

INDUSTRY-ACADEMIA COLLABORATION:
A COMPETENCE CENTRE APPROACH
FOR IRELAND

Studies in Public Policy

The series *Studies in Public Policy* is published by the Policy Institute at Trinity College. It aims to bridge the gap between the academic and professional policy communities and make a real difference to public policy debate in Ireland. Each *Study* takes a practical policy problem and analyses it in a way that is academically rigorous yet accessible for all that.

Current Titles

- 1 Michael Gallagher, Michael Laver, Michael Marsh, Robert Singh and Ben Tonra (1995), *Electing the President of the European Commission*
- 2 Michael Laver (1998), *A New Electoral System for Ireland*
- 3 John Fingleton, John Evans and Oliver Hogan (1998), *The Dublin Taxi Market: Re-regulate or Stay Queuing?*
- 4 Elizabeth Meehan (2000), *Free Movement between Ireland and the UK: from the "common travel area" to The Common Travel Area*
- 5 Orlaigh Quinn (2000), *A Review of the Free Schemes Operated by the Department of Social, Community and Family Affairs*
- 6 Greg Heylin (2001), *Evaluating Prisons, Prisoners and Others*
- 7 Brigid Laffan (2001), *Organising for a Changing Europe: Irish Central Government and the European Union.*
- 8 Simon Brooke (2001), *Social housing for the future: Can Housing Associations Meet the Challenge?*
- 9 Nóirín Hayes (2002), *Children Rights – Whose Right? A Review of Child Policy Development in Ireland*
- 10 Jonathan Westrup (2002), *Financial Services Regulation in Ireland – the Accountability Dimension*
- 11 Pat Cooke (2003), *The Containment of Heritage: Setting Limits to the Growth of Heritage in Ireland*
- 12 Jonathan Healy (2003), *Fuel Poverty and Policy in Ireland and the European Union*
- 13 Raj S. Chari (2004), *State Aids in the Airline Sector: a comparative review of Iberia and Aer Lingus*
- 14 Declan Purcell (2004), *Competition and Regulation in the Retail Pharmacy Market*
- 15 Anne-Marie McGauran (2005), *Plus ça change...? Gender Mainstreaming of the Irish National Development Plan*
- 16 Diane Mulcahy (2005), *Angels and IPOs: policies for sustainable equity financing of Irish small businesses*
- 17 Nigel Boyle (2005), *FÁS and Active Labour Market Policy, 1985-2004*
- 18 Paul Teague (2005), *Towards Flexible Workplace Governance: Employment Rights, Dispute Resolution and Social Partnership in the Irish Republic*
- 19 Martin Ruhs (2005), *Managing the Immigration and Employment of Non-EU Nationals in Ireland*
- 20 Charles Shipan (2005), *Independence and the Environmental Protection Agency: a comparative assessment*
- 21 Michel Peillon, Mary Corcoran and Jane Gray (2006), *Civic Engagement and the Governance of Irish Suburbs*
- 22 Nicki O'Connor (2007), *Industry-Academia Collaboration: A Competence Centre Approach for Ireland*

INDUSTRY-ACADEMIA
COLLABORATION: A COMPETENCE
CENTRE APPROACH FOR IRELAND

Nicki O'Connor

Studies in Public Policy: 22



2007

First published 2007
by The Policy Institute
Trinity College, Dublin 2, Ireland
www.policyinstitute.tcd.ie

© 2007 The Policy Institute

All rights reserved. No part of this publication may be reproduced in any form or by any means, electronic or mechanical, or by any information storage or retrieval system, without prior permission in writing from the publisher.

A catalogue record is available for this book from
the British Library

ISBN 1-902585-20-8

Cover design by Ed Miliano, Dublin
Origination by Carole Lynch, Sligo
Printed by ColourBooks Limited, Dublin

Contents

1	INTRODUCTION AND METHODOLOGY	1
	1.1 Background	
	1.2 Purpose of paper	
	1.3 Paper outline	
2	ECONOMIC CONTEXT	6
	2.1 Economic theory	
	2.1.1 Why does economic growth matter?	
	2.1.2 What makes an economy grow?	
	2.1.3 The knowledge economy	
	2.2 The European Union's quest	
	2.2.1 The Lisbon Agenda	
	2.2.2 EU policy initiatives to deliver the knowledge economy	
	2.2.3 Present situation	
3	INDUSTRY-ACADEMIA COLLABORATION: THEORY	13
	3.1 National innovation systems	
	3.1.1 National innovation systems theory	
	3.1.2 The position occupied by the firm	
	3.2 The relationship between industry and academia	
	3.2.1 Emerging trends	
	3.2.2 Benefits and barriers	
	3.2.3 Role of government	
	3.2.4 One type of support scheme: the competence centre	
	3.2.5 The national context	
4	INTERNATIONAL PRACTICE I: SWEDEN	25
	4.1 The Swedish landscape	
	4.1.1 The Swedish national innovation system	
	4.1.2 Future policy challenges	
	4.2 Competence centres	
	4.2.1 Establishment	

