus company in each university, it was at the discretion of the ILO. The ILO proved to be vital in terms of ensuring research access to the campus company and also in assigning credibility to the researcher.

With respect to EI personnel, there was bias in the selection of elites based on the programmes under the remit of the elites. Gaining access to interview EI personnel was not a problem, largely due to the status of the researcher as an *Enterprise Ireland Millennium Scholar*. There was an element of bias in the selection of other key actors in innovation in Ireland. As it was not possible to interview all of the key actors, those deemed to be most relevant to the research were selected. However, from this sample, not all of the elites agreed to be interviewed. Furthermore, those who did agree to be interviewed did so because they had previously met the researcher at a seminar or conference and were, therefore, more agreeable to participate in the research[25].

In Scotland, six broad categories of elites were identified: ILOs within universities; SE personnel; Scottish Executive[26] personnel; key actors in innovation, technology transfer and entrepreneurship; university personnel involved in commercialisation; and Scottish Institute for Enterprise (SIE) personnel (Appendix 3.23). The researcher had a total of nineteen working days in which to conduct the semi-structured interviews in Scotland and had to be selective as to the number and types of elites to be interviewed. In relation to the ILOs, an element of potential bias was introduced in that it was only ILOs in universities that had implemented the SIE initiative who were interviewed. Similar to EI in Ireland, it was the personnel from SE and Scottish Executive with responsibility for certain programmes related to this research who were interviewed. In relation to the personnel involved in

[25] In Ireland, one elite agreed to be interviewed on the condition that he/she be given the opportunity to comment on a draft version of the final thesis before submission. In this case, the researcher found this to be an unacceptable condition and, subsequently, decided not to interview the elite in question. While respondents do have the right to comment on what has been written about them as individuals (Healey and Rawlinson, 1993), they do not have the right to dictate what is included or excluded in the research report. In explaining the purpose of this research, the researcher stressed to each potential respondent that this was an independent piece of research. Furthermore, the interviewees were assured that their names would not be associated with the individual responses they provided in the interviews.
[26] Established in 1999, the Scottish Executive is the devolved government in Scotland.

commercialisation in the universities, gaining access to the appropriate personnel depended on whether or not they agreed to be interviewed. Finally, the SIE facilitators in each of the five universities were interviewed.

In all, the researcher completed 56 interviews[27] in Ireland. Of these, 54 were tape recorded and later transcribed in full. The transcripts for each was then coded and analysed.

3.9 THE RESEARCH METHODOLOGY IN SCOTLAND

An international comparison was made with the efforts of the Scottish Executive, SE and the universities of Scotland to facilitate the commercialisation of the Scottish science base. Between November 2000 and March 2001, a considerable amount of time was spent in correspondence via telephone, e-mail and by post in order to organise a schedule of meetings with the appropriate actors in Scotland. In March/April 2001, the researcher spent one month in Scotland conducting interviews with key informants in commercialisation there. Prior to the research trip, 43 interviews were scheduled to take place and 35 interviews were actually conducted[28]. A total of 34 interviews were tape recorded and later transcribed. The tape was not used with one interviewee who did not feel comfortable being recorded while divulging confidential information.

[27] Within a week of conducting each interview, a thank-you postcard was sent to each interviewee as a gesture of appreciation for participating in the research.

[28] A total of eight scheduled interviews were cancelled, one interviewee cancelled due to ill-health, one interviewee resigned from their post, one interviewee went on holiday at short notice and five interviewees were unavailable on the day of the scheduled interviews due to unexpected changes in their work commitments.

Table 3.9 Key actors in innovation interviewed in Scotland

ALBA Centre – Scotland's High-Tech Centre of Excellence
Centre for Enterprise Management, University of Dundee
CONNECT Scotland, University of Edinburgh
European Policy Research Centre, University of Strathclyde
Hunter Centre for Entrepreneurship, University of Strathclyde
Scottish Executive, Glasgow
SE, Glasgow
Scottish Institute for Enterprise, Glasgow (Head Office)
Scottish Institute for Enterprise in the Universities of:
Dundee
Glasgow
Heriot-Watt
Scottish Microelectronics Research Centre, University of Edinburgh
Strathcyde University Incubator, University of Strathclyde
The ILOs in the Universities of:
Dundee
Edinburgh
Glasgow
Heriot-Watt
Strathclyde
Technology Ventures Scotland (TVS), Fife
Targeting Technology Ltd., West of Scotland Science Park, Glasgow

The pool of interviewees was drawn from a variety of sources (Table 3.9; Appendix 3.23). Interviews were conducted with the ILO from the research and innovation offices of the universities of Dundee, Edinburgh, Glasgow, Heriot-Watt and Strathclyde. The aim of the interviews with Scottish ILOs (Appendix 3.24) was to elicit the various policies, practices and results of U-I interaction in the aforementioned universities. These universities[29] were selected because they are involved in an educational programme organised by SIE, which is designed to promote and deliver entrepreneurial education to academic researchers. Interviews were also conducted with the SIE representative in three of the five universities. The head of SIE was interviewed in Glasgow. Interviews were conducted with the staff of university departments related to business management, entrepreneurship, S&T, centres of research excellence and university-based agencies such as CONNECT Scotland, which has a specific role in the initiation and development of U-I links in Scotland. Non-university-based bodies which play an important role in creating U-I links in the high-tech sector, such as Technology Ventures Scotland (TVS), were also

[29] In Chapter 5, when reference is made to the 'five universities', it refers to the five universities (Dundee, Edinburgh, Glasgow, Heriot-Watt and Strathclyde) that were initially involved in the SIE programme.

interviewed. Interviews were conducted in the ALBA Centre, Scotland's main high-tech park with established links in microelectronics with a number of universities. Representatives from SE who work in the area of technology transfer and commercialisation of university R&D were interviewed. Within the government, three key figures from The Scottish Executive were interviewed.

3.10 QUALITATIVE DATA ANALYSIS

In all, 91 qualitative interviews were conducted in Ireland (56) and Scotland (35). Overall, 88 transcripts from taped interviews and notes from three interviews were analysed manually. The data gathered in the interviews was reduced, coded and grouped using the approaches outlined by Miles and Huberman (1994) and Robson (1995). As interviews were semi-structured, content/thematic analysis (Hussey and Hussey, 1997; Silverman, 1993, 2000) was used to analyse the data. This involved assigning thematic codes to the text of the interviews. Codes are tags or labels used to assign units of meaning to the information collected (Miles and Huberman, 1994). Each interview was coded separately. Codes were also assigned across interviews to facilitate cross-referencing and comparative analysis between different interviewees and groups of interviewees. Based on broad categories of themes, assigning codes to the text facilitated the development of a graphical 'map' or schema of how codes link to categories and how categories link to each other. In a case where there was more than one individual interviewed from the same organisation or from the same group of individuals (*i.e.* ILOs), the interviews were first analysed individually and then collectively. Furthermore, these interviews were numbered and the corresponding numbers were assigned to the quotations from the interview transcripts that are included in the analysis chapters.

3.11 CONCLUSION

In human geography research flexibility in the design and implementation of a research methodology is central in order to achieve the desired objectives of the research. Consequently, for the purpose of this research, the methodology employed a combination of both quantitative and qualitative fieldwork methods. Extensive research was conducted through the use of two questionnaire surveys, one for the indigenous high-tech firms and the other for the academics in S&T-based faculties in the universities and ITs of Ireland. Both generated a large quantitative data-base of empirical information.

In order to acquire qualitative data, intensive research was employed through the use of semi-structured interviews with government representatives, policy advisors, ILOs with universities and ITs, campus companies and key informants in the area of technology transfer and U-I links in Ireland and Scotland.

Both quantitative and qualitative methods complemented one another effectively. In particular, the qualitative material amplified and enriched the information derived from the quantitative data (Schoenberger, 1991). A case study analysis of U-I links in the National Technological Park, Plassey, provided an in-depth account of the barriers and stimulants to the development of links between the host university and science park firms located in an environment conducive to the creation of U-I links. In short, the research methodology undertaken provided an effective basis from which to examine the barriers and stimulants to the development of U-I links in Ireland. The following chapter will examine the policy background in which U-I links have evolved in Ireland.

CHAPTER 4

OVERVIEW OF UNIVERSITY-INDUSTRY LINKS IN IRELAND

4.1 INTRODUCTION

> *The interesting thing for Ireland then is moving on into a more creative phase in so far as recent growth has been maybe based on an implementation of other people's technologies and knowledge base. If you look at the multinational sector particularly American-generated knowledge and science you know the next challenge for Ireland is actually to contribute, to create, to attract people on the basis that knowledge is created here, that creative work is done here and therefore if a traditional logic was to manufacture here because it is English-speaking, it is in Europe, it is relatively low-cost, as those things become less competitively advantageous, that people would say I'd come there because valuable knowledge is generated there, there is a creative capacity and that is a good place then to locate things which are probably increasingly going to be non-manufacturing. They are going to have more to do with knowledge creation, knowledge management. That again is a challenge (Interview with an academic from a university in Ireland, 2001, number one).*

In Ireland, a combination of growing R&D costs within academia and industry, recent increases in government expenditure in research and innovation and the emergence of national and European-based policy initiatives in the area of industrial innovation have provided considerable impetus to the development of U-I collaboration. The number of technology centres, U-I R&D centres and university-affiliated institutes has grown. However, there are no quantitative measures available to indicate the actual level of interaction between industry and HEIs. While patent applications and royalties from IP are low, collaborative R&D projects involving formal agreements between public science institutions and industry appear to be common (European Commission, 2001). According to the European Commission (2001), research co-operation between industry and HEIs in Ireland has increased dramatically over the past few decades. However, there is no empirical evidence to demonstrate that this is the case. Focusing government finance on enhancing U-I links is not a prerequisite for increasing actual levels of interaction. Due to the paucity of research in this area, data on levels of U-I interaction are scarce. Hence, there is no way of knowing if levels of interaction have changed. According to the European Commission (2001), levels of U-I links are low due to the profile of knowledge sought by indigenous industry and foreign firms located in Ireland. Indigenous firms tend to be specialised in low- and medium-tech areas and the foreign-owned enterprise sector imports R&D from its headquarters abroad. To counteract low levels of U-I interaction, increased public expenditure has been directed towards fostering a variety of co-operative research programmes, ranging from specific collaborative research projects to specialised research centres facilitating a range of partnerships between industry and HEIs.

The purpose of this chapter is to explore the initiatives implemented by the Irish government in order to facilitate the development of U-I links. In particular, attention focuses on the literature dealing with U-I links in Ireland, Irish policy in this regard and the implementation of such policy initiatives by EI in partnership with the third-level educational sector in an effort to harness the expertise in HEIs towards the development of a competitive indigenous high-tech sector.

4.2 DEVELOPMENT OF A POLICY BACKGROUND OF U-I INTERACTION

In the mid 1980s, national policy statements, including the *White Paper on Industrial Policy* (Government of Ireland, 1984) and the *Programme for Action in Education 1984-1987* (Department of Education, 1984), highlighted the need to increase technology transfer from Irish HEIs to industry. The need to strengthen the interface between HEIs and industry based on the application and exploitation of scientifically derived knowledge was recognised in a report, *Barriers to Research and Consultancy in the Higher Education Sector*, published by the National Board for Science and Technology (NBST[1]) (1986). Following an examination of the barriers to commercial research and consultancy in Irish HEIs, the report found that the development of such activities was dependent on the achievement of two distinct objectives involving the:

- creation of a climate in which academics will be able and willing to interact with industry;

- establishment of new institutional mechanisms and structures at college and national level to facilitate the development of links with industry.

The recommendations for the achievement of the first of these objectives were directed specifically towards the Department of Education and HEIs. It was recommended that the Department of Education should highlight its support for commercial research and consultancy and provide HEIs with guidelines on the implementation of such activities. In relation to HEIs, the report recommended the development and implementation of appropriate policies, procedures and practices facilitating technology transfer from HEIs to industry. In 1987, NBST published a second report *The Limited Liability Company as a Vehicle for Technology Transfer from the Higher Education Sector* (NBST, 1987a). This considered, in part, a number of measures to meet the second of the two objectives listed above. In particular, it described a structure designed to enable HEIs to provide commercial services and create spin-off ventures. This was significant in terms of providing ILOs in HEIs with much needed direction in terms of providing advice supporting the creation of HEI spin-off companies.

Following the publication of the report, *Barriers to Research and Consultancy in the Higher Education Sector* (NBST, 1986), HEIs requested that NBST provide advice on the implementation of HEI policies and procedures for technology transfer. This resulted in the publication of a third report by NBST (1987b) entitled *Higher Education-Industry Co-operation and Technology Transfer: College Policies, Procedures and Structures.* The main emphasis of this report was on the commercialisation of HEI research and it did not consider any other form of U-I interaction (*e.g.* teaching/training). The purpose of this report was to:

- respond to HEIs seeking advice on HEI policies and procedures for technology transfer;
- persuade HEIs that a systematic and structured approach to collaboration with industry is both worthwhile and necessary;
- highlight the principal issues to be faced in drawing up appropriate policies and procedures, and to offer guidelines which would be helpful to HEIs in drawing up such policies and procedures;

[1] In operation from 1977 to 1988, NBST was the chief body responsible for advising the government

- provide models of specific structures, which have been developed in light of practice in other countries and which HEIs might use in developing their structures.

The advice provided by NBST (1987b) was general and lacked specific direction in the implementation of a structure within HEIs conducive to industrial collaboration and technology transfer. In particular, while it stated the important role played by ILOs, it failed to outline a strategic plan which would effectively integrate ILOs into an academic structure focused on effective technology transfer. For example, there was no mention of a support structure or defined educational programme which would enable ILOs to evaluate and assess technology for commercialisation. Instead, the report merely mentioned that training programmes should be made available to enable ILOs to familiarise themselves with new responsibilities in relation to the development and exploitation of IP. Furthermore, there was no mention of how ILOs would be trained to initially identify IP. To date, no such training has been made available to the ILO community in Ireland with the result that two ILOs from ITs in this research highlighted their lack of proficiency in relation to identifying and assessing technology with commercial potential.

By the early 1990s, Ireland's increasing dependency on FDI allied with a declining indigenous sector prompted the government to reformulate its industrial policy. The Report of the Industrial Policy Review Group, *A Time for Change: Industrial Policy for the 1990s* (Culliton, 1992) recognised that fundamental changes in industrial policy had to be implemented if industrial development was to evolve successfully to meet the challenges of the Single European Market (SEM), and increased global competition. With unemployment reaching 260,000 in 1991, the main objective of the group was to provide a systematic and structured plan to improve the effectiveness and competitiveness of the economy and to generate sustained employment growth.

In order to achieve this, the Culliton Report made a number of recommendations to condition the development and direction of future industrial policy. One of its main recommendations included the reorganisation of the Industrial Development Authority. Under the Industrial Development Act of 1993, Forfás with two sub agencies, Forbairt and IDA Ireland, was established and became responsible

on policy and planning in S&T (Quinlan, 1995).

for the promotion of industrial development in Ireland. In 1998, Forbairt was renamed EI and is responsible for promoting the development of indigenous industry, while IDA Ireland caters specifically for the attraction and development of the foreign sector.

The report emphasised the failure of previous policies to articulate a multifaceted approach to economic development, and create an effective environment for investment and growth. It recommended, therefore, a broader strategy be adopted to include an extensive range of policies in the areas of taxation, infrastructure, education and training and monetary, fiscal and budgetary allocations. The report, in particular, laid considerable emphasis on measures which would invoke a culture of innovation in the indigenous enterprise sector.

The publication of the Culliton Report (1992) coincided with the passing of the Regional Technical Colleges (RTC) (now ITs) Act and DIT Act, both of 1992, permitting these HEIs to undertake research and engage in commercialisation activities. This facilitated the potential for increased interaction between these HEIs and industry and recognised the role ITs play in economic development (Forfás, 1997[2]).

Established by the government in 1994, STIAC (1995) completed a report (referred to as the Tierney Report) highlighting the need for greater use of HEI resources and expertise by industry, in order to foster an NSI. The Tierney Report proposed that:

- curriculum development and research endeavour be linked to the needs of businesses in Ireland to the greatest extent possible;
- businesses, individually or collectively, define their research needs and communicate them to HEIs.

The report proposed that the traditional flow of knowledge from HEIs to industry be aligned with a flow of research ideas directed from industry to HEIs. A number of reasons were identified for developing U-I linkages. These included:

- HEIs should be regarded as an integral part of regional economic development;

[2] Forfás (1997) conducted a survey of the attitudes of ILOs and Deans of Research to links with industry. The findings concur with those of Pandya and Cunningham (2000) as highlighted in section 5.5.2.

- commercialsistion of HEI research can lead to the formation of spin-off companies;
- vibrant research activity in HEIs attracts high quality lecturers, thus enhancing the quality of graduates and research support for industry.

This analysis was significant as it set S&T policy for the first time in Ireland in the context of industrial innovation and growth (Royal Irish Academy, 1997). In particular, it equated the exploitation of Ireland's S&T base with industrial competitiveness. Recognising that knowledge is central to innovation-led development, the report stressed the need for a coherent national policy focused on the effective transfer of knowledge from HEIs to the commercial arena for the benefit of society. A number of recommendations were made in order to meet this aim. These included:

- measures to encourage increased levels of R&D activity in firms;
- increased public expenditure on basic research and enhancing research infrastructure of HEIs;
- a refocusing of the management structure of the PATs around a single entity.

In 1996, the government published *Science, Technology and Innovation: The White Paper* (Government of Ireland, 1996). This incorporated the government's response to the recommendations of the Tierney Report. While the White Paper gave approval for the development of a number of initiatives, such as the restructuring of the management profile of the PATs, it provided no attention towards the implementation of specific policy objectives designed to create an environment of U-I interaction. In all, there was only one reference to U-I links in the White Paper, in which it stated:

> *The Department of Education and the Department of Enterprise and Employment will explore, in consultation with the third level institutions, how best to maximise technology transfer out of the colleges (Government of Ireland, 1996, 113).*

In the mid 1990s, it is significant that Ireland did not have a coherent policy document focused on initiatives designed to promote U-I interaction and the development of a knowledge-based economy. The need for a policy framework document to align S&T with industrial innovation at this time cannot be underestimated, in light of the recent downturn in the economy allied with the mass exodus of multinational production facilities to cheaper locations in the Far East. Such disappointment is echoed also by the Royal Irish Academy (1997) when it stated how extensive consultation preceding the White Paper was not sufficient to prompt the government to plan and implement a much needed strategy for improving Ireland's R&D infrastructure and climate for S&T.

4.3 LEVEL OF R&D ACTIVITY IN IRELAND

During the 1970s and early 1980s, high-tech multinational firms located in Ireland in general failed to incorporate strategic business functions such as R&D and marketing while the existing indigenous sector did not engage in such activities (NESC, 1982). While R&D activity remains low in Ireland's manufacturing base relative to some countries, since the early 1990s the country has experienced a notable increase in R&D expenditure (Quinlan, 1997). In particular, a positive correlation has emerged between investment in R&D and increases in output and employment (NESC, 1998). For example, total R&D expenditure in Ireland increased from 0.85% of GDP in 1989 to 1.4% of GDP in 1995. However, such expenditure is concentrated within the major urban centres of Dublin, Cork, Galway and Limerick, which together account for 63% of total expenditure. Since the late 1990s, there has been a strong effort by the Irish government to encourage firms to engage in R&D. According to Forfás, the level of government expenditure on R&D in 1999 was 5.1% of Business Expenditure on Research and Development (BERD) (Sweetman, 2002). In the same year, BERD as a percentage of GDP was 0.88%, while actual public expenditure on R&D amounted to €187.5 million.

By 2000, the budget allocation for R&D amounted to just over €295 million, with BERD at 1.02%[3] of GDP in comparison to an OECD average of almost 1.5% (Sweetman, 2002). These low business expenditures can be explained in part by the state's limited success in encouraging Ireland's multinational high-tech manufacturing base to engage in R&D activities in Ireland and by an indigenous high-tech manufacturing sector which has yet to fully integrate R&D into its profile of activities (Sweetman, 2002). In 2000, despite the fact the EI provided an additional €14 million

[3] By 2001, while this figure had increased to 1.2%, it was still below the EU average of 1.9% (EI, 2003).

(from the Department of Enterprise, Trade and Employment), to fund its Research and Development Capability Initiative and the Research Technology and Innovation (RTI) Competitive Grants Scheme, the uptake from indigenous companies was lower than expected. According to Sweetman (2002), three key factors contributed to this situation. First, the schemes were in their start-up phase in 2000 and it takes time for them to reach full expenditure. Second, during the boom period of 2000 companies were too busy meeting market demands to invest in R&D projects. Third, indigenous companies face competition from the multinationals and HEIs in attracting high calibre researchers to work with them. One of the key challenges facing Ireland will be the ability to grow and retain the human capital necessary for creating and sustaining research and innovation in the indigenous high-tech sector in a context of increasing global competition. Overall, each of these factors contribute to low levels of R&D performance in Ireland's indigenous industrial sector.

Forfás conducts an Annual Business Survey of Economic Impact. This is a questionnaire survey administered by Forfás to all client companies under the remit of EI, the IDA, Shannon Development and Údarás na Gaeltachta. It is important to note that the firms under the remit of the IDA are foreign firms. The main purpose of this survey is to record details on the levels of sales, exports and R&D expenditure among the total population of client companies from each of the four specified government development agencies. In 2000/2001, Forfás conducted the questionnaire survey on a target population of 3,997 firms[4] and obtained information for 1999 and 2000 (latest years available). A total of 2,147 firms responded, a response rate of 53%. Of this total, 982 (45%) engaged in some form of R&D expenditure in 1999. In 2000, this had increased to 1,049 (49%). Of the firms which engaged in R&D expenditure in 1999, 346 spent in excess of €127,000 on R&D per annum, increasing in 2000 to 409 firms. In 1999, 948 (44%) respondent firms had an in-house R&D facility; in 2000 this increased to 1,013 (47%). In relation to expenditure on in-house R&D in 1999, 316 (15%) respondent firms spent in excess of €127,000 on in-house R&D. In 2000, this increased to 367 (17%) firms.

Overall, these figures suggest that a slight increase is occurring in the number of development agency-assisted firms in Ireland which are engaging in R&D expenditure and in the establishment of in-house R&D facilities. It is important to

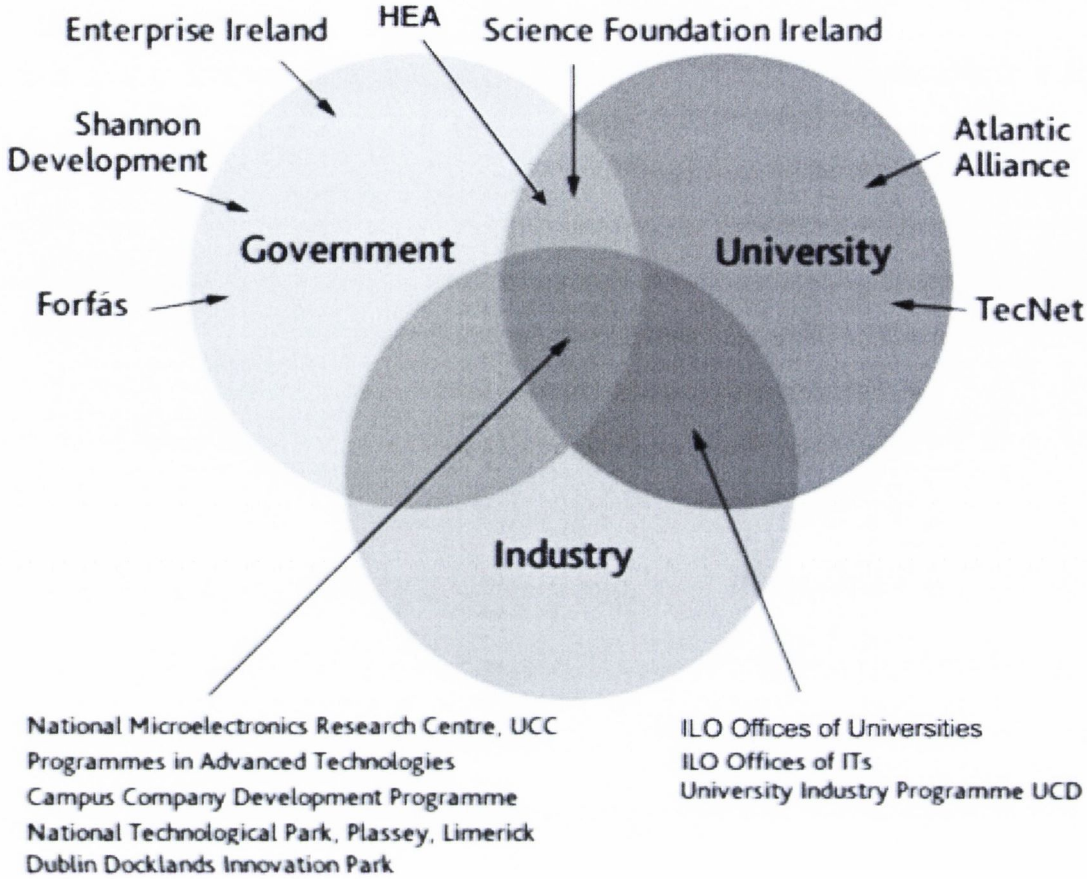
[4] The results of the Forfás survey are not published. However, access to and permission to quote these figures was acquired from Forfás.

note, however, that these figures may be negatively skewed by the inclusion of foreign IDA-assisted companies in the target population. In general, R&D intensity of indigenous firms is higher than that of foreign subsidiaries (OECD, 1999a). While foreign firms are more likely than indigenous SMEs to have a greater financial capacity to engage in R&D expenditure, foreign firms are not focused on engaging in R&D expenditure locally in their host country (OECD, 1999a). Instead, foreign-owned enterprises in Ireland obtain their primary entrepreneurial impetus and R&D capability from their parent companies abroad (European Commission, 2001). Similarly, the multinationals located in Scotland do not undertake R&D activities in their host country, and instead their R&D decision-makers are located elsewhere (Downes and Eadie, 1998). In analysing the R&D capabilities of firms in Ireland, it is more effective to analyse separately the populations of firms assisted by each of the four main industrial economic development agencies and then compare the results using industry-specific and firm-specific factors.

4.4 GOVERNMENT FUNDING AND SUPPORTIVE FRAMEWORK

Historically, funding for research from public funds has been limited (ICSTI, 2001). However, between 1997 and 2003, the government provided substantial funding through a range of programmes in an effort to promote the development of Ireland's S&T base and create an environment conducive to the creation and sustainability of U-I partnerships. In light of the recent downturn in the global economy, such expenditure is expected to decline in the coming years.

Figure 4.1 Government-university-industry interaction in Ireland: key players



Public finance was central to instigating a range of partnerships between the government, HEIs and industry (Figure 4.1). In particular, it facilitated the creation of partnerships at the interface between each of these key players. In Ireland, the two main bodies which fund R&D in the universities are Science Foundation Ireland (SFI) and the HEA.

The HEA is the government agency which administers government policy and funds for university level higher education in Ireland. Established in 1997, the HEA's Programme for Research in Third-level Institutions (PRTLI) provides financial support for priority research facilities, infrastructure and equipment in Ireland's educational research centres, as well as administering the combined teaching and education budget for HEIs (ICSTI, 2001; Sweetman, 2003). Under the PRTLI, the HEA has invested more than €600 million in equipment and facilities in Irish HEIs during the period 2000-2003. The disciplines supported include medicine, biotechnology, environmental science, marine science, neuroscience, information technology, food and health science, humanities and business. In 2000, SFI was set up to administer a fund of over €635 million which is to be invested in basic research in the areas of biotechnology and ICT during the period 2000-2006 (Sweetman, 2003). This amount was allocated on the recommendation of the Technology Foresight Reports and resulted in the formation of the Technology Foresight Fund (Sweetman, 2003). SFI was formed to administer this fund. While the finance provided by the HEA and SFI is critical in terms of enhancing the research profile and activities of HEIs, funding agencies such as EI and Shannon Development play an equally important role in terms of dispersing public funds through a range of programmes in order to develop partnerships between HEIs and industry.

4.4.1 Role of Enterprise Ireland

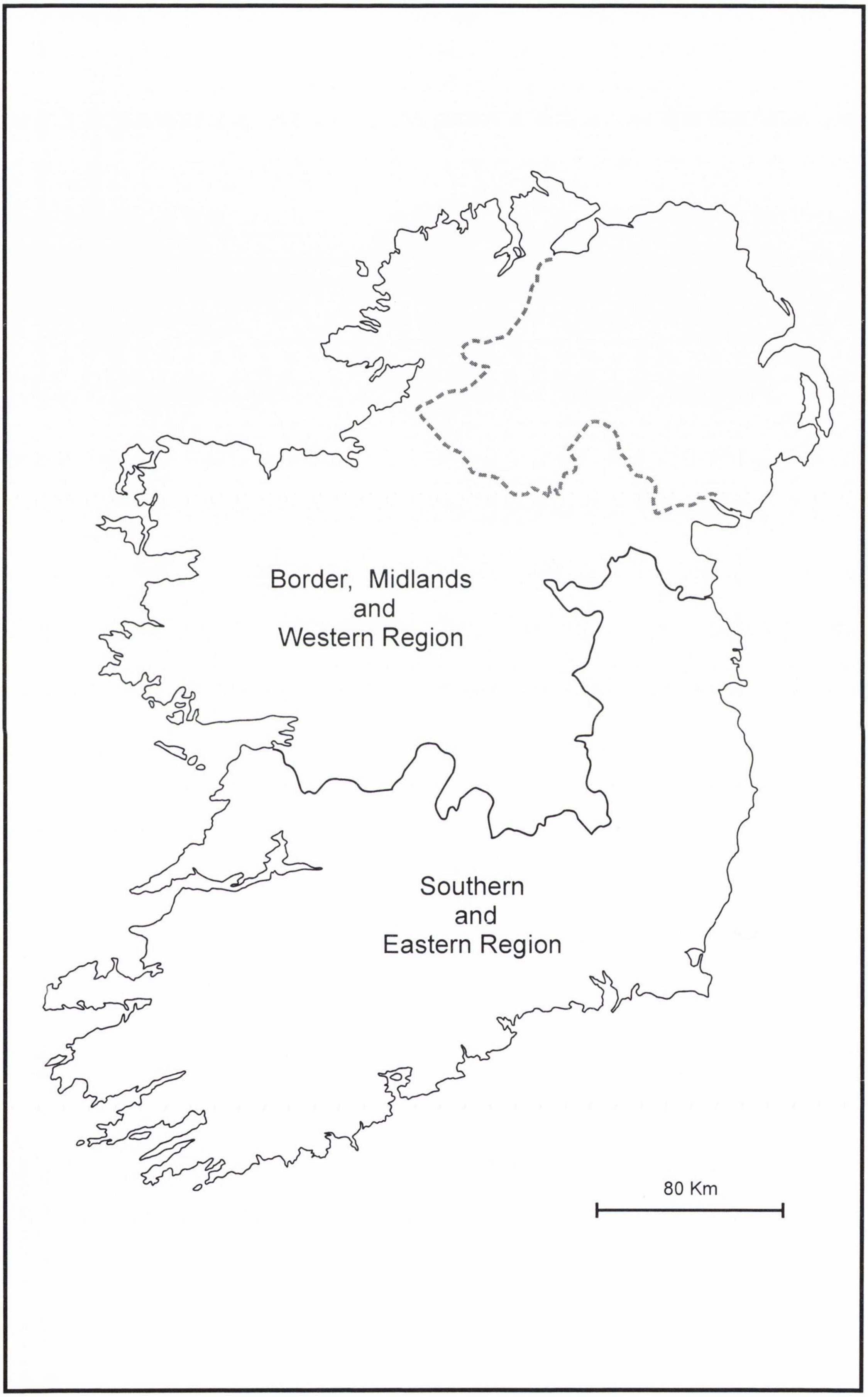
EI is the Irish government agency with responsibility for the development of indigenous industry. The key focus of EI is to develop high value added companies which are competitive in the international knowledge-based global economy. Its client companies are drawn from: manufacturing and internationally traded services (with 10 or more people); entrepreneurs (often owner-managers) with internationally competitive enterprise ventures; and Irish-based food and natural resource companies.

In recognition of the fact that innovation is central to indigenous enterprise development and enterprise growth, EI in partnership with the HEI sector in Ireland has introduced a number of initiatives aimed at stimulating technology transfer and enhancing the innovative capacity of indigenous enterprise in Ireland. There are two main criticisms of these initiatives. First, these initiatives are nothing more than sources of finance rather than specific programmes aimed at creating links between academia and industry. Second, there are a large number of these initiatives which are not marketed effectively leading to a lack of knowledge of their existence amongst both industry and academia. Such finance would be utilised more effectively if it was to be strategically directed into a specific programme with targets designed to create U-I links. To date, EI has implemented just two programmes aimed at facilitating the development of U-I links in Ireland. For the purpose of this research, both of these programmes are examined in detail, as both focus on creating interaction between existing indigenous EI-assisted firms and Irish HEIs. These are: AUA and TecNet.

4.4.1.1 Atlantic University Alliance

Atlantic University Alliance (AUA) is a collaborative project involving the three universities along the western and southern seaboard of Ireland working in

Figure 4.2 BMW and Southern and Eastern Regions



partnership with development agencies to promote the development of the indigenous SME sector. The objective of AUA is to harness the resources of three universities, namely UCC, UL and NUI Galway, to work primarily towards the development of indigenous industry in the West, Mid-West and South-West regions of Ireland.

The territorial focus of AUA is the western and southern seaboard of Ireland from Donegal to Kerry. It covers the Border, Midlands and Western Region[5] (BMW[6]) (Figure 4.2), as well as the South-West region (Chapter 3, Figure 3.1). The primary objective of AUA is to start-up new companies, regenerate existing enterprises and promote sustainable competitiveness in the total population of indigenous SMEs which come under the remit of EI, Shannon Development or Údarás na Gaeltachta. In order to achieve such competitiveness, it is essential for the economic and social development of the regions that the expertise of the universities is harnessed by the SME community.

Funded by EI, phase one of AUA was initially established as a Technology Transfer Initiative (TTI) pilot programme and implemented between May 1999 and December 2000. TTI is an inter-regional, inter-university project involving each of the participant universities of AUA. The aim of this programme is to harness the resources of the participating universities in collaboration with the development agencies for the benefit of indigenous SMEs in the Atlantic seaboard regions. Based on the success of this programme, EI decided to fund a further three-year TTI programme from September 2001 to September 2004 to the value of €1.12 million. The key focus of this programme is to connect the technology transfer teams in each of the participating universities to the client companies of EI, Shannon Development and Údarás na Gaeltachta, in order to provide opportunities to identify what the requirements of the companies are and to provide opportunities to meet these requirements. Furthermore, AUA is targeting specific sectors. These are biomedical/healthcare, engineering, food and ICT. Similar to the cluster approach

[5] In the NDP for the period 2000-2006, the country is designated into two regions, the BMW and Southern and Eastern regions (Government of Ireland, 2000). The Operational Programmes for each region are managed by regional assemblies which implement a variety of initiatives aimed at enhancing regional development. One of the initiatives includes a sub-programme on Local Enterprise Development. This includes a measure on Regional Innovation Strategies, the main focus of which is to provide a regional innovation infrastructure by providing finance to HEIs on a competitive basis to establish incubator units and provide space for commercial R&D enterprises. Particular emphasis is placed on providing funding to build incubators in ITs. The Regional Innovation Strategies are funded by EI under the NDP.

[6] EI grants are higher in the BMW Region than they are in the Southern and Eastern Region.

undertaken by SE in Scotland, AUA identifies centres of excellence in each of these areas in each of the participating universities and promotes the availability of such expertise to the relevant industry sectors in each of the regions.

While the programme is funded by EI, AUA is co-ordinated and managed by a board with representatives from EI, Shannon Development and Údarás na Gaeltachta, the ILOs from each of the participating universities and a representative from the SME community. In terms of the day-to-day management of the programme, the ILO of NUI Galway, who is the acting director of the programme, works in conjunction with each of the technology transfer managers in each of the participating universities. In all, AUA has a staff of ten personnel (six are full-time and four are part-time). One of the key strengths of AUA is that it has personnel based in each of the participant universities focused on establishing links with industry. This is somewhat different to the network-based initiatives of Connect Scotland and TVS which have personnel who engage in the same activities but who are external to the university.

> *The main function of Atlantic Alliance is specifically about the technology transfer initiative, which is to harness some of the expertise of those three universities and put them to work for the growth and competitiveness of Irish industry, particularly indigenous Irish industry. But it's also an exercise in networking, because it's the three universities that have to network among themselves to source the appropriate expertise as required by the companies. It's also a further exercise because if they don't have that expertise, part of their responsibility is to refer or try and source it elsewhere. But the primary objective is connecting Irish SMEs to the university and getting that expertise to promote development and growth of Irish companies (Interview with AUA, 2002).*

The main objective of AUA is to connect indigenous SMEs to the participating universities and encourage a flow of expertise from academia to industry through the implementation of special training programmes and collaborative R&D and to provide firms with the opportunity to engage in the commercialisation of research from the universities. Another activity of AUA is technology brokerage. In one of the universities, AUA will identify a technology or research project which has market potential and which could lead to an additional technology which could be licensed to a company in one of the regions under the remit of the programme or it may form the basis for a new start-up company. Another AUA activity is academic mentoring. As many SMEs experience technical problems, they are often not aware of how to access the appropriate source of expertise in the universities. In such cases, AUA sources the appropriate academic personnel in the universities for firms, and therefore is instrumental in establishing a variety of U-I consultancy and R&D links. AUA acts as a crucial network broker by facilitating communication between academia and the SME base in the regions. In particular, in the interview, the AUA interviewee was keen to stress the point that a lack of communication is a major barrier in the flow of know-how between academia and industry. For example:

> *I would see it as a very important barrier. It's a two-way thing, obviously. Communication is a two-way thing, but I would see it as a very important barrier and I would see it as one of the key interface issues that needs to be addressed, because as technical people we tend to talk techy. If we're talking to someone who's not a techy, we forget that, and we're trying to talk benefits, trying to communicate the benefits to someone. If they don't understand what we're saying, it won't relate so they won't see the benefit. Therefore, they won't necessarily buy into it, so there may be no transaction. So I would see that as very, very important [SIC] (Interview with AUA, 2002).*

According to AUA, one of the main reasons that a lack of communication exists between academia and SMEs is due to cultural differences. For example:

> *I would think that the people at the interface between the higher education institutes who are dealing with SMEs, they need to be given the opportunity in terms of mentoring and counselling SMEs. In the regions in Ireland, the third level institutes, e.g. the Institutes of Technology in some of the more dispersed regions, are the major intellectual asset in the region and perception can be the reality. People in the little companies can think – 'oh, the people with the white coats in there, they are up there and it doesn't really relate to us', whereas it isn't so. So the communication thing is a two-way thing, but there's counselling and training and grooming of people in higher education who are going to be dealing and interfacing with it, that's number one (Interview with AUA, 2002).*

In order to overcome the barriers to the establishment of links between the SME base and the universities, AUA has five action lines. The first is a programme of creating awareness[7]. This involves communicating the programme to SMEs in the BMW and South-West regions to the firms under the remit of EI, Shannon Development and Údarás na Gaeltachta. The second one is promoting collaborative

[7] In an effort to create more awareness of the TTI project, EI funds a user-friendly interactive website, *www.technologytransfer.ie*, which highlights the activities, targets and outcomes of TTI under the auspices of the AUA.