	4.2.2 Operation	
	4.2.3 Evaluation	
5	INTERNATIONAL PRACTICE II: AUSTRIA	35
	5.1 The Austrian landscape	
	5.1.1 The Austrian innovation system	
	5.1.2 Recent policy developments	
	5.2 Competence centres	
	5.2.1 Establishment	
	5.2.2 Operation	
	5.2.3 Evaluation	
6	IRELAND	45
	6.1 Irish economic performance and policy development	
	6.1.1 The health of the economy	
	6.1.2 Policy evolution	
	6.2 The Irish national innovation system	
	6.2.1 Overview of current R&D performance	
	6.2.2 Features of the system	
	6.2.2.1 A favourable framework environment	
	6.2.2.2 Industry in Ireland	
	6.2.2.3 The higher education sector	
	6.3 Industry-Academia collaboration	
	6.3.1 Parameters	
	6.3.2 Current levels of collaborative activity	
	6.3.3 The role of the state	
7	PLANNING FOR THE FUTURE	67
	7.1 Developing a framework	
	7.1.1 Companies: developing in stages	
	7.1.2 Prioritising areas for future investment	
	7.1.3 Existing research competence	
	7.1.4 Mapping out a framework	
	7.1.5 State interventions	
	7.2 Accessing and applying research competence to industry needs	
	7.2.1 Objective	

7.2.2	Activities	
7.2.3	Role of the state	
7.3	Plans for centres	
7.3.1	Establishment	
7.3.2	Operation	
7.3.3	Evaluation	
7.4	Some concluding thoughts	
APPENDIX A		83
	Those consulted	
APPENDIX B		84
	Listing of Swedish competence centres	
APPENDIX C		85
	Listing of Austrian Kplus centres	
APPENDIX D		86
	Summary comparison of Swedish and Austrian competence centre models	
APPENDIX E		88
	PRTL-funded facilities	
APPENDIX F		91
	Irish initiatives relevant to industry-academia collaboration	
BIBLIOGRAPHY		95

Introduction and methodology

1.1 Background

Ireland's economic fortunes have witnessed a well-documented transformation in recent times. The country has moved from an environment of high unemployment, high inflation and relatively low levels of GNP per capita to quite the opposite. The Irish economy is unsurprisingly therefore often the envy of its counterpart member states in the European Union and of many countries further afield.

This position cannot, and is not, being treated complacently. There are many threats to Ireland's recent sources of competitive advantage, for example the rapid pace of globalisation and a rising cost base at home, as were highlighted by the Enterprise Strategy Group in its landmark industrial policy review in 2004.

Consequently new competitive edges must be developed. The Enterprise Strategy Group (2004) identified two key priorities for future Irish growth:

- 1 developing expertise in international markets to promote sales growth
- 2 building technological and applied research and development (R&D) capability to support the development of high-value products and services.

The latter reflects international recognition of the importance of 'moving up the value chain', that is to say evolving towards a more knowledge-intensive economy in which there is a higher proportion of high-technology industry and increased development and application of technology within more traditional sectors.

This shift is at the heart of the European Union's Lisbon Agenda. It is also a fundamental objective of the Irish government's recently launched *Strategy for Science, Technology and Innovation 2006-2013*: 'Across the economy, global competition is creating pressure for improvements in efficiency, quality and productivity and a growing

need to innovate and add value across all aspects of business' (Government of Ireland, 2006).

A range of dimensions within what is often called the national innovation system need to be enhanced in order to achieve this, including:

- building on previous far-sighted investments in Ireland's human capital development, in other words investing in people at all educational and training levels and providing appropriate infrastructure for this
- enhancing the R&D capability and activity of firms operating in Ireland
- increasing the attractiveness of Ireland as a global location for higher value-added activities
- creating new knowledge-intensive firms with high-growth potential
- strengthening the linkages between all parts of the system:
 - between companies in Ireland
 - between companies and higher education institutions in Ireland
 - between companies in Ireland and overseas actors
- improving framework conditions for economic growth, for instance telecommunications and transport infrastructure.

Among these lies the imperative to improve interaction between companies operating in Ireland and higher education institutions here. As knowledge generation, use and dissemination become increasingly pervasive, the interests and needs of firms and higher education institutions will become ever more intertwined.

Current levels of industry-academia collaborative activity in Ireland are generally viewed as low. By way of example, funding of R&D in the higher education sector financed by industry fell significantly between 1998 and 2002, and remained static between 2002 and 2004 (Forfás, 2005b). That said, further information on the extent and type of interactions that are taking place would be helpful in clarifying this picture.

The weakness of the linkage is recognised by many and there is an evolving collection of state support in place or in planning to

address this, e.g. Enterprise Ireland's industry-led networks, the Tyndall Institute in Cork, Science Foundation Ireland's Centres for Science, Engineering and Technology.

Nevertheless, it is widely accepted that more needs to be done to improve the situation. In line with this, the *Strategy for Science, Technology and Innovation* (STI) (Government of Ireland, 2006) includes plans for the establishment of competence centres, advising that 'Along with investments in the science base, specific measures are needed to more closely couple scientific expertise with industrial needs and to build an infrastructural base in the research system that is closely linked with the express needs of enterprises'.

Competence centres are a tool used internationally to support industry-science relations. They are typically based in the third-level sector while, critically, being driven by a medium-term industry research agenda. Their activities are therefore shaped by ongoing company engagement at both a strategic and an operational level. Research programmes underpin other industry-academia linkages such as personnel mobility, training and access to specialised equipment. Centres developed in Ireland in the late 1980s under the Programmes in Advanced Technologies could be seen as an earlier Irish foray into this space. In the light of the changing environment and evolving industry needs, these are currently being phased out.

The Strategy for STI allocates responsibility to Enterprise Ireland, working with IDA Ireland, to develop future competence centres in Ireland and these centres similarly feature in Enterprise Ireland's plan, under its 2005-7 strategy *Transforming Irish Industry*, to 'work in collaboration with other relevant agencies to develop technology collaboration centres strongly linked to Universities and Institutes of Technology. The mission of these centres will be focused on working in collaboration with industry on research issues of medium-term interest to Irish-based industry and providing improved access to technology solutions'.

1.2 Purpose of paper

Originally, it was anticipated that this paper would concentrate on the particular characteristics of these planned centres, e.g. how many companies would be involved, what types of activities would be undertaken, etc. After initial consideration, it was concluded that such an exercise would lie in something of a vacuum if the wider

context was not explored: this is therefore the subject of considerable discussion.

In order to assess how the state's planned investment can best benefit Ireland, it is useful to consider the present environment, to reflect on the framework within which one wishes to operate in the future and to then explore possible ways of making the transition. Such an approach should assist in the enhancement of industry-science relations in Ireland through the establishment of an appropriate competence centre model (or models) and related interactions.

Key questions explored in this paper include the following:

- what is the current situation with regard to Ireland's national innovation system and the connection between industry and academia?
- what is an appropriate strategic framework for consideration of future state support for industry-academia collaboration in Ireland?
- in seeking to access and apply research competence to industry needs, what are the types of activities involved and how can these be supported?
- what are the relevant issues to be considered in the development of an Irish competence centre model?
- what insights does international experience provide for the development of such a model for Ireland?

1.3 Paper outline

Chapter 2 begins by considering the knowledge economy, economic theory underpinning it and a striking example of the importance being afforded it in the form of the European Union's Lisbon Agenda.

In chapter 3, a literature review of industry-academia collaboration looks at general theory on the importance of the industry-academia relationship, what activities it comprises, and what factors can hinder or promote its development.

Two international case studies are then examined in chapters 4 (Sweden) and 5 (Austria) to draw on practical experience. These countries were selected because they are two of the countries that are most frequently cited as demonstrating good practice in the operation of competence centres. Their approach to – and success with – such centres are explored with a view to identifying relevant lessons for Ireland.

Chapter 6 details the current situation in Ireland. Progressing from the economy and current R&D performance, the three main players in the 'triple helix' of company-college relations (industry, academia and the state) are considered. A range of reports were reviewed and nearly twenty bodies consulted for this exercise, including higher education institutions, industry representative groups and state agencies (for details please refer to Appendix A).

Building on this, chapter 7 explores the development of a strategic framework for optimising future state investments in this space. This involves

- the delivery of supports for companies that are appropriate to their stage of development
- the identification of future R&D investment priorities for Ireland
- assessment of existing research competence.

The use of a strategic framework should help to optimally build industry-relevant research competence in Ireland and to access and apply that competence to industry needs. Within the latter, issues pertinent to Ireland are highlighted and insights from the Swedish and Austrian experiences brought to bear on the establishment of competence centres in Ireland.

Economic context

2.1 Economic theory

At the outset, it is helpful to be clear on why economic growth is consistently in the headlines, what makes an economy grow, and why the 'knowledge economy' is to the forefront of so many policymakers' minds.

2.1.1 *Why does economic growth matter?*

The overarching aim of industrial development everywhere is to deliver sustainable economic growth, where the latter is typically defined as the increase in a country's Gross National Product (GNP), i.e. the value of the output (goods and services) that it produces. Such growth is vital because – in economic terms – it shifts out the production possibility frontier.

In lay terms, economic growth has the potential to improve the standard of living and quality of life of the citizens of a country by expanding the range of options available to that society, e.g. increased leisure time. If the economy grows, a citizen's standard of living should improve (calculated as GNP per capita). Of course, issues such as the distribution of wealth created and the provision of public goods and services (such as defence) must be addressed properly if economic progress is to be enjoyed by the wider population and not just by a few.

Moreover, economic growth will only be sustainable in the long run if it is grounded in a stable system that prioritises the ability of its people to benefit from, and to participate in, the evolving socio-economic landscape.

2.1.2 *What makes an economy grow?*

Basic economic theory finds that the production possibility frontier can be pushed out in two broad ways:

- 1 an increase in the quantity of productive factors
- 2 an improvement of the productivity of these factors.

Globalisation has revolutionised sources of economic growth. Over the last number of decades, it has manifested itself in an increasing variety of forms. First and foremost, trade in goods and services has underpinned development internationally. According to Ricardo's landmark work (1817), countries specialise in the production and export of those goods in which they have a comparative advantage, e.g. labour-rich countries will export labour-intensive goods. His analysis found that all countries, in theory, benefit from the increased productivity resulting from such trade. This has formed the basis of international trade theory since the late nineteenth century.

The environment for international trade has changed in three major ways in recent decades according to McAleese (2004):

- 1 growth in trade
- 2 composition of trade
- 3 liberalisation of trade flows.

Globalisation has also come to mean much more than the sale of goods and services abroad. The strong growth in world trade since the 1950s has been followed by greater levels of capital mobility from the 1960s. The more recent increasing mobility of the R&D operations of large multinationals (Howells and Wood, 1992) has generated a fresh opportunity (and threat) for the industrial development of nations.

What this means is that a country's economic growth now more than ever depends on its performance on the global stage. And, in effect, it is a function of the international success of its constituent firms since:

Economic growth takes place in the first instance because of a myriad of decisions made by individual firms. Decisions on when, where and what to invest, how much to spend on R&D, the development of a new product or process, collectively constitute the driving forces of growth.

(McAleese, 2004)

Moreover, as access to greater quantities of productive factors has become more constrained over time, emphasis has moved towards the 'quality' of these factors, i.e. how much they can produce.

Output per person can be defined as f (capital per person) \times residual factor, where the residual reflects factors that improve productivity but that are not amenable to exact measurement.