R&D. The third focuses on technology brokering and exploitation of research in the universities which could be a basis for a new start-up company or an additional technology for an existing company. The fourth one is the pilot mentoring programme with academic mentors. The fifth action line is specialist training activities and outreach programmes, particularly for small companies which are not based in major centres. Each of the five main action lines has specific annual targets.

While it is too early to assess the impact of AUA in terms of promoting increased levels of technology transfer between the universities and SMEs, in the context of Ireland AUA represents the only inter-regionally focused model of U-I interaction which focuses exclusively on the universities. If AUA is successful in achieving its targets, this model could well emerge as a show case in Ireland of how all Irish universities can successfully integrate their missions of teaching and research into a profile of activities which also includes a focus on regional development. Furthermore, AUA can in the future become the medium through which the academic community in each of the participant universities can market its capabilities to the indigenous SME base in each of the regions. It is interesting that in the East region, TCD, UCD, DCU, NUI Maynooth and DIT have not formed a similar initiative to AUA. This is surprising considering that a large population of indigenous firms is located in Dublin and in the Greater Dublin Area (GDA) (Chapter 6, Figures 6.5 and 6.6).

In Ireland, a similar network-based initiative to AUA which focuses on making the resources of HEIs available to industry is TecNet, which is a nationally focused model that deals exclusively with the ITs and not the universities.

4.4.1.2 TecNet

> *We have also supported a network between the institutes of technology called TecNet and the interesting approach there is that the ITs said to us we will not be able to build up huge research capability in each college but if we work together all of the people who are interested in software we have more people than the biggest university has so they are talking about, well in Europe you would call, a laboratory without walls (Interview with Science and Innovation, EI, 2001, number one).*

In 1998, EOLAS (now EI) commissioned a feasibility study to explore mechanisms and initiatives which would enhance the capacity of ITs to support regional economic development based on collaborative activity and institutional partnership (McCarthy, 1998). The motivation for this study was (a) the publication of the RTC Act (1992) permitting the ITs to engage in R&D, technology transfer, consulting and the promotion of spin-off companies and (b) the White Paper on *Science, Technology and Innovation* (Government of Ireland, 1996) encouraging the involvement of ITs in developing the innovative capabilities of companies at the regional level. The purpose of the study was to: assess the level of interaction between ITs and industry; assess the degree of collaboration between researchers within and between each of the ITs and; devise an appropriate mechanism which ensures that the exploitation of the expertise of ITs would improve regional economic development and the competitive stance of the national economy. The report found that despite the lack of a strategic vision in ITs focused on public/private sector partnerships, there was a high level of interaction between ITs and industry based on personal contacts. In particular, the study found that the delivery of high quality graduates with skills relevant to Irish companies was by far the most efficient mechanism supporting regional economic development. Furthermore, the study found that the most successful form of interaction between ITs and industry was based on identifying and solving small industrial problems. In relation to interaction between researchers, the study found that networking between researchers both within and between ITs was practically non-existent. One of the main recommendations of the study was to create a separate structure as a joint venture with other public and private organisations. The recommendation was to set up a body which creates a stakeholder partnership between government, industry and ITs which is focused on creating and maintaining links between the public and private sectors. Based on the findings and recommendations of the study, TecNet was formed.

Established in 1999[8] by the Council of Directors[9] of the ITs, TecNet (The Technology Network) is a company limited by guarantee. It is jointly funded by EI and the Council of Directors and it has a chief executive who reports to the Board of TecNet. This board consists of one representative from the Council of Directors,

[8] While TecNet was established in 1999, it did not come into operation until September 2000 with a total staff of four people.

[9] The Council of Directors is the representative body of the heads of the ITs and is the equivalent of the Conference of Heads of Irish Universities (CHIU), the body that represents the heads of the universities. The Council of Directors of the ITs was set up to ensure that each of the ITs addressed commonality in the way that issues such as terms and conditions of employment were dealt with in each of the ITs. Other areas that are addressed are R&D, links with industry and approaches to regional economic development.

ILOs from three ITs (two heads of development and one industrial liaison manager), one active research manager from an IT and two representatives from EI.

The primary objective of TecNet is to provide industry with a comprehensive range of R&D and consultancy services by utilising the skills and facilities available in ITs. The mission of TecNet is to foster collaborative research between researchers in each of the ITs and to encourage industry to avail of these skills and resources in ITs, and, thereby, support regional economic development in Ireland. While the remit of TecNet is the ITs, it is not located in an IT and is based in an office in Glanmire, outside Cork City. In contrast to Connect Scotland, which was initially hosted by the University of Edinburgh, TecNet is an autonomous unit not linked to any single IT but representing all of the ITs in Ireland, with the exception of DIT. According to TecNet:

> *The institutes of technology were set up specifically to deal with industry as opposed to being educational, as opposed to universities which are about education...I think it is fascinating. I did an interview with the Irish Times the other day. I said that I found it fascinating that institutes of technology do their best to pretend they are universities and the universities at this stage are now doing their best to become institutes of technology. They are being told to go back and look at research, look at industry links, look at whatever it is. That is why the institutes were set up, initially to provide technician level education for industry. It then started off to go from technician into a kind of supervising technician, they actually came out with degree courses and now you can do your Ph.D. in institutes of technology (Interview with TecNet, 2002).*

TecNet represents a collaborative forum between the government, industry and academia which seeks to co-ordinate a variety of partnerships between public and private stakeholders. It facilitates the development of links between researchers and Irish industry and represents a single but crucial point of entry for firms to access the expertise and resources of Ireland's fourteen ITs. It is a national organisation focused on providing Irish industry with access to the research and knowledge base that exits in ITs. On the industrial side, TecNet offers indigenous SMEs access to a network which encourages links with ITs. On the academic side, TecNet provides a variety of services which include identifying researchers to work with industry or in collaboration with other researchers in the ITs, arranging funding for projects and advising on IPR.

TecNet is also focused on developing a profile of the knowledge capacity of the ITs which is networked between the ITs to ensure the development of collaborative research projects. Following the establishment of inter-institutional research networks between the ITs, the objective of TecNet is to ensure that the knowledge base and resources of these networks are transferred to industry. Through these networks, TecNet identifies the needs of industry and can source solutions to technical and design problems experienced by industry. A further dimension to TecNet's role is its focus on adding value to the knowledge capacity of each of the regions in which the ITs are located. While the ITs are small compared to other European HEIs, in the context of Ireland the ITs represent a major intellectual asset to the regions in which they are located. The aim of TecNet is then to transfer such capacity to meet the needs of local industry at the regional level. Therefore, the ITs are geographically well positioned to enhance the regional innovative capacity of firms, and thereby encourage regional development in Ireland.

Furthermore, TecNet is a strategic body which not only engages in networking between industry and academia but it also manages the link between the two once a partnership has been established and, thereby, endeavours to dispel the cultural barriers which often inhibit the development of effective collaborations between the two partners. For example:

> *Industry is very worried about dealing with the academics because they go into labs and they go into classrooms and they are never seen again. You know yourself if you are trying to find somebody who is an academic, I mean if we looked at your card index book now or your diary and we picked five academic contacts that you had, I put a reasonable bet that if we got one of them on a first phone call we would be doing very well. Imagine if you are a client who has committed €30,000 worth of research with these people and need a result by next Tuesday morning and the phone is not answering. We take over that role; we manage the process, we will organise the deliverables, all the various bits and pieces. From the point of view of the researchers they are happier too because they are dealing with somebody who understands them (Interview with TecNet, 2002).*

There are a number of significant differences between TecNet in Ireland and Connect Scotland and TVS in Scotland. First, TecNet deals only with the ITs and not the universities. Second, TecNet not only links the academic and industry partners together, but also it manages that partnership. As a network facilitator, TecNet is more like Connect Scotland, as it focuses on developing contacts between academics and industrialists through informal networking. It does this by organising conferences, seminars, workshops and trade fairs. The stage of development that TecNet is now at is similar to that of TVS in Scotland. For example:

> *We are still learning, we are not quite sure what is the best way to do it (Interview with TecNet, 2002).*

While TecNet also visits the ITs to understand the research capacity and expertise in each and while they work with each of the regional offices of EI throughout Ireland, TecNet currently is not aware of the needs of industry. TecNet, like Connect Scotland and TVS, considers this to be one of the key barriers to the establishment of U-I links. Similar to Connect Scotland and TVS, TecNet is viewed by some of the ILOs as a threat to their position in the ITs and is not perceived to be a facilitator of the process of commercialisation in Ireland.

Similar to Connect Scotland and TVS, TecNet in Ireland is still in its early stages of development and, therefore, it is difficult to assess its outcomes. However, in the context of Ireland, it is important to understand that TecNet is the only independent autonomous network facilitator which is not directly under the remit of any government department, university or IT and is focused specifically on developing links between ITs and Irish industry.

4.5 COMMERCIALISATION OF HEI RESEARCH IN IRELAND

Recognising the important role played by the effective exploitation of science and technology since the late 1990s, the Irish Government has increased its investment in knowledge generation (ICSTI, 2001). At the same time, Irish HEIs are realising the potential benefits of commercialising their research base with existing firms and through the formation of new HEI-derived ventures. Increased commercialisation of both commissioned and non-commissioned research in Ireland is expected to facilitate the development of an economy on track to becoming increasingly knowledge-based (ICSTI, 2001). In this context, it is appropriate to analyse the barriers and stimulants to the commercialisation of HEI research in Ireland.

To date, two studies have examined barriers and stimulants to research commercialisation in Ireland. The studies are:

- Jones-Evans (1998)[10] examined university technology transfer and spin-off activities in seven regions across Europe including Ireland as well as Northern Ireland, Wales, Portugal, Spain, Finland and Sweden;
- Pandya and Cunningham (2000)[11] focused on barriers and stimulants to the commercialisation of research in Irish HEIs and public research centres[12].

4.5.1 Study 1: Jones-Evans (1998)

Universities, Technology Transfer and Spin-off Activities – Academic Entrepreneurship in Different European Regions.

As part of a European Commission project examining universities, technology transfer and spin-off activities within peripheral regions, Jones-Evans (1998) examined the general policies associated with the development of academic entrepreneurship in Ireland. This research focused on an analysis of the processes by which U-I links are formed, the university strategy towards technology transfer, and how these may affect the development of academic entrepreneurship in Ireland. Semi-structured interviews were conducted with each ILO in the universities of TCD, UCD, UCC, NUI Galway, and UL. Four main areas of interest were discussed in the interviews:

- General role and function of the ILO and how this has changed;
- Involvement of the university in different types of industrial links;
- Main opportunities and barriers to the development of links between university and industry;
- Benefits to the university from industrial links and the perception of industry's assessment of the relationship with universities.

The main benefit perceived by ILOs of increased U-I interaction was an increase in funding for research in universities resulting in better teaching and research facilities, as well as access to new ideas, techniques and research initiatives within industry. In relation to barriers, ILOs indicated that a lack of resources (both at an individual and institutional level) was a significant barrier to the development of the ILO function. The author highlighted that this is despite recommendations in the

[10] Results from this research were also presented in conference papers by Jones-Evans *et al.*, (1997a); Jones-Evans *et al.*, (1998); and Jones-Evans *et al.*, (1999).
[11] Results from this research were also presented in a conference paper by Pandya *et al.*, (2001).

STIAC (1995) report, which proposed that all state sector and third level institutions involved in research or technological development should devote sufficient resources to a specific function for technology transfer. Jones-Evans (1998) concluded that one of the solutions to the problem of a lack of resources and support for ILOs would be a stated policy providing guidelines on research commercialisation for HEIs and industry.

4.5.2 Study 2: Pandya and Cunningham (2000)

A Review of Issues with respect to the Commercialisation of Non-commissioned Research in Ireland.

Pandya and Cunningham (2000) identified the barriers and stimulants to research commercialisation with particular emphasis on the creation of academic spin-offs in Ireland. During the summer of 2000, 41 semi-structured interviews were conducted with a wide range of key informants from funding agencies, recipients of non-commissioned funding, ILOs and IPR experts and campus companies[13].

Important barriers to research commercialisation identified by the study related to human resource issues, particularly with regard to the personal motivation of a researcher and the lack of awareness of the commercialisation process. Moreover, the high number of contract researchers, lack of full-time research positions in universities and the fact that no reward value is placed on commercialisation by HEIs were cited as significant constraints to commercialisation of non-commissioned research. General resource deficiencies, both in terms of monetary and support structures, were also highlighted as a major barrier. This deficiency was highlighted in the form of under-resourced ILOs, the lack of clear guidelines to facilitate and govern commercialisation within funding agencies, HEIs and public research institutes, and the general lack of IP expertise. Emphasis was also placed on the gap in terms of perception and proximity between industry and public research centres. Factors which contribute to widening this gap were identified as lack of funding for prototype development, short-term focus of industry and lack of confidentiality.

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[12] ICSTI (2001) produced a statement *Commercialisation of Publicly Funded Research*. This was in response to the research findings of Pandya and Cunningham (2000).

[13] Although Pandya and Cunningham (2000) interviewed three campus companies, they did not report their findings in relation to these ventures.

Amongst the stimulants to research commercialisation was the motivation and personal characteristics of the individual academic or researcher. Academics who had experienced academic entrepreneurship elsewhere displayed a greater propensity to exploit their IP for commercialisation purposes. Developing a culture of innovation and entrepreneurship at the institutional level was also found to be very effective in the support of commercialisation activities. In addition, explicit support for commercialisation in HEIs and public research centres, in terms of leave of absence for staff, reduced workloads, training courses in IPR and a supportive informal framework, was found to be significant in the creation of an environment conducive to commercialisation of non-commissioned research. Finally, the ongoing desire to be at the 'cutting-edge' of one's discipline and to be continually pushing the scientific boundaries out as far as possible was also cited as a major stimulant.

4.5.3 Role of the Industrial Liaison Office

In the context of this research, in order to analyse the barriers and stimulants to the commercialisation of HEI research, the ILO in each of the HEIs was asked to participate in a semi-structured interview. As already noted (Chapter 3), ten ILOs participated. They represented two universities (TCD and UCD), DIT and seven ITs (AIT, CIT, DKIT, IT Carlow, IT Tallaght, IT Tralee and WIT). The purpose of these interviews was to assess the barriers and stimulants experienced by ILOs in the commercialisation of HEI research.

Barriers and stimulants to research commercialisation identified by this research are largely consistent with those found by Pandya and Cunningham (2000). This is significant given that Pandya and Cunningham (2000) focused exclusively on the commercialisation of non-commissioned research while this study focused on both commissioned and non-commissioned.

Table 4.1 Barriers to research commercialisation

Barrier	Number of interviews in which barrier was cited
Human resource issues	
Excessive teaching and administrative workloads of academics	9
Commercialisation not valued for promotion in academia	4
Conflict between publication & maintaining confidentiality of the IP	3
Lack of resources for commercialisation role of ILO	
Lack of personnel and resources	9
Lack of time to market research capabilities of HEI	6
Lack of a culture of academic entrepreneurship on campus	3
Lack of expertise and information regarding IPR, technology transfer and patents	2
Lack of incubation space	1
Issues relating to funding agencies and schemes	
More funding required for basic research	4
Lack of 'seed funding' for start-up companies	2
Lack of 'proof-of concept' funding	1
Barriers within ITs	
Lack of projects which have the capability of being commercialised	3

Source: Interview with ILOs

Regarding the barriers to research commercialisation, the majority of ILOs considered there were problems with resources at both an individual and institutional level (Table 4.1). In relation to human resource issues, ILOs stated that excessive teaching and administrative workloads of academics was a significant barrier to commercialisation. This was particularly the case with the ITs, where academics have 16 hours teaching per week. Of equal importance were general resource deficiencies. In particular, ILOs noted that a lack of personnel and resources constituted a major inhibiting factor. As a result, each of the ILOs stated that they are reactive rather than proactive in the commercialisation of HEI research. They do not have the personnel or resources to enable them to be reactive to the emerging research base with potential commercial application in Irish HEIs. The resources available to Irish ILOs are insufficient in proportion to the emerging commercialisation opportunities. According to ICSTI (2001), even a ten-fold increase in resources would not bring Ireland to the same level as its principal competitor countries. The necessary requirements are for appropriately qualified and experienced personnel with the ability to recognise and exploit IP and equipped with the necessary finance dedicated to the technology transfer function.

Table 4.2 Stimulants to research commercialisation

Stimulant	Number of interviews in which stimulant was cited
Personal motivation and background	
Personal motivation of academic staff to engage in research commercialisation	6
Academic staff with an industry background	2
Culture of Innovation and entrepreneurship	
Supportive culture of innovation on campus	5
Industry collaboration	
Student placement in industry	1
Being at the 'cutting-edge' of discipline	5

Source: Interview with ILOs

The key stimulants identified by ILOs focused almost exclusively on the personal motivation of individual academics, on the existence of a culture on campus which is supportive of academic entrepreneurship and on the desire for academics to be at the 'cutting-edge' of their discipline (Table 4.2). Similar to the findings of Pandya and Cunningham (2000), the ILOs in this research stated that it was those academics who had experienced academic entrepreneurship elsewhere that exhibited a higher propensity to engage in the commercialisation of their research findings. ILOs also stated that an explicit acceptance by the governing authorities of HEIs of commercialisation as a key activity of HEIs was central to creating a culture of academic entrepreneurship on campus which facilitates commercialisation. Finally, the ILOs noted that it was those academics who continuously want to extend the scientific boundaries of their research that have a higher propensity to engage in research commercialisation.