Total factor productivity, as the residual is commonly called, accounts for a growing proportion of output growth and governments are therefore placing more and more emphasis on it as a means to deliver national economic growth. Technological advance is viewed as fundamental to the residual effect. According to Everett Ehrlich (1997), technologically-driven productivity advances are key to long-term economic development¹ and firms are the vehicles through which innovation is translated into growth.

Backing this up, Kearns (2001) found that technologically active firms enjoy superior probabilities of survival relative to less technologically active firms. This result was consistent across the range of variables typically used to measure a plant's technological activity:

- scale of R&D activity
- R&D intensity
- sales of innovative products developed within the plants.

He also found that, while R&D active firms may not create substantially more employment, the employment those firms do create persists for a relatively longer period of time.

2.1.3 *The knowledge economy*

The emergence of the 'knowledge economy' is a culmination of evolving globalisation and the increasing significance of technological advance in a country's competitive position. In such an environment the creation, dissemination and use of knowledge are a pivotal source of competitive advantage. A shift towards this model can be seen in

- workforce movement from manufacturing to service jobs

¹ Technological advance is not the only form of total factor productivity. Others include a country's institutions and political stability and the quality of its labour force. These are essential to maximising the outputs from a country's productive inputs and, unsurprisingly, are therefore also state priorities.

- growth in investment in intangible assets
- growth in employment in knowledge-intensive fields e.g. high-tech industries such as pharmaceuticals
- the higher education requirement of 'knowledge work' and the relatively better remuneration for those who conduct it.

(Schwartz, Kelly and Boyer, 1999)

While, as noted earlier, it will be individual firms who develop competitive advantage, there is a role for state policy (Porter, 1947) since private sector under-investment in R&D is a generally acknowledged market failure. Many countries' governments, not least Ireland's, are devising strategies to transform their economies into knowledge-intensive environments in which there is

- a focus on existing and emerging high-tech industries
- increasing levels of R&D activity by enterprise
- an academic research environment in which top quality research is undertaken by world class researchers
- a research base tuned into the longer-term strategic research needs of industry
- attraction for MNCs' R&D operations and internationally mobile researchers.

Ireland's policies will be discussed in detail in chapter 6.

2.2 The European Union's quest

To achieve sustainable global competitiveness, the EU has no choice but to become a vibrant knowledge economy.

European Commission, COM (2005) 488

The European Union (EU) provides a good example of the importance being attached to the transformation of the economic model as well as the obstacles encountered in trying to realise this.

2.2.1 *The Lisbon Agenda*

In 2000, the EU set what has become commonly known as the 'Lisbon objective' which aims to develop the Union into the 'most

competitive and dynamic knowledge-based economy in the world, capable of economic growth with more and better jobs and greater social cohesion by 2010' (European Council, 2000).

In order to achieve this, the Barcelona European Council launched a call for action in June 2002 to increase investment in research and technological development from 1.9% to 3% of GDP by 2010. The underlying objective of the plan is to develop a European Research Area that will create an 'internal market' in research, stimulating co-operation and better allocation of resources, and that will restructure European research through improved co-ordination of national research activities and policies. Ultimately the aim is, in line with the Lisbon objective, to optimise the EU's competitive advantage in the global market.

Within this goal, business expenditure is targeted to account for two thirds of the total. This recognises the strategic necessity of R&D to companies' future performance and, by extension, to overall economic growth. According to an econometric study undertaken for the European Commission (cited in COM (2003) 226), attaining the 3% of GDP objective for research investment would have a significant effect on long-term growth and employment in Europe. This could be in the order of 0.5% of supplementary output and 400,000 additional jobs every year after 2010. SMEs² play a pivotal role in the realisation of the Lisbon objective since they account for approximately 66% of private employment and 57% of value added in the EU-25 (COM (2005) 488).

² In line with Commission Recommendation of 06/05/2003 (- OJ L 124, 20/05/2003), an SME is defined as an enterprise which

- has fewer than 250 employees
- has either an annual turnover not exceeding €50m or an annual balance sheet total not exceeding €43m
- conforms to the criteria of independence: an independent SME is one that is not owned for 25% or more of the capital or the voting rights by one enterprise or jointly by several enterprises falling outside the definition of an SME – the threshold may be exceeded in the following two cases:

The SME is held by public investment corporations, venture capital companies or institutional investors, provided no control is exercised either individually or jointly, or If the capital is spread in such a way that it is not possible to determine by whom it is held and if the SME declares that it can legitimately presume that it is not owned as to 25% or more by one enterprise, or jointly by several enterprises, falling outside the definition of an SME.

2.2.2 EU policy initiatives to deliver the knowledge economy

How the Lisbon objective can be achieved is the subject of much discussion and work across Europe. Progress to date has been underwhelming, for which many reasons are cited, as well as suggested solutions. Insufficient innovative activity is identified in a number of reports as a key factor behind Europe's underperformance (COM (2002) 262, European Innovation Scoreboards, Global Competitiveness Reports).

The EU operates a range of initiatives to realise the Lisbon Agenda, including the Framework Programme for research, and various innovation policy measures such as the relatively new Competitiveness and Innovation Programme.

Within the Framework Programme, the Commission identifies industrial partnership with public research organisations as a potentially extremely powerful tool that can benefit both industry and academia alike (COM (2003) 226). These linkages have formed an important dimension of the Sixth Framework Programme (2002-2006). Looking ahead, the Commission is planning a number of major initiatives such as centres of excellence and technology platforms within the Seventh Framework Programme to facilitate industry-academia collaboration (COM (2004) 353). This latest Programme involves a budget in the region of €50bn over seven years and comprises four main components:

- *co-operation*: covers collaborative research and proposed new 'Joint Technology Initiatives'
- *ideas*: includes proposed European Research Council
- *people*: 'Marie Curie' actions for researcher mobility and career development
- *capacities*: includes research infrastructures, dedicated measures for SME research, international co-operation.

A notable proportion of the Commission's efforts to build research capacity and activity in SMEs in the future will be captured under the Competitiveness and Innovation Framework Programme (CIP). This is intended to provide a coherent framework for all Community actions implemented in the fields of entrepreneurship, SMEs, industrial competitiveness, innovation, ICT development and use, environmental technologies and intelligent energy (European Commission, 2005d). It has three broad areas:

- 1 the Entrepreneurship and Innovation Programme, with particular focus on SMEs
- 2 the ICT Policy Support Programme to foster the adoption of ICT in business, administrations and public support services
- 3 the Intelligent Energy Europe Programme.

To what extent these initiatives will help develop SME research-driven innovation and, in turn, drive collaboration between SMEs and public research organisations is hard to predict and promises to be an issue that will be monitored with interest by many.

Recently, the EU has increased its emphasis on the need to co-ordinate policy work relevant to the Lisbon Agenda, in particular between research policy and innovation policy. In its October 2005 communication (COM (2005) 488) on its implementation, the Commission declared its intention to strengthen the links between the two, 'with research policy focusing more on developing new knowledge and its applications and the framework conditions for research, and innovation policy focusing on transforming knowledge into economic value and commercial success'.

2.2.3 Present situation

The European Commission's 2005 Key STI Figures find that EU R&D intensity is close to stagnation. Growth of R&D investment as a % of GDP has been slowing down since 2000 and only grew 0.2% between 2002 and 2003. Europe devotes a much lower share of its wealth to R&D than the US and Japan (1.93% in the EU in 2003, as compared to 2.59% in the US and 3.15% in Japan). One of the reasons for this has been a slow-down in business funding of R&D. In 2002, business expenditure on R&D grew at a slower rate than GDP though this was compensated for by a slightly higher growth of government funding as well as growth in R&D financed from abroad. If this trend is not reversed, not only will the EU miss the overall target for business expenditure on R&D by 2010, but the situation will in fact have worsened.

It is also vital to remember that achievement of the Barcelona objective is not the final aim, rather it is the means to an end: improved company competitiveness and greater economic growth in Europe for the ultimate benefit of its citizens.

Industry-Academia collaboration: theory

3.1 National innovation systems

3.1.1 *National innovation systems theory*

The systems approach to innovation is based on the belief that understanding and improving the relationships between the many actors involved is key to improving technological – and consequently economic – performance. It has taken on increasing importance in policy circles because of the

- 1 recognition of the economic importance of knowledge
- 2 growing use of systems approaches
- 3 increasing number of institutions involved in knowledge generation.

Lundvall (1992) defined a national innovation system as ‘the elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge ... and are either located within or rooted inside the borders of a nation-state’.

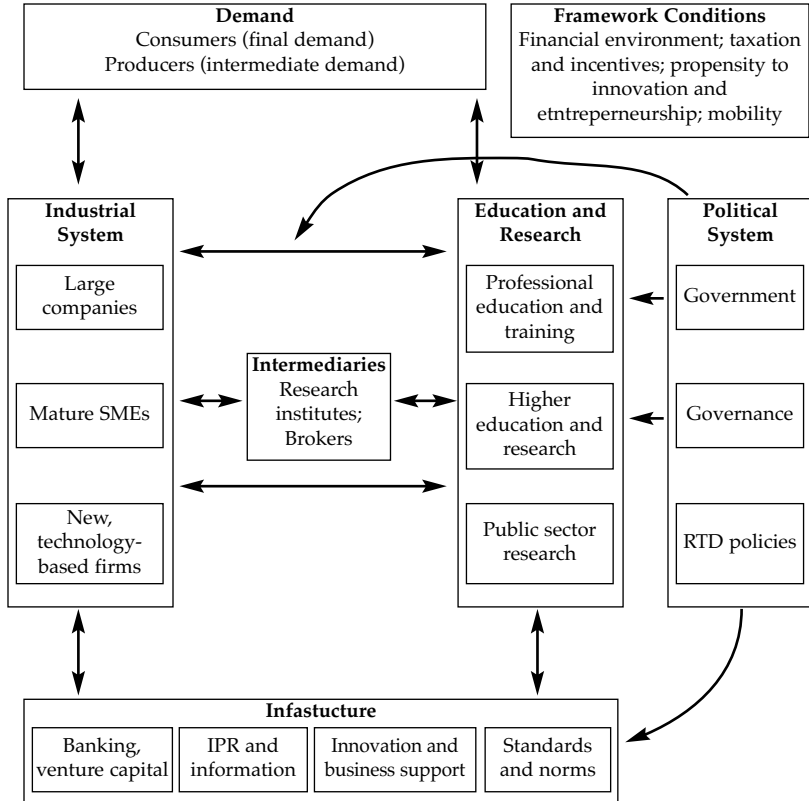
The diagrammatic representation below illustrates the key features and linkages in the system. The shape and structure of such a system naturally vary across different economies. The specific characteristics of Ireland’s will be discussed in chapter 6.

Innovation is the outcome of a highly complex and uncertain process that involves many actors and information sources acting through a range of feedback loops (Kaufman and Todtling, 2001). Understanding it can help to identify leverage points for enhancing innovative performance and to highlight weaknesses in the system (OECD, 1997).