4.5.4 Interviews with campus companies

> *It is a bit like walking through fog when starting up a campus company (Interview with an academic entrepreneur, 2001, number one).*

To date, there exists a lack of research on campus companies in Ireland. As a unit of study, campus companies are difficult to access during their formative/incubation phase in HEIs, often due to a high level of confidentiality associated with the new venture on campus. If they survive the incubation period and become successful spin-offs from the HEI, their management structure changes and it is often difficult to gain access to the appropriate individual with knowledge of the initial formation of the commercial venture. For the purpose of this research, three campus companies which were in the process of spinning out of their respective HEIs were interviewed. The purpose of these interviews was to assess the barriers and stimulants experienced by the academic entrepreneur in the formation of a campus company.

Each of the three companies was set up in a HEI in the late 1990s and was initially funded by EI. One of the companies provides a product based initially on a research project within an academic department. The other two companies provide a training and consultancy service, one to the medical sector and the other to the engineering sector. Both of these companies were initiated by academics with an idea to create a company focused on providing a specialist training and consultancy service.

In terms of initially financing the venture, each of the companies agreed that the funding provided by EI through the CORD grant was too little too late. It funded IR£15,000 on expenditure of up to IR£30,000. The remaining IR£15,000 had to come from personal resources. However, having spent IR£30,000, each of the companies did not receive their CORD money until two years later. Each of the companies agreed that delayed payment of the CORD grant was the most significant and difficult barrier to overcome. Each of the remaining barriers highlighted by the companies all related to the HEI and ILO.

Barriers relating to the HEI:

- No supportive culture of academic entrepreneurship on campus;
- HEI bureaucracy relating to definition and formation of a campus company;
- Lack of appropriate incubation space on campus.

Barriers relating to the ILO:

- ILO did not have sufficient time to deal with academic entrepreneur;
- ILO did not have sufficient empathy towards academic entrepreneur;
- ILO exhibited lack of knowledge on the commercialisation process;
- Ambiguity over ownership of IP.

In relation to the stimulants which encouraged the three academic entrepreneurs to form a campus company, each stated one factor, personal motivation. This motivation inspired each of them to come up with the idea to commercialise, to fund the project, to develop the business and take their venture to the international market. At no time did any of the respondents praise the efforts of either the ILO or the HEI in which they are located. Each of the interviewees stated that developing a campus company in an Irish HEI is a long, arduous and lonely process devoid of a proper support structure either from the HEI (including the ILO) or EI.

4.6 CASE STUDY OF NATIONAL TECHNOLOGICAL PARK, PLASSEY

In order to assess the level of interaction between a science park and its associated university, a case study of the National Technological Park, Plassey and its associated university UL was undertaken. In Ireland, this is the only science park linked to a university. Given that the firms are located on a science park, are in close proximity to the university allied with the likelihood that some may be spin-outs from the university, the hypothesis behind this phase of the research was that a high level of interaction should be evident between the firms and the university (Chapter 2, section 2.4.1). However, before analysing the findings from this phase of the research, it is first important to understand how the park developed *vis a vis* the role of Shannon Development.

Established in 1959 to promote Shannon International Airport, Shannon Development is the Irish Government's Regional Economic Development Company with responsibility for Ireland's Shannon Region (Counties Clare, Limerick, North Tipperary, West and South-West Offaly and North Kerry) (Chapter 3, Figure 3.2). Shannon Development is the State's only dedicated regional development company. Part of its mission is to develop and strengthen the indigenous and foreign industrial sectors in the Shannon Region through the creation of a knowledge culture in an industrial environment allied with creating an awareness of the benefits accruing to industry from the information society (Shannon Development, 2000). The company's direct responsibilities include the development and promotion of indigenous industry and FDI, the development of tourism, the development of an infrastructure for industry and tourism, rural and local development, and the development of the National Technological Park, Plassey.

In the early 1970s, the president of UL, Professor Edward Walsh, recognised the need to have a science park associated with the university. In 1980, the Innovation Centre was built. Throughout the 1980s, a physical site with a third-level linkage was developed with an incubator facility, a telecommunications infrastructure and with an active management of innovation processes through the work of Shannon Development. Established in 1984, the National Technological Park is Ireland's only S&T park and comprises a 650-acre site located in close proximity to UL. It is managed by Shannon Development in close partnership with UL, IDA Ireland and the private sector.

Shannon Development is represented at the National Technological Park, Plassey through three main entities. The first is a company, National Technological Park Plassey Ltd., which is a Shannon Development subsidiary company with responsibility for the overall management and development of the park. The Department of Enterprise, Trade and Employment, UL, EI, IDA Ireland and the private sector are represented on the Board of Directors of the Park management company, which provides a range of services to client science park firms. These include the planning and physical maintenance of property development and marketing of the park as a location for the growth and development of technology-based enterprises. A core activity of the park's management team is to encourage firms to establish a range of links with UL. Furthermore, through a joint venture between Shannon Development and Esat Telecom, the park's management team has ensured the establishment of a sophisticated telecommunications infrastructure equipped with international broadband connectivity. Finally, the park's management team organises a range of social and sports events for its client base of firms. The second way in which Shannon Development is represented on the park is through the Innovation Centre, which was established in 1980 by Shannon Development and UL. This centre provides an integrated system for incubating and growing new technology/knowledge-based export-orientated, indigenous, high-growth companies and provides them with the necessary business support services. The Innovation Centre is a member of both the European Business and Incubation Centres Network (EBN) and the American National Business Incubation Association (NBIA). The third entity is the Investments Department that manages Shannon Development's portfolio of investments in industry and tourism and provides new equity to qualifying businesses in the industrial and tourism sectors on a commercial basis.

4.6.1 UL's involvement with the Programmes in Advanced Technologies

In UL, AMT Ireland and Materials Ireland were the PATs which were interviewed. The purpose of these interviews was to assess the barriers and stimulants experienced by these centres in the commercialisation of university research. One of the strengths of the PATs is that up to now EI funded the PATS and provided personnel with the responsibility for the organisation of centres. The PATs are currently being restructured to become autonomous, self-funding centres run completely by university personnel as opposed to EI personnel. Once a government-funded initiative is working well, there is a tendency to encourage that initiative to become autonomous and redirect funding towards other newly emerging projects. It emerged in both interviews that one of the problems with the new PATs model will be an inability of academic staff to meet the demands of industry on time. Both PATs centres go out to industry and market their research capabilities. While they considered this to be a significant stimulant which facilitates the transfer of technology from UL to industry, both interviewees stated that their units were nothing more than commercial service providers for industry in R&D. Commercialisation of a HPSU or the formation of a campus company based on research completed in either of the PATs centres has yet to occur since their establishment in 1988 and 1990.

4.6.2 Shannon Development and the promotion of U-I links

> *In relation to innovation, the difficulties are that a large proportion of indigenous firms are subcontracting to large companies. Very few of them are developing their own stand-alone products and, therefore, they don't have internal capacity for product development. So, the challenge for them is how to access the research activities in the college in a fairly easy way and in a way that's easy to apply for their enterprises. Now, the big challenge for us [Shannon Development] is to come up with good funding programmes that can make that easy. It's relatively easy for the larger indigenous firms that employ more than 30 people, but for a firm employing less than 30 people, they often don't have the internal capacity to absorb this research results and knowledge (Interview with Shannon Development, 2003, number one).*

The organisation of Shannon Development is structured around four different groups, each with their own remit of responsibilities in the region. These groups comprise (a) tourism, (b) property development, (c) R&D and communications and (d) knowledge enterprise. Representatives from the two latter groups were interviewed for this research.

Under the remit of knowledge enterprise, Shannon Development runs a Campus Industry Programme designed to (a) increase the level of collaboration between HEIs and industry and (b) increase the number of campus companies emerging from UL and the ITs of LIT, IT-Tralee and TRBDI.

In order to (a) increase the level of collaboration between HEIs and industry, in December 2002, Shannon Development launched an EU-funded Innovative Actions Programme designed to encourage rural indigenous SMEs to link with HEIs in the Mid-West, South-West and South-East Regions (Chapter 3, Figure 3.1). This geographical area extends outside that of the Shannon region as the EU considers these regions to constitute one region. The European Commission under the ERDF funded €400,000, while Shannon Development with each of the four partner HEIs (UL, LIT, IT-Tralee and TRBDI) funded the project with a combined total of €200,000. As a pilot programme which will run to December 2004, the objective is to promote technology transfer from the HEIs to rural SMEs outside Limerick. The Innovative Actions Programme is an EU-wide regional innovation strategy designed to encourage new approaches to regional development. Shannon Development submitted an application based on knowledge transfer from HEIs to rural SMEs. On the basis of this application, the project was awarded €400,000 from the EU. Under the Innovative Actions Programme, Shannon Development personnel based on the National Technological Park, Plassey and in Shannon identify the resources available to industry in the HEIs and at the same time identify the needs of companies. In many respects, this programme is a pre-feasibility project focused on creating awareness amongst rural indigenous SMEs of HEI capabilities which have an industrial application.

In order to (b) increase the number of campus companies emerging from UL and the ITs of LIT, IT-Tralee and TRBDI, Shannon Development has two liaison personnel who work at the interface between the HEIs and industry. Both are based on the National Technological Park, Plassey. One has direct responsibility for the ITs (LIT, IT-Tralee and TRBDI), while the other has responsibility for UL. Both personnel work directly with the ILO in each of these HEIs. The focus of this relationship is directed specifically towards two areas: (1) the commercialisation of HEI research through the formation of campus company start-ups and; (2) facilitating the development of linkages between the HEIs and existing Shannon Development companies both on the science park and in the Shannon Region. Attention is directed more towards academics interested in commercialising their research. Shannon Development organises lunchtime seminars on various aspects associated with commercialisation and IP. Less emphasis is placed on marketing the capabilities of HEIs to the existing indigenous high-tech base in the region.

Shannon Development has direct responsibility for the Innovation Centre on the National Technological Park, Plassey. In March 2003, there were 25 companies housed in the Innovation Centre. The main focus of the centre is to provide incubation space and support for indigenous high-tech HPSUs. Before obtaining space in the centre, companies have to meet certain eligibility criteria. In particular, the business must be focused on a new technology, be export-orientated and exhibit the potential to internationalise the business and/or provide an international service. Shannon Development utilises the same criteria as EI in assessing companies for HPSU status (Appendix 2.1). The majority of companies located in the centre are software-focused companies and/or international trading services. Following the incubation period of two years and having received a range of supports from Shannon Development, the firms relocate to a new site on the park. At the time this research was conducted, none of the companies were academic spin-outs from UL. Each of the HPSUs in the Centre were set-up by non-academics and entrepreneurs who had previously worked in multinational companies in the region (which had downsized or relocated). The very fact that none of the HPSUs are academic spin-offs provided the first indication of the low level of commercialisation of university research from UL. According to Shannon Development, the proportion of its companies which are academic-spin-offs from UL is less than 10%. The same is true at national level with EI stating that less than 10% of all new indigenous EI-assisted start-ups are academic spin-offs from HEIs (Chapter 4, Section 4.4.3).

At the time this phase of the research was completed, the total number of companies located on the park was estimated to be 80-90, employing *circa* 8,000 people. A definitive list of 49 indigenous companies was acquired from Shannon Development with the remainder being overseas companies.

4.6.3 Study: Shannon Development (2003)

Entrepreneurs in the Shannon Region: Results of an Interview Survey.

During the period 1998-2001, the EU supported a regional innovation strategy for the Shannon Region. Central to this strategy was the principle of partnership, with key action in:

- Support for the development of an innovation infrastructure;
- Facilitation of education and training for innovation;
- Provision of supportive financing;
- Mobilisation of higher education resources;
- Promoting innovation;
- Development of sectoral networks.

During the development of the strategy for the region, Shannon Development recognised the necessity to gather information on the characteristics and experiences of innovators and entrepreneurs. Up to this point, very little was known about the indigenous industrial base in the region. Key information deficits at the firm level related to R&D, knowledge and access to markets and training and human resource development. The objective of the research was to provide empirical evidence of selected variables affecting entrepreneurship in the Shannon Region, with the aim to inform education and support policies for innovation in the region (Shannon Development, 2003). Information was sought on a number of features such as:

- Demographic profile of entrepreneurs;
- Occupational background;
- Educational attainment;
- Entrepreneurs' views of the education system and other supports;
- Motivational factors;
- Profile of the enterprises.

The research methodology involved a random sample of 100 entrepreneurs who had established their business since 1980 and who were supported either by Shannon Development or one of the CEBs in the region. The total population was 425 enterprises. These were stratified in accordance with the number of enterprises in each administrative district in the region. In all, 85 usable interviews were completed, representing 20% of the total population. The data were primarily collected by means of telephone interviews, supplemented by a mail survey in some instances.

Amongst the key findings to emerge which are relevant to this research was that only 15% of entrepreneurs had used HEIs for R&D support. Reasons cited by non-users included a lack of awareness of HEI services and a belief that HEIs have little to offer industry. A related issue was that less than 10% quoted research or college support as an origin of their business idea. Amongst the recommendations cited by the report was that the region's HEIs must promote more effectively the variety of R&D, teaching/training and consultancy services they provide to the industrial base in the region. Furthermore, the report stated that the HEIs in the region must promote the nature and extent of the relatively untapped expertise available through the academic staff of those institutions.

4.6.4 Interviews with science park companies

Very little is known about National Technological Park companies, their reasons for locating on the park and their interactions with UL. For the purpose of this research, three companies agreed to be interviewed on the basis that they would not be identified. The purpose of these interviews was to assess the reasons why the firms located in the park, their level of interaction with UL and the barriers and stimulants they experienced in relation to such interaction. The company responses are categorised according to firm origin. One of the companies was an academic spin-off from UL and was based on the park (*i.e.* not in the Innovation Centre), while the other two were new independent start-up companies in the Innovation Centre.

4.6.4.1 Academic spin-off from University of Limerick

Funded by the EU Esprit project, two academics in UL conducted research in software development. In the early 1990s, they realised that the project had commercial potential so they formed a campus company and in 1994 spun-out of UL onto the park. The company located on the park for two reasons: first, to gain access to graduates for recruitment at a time when companies experienced great difficulties in recruitment, and second, to maintain links with UL. Having spun-out of UL, all links between the university and the company were severed by UL. The company stated that:

> *UL would be a shareholder of ours and we would be pretty disappointed with the linkages, to put it mildly. In fact we're very disappointed with the links. The university has been very poor in relation to helping us from a business perspective or even giving us business from the university itself. We've had no links, despite efforts, strenuous efforts from ourselves, they haven't, and it wasn't that they knocked us on cost or anything, they just haven't been very proactive in looking after spin-out companies (Interview with a science park company, number one).*

The company went on to state that there is no culture of academic entrepreneurship either in UL or on its associated science park. Furthermore, they stated that there are no benefits for their business development associated with being located on the science park in close proximity to the university. The company stated that the ILO function was not focused on commercialisation of spin-off activities and instead directed its attention towards sourcing EU grants for research. Within UL, the company found that there were no stimulants which would encourage academic entrepreneurs to commercialise their research. They also stated that there is a lack of an appropriate infrastructure within UL which would encourage existing companies to link with UL. At the time of the interview, the company was in the process of ceasing production. The company stated that its failure was due to the inability of UL (and *vice versa*) to engage in a range of R&D, teaching/training and consultancy links which would have secured the company's growth in a competitive knowledge economy.

4.6.4.2 Non-academic start-up science park companies

Two of the three companies interviewed were non-academic start-up firms located in the Innovation Centre. Both companies were in the first year of their start-up and stated that they located in the Innovation Centre in order to acquire Shannon Development funding and gain access to the mentoring and business support structure provided by Shannon Development personnel in the Innovation Centre. Neither of the firms had any links with UL nor did they intend to have such links in the future. While they envisaged that they would relocate on the park upon leaving the Innovation Centre, they did not foresee a need to engage in links with UL. Should the need arise, both firms stated that they were not aware of the capabilities of UL and questioned the industrial relevance of UL's activities to their specific high-tech sectors. Both companies stated that UL should market their capabilities to companies in the Innovation Centre and should be pro-active in instigating and maintaining links with companies located on the park as a whole. In any case, the picture which emerged is of a National Technological Park with low levels of interaction between the science park companies and the associated university.

4.7 CONCLUSION

The purpose of this chapter has been to review the role played by the Irish government in creating an environment conducive to the development of U-I links and the commercialisation of HEI research. During the 1980s and much of the 1990s, the government failed to provide a policy framework focused exclusively on the exploitation of Ireland's S&T base in order to enhance industrial innovation and competitiveness. It was not until the late 1990s that a concerted effort was undertaken in this area as a measure towards ensuring Ireland's participation in the emerging global knowledge economy. By this time FDI into Ireland had declined significantly while existing multinational manufacturing facilities were in the process of relocating to cheaper locations in the Far East. At this juncture, the development of an indigenous enterprise sector focused on innovation and interaction with HEIs became a priority.

Similar to Scotland in the late 1990s, the environment in Ireland was one with a HEI sector rich in expertise relevant to indigenous industry but lacking in the effective transfer of knowledge and innovation due to organisational rigidities and a lack of communication between the key players at the interface of U-I links. With responsibility for the development of the indigenous sector, EI (and Shannon Development) implemented a range of initiatives aimed at creating partnerships in innovation between the government, indigenous enterprise and HEIs in Ireland. Like Scotland, the aim is to create an indigenous enterprise sector focused on the commercial exploitation of S&T. The general consensus to emerge from interviews with key regional actors in Ireland is that indigenous high-tech companies do not have the critical mass to build up their technologies by forging HEI links. This is further compounded by a lack of investment in the ILO function in Irish HEIs. While the initiatives implemented by EI and Shannon Development have been innovative and broad in terms of their range and scope, it is too early to assess their outcomes in terms of creating an environment in Ireland conducive to U-I interaction and the commercialisation of HEI research. Given that U-I links are shaped by different factors in different countries, the following chapter will examine the environment in Scotland in which the commercialisation of university research has evolved.

CHAPTER 5

COMMERCIALISATION OF UNIVERSITY RESEARCH IN SCOTLAND

5.1 INTRODUCTION

> *For a country [Scotland] that's produced the TV and the telephone penicillin and all this type of thing it is perfectly respectable to say 'oh I don't know anything about science'. But it is not perfectly respectable to say well 'I've never heard anything about Shakespeare'. There is a long tradition in Britain of being run by arts and classics, so there's a set-mind set nationally I think has to be overcome, and, we are a nation which traditionally was based in engineering, shipyards and steel. The shipyards have gone. The steel has gone. IT [Information Technology] in many circles isn't seen as an appropriate substitute. Among young people yes, but its not even older I mean there's guys only in their fifties who have worked in the shipyards and yet they are skilled men they have time served but their trade has gone. So we still have a kind of traditional heavy engineering but I don't believe firms that employ 6,000 people are going to be here anymore. We are turning into a knowledge economy and perhaps some of us have not got our heads around that yet (Interview with SIE Commercialisation Facilitator, 2001, number one).*

In order to analyse how the environment for the commercialisation of university research has evolved in another country, it was necessary to place the research in an international context. Scotland was selected, as similarities exist between Ireland and Scotland's economic history. Both are geographically peripheral EU regions which have attracted assembly-based multinational high-tech firms, particularly in electronics, by adopting export-led development strategies. Although both Ireland and Scotland had been very successful in attracting foreign investment, the indigenous sectors in both economies tended to be weak and vulnerable. The foreign sector became the main source of job-creation in manufacturing while it also dominated in terms of output and export growth. Such dominance, allied with a declining indigenous industrial sector in both economies, led to an increasing dependency on foreign direct investment (FDI).