Even within the systems approach, thinking is evolving. Theory on national innovation systems has shifted away from a linear model in which the science base was seen as creating new inventions that were transferred to enterprise for commercialisation

in the marketplace. A greater focus on improving linkages between actors is sometimes referred to as second generation innovation policy, while third generation innovation policy entails placing innovation at the heart of all policy-making, not just that concerned with industrial development.

Exhibit 1: A national innovation system model



Source: (Arnold and Kuhlmann, 2001)

The OECD recently suggested an underpinning shift in innovation activity: from one in which such activity mainly takes place in processes developed in large established firms based on integrative technologies, to one where it mainly occurs in products incorporating science-based modular technologies developed by new and/or small firms.

This shift points to a number of future priorities:

- 1 enhancing industry-science linkages
- 2 strengthening public sector engagement with industry
- 3 promoting collaboration among firms
- 4 fostering SMEs and new technology-based firms
- 5 rationalising innovation policy
- 6 R&D globalisation
- 7 innovation in services.

(OECD, 2005)

3.1.2 The position occupied by the firm in a national innovation system

As noted in the previous chapter and in the diagram above, companies perform a vital function within the national innovation system. The innovation process will deliver wealth and job creation through industrial activity. It is firms (either new or existing) that will ultimately commercialise emerging cutting-edge technologies. Moreover, firms will not survive in today's highly competitive global environment without tapping into and developing such technology for commercial application.

Among companies themselves, a well documented linkage is that between domestic firms and foreign-owned multinational subsidiaries. Foreign direct investment (FDI) flows have increased dramatically in recent times and the attraction and retention of FDI within an economy is one of the key tools employed to foster industrial development (Narula, 2004). That said, certain questions need to be answered if the presence of multinationals is to translate into national economic growth:

- 1 does the type of FDI being attracted generate significant spillovers?
- 2 is the FDI that is being attracted a substitute for or complementary to domestic industry?
- 3 does the domestic industry have the capacity to absorb these spillovers?

(Narula, 2005)

The final question is equally relevant when we come to consideration of linkages between industry and academia.

Indigenous industry must increase its own R&D capability in order to have the capability to absorb any spillovers from FDI (Kearns, 2001) and from engagement with the academic community.

Another important linkage for firms, and also for the wider system, is that with international actors. The ever more diffuse nature of knowledge generation and application today necessitates an all-encompassing perspective on sources of competitive advantage. International knowledge flows can come about in a range of ways, including:

- FDI (as discussed above)
- technology acquired from abroad in capital and intermediate goods
- purchases of foreign patents and licences
- technical alliances between firms from different countries
- internationally co-authored publications.

(OECD, 1997)

3.2 The relationship between industry and academia

3.2.1 *Emerging trends*

One of the pivotal relationships within the national innovation system (and the one of particular interest in this research paper) is that between industry and academia within a country.

The OECD finds a transformation emerging in recent years in the relationship between (curiosity-driven and mission-oriented) public research and (profit-driven) business R&D, due to the combined effect of the following factors:

- technical progress accelerates and markets expand greatly in areas where innovation is directly rooted in science (biotechnology, information technology, as well as new materials)
- new information technologies facilitate easier and less expensive information exchange between researchers
- industry demand for linkages with the science base increases more broadly as: innovation requires more external and multidisciplinary knowledge; tighter corporate governance leads to the downsizing of

corporate labs; and more intense competition forces firms to save on R&D costs while seeking quick access to new knowledge

- the imperative to respond to new social needs (ageing population, sustainable development) calls for innovations that often require mobilising complementary competencies of the public and private research sectors
- financial, regulatory and organisational changes boost the development of a market for knowledge by enabling the financing and management of a wider range of commercialisation activities
- restrictions on core public financing encourage universities and other publicly funded research organisations to enter this market, especially where they can build on existing linkages with industry.

(OECD, 2002)

A newer development again is that while firms are tending to focus on fewer products, the number of technologies incorporated in any one of them is increasing. Science-based technologies thus become more relevant to traditional sectors whose technology has been largely engineering-based to date. Firms will need to have in-house capability in, or access to, an increasing range of technologies and government support for collaborative research and related public-private partnerships is hence ever more important (OECD, 2005).

3.2.2 Benefits and barriers

It is clear that industrial development policy-makers widely accept the importance of the relationship between a company and public research organisations. It is unfortunately not as easy to quantify the benefits that flow from this relationship. Numerous studies have considered this issue and have commented on the difficulties involved. David and Hall (2000) described the space where public and private R&D interact as a 'heart of darkness'. They suggest that a major cause of inconsistencies in the literature is caused by the failure to recognise key differences among the various policy 'experiments' being considered – depending on the economy in which they are embedded and the type of public sector R&D that is being contemplated. They believe that the fact that the matter is

continually raised is symptomatic not only of the interest that attaches to it but also of the elusiveness of a satisfyingly conclusive answer.

Benefits

Scott et al (2001) came to the conclusion that the complexity of the relationship between research and innovation means that the returns to basic research are probably much higher than those imagined using a linear approach. This means, somewhat ironically however, that it is harder to calculate accurately rigorous quantitative figures.

Despite these difficulties in pinning down and quantifying the benefits, it is commonly accepted that the public and private returns from the relationship are sufficiently positive to merit ongoing attention and support. The OECD put forward the following as the contributions that the research base can make to innovative performance:

- trained researchers and qualified scientists and engineers
- knowledge
- some discrete technologies
- problem-solving
- research methods
- equipment prototypes.

(OECD, 2005)

It also proposes the following activities (in ascending order of formality) as those which are most likely to deliver these benefits:

- flow of graduates to industry
- informal contacts with professional networks
- conferences, expos and specialised media
- co-publications
- mobility of researchers
- research contracts
- licensing
- spin-offs
- joint labs.