During the 1980s, both the Irish and Scottish economies experienced recession with high unemployment levels and dependency on foreign-dominated industrialisation. A poorly developed indigenous sector and a heavy reliance on declining flows of FDI were key features which led to significant job losses for the manufacturing sector. A decline in the flow of FDI, allied with a high rate of firm closures or a significant downsizing of existing foreign firms, were key factors that led to a marked rise in job losses from the foreign sector.

Although the indigenous sector experienced the majority of job loss, the apparent instability of the foreign-owned sector resulted in declining employment, high closure rates and few backward linkages into both the Irish and Scottish economies. A growing realisation that the policy of foreign-dominated industrialisation was no longer an adequate strategy for achieving development prompted the Irish Government and the Scottish Development Agency (SDA[1]) to reformulate their policies and focus instead on the development of a product-orientated and market-driven enterprise sector. Irish and Scottish state-sponsored development agencies laid considerable emphasis on measures which would foster an enterprise culture within the indigenous sectors. Both directed public money to support research in the university sector and implemented a range of initiatives to encourage the development of links between indigenous high-tech firms and the university sector. Initiatives focused on developing the commercial exploitation of the science base to enhance the growth of indigenous high-tech enterprise, thereby encouraging economic development.

This chapter reviews the strategies employed to encourage the commercialisation of the Scottish science base. Barriers and stimulants to the commercialisation of research in Scotland are identified. This is discussed from the perspectives of HEIs, Scottish Executive, SE and key actors committed to the Government's policy of collaboration between academia and industry, and to the commercial exploitation of university research. The chapter provides exploratory evidence on the process of commercialisation from the perspective of the public

[1] In order to focus greater attention on indigenous business development, the SDA was set up in 1975 (Botham, 1997). In 1990, following a merger with the Scottish Training Agency, the SDA became SE.

sector, key players committed to commercialisation and key regional actors in innovation in Scotland.

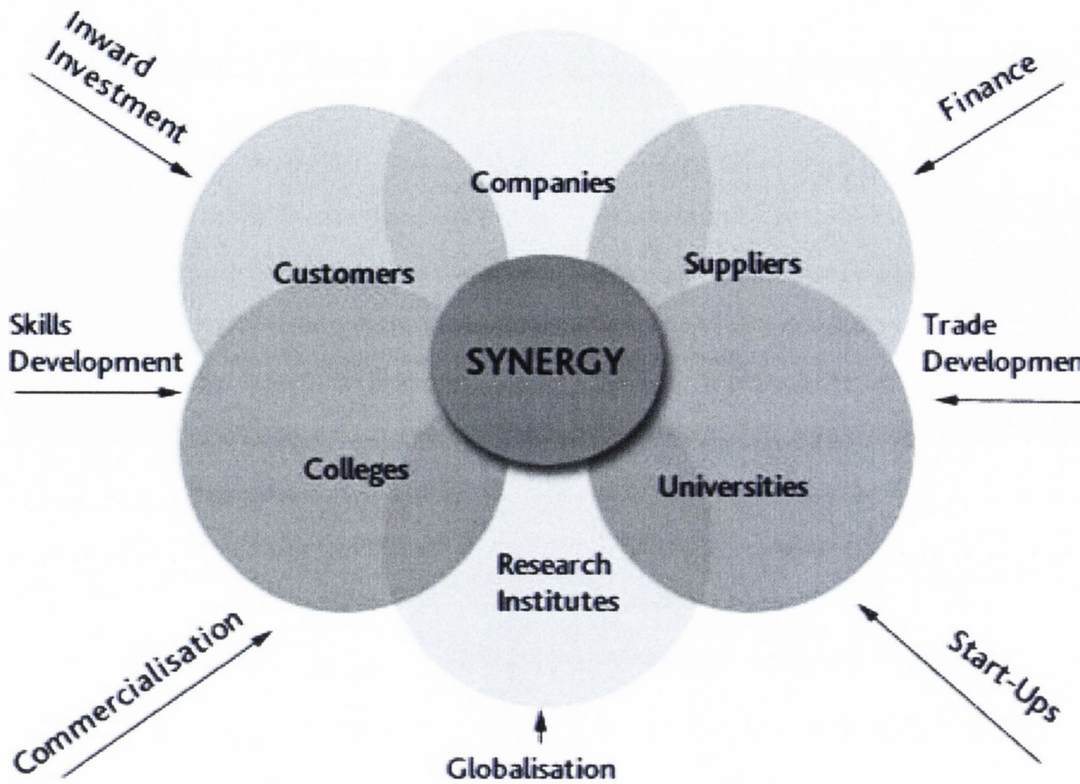
While an analysis of the process of commercialisation includes a broad spectrum of activities, this chapter focuses on the role of SE and on four initiatives designed to promote the development of an environment conducive to the commercialisation of Scotland's S&T base. These initiatives are Connect Scotland, TVS, the University Challenge funding programme and SIE. In the context of Scotland, and the UK in general, a number of studies have been completed on the commercialisation of university research (Martin, 1996; SE and RSE, 1996a; MacBryde, 1997; Downes and Eadie, 1998). However, very little is known about the key initiatives that have facilitated the overall development of an environment in which the commercialisation of university research has evolved. Following a review of the main initiatives introduced in Scotland, the final section of the chapter will focus on the barriers and stimulants experienced by the ILOs in five Scottish universities.

5.2 ROLE OF SCOTTISH ENTERPRISE

SE is the lead agency for economic development and the Scottish national body that deals with economic development in Scotland. Annually, it controls a budget of £450 million (€633.3 million)[2] of public money. SE's operational area is Scotland, with the exception of the Highlands and Islands, which are the responsibility of Highlands and Islands Enterprise (SE, 1996). The Local Enterprise Companies (LECs) are under the remit of these bodies and these implement SE's strategy. There are thirteen LECs, the largest of which is Scottish Enterprise Glasgow (SEG). Under SEG are other smaller development units *e.g.* Glasgow Opportunities (another private company targeting specific areas, sectors or issues, *e.g.* the Gorbals Initiative). An initiative that further cements SE and its thirteen subsidiaries is the Small Business Gateway Network.

[2] The exchange rate used throughout was the rate at the time of writing (£1 = €1.40/€1 = £0.71). This applied for all currency conversions from UK pounds to Euros and *vice versa*.

Figure 5.1 The SE cluster development model



Source: SE and RSE (1998)

SE identified strategically important clusters for the Scottish economy (Figure 5.1). These clusters include biotechnology, microelectronics, optoelectronics, creative industries, food/drink, oil/gas and tourism. The best-developed clusters in Scotland are biotechnology and microelectronics. SE then set up a task team to investigate how best to support the development of each cluster. A task team with responsibility for each cluster develops a strategy to support and develop that cluster and it then identifies and enables the most appropriate organisations, whether it be SE or the universities, to implement that strategy.

One of the major criticisms of the cluster approach emerged in the interviews with the ILOs. According to the ILOs, one of the main reasons that such an approach has not been as successful as it could have been, is based on the lack of knowledge of SE on the research base in Scottish universities. Furthermore, the ILOs argued that the cluster approach has failed to merge the research capabilities of the universities with the industrial needs and strengths embedded within the regional and national economy of Scotland. For example, one ILO commented:

> *So you can have an economic development agency sit in a room and write a bunch of cluster maps and say we are going to do the following things in this country. Then we say to them what research is Scotland strong in? What do we have 20 or 30 years of strength in? I don't know? So how can you make clusters when you don't even know that? I am going to sit down with Scottish Enterprise and say I'm going to map Scotland for you in research terms. We are going to map what those five universities have in technology areas as a country. I'm then going to require you to map that lot on to it. If you don't do it enterprise agency I'm going to Singapore, Ireland, Thailand, and Israel and I'm going to map it on their industrial base, so let the games commence [SIC] (Interview with an ILO in Scotland, 2001, number one).*

SE also sponsors or co-sponsors other bodies created in partnership with the private sector. One is TVS, a strategic body that seeks to help technology transfer and start-ups. Other bodies include the RSE and the Scottish University for Industry, which are funded partly by public money and which aim to develop the SME sector in Scotland. SE also has sectoral companies or groups such as the Scottish Biotech group or Scottish Trade International. SE also has strong links with the Chamber of Commerce network. In relation to commercialisation, SE has a commercialisation manager programme and it part funds, usually with the university or research institute, commercialisation managers or ILOs whose job it is to identify commercial opportunities arising out of research or consultancy. Other interaction occurs with the TCS, where a company and an academic supervise a research student in a project to transfer knowledge from one sector to another.

SE also plays a crucial role in administering SIE. One of the bodies that liaises between the university sector and industry, it also promotes linkages in terms of entrepreneurship education and the transfer of university technology to the market place. However, SIE has been in existence for only a very short period of time. SIE extends university interaction because its centres for enterprise (originally there were five centres, being the five universities in the original SIE consortium) have the responsibility to develop entrepreneurship courses for the SME sector over a four-year period.

5.3 COMMERCIALISATION ENQUIRY

In the early 1990s, SE identified a problem in Scotland with regard to the poor rate of new firm formation. A review of the electronics industry in Scotland in the early 1990s highlighted the need to diversify the industry, to encourage indigenous development and to create links between academia and high-tech industry (Botham, 1997). The review noted the existence of a strong science base in Scotland and the important role commercialising S&T could play in the process of indigenous enterprise development and diversification. Following a visit to Silicon Valley in California and having reviewed its electronics industry, the Chief Executive Officer of SE was particularly aware of the contribution that both indigenous entrepreneurship and the commercial exploitation of the science base can make to economic development. As a consequence SE introduced an initiative called the Business Birth Rate Strategy in 1993 (SE, 1993; Collinson, 2000). The aim of this initiative was to address the cultural and structural issues that have traditionally prevented the development of an entrepreneurship culture in Scotland thereby stimulating the development of entrepreneurial companies. Scotland had a low rate of new firm formation compared to the rest of the UK and Europe. In implementing its initiative, SE focused specifically on the development of technology companies. SE was aware of the fact that technology companies emerged from pre-existing technical activity and the majority of technical activity in Scotland is in the science base in universities. This point was reiterated a number of times during interviews with SE personnel.

> *Now this is one of the challenges that we face in terms of the indigenous corporate sector in Scotland and it's that we have a Scottish Higher Education Sector a substantial significant part of which is world class in terms of research capability but in terms of transferring that value to the indigenous company base it is market constrained...We don't have the range and number of highly sophisticated research-aware companies that would provide a good fit with our top class university researchers (Interview with SE, 2001, number one).*

A logical extension of both the birth rate and electronics strategies was to assess ways in which Scotland's science base could contribute to economic development (Botham, 1997). The question for SE then became focused on how it could become more effective in commercialising the research base in Scottish universities? In 1994 an enquiry was undertaken through a partnership of SE and the RSE[3] in order to answer this question.

The main aim of the enquiry was to develop a programme of informal consultation with over 120 people representing focus groups from industry, academia, finance, government bodies and other interested parties in the process of commercialisation in Scotland. The objective was to gather evidence on Scotland's commercialisation activity. A further aim of the enquiry was to understand the barriers to the commercialisation of Scotland's S&T base. Furthermore, the enquiry sought to deduce areas of weakness and difficulty in Scotland and analyse how other countries commercialise their research.

The results of the enquiry were published in 1996 in a report *Commercialisation Enquiry: Final Research Report* (SE and RSE, 1996a). The enquiry assessed the commercialisation environment in Scotland by analysing the existing situation in relation to a number of key factors. These included: the Scottish economy; universities; the S&T base; the various routes to commercialisation; the availability of appropriate funding opportunities; corporate attitudes; science parks and incubator units; the industrial community; links between academia and industry and *vice versa*; and the experiences of other European regional economies in the process of commercialisation. The enquiry highlighted a number of findings (SE and RSE, 1996a, 1996b). These included:

- The science base is important to the future of the Scottish economy;
- Scotland has a strong science base with much industrial relevance;
- When compared to the US, Scottish academics are more involved with industry, but opportunities for commercialisation are being missed;
- Many companies have links with academics, but few result in innovation;
- While some companies have links with universities abroad, they consider local universities to be important;
- The majority of companies are not adequately equipped to exploit knowledge;
- Graduates are crucial to enhancing company innovation;
- Spin-offs are important but face a number of barriers to their development[4];
- Finance is more widely accessible in other high-tech regional economies;
- While there is academic interest, the academic environment in Scotland is not conducive to commercialisation;

[3] Founded in 1783, the RSE is Scotland's National Academy of Science and Letters.
[4] In the context of Scotland, Downes and Eadie (1998) provide an analysis of the factors which encourage and constrain the creation and growth of university spin-off companies.

- Academics need experience in the process of commercialisation;
- The infrastructure for commercialisation is poor in Scotland when compared to other countries;
- Scotland is not as effective in commercialisation when compared to successful high-tech regional economies in the world.

A range of strategies to implement the findings of the *Commercialization Enquiry* were subsequently published in the *Technology Ventures* (SE and RSE, 1996b) initiative. Such strategies were designed to facilitate the commercialisation of the Scottish S&T base. A number of programmes were outlined and implemented under six parallel strategic directions. These included:

- Maximising the contribution of existing companies;
- Maximising the potential of spin-offs;
- Strengthening the corporate base;
- Improving the financing of commercialisation;
- Improving the academic environment;
- Developing an effective institutional infrastructure.

One of the programmes outlined under the strategy for developing an effective institutional infrastructure was to establish a network and business support infrastructure to generate effective U-I links, and to facilitate the multi-directional flow of information between academia, companies and service providers (SE and RSE, 1996b). It is interesting to note that in Scotland a Connect initiative was already coming into existence and was launched two weeks after the *Technology Ventures* strategy was published.

5.4 CONNECT SCOTLAND

> *CONNECT-Run from the University of California at San Diego and funded by the private sector, it promotes the development of the region's high-tech industries and the commercialisation of the university's research. It creates networking opportunities, stimulating the flow of ideas and knowledge between the academic, business and financial communities, and offers business development services, assisting, for example, companies to obtain finance and academics to commercialise their research. Within the high-tech community it acts as a hub, linking local and global networks (SE and RSE, 1996b, 22).*

Connect Scotland was set up to make industry and business more aware of the commercial potential of university research. Its key focus was to make small high-tech companies aware of university commercialisation initiatives and highlight the availability of public and private support in commercialisation, facilitating the growth of both university and non-university-based high-tech companies. In particular, Connect Scotland sought to increase the opportunities for the creation of collaborative links between universities, research institutes and high-technology companies in Scotland.

The Connect initiative in Scotland was inspired by Connect at the University of California in San Diego (UCSD). The idea of Connect was conceived by Professor Mary Lindenstein Walshok at UCSD and was initiated in 1986. Connect's vision was to leverage the multiple resources of the San Diego region (associated with corporate, research and business support communities) towards the growth and support of locally-based high-technology companies. The focus of Connect San Diego was to become a crucial regional resource focused on new enterprise formation, on the growth and diversification of high-tech SMEs and on the transfer of new knowledge from the universities into the marketplace (Walshok, 1994, 1996). Modelled on UCSD Connect, Connect Scotland is based on the rationale that the growth of high-tech companies requires interaction between the university sector, large corporations, emerging companies, regional government and business support groups (SE and RSE, 1997).

5.4.1 Aims

> *An issue in Scotland is that we do not have a large population of technically sophisticated companies, so we don't have a large population of companies who have the expertise, the know-how and sophistication to work with university type projects. So that's one issue. So to actually stimulate more university-industry collaboration, one of the measures or activities has to be to focus on the company base and create incentives for them to become more innovative, shall we say, and, therefore work more with universities (Interview with Connect Scotland, 2001)*[5].

Established in 1996, the Connect initiative (which was initially located in The University of Edinburgh) supports the creation, development and growth of

[5] It is interesting to note that in Scotland this interviewee suggests that industry needs to become more accommodating to HEIs. The reverse is the case in Ireland, with most interviewees stating that HEIs should accommodate the needs of industry.

technology-based ventures throughout Scotland (Connect Scotland, 2001). Initially, the start-up finance for Connect was provided by 20 founding sponsors, each providing £3,000 (€4,225) per annum for three years. Following the successful completion of the pilot programme for Connect, it secured 60 sponsors/participant organisations including universities, banks, venture capital (VC) funds, economic development agencies and large corporations. In addition, a grant of £90,300 (€127,185) was provided by SHEFC with a 'matched fund' provided by the European Regional Development Fund (ERDF) (Connect Scotland, 2001). Connect Scotland has five objectives (Connect Scotland, 2001). These include:

- Provide aspiring technology companies with access to an expert network of individuals and organisations that understand and can support their needs;
- Facilitate and support the transfer of technology from the Scottish science base to new and existing firms, either by the spin-off route or through collaborative projects;
- Enable the development of 'investor ready' companies;
- Create the virtual resource – matching the human network;
- Add value to the activities of sponsoring organisations.

In June 2001, Connect became independent of The University of Edinburgh and a new company called Connect Scotland was formed. It is a university-private sector partnership which focuses on the development of high-tech firms by linking them with the appropriate financial, managerial and technical resources required for success in national and international markets. Designed as a U-I programme, the aim of Connect Scotland is to facilitate interaction between high-tech industry, the university sector, and the business support services, thereby creating links that are focused on developing new technology companies. The aim of Connect Scotland is to develop mechanisms to promote technology transfer and commercialisation between new and existing technology-based companies and the university sector. Connect Scotland has a business support infrastructure that is designed to aid the growth and development of new technology companies.

The focus of Connect Scotland is on the creation and development of technology-driven entrepreneurial ventures. If a university has a technology that may be of interest to existing companies locally[6], Connect Scotland will organise and promote a technology briefing on the potential commercial applications of the new innovation to high-tech companies who may be interested in developing the technology commercially. Connect Scotland also promotes new technologies to the general business community, which includes bankers, lawyers and accountants. Subsequently, the business community has become more technology literate and, therefore, has an understanding of both the financial and technology aspects associated with the commercialisation of research. A further way in which Connect Scotland facilitates the commercialisation of university research is through its work with spin-off companies. If a university has a potential spin-off company, the university will provide the incubation space and the resources necessary to develop the company. The university then uses Connect Scotland as an out-reach programme and encourages the academic entrepreneur to go to Connect Scotland in order to access the appropriate managerial, financial and technical resources required to develop the company. In essence, Connect Scotland creates an environment for technology entrepreneurs that facilitates the growth and development for new technology businesses. When academic entrepreneurs approach Connect Scotland, an assessment is made of their specific needs. Once these are identified, Connect Scotland introduces the companies to the relevant managerial, financial and/or technical expertise required to meet the specific needs of the academic entrepreneur.

5.4.2 Structure

Connect Scotland is made up of three constituent parts. One is the technology company or the technology business[7] that is either a spin-off from a university or a start-up company from a university. While the main focus of Connect Scotland is to stimulate and support university-based spin-off and start-up companies, the focus is also on non-university-based exploiters of university technology. Often funded by

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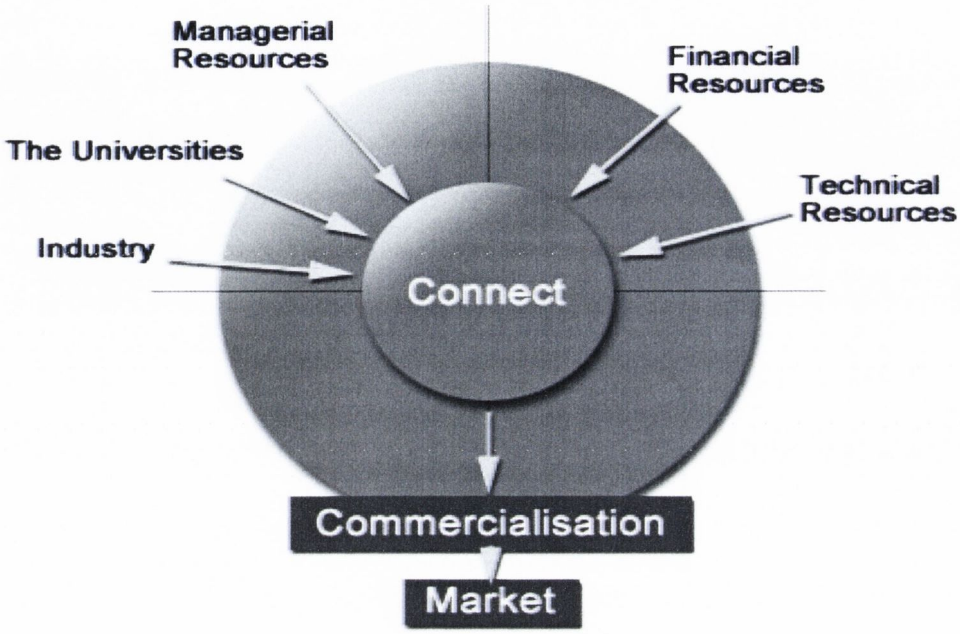
[6] Connect is more interested in local technology transfer rather than licensing to large multinational corporations.

[7] A technology business is defined as a company competing on the basis of propriety technology or know-how. According to Allen (1992) a technology-based company is defined as "a business whose products or services depend to a significant extent on the application of scientific or technological skills or knowledge (whether it be a novel application of advanced technology to provide a totally new product or service, or an application of existing technology in an innovative manner)" (cited in Bank of England, 1996, 10). McNally (1995), defines technology-based firms as those "whose activities embrace a significant technology component as a major source of competitive advantage" (cited in Bank of England, 1996, 10).

VC, these technology companies exploit the university-derived R&D by engaging in licensing deals with the university.

Figure 5.2 The constituent parts of Connect Scotland



The second constituent part of Connect Scotland is the support infrastructure which includes access to managerial, financial and technical resources (Figure 5.2). One of the main strengths of Connect Scotland has been its ability to serve the needs of high-tech entrepreneurs by providing access to business support structures such as banks, accountants, VC and corporate finance options, lawyers and personnel with skills and resources required to develop new technology companies. The third constituent part is the university sector, equipped with a pool of human capital with the knowledge and expertise to generate research and innovation necessary for enhancing the competitiveness of high-tech industry in the context of increasing global competition.

5.4.3 Links with universities and government departments

While The University of Edinburgh initially incubated and hosted Connect Scotland, each of the fourteen universities of Scotland sponsored Connect Scotland. It is crucial to Connect Scotland's success that it is strongly linked to the university sector. All Scottish universities use it as an outreach mechanism to facilitate access to technology and business communities. This is a key component of Connect Scotland's appeal to its private-sector sponsors, as approximately 50% of technology start-ups are university spin-offs. It is interesting that in Ireland, according to an internal audit conducted by EI in 2001, the comparative figure is 9.8% for EI-assisted technology-based companies. Connect Scotland was established as an independent, not-for-profit company due primarily to the fact that the key processes and procedures associated with the administration of a university are not designed to support (over the medium/long term) what is in effect an entrepreneurial trading entity. The role of the University of Edinburgh was to incubate Connect over a five-year period. Without the support of the University of Edinburgh, it is highly unlikely that Connect Scotland would have been a success. Moreover, the fact that Connect was a centre located within the University, enabled it to secure ERDF and SHEFC grant funding to facilitate its development within the national context of Scotland. Although Connect Scotland has spun-out out of the University of Edinburgh, the University continues to sponsor it. The main advantage for Connect in being an independent unit from the University of Edinburgh is that it has more administrative flexibility with regard, for example, to remuneration structures and more effective management accounting information. As an independent unit Connect also has a board of directors that is representative of all its stakeholders and is able to make decisions without referral to the University of Edinburgh. The key difference between Connect Scotland and the UCSD-hosted Connect in San Diego is that the latter works with a single institution within the context of a region. Connect Scotland, on the other hand, deals with each of the Scottish universities and has very strong relationships with various government departments. Such relationships are strengthened by the fact that Connect Scotland is an autonomous body that is focused on a niche sector but yet is inclusive of all the universities, a number of government departments and a broad mix of private sector organisations.

5.4.4 Outcomes

In the first two years of its formative phase, the focus of Connect Scotland was to create a community that technology entrepreneurs could access in order to receive advice from a network of established support systems organised by Connect Scotland. This community has expanded and is very proactive in its approach to the development of an entrepreneurial culture based on the commercialisation of Scotland's S&T base. According to Connect Scotland:

> *I suppose in our evolution when we started Connect, we just wanted to create a community that technology entrepreneurs could go to, to back them in different ways to help advise them. That was the first two years and we grew that community. This community now exists and is relatively proactive, it is relatively sophisticated so maybe that part of our job to a large extent has been done so we got the community. We are developing that community all the time with new sponsors, but what we are focusing on now is particular issues in leveraging the value of that community, using that community to help develop investor ready companies, using that community to transfer know-how to support companies with time and resources to get involved in the investment process in our investment conferences. We have the basic community of the right mix of people in organisations, the money and the advisors and people. How do we now make that work better? And that's what we are doing now. That's where we are in our stage of development [SIC] (Interview with Connect Scotland, 2001).*

According to Connect Scotland, 6,000 people had been involved in the programme by March 2001 and Connect Scotland had helped over 200 companies raise investment finance. Connect Scotland is now focused on leveraging the value of this community using it to develop investor-ready companies while also facilitating technology transfer from universities to high-tech companies. However, following a review of the activities of Connect Scotland, Collinson and Gregson (2001) found that there is little evidence to suggest that participants are using the networking events to either obtain financial backing for business ventures or to invest in new ventures. This indicates that contacts are being made, but as yet investments have not materialised. However, according to Connect Scotland:

> *I think we still have a long way to go, I don't like being described as being very successful, we have achieved much more than we actually set out to achieve. We now employ five full time staff. We are certainly the largest and most active technology network in Scotland, and we are probably the best in Scotland. In fact there isn't another technology network in Scotland. So we have been successful in terms of achieving the mile stones which we set ourselves. We have probably helped well over 200 companies. That is like a company a week for the past four years. Our most successful initiative has been our investment conference, where we identify companies seeking investment finance, we then screen them, rehearse them, coach them, that's one half of our job. The other half is to get VC investors to come to Edinburgh to look at these pictures and last year we managed to get about 35 VCs to come along [SIC] (Interview with Connect Scotland, 2001).*

While it is difficult to quantify the extent to which Connect Scotland has increased the rate of commercialisation in each of Scotland's universities, it is important to note that it has played a crucial role in facilitating the development of an entrepreneurial culture in Scotland's university sector. Overall, the success of Connect Scotland has been based on its ability to act as an agent by creating networks of interaction between the various academic, industry and business partners. Therefore, Connect Scotland has played a pivotal role in the global positioning of Scotland as a centre of excellence in research, based on an internationally-competitive, entrepreneurial high-tech enterprise sector.

5.5 TECHNOLOGY VENTURES SCOTLAND

A second initiative that has recently been implemented in Scotland and is not a feature of the current commercialisation process in Ireland is the TVS initiative. Prior to the development of TVS, there existed a Technology Ventures Initiative (TVI), initiated by SE as an internal department of SE. The role of TVI was to encourage the universities of Scotland to set up commercialisation departments. While the universities did support a policy of developing commercialisation as a key function of the university sector, the reality was that there existed an academic climate unsupportive of the commercialisation of university research in Scotland. In contrast, the polytechnics[8] of Scotland were much more pro-active in commercialisation because it provided their main source of revenue. In April 1999, Lord MacDonald published the report *Scotland: Towards the Knowledge Economy* (MacDonald, 1999), which was completed by a Knowledge Economy Taskforce[9]. The objective of the taskforce was to examine four issues, namely: (1) develop a possible framework for the commercialisation of university research, coupled with a refocusing of the TVI; (2) create initiatives within the universities to encourage collaboration with industry; (3) develop a framework within which the science base of universities can assist with the development and implementation of SE's cluster action plans for key industry sectors and; (4) create a blueprint that Scottish universities could adopt for a

[8] In Scotland, prior to 1992, the HEI sector consisted of eight 'Old' Universities and five Polytechnics. The pre-1992 old universities were Aberdeen, Dundee, Edinburgh, Glasgow, Heriot-Watt, St. Andrews, Stirling and Strathclyde. In 1992, the Polytechnics were granted university status in the UK. The post-1992 'New' Universities are Abertay Dundee, Glasgow Caledonian, Napier, Paisley and Robert Gordon. In all, there are fourteen universities in Scotland, when the Open University is included with the total number of pre-and post-1992 institutions.

collaborative bid under the UK Government's Science Enterprise Challenge for a single entrepreneurial 'Centre for Enterprise'[10], which would assist individual universities in commercialisation and act as a centre for entrepreneurial education.

Following the review of TVI, the taskforce found that while TVI was effective in raising the profile of commercialisation, there was little or no interaction between the knowledge bases of academia and industry. In particular, the taskforce highlighted the inability of the Scottish industrial base to absorb and convert scientific research into commercial practicality in the marketplace. The industrial base was fragmented, disenfranchised and excluded from the process of effective technology transfer from universities to industry. Instead, the taskforce found that the university sector forced research out of universities in the hope that industry would 'pick it up' and convert scientific breakthroughs and technological achievements into commercial successes. There existed a lack of effective communication between the university and industrial sector. In order to remove the barriers to effective collaboration and make linkage opportunities accessible to the Scottish industrial base, the taskforce highlighted the need for more effective interaction between the knowledge base and existing companies in Scotland. The recommendation of the taskforce was to pool the direct needs of industry towards university research capabilities. In order to encourage the formation of mutually beneficial co-operation and interaction between academia and industry, the taskforce recommended a return to the original concept of a pluralistic TVI. The relevant actors and stakeholders from science, industry and policy would be drawn together under an umbrella initiative called TVS. The main goal of TVS would be to help facilitate technology transfer from universities to industry and effectively commercialise the science base of Scotland.

5.5.1 Aims

> *The TVS role is first of all to take a strategic look at the commercial processes, take a look at the organisations involved, find out where things work, find out where there are gaps and then stretch existing organisations to cover the gaps or if necessary recommend a new solution (Interview with TVS, 2001).*

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[9] In January 1999, Lord MacDonald, the Minister for Business and Industry at The Scottish Office, announced to the Scottish Grand Committee that he was setting up a Knowledge Economy Taskforce.

[10] The concept of developing a 'Centre for Enterprise' was later developed into the 'Scottish Institute for Enterprise' (SIE) and was launched in 2000.

As an interface between industry and academia in Scotland, TVS has three main objectives. These aims are: (1) to encourage increased investment in technology R&D, (2) to identify and pursue priorities for investment in technology R&D and (3) to promote and accelerate the commercialisation of Scotland's S&T base. TVS has six strategic objectives providing a focus for achieving its aims. These are: (1) increase the number of industry-academic links that result in commercialisation, (2) increase the number of new high-tech companies based on Scotland's S&T base, (3) increase the number of high-tech companies that have the potential to commercialise university research, (4) increase the availability and accessibility of funding for commercialisation, (5) improve the academic environment for commercialisation, and (6) bridge the gap between universities and industry by encouraging better co-ordination and co-operation through increased networking between both partners.

5.5.2 Structure

Launched in January 2000, TVS did not come into existence until September 2000 with the appointment of its Chief Executive. The six founding organisations of TVS are Universities-Scotland (formerly the Committee of Scottish Higher Education Principals (COSHEP)), Connect Scotland, the RSE, the Scottish Executive [Enterprise and Lifelong Learning Department (ELLD)], Scottish Enterprise-Network (SE-N), and SHEFC.

The organisation of TVS is different from TVI in three ways. First, TVS is a private independent company limited by guarantee. Second, TVS is jointly funded, 50% by SE-N and 50% by SHEFC for a period of three years to March 2003. Subsequently, TVS has a connection with industry because SE-N is focused on enhancing the competitiveness of Scottish industry. In addition, TVS also has a connection with the university sector because SHEFC funds the HEIs in Scotland. Third, TVS has two bodies. One is an advisory board consisting of interest parties in the commercialisation process and the other is a legal board. As a private limited company, TVS requires a legal structure, which comprises the company directors who are responsible for the allocation of public money for TVS activities. The legal board of TVS consists of directors appointed from SE-N, SHEFC, Universities-Scotland and Connect Scotland. The legal board has an independent Chairman. If the advisory group wants to implement a strategy/initiative, the legal board must approve the allocation of funds.

In the 18 months following the launch of TVS, new members were invited to join the advisory board, which now consists of 18 organisations, all represented at senior level. These have been selected to provide a balance between public and private sector interests, and now include CBI Scotland, Scottish Executive Chief Scientist Office, Scottish Executive Rural Affairs Department (SERAD), Scottish Biomedical Foundation, Scottish Financial Enterprise (resigned in August, 2001), Electronics Scotland, SIE, Startech Partners, Lithgows Ltd., and the Royal Bank of Scotland.

Table 5.1 TVS advisory board/legal board members

ORGANISATION	BOARD*
CBI-Scotland	A
Connect Scotland	A/L
Electronics Scotland	A
Glasgow University	A
Lithgows Ltd.	A
Research & Commercialisation Committee (Universities-Scotland)	A/L
Royal Bank of Scotland	A
Royal Society of Edinburgh (RSE)	A/L
Scottish Biomedical Foundation	A
Scottish Enterprise- National (SE-N)	A/L
Scottish Executive	A
Scottish Financial Enterprise (Resigned in August 2001)	A
SHEFC	A/L
SIE	A
Startech Partners	A
Strathclyde University	A
TVS	A/L

Source: Interview with the Chief Executive of TVS (2001)

* Key: A = Advisory board
L = Legal board

The advisory board plays the central role in making the decisions and implementing the strategies of TVS[11]. It is a unique body in that it brings together

[11] This board is comprised of representatives from industry, Scottish universities, the Scottish Executive, SE-N, the RSE, SHEFC, Connect Scotland, SIE, Scottish Biomedical Foundation and Universities-Scotland (Table 5.1). The advisory board is a unique body; it brings together key groups interested in technology transfer from government, the university sector, industry and the business support agencies to focus on and influence the development of the commercialisation process in a way that no other single committee can achieve in Scotland. As a collective group, the advisory body is not only crucial in terms of making recommendations and implementing the strategies of TVS, but the individual representatives from the government, the university sector and industry have a responsibility to ensure that their respective organisations follow the policies and strategies implemented by TVS. Consequently, TVS is a strategic, policy forming mechanism which seeks to develop the commercialisation of research from Scotland's S&T base, create new jobs and enhance the competitiveness of Scotland's industrial base.

three key departments of the Scottish Executive: SERAD[12], the ELLD (headed up by the Minister for Enterprise and Lifelong Learning) and the Chief Scientist Office. While they each represent key departments in the Government, they do not meet unless it is in a TVS advisory board meeting. The push from government for the TVS initiative comes from the ELLD of Scottish Executive. This department is central to TVS, as it possesses two strands which are crucial to the successful development of the TVS initiative. One is SHEFC, which funds universities, and the other is SE, which funds a range of business support mechanisms, administers the Proof of Concept (PoC[13]) fund, administers the funding allocated to the SIE initiative, initiated the development of Connect, and has a Competitive Business Directorate[14] which focuses on enhancing competitiveness and innovation through the commercialisation of the Scottish research base.

On the side of the universities, TVS has several key players in the commercialisation process. Representing the ILO perspective of Scottish universities is the director of Research and Enterprise, Glasgow University and the director of Research and Consultancy, Strathclyde University. Both are commercialisation directors from the West of Scotland. In Edinburgh, the Principal of Heriot-Watt University, represents Universities–Scotland, formerly known as COSHEP. Universities–Scotland is the representative body to which each of the Principals of each of the fourteen universities of Scotland adhere and it represents their mouthpiece to the government. Within Universities–Scotland, there is a research and commercialisation committee of which the Principal of Heriot-Watt University is the Convenor. Essentially, TVS is represented by a Principal of a university from the East as well as two commercialisation directors from the West. The RSE is also represented on TVS. This is the Scottish equivalent of the Royal Society of London in England or the Royal Irish Academy in Ireland, which is the premier academic body into which academics are elected. Fellows of the RSE are very influential

[12] While the focus of SERAD is on agriculture and land-use, it does engage in varying levels of interaction with universities. Indeed, it has six research institutes under its remit called the Scottish Agriculture and Biological Research Institutes (SABRIs).

[13] PoC provides funding to universities, research institutes and the NHS Trusts for prospective projects at the pre-development conceptual stage. It is designed to take the basic research and complete proof of concept work on the technology, to analyse whether or not it has market potential, specify the level of that potential and to develop the technology to a near market stage of completion.

[14] The Competitive Business Directorate is run by the Head of Commercialisation in SE. This individual is also on both the Advisory and Legal Boards of TVS (Table 5.2). Furthermore, TVS is the only body under which SHEFC and SE-N formally interact with one-another.

within universities and can play a pivotal role in changing academic opinion in the direction of developing commercialisation as a key function of the university sector in Scotland. Since 1995, the RSE has run a programme of commercialisation workshops in universities and was also instrumental in setting up TVS. The remaining members of TVS are key interest parties in commercialisation: Connect Scotland, Startech Partners, Electronics Scotland, CBI Scotland and Lithgows Ltd.

Connect Scotland is linked directly to the TVS initiative as it has to work in close collaboration with both TVS and SIE. Connect Scotland, TVS and SIE share the same responsibility to the SME community, to the wider business community in Scotland, to the universities, to SE-N and to the Scottish Executive. The focus of this responsibility is to ensure that the commercialisation of the science base will become a key component in the development and activities of the indigenous high-tech SME sector in Scotland. While TVS has been successful in terms of bringing together key representatives from the government and the universities of Scotland, similar representation both in numbers and influence from the side of industry does not exist. The SME sector should play a greater role in the decision-making processes implemented by TVS.