(OECD, 2002)

The importance of informal contacts and researcher mobility in strengthening industry-science linkages has been emphasised and this will be relevant when we come to look at the Irish situation and related supports for collaborative activity here. Another form of interaction worth mentioning is that of consultancy.

A noteworthy caveat when considering generic activities is to avoid over-generalisation. The OECD distinguishes between three types of industry-science relations:

- 1 those involving multinational enterprises and world class universities
- 2 relations between universities and high-technology small firms
- 3 relations developing in a regional context between firms (often SMEs looking for shorter-term problem solving capabilities) and the local university.

(OECD, 2002)

It is important at this juncture also to recognise this clearly as a two-way interaction. As well as taking into account the earlier detraction of the linear model, interaction will not take place in any sustained fashion, if at all, if there are not clear benefits to both the enterprise and academic bases. If it is to be fostered, there must be something to be gained by all involved.

Barriers

According to the European Commission (2001), the level and pattern of industry-science linkages are largely determined by the structural features of a national innovation system, i.e. the demand for and supply of knowledge as a result of industrial and scientific specialisation. The Commission concluded that lower levels of industry-science relations can be mainly attributed to a lack of demand on the enterprise side and to a lack of incentive structures and institutional factors on the science side.

Relations can be difficult to initiate and even harder to sustain for a range of reasons including:

- a lack of available science institutions (in sufficiently close proximity)
- a mismatch of information, knowledge or services needed by industry and offered by academia

- little willingness to co-operate or involve external partners
- communications barriers
- incompatible rules and routines.

(Kaufman and Todtling, 2001)

The OECD cites three factors in the effectiveness of industry-science relations:

- 1 the need of business firms for the outputs of the research base and their ability to absorb and exploit them
- 2 the orientation of universities and PROs to the needs of business
- 3 the links between universities/PROs and business firms.

(OECD, 2005)

With respect to firms, absorptive capacity is an issue that excites policy-makers and analysts alike. It can be defined as 'the ability to absorb, internalise and utilise knowledge potentially made available' (Narula, 2004). It is significant for development because it allows actors to internalise knowledge generated elsewhere that is made available to them. It is worth noting that absorptive capacity is a function not just of a firm's efforts, but also of the degree to which outside knowledge corresponds to the firm's needs. It is an issue particularly relevant, but not exclusively, to smaller firms who lack resources and appropriate skills to identify, search for and internalise knowledge.

Unsurprisingly, multinationals with significant R&D capability find it relatively easier to access the research base. That said, the need for science-based technologies is spreading to more sectors and large companies are looking to their suppliers to play a much greater role in developing new products and processes (OECD, 2005). Many companies who did not previously need to interact with universities and PROs must thus now do so if they are to survive and grow.

This changing type of industrial partner naturally has implications for the third-level institutions that may enter into collaborative arrangements. The engagement that is needed by the smaller, relatively less technologically intensive firms may be less

advanced than that of immediate interest to many academics (Forfás, 2005a).

On the second dimension highlighted by the OECD – the orientation of universities and other public research institutions – there are numerous issues that must be taken into consideration and addressed if collaboration levels are to increase:

- human and financial resources
- prioritisation of industry-academia collaboration on the institute's strategic agenda, e.g. by its leadership
- differing means of recognition in job promotion processes, e.g. publications and patents.

It goes beyond the scope of this particular paper to delve into these issues, suffice to say that linkages can only be built up if both sides are able (and willing) to engage with each other. The issues identified above need to be addressed comprehensively if attempts to foster collaboration are to work. This is consistent with the Irish environment which will be discussed in more detail in chapter 6. Moreover, collaboration is not necessarily right for all companies or all academics. This is worth bearing in mind when considering how much collaboration – and what type – we are seeking to foster in Ireland.

Kaufman and Todtling (2001) make interesting observations about the third factor cited by the OECD in the effectiveness of industry-science relations: the linkages themselves. Reducing the barriers blocking co-operation between industry and science should not try to make all the operating principles of science-linked organisations similar to those of the business sector. Their argument is that adjusting the science system's modes of interpretation, decision rules, objectives and specific communicative standards to those of the business sector eliminates exactly the factor that stimulates innovation: diversity. They call for instruments that will 'bridge' industry and science while respecting the different nature of each. Such bridging involves making one's system understandable and, thus, its output usable for another system.

3.2.3 Role of government

The European Commission (2002) advises that there is neither one best practice example for industry-science relations nor an optimal

level of interaction that can be identified. Nevertheless, it identifies some general principles that state intervention can take into consideration and areas in which it can act to address this market failure.

It advises that high levels of industry-science interaction occur when

- industry demand is high because of the innovation strategies used by the enterprise sector, and due to market incentives to engage in new technologies and apply new scientific knowledge
- there are well-developed incentive schemes in science institutions to engage in industry-science relations including individual remuneration, institutional mission and objectives, administrative and managerial support, balancing with other major objectives of science
- there are special programmes to support SMEs in raising awareness in science, increasing innovation management capabilities and increasing R&D activities
- legislation does not constitute a barrier for interaction
- there are public initiatives to foster industry-science relations (via financial support, information provision, networking through intermediaries, training) on a sufficiently large scale
- S&T policy follows a sufficiently and long-term oriented approach of strengthening industry-academia collaboration, taking into consideration the various channels of knowledge interaction and technology transfer and fostering an overall climate favourable towards industry-science relations.