5.5.3 TVS and its role with spin-offs and SMEs

U-I interaction has been successful only in selected areas of Scotland, as the university sector has largely ignored the needs of existing businesses, and has been too focused on spin-offs rather than start-ups. TVS was developed to address this problem. TVS not only meets the needs of existing industry in Scotland, but it also encourages the development of start-ups as opposed to spin-offs from the universities. As a route to commercialisation, spin-offs occur when an academic leaves the university and engages in the commercial exploitation of a new finding by developing the research into a new business venture. This creates a void within university which can be difficult and expensive to fill. According to Martin (1996), academics in Scotland have not recognised the potential value associated with developing entrepreneurial expertise and aligning this with their research capabilities to form new business ventures. The result has been a low level of spin-off activity. Scottish spin-offs from the university sector have, up to the mid 1990s, experienced difficulty in raising funds and VC finance. Start-ups are the preferred option, as the academic continues to work for the university but is allowed the flexibility to spend part of his/her time working with the company which is equipped with appropriate management and marketing expertise. Universities do not lose the academic expertise in terms of teaching and research while the academic may become involved in several successfully managed start-up companies. Start-ups, therefore, have become the preferred option to spin-offs in Scotland.

While the role of TVS is to help increase the number of start-ups, its primary focus is to help existing indigenous high-tech SMEs to source information on research and new technology which can play a significant role in strengthening their industrial competitiveness. However, from a spatial perspective, Scotland's SME base is widely dispersed. The industrial community is a separate entity and the university community and business support networks have not worked effectively with industry. In order to facilitate effective communication between the industry and university sectors and bring the dispersed SME base into a network that fosters U-I interaction, TVS has created an interactive website. The purpose of this website is to bring the geographically fragmented SME base of Scotland together in cyberspace to debate issues relevant to the SME community, to highlight the specific requirements of SMEs from business support networks and to state the deliverables that industry requires from the university sector. The website is structured to provide a map of the advice and support sources for SMEs in Scotland. In addition, the website has a research button highlighting an information database relating to the research activities and capabilities of university research in Scotland. This search engine is called the Scottish Research Information System (SRIS) and is currently being funded by SHEFC as a pilot project. The problem with SRIS is that there is no financial incentive for academics to keep up-dating their research. The database is not user-friendly and is time-consuming and difficult to update. As is the case with any database, once information is inputted, it quickly becomes out of date.

In 2002, an extensive database of Scottish research was developed. The new site, *www.ScottishResearch.com* is funded by SHEFC and is being developed by each of the Scottish universities, the Principals of the Scottish universities, the Scottish Executive and SE. The aim of the site is to elucidate the research capabilities and resources of Scottish universities for the industrial and business community. However, by January 2003 while the actual site was established, it was not a functioning website with the relevant information regarding the research activities of the Scottish university sector. In Ireland, such an initiative already exists in a form that is only relevant to the biotechnology sector.

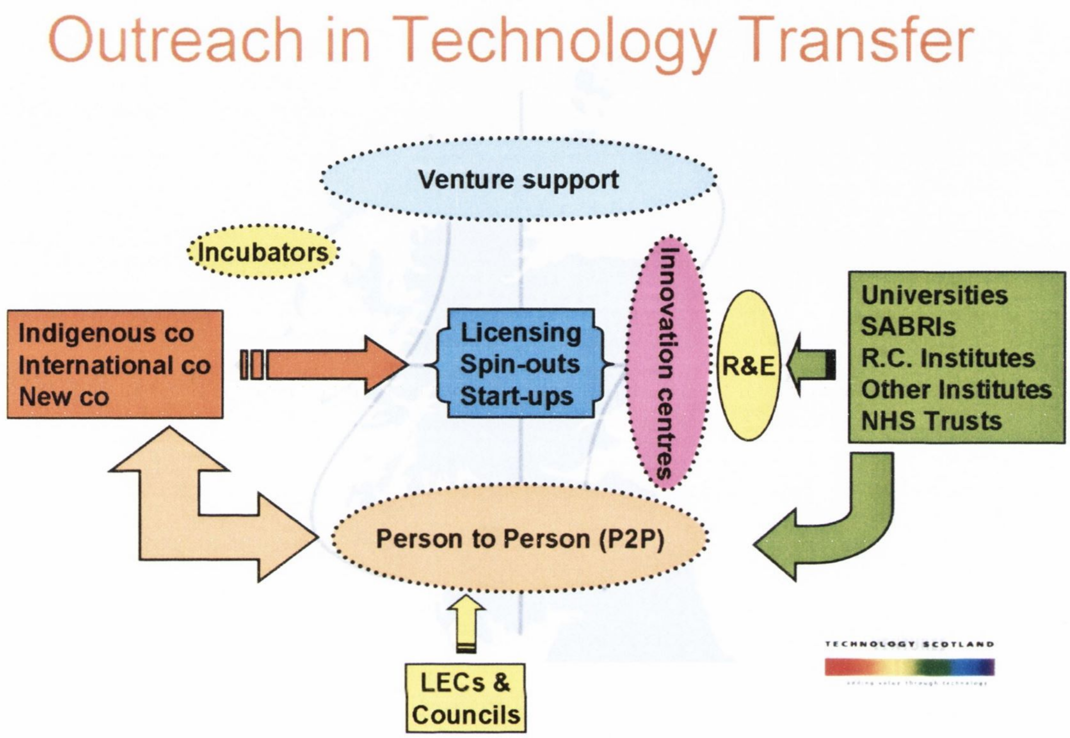
In February 2001, the Scottish Executive published the *Scottish Executive Report on the Knowledge Economy Cross-Cutting Initiative* (Scottish Executive, 2001) which built on the recommendations of Lord MacDonald's earlier report *Scotland: Towards the Knowledge Economy* (MacDonald, 1999). The Scottish Executive report highlighted a number of initiatives to develop the commercial exploitation of the research base in Scotland. To counteract the problems associated with SRIS, the Scottish Executive on the recommendation of the Minister for Enterprise and Lifelong Learning, recommended the development of a new database called Intellectual Property Exchange (IPX)[15]. TVS initially developed IPX, but in March 2001, the Director of SIE agreed to take over responsibility for the implementation, management and development of the IPX initiative. Previously, IPX was viewed as a Scottish Executive-based initiative and was not successful in terms of gaining participation from the academic community. SIE is viewed as a more independent body. While it has direct links with five universities (Dundee, Edinburgh, Glasgow, Heriot-Watt and Strathclyde), it is sufficiently autonomous to facilitate collaboration between all of the fourteen universities in Scotland in terms of developing a database highlighting current academic research in Scotland. One of the main objectives of SIE is to make IPX a success while TVS is encouraging SHEFC to end the SRIS initiative and allocate more funding to the development of IPX. While SIE is promoting the development of IPX amongst the universities, TVS is promoting the initiative to SERAD and to each of the six SABRIs. TVS is encouraging the SABRIs to participate in IPX for two reasons. First, the SABRIs engage in research complementary to the universities and are an important source of research and innovation in Scotland. Second, by including the SABRIs, TVS can persuade SERAD to allocate funding to IPX, along with the funding provided by SHEFC. Having initiated the appropriate mechanisms to develop a database on the research expertise and capabilities of the university sector in Scotland, TVS has a mandate to develop an effective model of U-I linkage that will establish collaborative projects between industrial research sectors and universities in Scotland.

[15] In Ireland while there is currently not an initiative such as IPX, it is intended that all of the nine universities on the island of Ireland will contribute to a research information database that will be funded jointly by the universities and the North-South body Inter*Trade*Ireland.

5.5.4 TVS model of technology transfer

The main goal of TVS is to develop U-I links and enhance collaborative R&D activities between industry and universities in Scotland.

Figure 5.3 Outreach in technology transfer in Scotland



Source: TVS

TVS has developed a model to facilitate the commercialisation of Scotland's science base (Figure 5.3). The development and implementation of this model is focused on the commercialisation of the science base of the universities, SABRIs, Research Councils, National Health Service (NHS) Trusts and other research institutes. It has two main objectives. The first is to create start-ups and university spin-offs via the commercialisation of new technologies. The second is to target the development of licensing deals between universities/research institutes and existing indigenous and international companies located in Scotland. Up to now, commercialisation was practiced almost exclusively in the Research and Enterprise (R&E) departments (or ILOs) of the universities without support from personnel external to universities. TVS is focused on enhancing this practice of commercislisation by focusing on 'person to person' contact. Its aim is to bridge the gap existing between the ILO and the company. The model proposes to place personnel, with a business background, an awareness of the needs and aspirations of companies and a knowledge of what universities/research institutes can provide, in each of the LECs, local Councils and Enterprise Trusts. TVS personnel would act as network facilitators between the worlds of academia and industry, by connecting researchers with the appropriate business support mechanisms (*i.e.* Ventures Support), and also by highlighting the appropriate researchers for firms seeking to engage in R&D links with universities/research institutes. They would have knowledge of the venture support available from the VCs and also of the availability of space in innovation centres and incubators and of the types of start-ups and spin-offs located in each of these entrepreneurial environments. According to TVS:

> *So in summary we have got IPX coming together to actually know what research is going on in Scotland where the expertise/help is. We are now looking at bridging the gap that businesses sense to make it easy to work with the Higher Education Institutes and Business Support Institutes by having it person to person. Thirdly we're looking at how to change the funding of universities to force commercialisation onto the academics' agenda and at the same time as SHEFC changing the funding. SIE is making changes within the modules so that most students have to have done a module in entrepreneurship and the academics are getting tutorials to encourage them to be more entrepreneurial on their outlooks. Now if all of these things can come together and it has been ten years in making mistakes, if all of these things come together we actually have for the first time the potential of agreement and TVS is a facilitator, broker within this, an agreement of how to get the research visible, an agreement of how the deliverable mechanism should work, an agreement on how to make the whole of this complex process join together (Interview with TVS, 2001).*

It is important to note that in relation to universities, the commercialisation of research will still remain the key function of the ILO. The model proposed by TVS is to facilitate this process and create networks of interaction outside universities which will play a key role in commercialising research within universities. Furthermore, as interface agents focused on creating a synergy between academia and industry, such personnel will also have the responsibility to market the capabilities of the universities to industry and, in particular, to the SME sector. In Ireland, one of the key problems highlighted in interviews with ILOs is the lack of time and resources for engaging in such marketing activities.

While the model proposed by TVS is very progressive, if it is to be effective a number of factors will have to be considered. First, it will take a number of years to raise awareness of the potential benefits of this initiative to both academia and industry. Second, there is the crucial question of whether or not the networking personnel are to be university-based. One of the recommendations of TVS is to have the personnel based in each of the universities. A potential problem associated with this could be that the TVS person may focus exclusively on the needs of the university they represent thus creating a level of competition that already exists between the universities, particularly in relation to procuring public research finance[16]. It may prove more effective for TVS personnel to remain autonomous from universities/research institutes. Instead, TVS should provide its personnel with responsibility for certain industrial sectors and research areas and have a remit of dealing with all of the universities/research institutes. Third, if the model is to work effectively, TVS must have the support of all the key players in commercialisation in Scotland. In particular, it must have the support of the ILOs, who may view this initiative as an indication of failure on the part of the ILOs to effectively commercialise the research base of the university sector in Scotland.

In relation to a comparison with Ireland, AUA is more like TVS than Connect Scotland. However, there are three significant differences between AUA and TVS. First, AUA is more geographically focused on a number of regions. TVS is nationally focused, and, therefore, in greater danger of not being able to access all SMEs in Scotland, which are widely dispersed across Scotland's geography. Second, AUA is also more target-focused than TVS. Third, AUA is focused on a number of sectors while TVS deals with all sectors.

5.6 UNIVERSITY CHALLENGE

In March 1998, the Chancellor announced the University Challenge Fund Scheme in the UK. The purpose of this fund was to enable universities to acquire finance to facilitate the transfer of research in S&T into the formation of new businesses and/or

[16] In the UK, there is a dual support system with Funding Councils providing 'enabling' funds and Research Councils providing research project/programme funds. The former allocate most of their money by formula based on the results of the Research Assessment Exercise (RAE). In Scotland, one of the barriers to commercialisation rests on the contradictions posed by the attitude and actions of the university sector towards the commercialisation of university research. On the one hand academics are assessed in the RAE on the numbers of publications produced while enterprise staff are assessed on income. Consequently, there is a clear imbalance between the university sector's philosophy and its actions towards commercialisation. In the RAE, the quality of the research and the number of publications produced are the prime governing factors. The Funding Councils provide only just over a third of research income and the balance is provided by the Research Councils, Charities, Government Departments, Industry and Commerce (SE and RSE, 1998).

products. In particular, it was focused on enabling academics to scope out the commercial potential of research outcomes and take the first steps towards commercialising the research (PREST, 1998). Funded by the OST, which is part of the DTI, University Challenge provided universities in the UK with an opportunity to bid on a competitive basis for pre-seed[17] finance. The total fund was worth £45 million (€63 million) and represented a collaboration between the UK Government [provided £25 million (€35 million)], the Wellcome Trust [provided £18 million (€25 million)] and the Gatsby Charitable Foundation [provided £2 million (€2.8 million)]. Launched in June 1998, all UK universities or consortia were encouraged to submit bids. In the UK as a whole, the first round of University Challenge created fifteen funds and awarded 31 universities and seven institutes access to investment capital.

In Scotland, three universities and four institutes were successful in securing funds from the University Challenge competition. University of Strathclyde and the University of Glasgow submitted a collaborative bid and became the recipients of an award worth £3 million (€4.2 million) which became known as the Synergy Fund. The University of Edinburgh formed a consortium with The Moredun Foundation, The Roslin Biotechnology Centre, The UK Astronomy Technology Centre of Particle Physics and Astronomy Research Council (PPARC) and the Edinburgh Station of the British Geological Survey. The consortium was awarded £2.2 million (€3.0 million). Following this success, a company called the Edinburgh Technology Fund (ETF) was established to allocate the pre-seed finance to academic projects exhibiting the potential for commercialisation. Allocated funds ranged from £10,000 (€14,084) to £50,000 (€70,422) for each project. On an annual basis, for every £50,000 (€70,422) that the ETF put into an initiative it required 10% of the benefit that would come from the project.

The PoC fund from SE was established after University Challenge results were known and interviewees felt that there was a need to have funds available particularly for those institutes that were unsuccessful in acquiring University Challenge funding (Section 5.4.2, Footnote 14, 128). However, a problem emerged

[17] From the perspective of firms, the term 'seed' refers to investment in companies in the early stages of their development. An example of a seed fund for early stage ventures in Scotland is the Scottish Technology Fund, a joint venture between SE and a VC company called 3i. This fund also focuses on financing new technology projects within Scotland's universities. VCs also provide seed funds for companies in early stages of development. From the perspective of universities, the term 'seed' refers to initial finance allocated to a establish a research project, usually with a view to commercialising the

for universities and consortia who were successful in their bid for University Challenge Funds. They had to predict how many opportunities were going to come forward in their respective institutes. In the case of The University of Edinburgh and its consortia, if they did not draw down the money from the ETF at the correct level, they were ineligible to apply to SE's PoC fund competition. Essentially, they were split in their applications between SE's PoC fund and the ETF. Restrictions were placed by SE on applications made for PoC funding by successful recipient institutions of the University Challenge Fund. The timing of the launch of PoC was deliberate, as it was the result of political pressure applied by institutions who failed in their University Challenge bid. In retrospect, had universities and consortia who were successful in the University Challenge bid been aware that SE would introduce PoC, they would not have applied to University Challenge. Recipients of University Challenge allocations were required to provide 25% matching funds of the total amount that they received from the fund. For example, the University of Edinburgh and its consortia had to provide a matching fund of £750,000 (€1,056,294) in order to receive the £3 million (€4.2 million) awarded to them by University Challenge. PoC does not require participants to provide matching funds. In general, the attitude of the interviewees towards University Challenge funding was positive. For example:

> *Now the Challenge Fund, funds are very good because very quickly you can get up to £25,000 [€35,209] to do seed corn work to see if any ideas get any chance of flying. If you get through that hurdle you then have had the opportunity of building and you go through a second round within the challenge funds and you can get up to about £100,000 [€140,834] to take your project to a stage where its investor is ready. The other mechanisms are fairly new. Most of the work is still in the £25,000 [€35,209] early bit, there are a few projects coming through in the second stage now. A year or so down the line we'll know whether they're really robust or not. But one of the things I really liked about this early stage was that if you get your money and the project fails, i.e. the idea isn't good enough or for what ever reason it fails, instead of the typical British attitude of failure is a black mark against you, it's actually seen as getting your first stripe on your arm, a tick in the box and you are then encouraged to go and have another go, come up with a better idea and come back in. So you find that you're building encouragement for the entrepreneur instead of slapping him or her in the face, which is what the banks do. The banks would fund you to £25,000 [€35,209] and then you fail they'll say we've lost money over that*

research results. An example of this type of fund in Scotland is the University Challenge Fund Scheme (Section 5.6).

we don't like you, go away. So I like that about Challenge but the trouble is you can't access Challenge funds unless you're a member of the winning consortium. It's got to be a research project in part, it's got an idea that is part of the consortium if it doesn't hit that it can't play so what I want is the University Challenge funds widely available across Scotland, now I don't know how to tackle it yet, but I can see the bits that work and what we need to do is get money in that particular arena and that's somewhere down the line (Interview with TVS, 2001).

In 2000, the UK's Science and Innovation White Paper *Excellence and Opportunity – A Science and Innovation Policy for the 21st Century* (DTI, 2000b) was published. In this Paper, it was announced that the government would allocate a further £15 million (€21 million) pounds for a final round of University Challenge. The aim of the fund was to provide researchers with access to seed-corn funding for the development of new commercial initiatives and bring them to a point where the venture capital market would take them up (DTI, 2000b). While the same rules applied in the second round as in the first, this was the final University Challenge Competition. As this fund was being phased out, a new scheme, the Science Enterprise Challenge, was already in place. Launched in February 1999, the Science Enterprise Challenge represented a further initiative by the UK Government to introduce and develop the 'third mission' of universities which was the commercialisation of new knowledge generated by the university sector. Similar to University Challenge, Science Enterprise Challenge is a UK-wide initiative funded by the OST under the auspices of the DTI.

A total of £29 million (€40 million) was allocated to the Science Enterprise Challenge, leading to the establishment of twelve Science Enterprise Centres[18] (SECs) in various universities in the UK. One of the main objectives of this competition was to encourage leading-edge research universities to bid for this money based on their ability to provide education in entrepreneurship to their S&T students equipping them with the skills to set up their own companies and, thereby, increasing the rate of commercialisation in the UK. A consortium of Scotland's leading research universities (Dundee, Edinburgh, Glasgow, Heriot Watt and Strathclyde) was formed

[18] The centres established under the Science Enterprise Challenge are: The Bristol Enterprise Centre; The Cambridge Entrepreneurship Centre; The Centre for Scientific Enterprise; The Imperial College Entrepreneurship Centre; The Manchester Science Enterprise Centre; The Mercia Institute of Enterprise; The Northern Ireland Centre for Entrepreneurship; Oxford Entrepreneurs; The Science Exploitation and Enterprise Centre; SIE; The University of Nottingham Institute for Enterprise and Innovation; and The White Rose Centre for Enterprise.

and secured £4 million (€5.6 million) from the OST in 1999 to establish a SEC in Scotland - SIE. In the UK, SIE received the second highest award and was also given an additional £500,000 (€704,120) from the Scottish Executive which secured further funding from the ERDF. Furthermore, each of the universities received funds from their LEC for specific initiatives that were in line with the commercialisation objectives of each LEC.

5.7 SCOTTISH INSTITUTE FOR ENTERPRISE

> *Scotland has traditionally being very inventive. We have given the world most of the things they take for granted day in day out. But as a country we have not benefited in terms of the revenue streams that could have been generated from that and we have a long history in getting it wrong. Now at one level there is a question of the entrepreneurial Scot? Are we entrepreneurial enough? This is where the Scottish Institute of Enterprise comes in to try and make students and academics and universities more commercially aware, more entrepreneurial in their attitude. Therefore, we are addressing a base problem that has been around for decades in Scotland. We want more businesses whether spin-offs, whether start-ups, whether it is technology transfer or knowledge transfer into indigenous companies, it really doesn't matter but there is not enough of it happening in Scotland (Interview with TVS, 2001).*

SIE was launched in March 2000 and has three objectives. The first is to create an entrepreneurial culture and infrastructure within universities which will support increased commercialisation in Scotland. The second is to increase the number of university-based start-up and spin-off companies formed by students and academic staff in universities. The third is to increase the number of links between industry and academia. The establishment of SIE is both a core and gateway model with five original centres based around each of the SIE partner universities and a core team, led by a director who is the focal point for external parties[19]. The director is responsible for establishing the profile of SIE at national and international level. He/she is also responsible for creating linkages at those levels with industry. The commercialisation facilitators and their education counterparts[20] also encourage companies and private sector organisations to sponsor training and placement schemes. For the purposes of this research, the Director of SIE was interviewed in Glasgow, as were the SIE commercialisation facilitators in Dundee, Glasgow and Heriot Watt.

[19] The Director of SIE was appointed in January 2001, and took up her post on the 8 of January 2001.
[20] The SIE education personnel are responsible for the development of education policy and strategy.

In Scotland there are a number of schemes linking the private sector and universities, such as undergraduate and graduate placement programmes and initiatives sponsored by various economic trusts and development agencies. However, SIE is the first collaborative cross-university project in Scotland which aims to initiate and develop the teaching of entrepreneurship in the university sector and to encourage the development of academic entrepreneurship in terms of generating start-ups in the S&T sector. Furthermore, the aim of SIE is to develop U-I links in the long term. For example:

> *The plan for our project. It is a three to four year project. The idea of enterprise will be imbedded in the university. Students will think about enterprise, think about business and they will tie their own studies into business. And shall we say not three years or five years from now, but maybe ten years on those students when they are successful or are in a company or have a company of their own will say right "[Name of university] is our university of choice for prototyping for research, we are going to go to [Name of university] to get our basic research and so on done for us". So that is our picture (Interview with an SIE Commercialisation Facilitator, 2001, number one).*

SIE is very much in its infancy and for the first two years (2000-2002) the focus was on building its profile[21]. While Glasgow University is the lead partner for administrative purposes, each of the five original universities were equal partners in SIE. In 2001, SIE were invited by the OST to bid for further funding in the second round of the Science Enterprise Challenge. Again, SIE was successful in its second bid and secured a further £2 million (€2.8 million) pounds. In 2002, this funding enabled SIE to expand its remit to the remaining eight universities in Scotland by appointing commercialisation facilitators in each of Scotland's fourteen universities, including two associate HEIs, Glasgow School of Art and Queen Margaret University College in Edinburgh.

In terms of the management structure, SIE now has four overarching bodies. It has a Board, a Management Executive Group, an Education Advisory Group and a Commercialisation Advisory Group. These groups are made up of the ILOs of each of Scotland's fourteen universities, a number of academics and a small number of VCs and companies. While some members on the SIE boards are also on one of the two TVS boards, one notable difference between the board membership of SIE and

[21] Each of the SIE teams at the universities have been in place since July 2000.

TVS is that the Scottish Executive and SE are not represented on any of the four SIE boards. While the number of universities under SIE has increased SIE objectives remain the same. The next major challenge to face SIE is funding, as the OST funding comes to an end in 2004.

5.8 COMMERCIALISATION AND THE INDUSTRIAL LIAISON OFFICE

> *I don't like the terminology 'third leg'. It's being used by people who don't understand that much, commercialisation isn't a third leg, the whole knowledge of economy is built on commercialisation (Interview with an ILO in Scotland, 2001, number two).*

In Scotland, each interviewed ILO agreed that their main functions are focused on identifying and protecting IP, commercialising IP (either through licencing to established companies or investing the IP through the formation of spin-offs) and administering research grants and managing research contracts with industry. However, in analysing the role of the various universities in commercialising their research base, it is important to note that the five universities have different ways of approaching commercial activity; their ILOs are established differently, and they have different research strengths attracting a variety of industrial partners. Furthermore, the directors of ILOs have different philosophies and approaches, not only in relation to the practice of commercialisation, but in their attitude towards the academic community, industrial partners, government development agencies and a broad range of funding sources. One ILO described the job as:

> *It's the best job in the world because it is the most difficult thing in business management especially technology business. I think because of the sheer volume of different parties, I can't think of another job in life that you're dealing with everything from government funding bodies to academic research to west coast venture capitalists, public sector development agencies, private entrepreneurs, and every type/shape of company small, medium and large, 70 countries around the world. I can't think of a business field in life that isn't part of that and you have to juggle all the extended wishes of all those involved (Interview with an ILO in Scotland, 2001, number one).*

It is within this framework of diversity that the attitudes and experiences of five ILOs in Scotland were ascertained. Despite such diversity there was some common ground in the responses of ILOs in relation to the barriers and stimulants they experienced in their practice of commercialising the S&T base of five Scottish universities. It is important to note that these barriers and stimulants are those from a university perspective.

The first major barrier to emerge from the interviews was the historical struggle of ILOs to become established in the university sector in Scotland. The majority of ILOs were established in the mid to late 1980s and were formed with the intention of transforming research results into commercial entities. Since then, ILOs have faced two opposing views within Scottish academia on the role of research and its commercial application. According to Botham (1997), one third of Scottish academics appear to hold what may be described as 'traditional' academic views believing, for example, that academics should undertake basic research and not be concerned with its application. On the other hand, the majority are interested in the commercial exploitation of their research.

The next significant barrier faced by ILOs in Scotland was the publish versus patent argument. The academic community felt that the requirement by industry to patent a technology negatively impinged upon their academic freedom to publish research findings. This is a barrier continuously faced by the ILO community in Scotland and one that each ILO addresses in a way that suits the particular agreed academic-industry deal. Similarly, there have been cases in Scotland where academics will by-pass ILOs and will make an offer to a company without the direct input or knowledge of the ILO. There are a myriad of legal and financial problems associated with this type of arrangement. Under European Patent Law, the university has ownership of the IP of the new technology. The academic may not be aware of the financial value of the IP and may sell the technology at a very low cost to a company or a VC. A situation of this nature has a series of negative ramifications for the academic, the company, the ILO and the university involved. However, the question must also be asked as to why, in the first instance, the academic by-passed the ILO. Often the answer lies in the negative attitude of the ILO towards the academic. A comment by one of the ILOs on the academic community provides an example:

> *They [academics] don't know and they will never accept it and they think people like us [ILOs] are people that should only have rubber stamps that when they walk into the office anything they put down as a proposal we should put past and preferably just send them the stamp. They have no understanding of the importance and value of getting any of that [IP deal] right, they don't care about things like*

> *national economy, the financial integrity of the university, they only care about their little research group. They're not institute loyal and they are certainly not economic development loyal, when what we want is their intellectual property that they generate to be managed to the best regional economic effect, so you start from that (Interview with an ILO in Scotland, 2001, number one).*

The next major barrier experienced by ILOs is the willingness and appropriateness of an academic starting a technology company. Very often academics may not have the management and business acumen required to build a successful company. Furthermore, there is a danger that the academic will not have sufficient time to engage in research.

In the interviews, it emerged very quickly that IP is the key financial asset of any university. One of the key concerns of ILOs was their ability to protect this IP, particularly from VCs who were routinely referred to as "opportunists" in the interviews. One ILO made the point that VCs have infiltrated the boards of TVS and Connect Scotland in an effort to acquire a greater share of IP business. The response of some of the ILOs has been to distance themselves, their offices and the academics whom they represent from both the VCs and the boards of which they are panel-members. This has negative repercussions for bodies such as TVS and Connect Scotland. While a number of ILOs provided negative comments on the role of VCs, one comment by an ILO provides a good indication of the general attitude of the ILOs towards VCs.

> *It takes us a year to dance with these people [VCs] because they don't get it, they just don't get how that works, they don't understand the politics, they don't understand the environment, they don't understand the contacts and they don't give a damn about the R part of research enterprise. They only care about enterprise and if they hike out ten researchers out of a department that only had twelve they don't care. So they've created a nice little spin-off but they've killed all the value that might have had a 30 year history of being world leading in a research area and they killed the department that might have done £3 million [€4.2 million] pounds of research every year (Interview with an ILO in Scotland, 2001, number one).*

A further barrier highlighted by the ILOs was the role of the companies. Like Ireland, Scotland does not have a large population of technically sophisticated companies with the managerial and technological sophistication to work with university R&D projects. In order to stimulate more U-I links, ILOs felt it was important to focus on the companies and create incentives for companies to become more innovative and to collaborate with the university sector. ILOs found that Scottish companies (of all sizes) are not willing to engage in links with universities in Scotland. Increasingly, the business of ILOs in Scotland is global, as Japanese, American and European multinational companies have the capital to commercialise the S&T research base of Scottish universities.

In relation to the stimulants to shape research technologies into commercial effect, only two of the five ILOs provided an answer. Furthermore, both ILOs provided the same answer. They both emphasized the crucial role played by academics and the network of connections that they establish with industry as the main driving force for U-I collaboration. It was interesting that this was the only stimulant mentioned by two ILOs. While the majority of the responses to questions on barriers and stimulants were almost exclusively focused on the barriers, it is appropriate to look inside an ILO and gain some perspective on the activities and outcomes of a Scottish technology transfer office to determine its resources, what its deliverables are and what are its targets for the future. For the purposes of profiling ILOs, the Edinburgh Research and Innovation (ERI) Office was selected as it was the only ILO in Scotland to provide the necessary data on commercialisation activities and it is also the most successful research university in Scotland.

5.8.1 Profile of an Industrial Liaison Office: Edinburgh Research and Innovation

The University of Edinburgh established its first technology transfer company ERI in 1984. In April 2001, ERI had a total staff of 49 people. In Ireland in the same year, the sum total of staff employed in all ILOs combined was 63. The average staff number was 2.8 people. However, this figure was inflated by UCD with a staff of 10 and DIT with 18. If UCD and DIT are excluded there was an average of 1.75 people per ILO in Ireland. The occupational categories of ERI include legal advisors, European grants officers, policy managers, research promotion managers, research consultancy managers, business development executives, business analysts and dedicated technology transfer managers in the physical sciences, in medicine and in arts.

ERI has two incubator units, one for microelectronics and one for biotechnology, and it has its own technopole. In April 2002, the university formed a partnership with a private investor, *Grosvenor Developments Limited*, to co-operate with the development of the Edinburgh Technopole which will be managed by ERI. In all, two companies were on site in April 2002 while the twelve companies operating in the technology transfer centre (seven of which came through and are supported by SIE) will locate to the technopole as soon as it is completed. A number of these companies also received seed money from ETF.

The focus of ERI is on the commercial exploitation of the research base of the university. In all, 100% of its commercial activity is with industry while 70% of its consultancy activities are with industry. ERI is focused on marketing the research base of the university and is also engaged in the exploitation of the academic teaching base. ERI has five sources of income from industry; (1) sponsored research, (2) collaborative research, (3) donations from industry, (4) industry funded studentships and (5) consultancy. In 2000-2001, the value of ERI's total income from research awards and industry contracts was £117 million (€164 million). Of this total, £13 million (€18.3 million) came from industry (11% of the total. Since the foundation of ERI, the average is 10% p.a. of total ERI income[22]), £3.3 million (€4.6 million) came from licensing royalties and £2.1 million (€2.9 million) came from consultancy activities. The remaining finance came from Research Councils[23] (41%), Charities[24] (27%) and the EU (32%).

Table 5.2 ERI commercialisation outcomes

	July 2000	July 2001	July 2004 (projected)
Commercial Research Awards	£7.5m (€10.5m)	£13 (€18.3m)	£15m (€21m)
Technology Disclosures	82	76	100
Patents Files	19	10	25
Licenses Granted	11	13	15
Spin-offs	4	4	5
Start-ups	4	11	10-15

Source: Interview with the ILO of ERI (2001)

[22] In the USA in the early 1990s, it was forcasted that corporate funding for research would never exceed 8% (Phillips, 1991).

[23] Examples of funds from the Research Councils include the Research Development Grant (RDG), the Joint Infrastructure Fund (JIF) and the Joint Research Equipment Initiative (JREI).

[24] Examples of Charities include the Wellcome Trust and the Gatsby Charitable Foundation.

Despite an income of £117 million (€164 million) in 2000-2001, ERI's output was low in terms of patents filed, licenses granted and the number of spin-offs (Table 5.2)[25].

Table 5.3 ERI deliverables compared to the Scottish average

	ERI 2000-2001	Average of Eight Scottish Universities
Volume of Sponsored Research (M)	\$110.9 (€98.3)[26]	\$53.3 (€47.2)
Number of Technology Disclosures	76	37
Number of Patents Filed	10	14
Number of Licenses Granted	13	12
Royalty Income (M)	\$4.9 (€4.3)	\$1.6 (€1.4)
Number of Spin-offs	4	2

Source: Interview with the ILO of ERI (2001)

However, if the figures are compared with average figures for Scotland, then ERI would appear to be doing quite well[27] (Table 5.3). It is perhaps unfair to compare institutions for their individual deliverables in terms of patents, licensing and royalty income, as these are relative to the total income of ILOs, the relative size of the institution and the total number of academics engaged in commercialisation within it. What is required is a series of benchmarks from which to compare the performance of different universities.

In 2000-2001, ERI's ILO completed an exploitation efficiency survey comparing Scottish universities and US universities. Up to this point it was difficult to comprehend how Scotland's strong science base was not being translated into high-tech industrial successes (Collinson, 2000). It was perceived that US institutions were more successful. When the top eleven US research universities were compared with the sample of eight Scottish universities (already outlined), the results were surprising. Most notably, it takes \$89 million (€78.8 million) dollars per annum of sponsored research to lead to one spin-off company in the US. This compares with \$24 million (€21.2 million) per annum per company for Scottish universities[28].

[25] Unfortunately, comparable data are not available for Ireland as only two ILOs were able to provide such figures. These results are presented in Chapter 6, Table 6.2.

[26] The exchange rate used throughout was the rate at the time of writing (\$1 = €0.88/€1 = \$1.12). This applies for all currency conversions from US dollars to Euros and *vice versa*.

[27] This is data provided by the Universities of Aberdeen, Dundee, Edinburgh, Glasgow, Heriot-Watt, St. Andrews, Stirling and Strathclyde.

[28] Williams (2002) confirms these international comparisons when he compared data from the annual US AUTM 2000 survey with a UK survey completed for 2000 by the CURDS (2001). Comparing the AUTM and CURDS surveys, Williams (2002) found the following:

- US universities, with a research base of €32 billion (\$36 billion), created 368 spin-off companies or created one company per €87 million (\$98 million) of research spent.

On the surface, it would appear that Scotland is doing well. However, there are a number of problems with these findings. First, the figures were not produced by an independent research body. Second, the sample of universities selected in both the USA and Scotland are not representative of all universities in their respective countries. Third, due to the highly diverse nature of U-I links, the attention focused on commercialisation is different in each university. The primary focus may not be on spin-off activity. For example, federally funded research in areas such as tropical diseases in the medical sciences may not lend itself to the formation of spin-offs. In light of these observations, correlating the level of research income with the number of spin-offs generated is not a sufficient benchmark to assess the level of success in the commercialisation of university research.

Rather, it is important that the whole spectrum of activities in technology transfer be taken into account in individual universities when assessing the level of success associated with commercial exploitation activities. Subsequently, it is difficult to compare how efficiently universities exploit their commercial potential on an international basis. It is far more effective to analyse the activities of universities at a national level within the context of understanding the key factors leading to the development of an environment conducive to the commercialisation of research. This has been a key objective of this chapter within the Scottish context.

5.9 CONCLUSION

In Scotland, the drive to develop a knowledge economy based on the commercial exploitation of research has resulted in the development of a series of partnerships between university, industry, economic development agencies and key regional actors with vested interests in the commercial application of Scotland's S&T base. It is within the formation of networks of interaction between these key players that an environment conducive to commercialisation has evolved in Scotland. One of the major criticisms of this model of commercialisation is that there is too much overlap in the aims and objectives of the different groups. In any case, a number of initiatives have been implemented to enhance the rate of commercial activity in Scottish universities. In relation to funding, SE and SHEFC have played a crucial role in the provision of finance to implement a number of initiatives. Connect Scotland, TVS

- UK universities, with a research base of just €5 billion ($5.6 billion), created 199 spin-off companies or created one company per €25 million ($28.2 million) of research spent.

and SIE are the national programmes in Scotland aimed at promoting increased commercial activity and the development of Scotland's high-tech industrial base. While the profile of activities being pursued by each of these initiatives is impressive, it is not evident that such ventures will have positive long-term outcomes.

What is evident is that there are two major flaws with the model of commercialsiation being pursued in Scotland. First, there is a lack of knowledge by the universities and each of the key players in Scotland on the needs of industry. Not only is there a lack of research completed on this key question, but there is a lack of knowledge on what firms may require from the university sector. Furthermore, firms are not aware of what the university sector can provide in relation to innovation and in particular in areas of R&D, consultancy and teaching/training. Second, Scotland does not have a large population of technologically sophisticated, research-dependent firms. The Scottish model is very much based on the institutional 'push' of research-based commercial technologies and lacks the industrial 'pull' to complete the full cycle of commercialisation.

Scotland needs to focus on three types of firm. First, it needs to focus on the creation of new indigenous high-tech Scottish companies with a commitment to R&D, a willingness to engage in strategic partnerships with Scottish universties and a drive to become market 'creators' with a range of new technologies. Second, it needs to direct the management culture of existing Scottish companies towards innovation. Third, Scottish universities must increase the annual number of spin-off companies. ERI have demonstrated that they can achieve such objectives on a limited budget. There is no reason why other Scottish universities should not be able to generate similar numbers of spin-offs. The challenge now facing Scotland is to create and mobilise an industrial base of R&D-focused companies that demand the technologies being pushed out from the university sector. Only then can Scotland benefit fully from the environment of commercialisation, created by such initiatives as Connect Scotland, TVS and SIE, and emerge as one of the most competitive economies within the knowledge-driven global market economy.

For the purpose of this research, Scotland provided an alternative context in which to assess the policy environment in which U-I links have evolved. However, it is more effective to assess the extent to which companies have linked with HEIs, the profile of such links and the barriers/stimulants associated with the creation of such interaction from the perspective of firms. Due to time constraints and the scholarship requirement to focus on indigenous Irish companies, the questionnaire survey for firms was not replicated in Scotland. Instead, the focus was on EI-assisted high-tech companies and their level and type of interaction with Irish HEIs. The task of the following three chapters is to focus on EI-assisted high-tech companies and their links with HEIs in the context of Ireland.