(European Commission, 2001)

According to the OECD, government policy to foster industry-academia collaboration can be broadly divided into

- 1 framework conditions such as
 - specific regulations, e.g. intellectual property rights
 - education policy
 - labour market policy

- public procurement
 - financial policies
 - regional and urban planning policies
 - competition policy.
- 2 specific support schemes such as
- financial incentives for collaborative research
 - co-operative research centres
 - publicly funded intermediaries
 - thematic research networks
 - promotion of researcher mobility.

(OECD, 2002)

3.2.4 *One type of support scheme: the competence centre*

According to Freeman (1997), the capacity to adapt to major changes in technology has depended historically on the development of a network of scientific and technological institutions, both in the public and private sectors. He believes that strong interaction between technical innovation and institutional innovation is a fundamental feature of contemporary economic development. Kaufman and Todtling (2001) have argued that 'bridging' institutions, as they describe them, must shift their focus from mediation to translation and active linking and to target more explicitly R&D co-operation involving science. They believe that the traditional uni-directional technology transfer function is insufficient and that 'bi-directional exchange of knowledge' should become the main objective. They therefore envisage a role for hybrid organisations, as mentioned earlier. While not underestimating the challenge that this involves, it is seen as one which is sufficiently important to tackle.

The establishment of competence centres, i.e. centres based in the third-level sector that are strongly driven by an industry research agenda, can be seen as one form of effort to take on this challenge. As ways are constantly sought to create competitive advantage, competence centres can respond to this ongoing need to pursue knowledge for use in change and growth (Technopolis, 2004a).

3.2.5 *The national context*

The innovation systems concept has been applied within a national framework because studies have shown that such systems differ significantly between countries depending on their economic structure, knowledge base and institutional specificities (Kaufman and Todtling, 2001). Once differences are understood and taken into account, looking at other national systems can aid policy decisions because advanced industrial countries share a number of characteristics in respect of innovation (OECD, 2005) and suffer from the same underlying market failure.

Nevertheless, in order to determine what governments should do to promote innovation, it is essential to understand the specific systemic context in which a national government intervenes. Otherwise, government policies may either reproduce weaknesses of the national system or introduce mechanisms incompatible with the basic logic of the system (Lundvall, 1992).

International practice I: Sweden

4.1 The Swedish landscape

4.1.1 *The Swedish national innovation system*

The Swedish innovation system is set against a strong socio-economic backdrop:

- a small population (approximately nine million) resulting in a small domestic market
- stable macroeconomic conditions as well as a political and legal framework characterised by a high level of trust
- an extensive digital infrastructure
- a well-educated population open to new technology (early adapters)
- the smallest gender gap in the world
- a world-leading business environment
- a relatively large public sector constituting the basis of the Swedish welfare system
- strong labour unions and business confederations controlled by unionists
- positive attitudes towards labour mobility in the work force.

(European Commission, 2006)

According to the European Commission, the current development of the economy is mainly driven by exports and is demonstrating signs of jobless growth, i.e. wealth creation without raising employment rates.

The government has set itself the following economic priorities for the coming years:

- 1 keep the inflation rate at 2%
- 2 maintain the unemployment rate below 4%

- 3 government net lending to average 2% of GDP
- 4 reduce the amount of sick leave by half between 2002 and 2008.

Framework conditions for R&D and innovation such as general tax structures, labour market structures and public attitudes have all helped to stimulate large-firm capital accumulation and growth in Sweden. Another key strength is the high level of investment in, and use of, ICT (OECD, 2005). The general incentives for starting firms and generating SME growth have been much weaker. It is worth noting that academic researchers, rather than their host institute, hold the intellectual property rights to their work, though this is the subject of some debate at present.

Sweden's national innovation system is among the most impressive in the world. In relation to the size of its population, it invests more resources than any other OECD country on R&D (approximately 4%). It is dominated on one side by a small number of very large multinationals, and on the other by what is – relative to the size of its population – the largest university system in the world (OECD, 2005). By Swedish standards, SMEs only account for a tiny proportion of R&D expenditure yet they compare favourably against international levels.

In terms of industry investment, a small number of large companies within telecommunications, pharmaceuticals and automotive industries accounted for almost 70% of Swedish business R&D investment in 2003. Somewhat worryingly, while their activity grew consistently up to 2001, in 2002 they started to reduce their investment in R&D and, as a percentage of GDP, it stood at 2.95% in 2003 (European Commission, 2005a). In addition, production appears to be gradually re-locating overseas.

With regard to public investment, public R&D financing stands at approximately 1% of GDP, i.e. €2.6bn in 2006, which includes:

- €1.1bn into universities
- €0.5bn to the Ministry of Defence
- €150m to Vinnova (agency responsible for competence centres).

(European Commission, 2006)

4.1.2 Future policy challenges

A prime concern for Swedish policy-makers has been what is labelled the 'Swedish paradox': fluctuating levels of economic growth despite the consistently high levels of R&D investment (European Commission, 2004a). One possible factor, as noted above, is the multinationals that are re-locating production to more competitive areas overseas.

Future innovation policy challenges that need to be addressed include:

- start-up, innovation and growth in knowledge-intensive SMEs
- improved supply, use and mobility of human resources
- a new regime for user-producer public-private partnerships
- increased volume and impact of mission-oriented research
- centres of excellence for research and innovation (that simultaneously attract investments by tech-leading firms and improve start-ups and SME growth).

(OECD, 2005)

In 2004 a strategy for Swedish innovation policy, *Innovative Sweden*, was launched (Swedish Government, 2004). It was accompanied by the formation of the Innovation Policy Council that is intended to be a forum for discussions on innovation policy and is headed by the Minister for Industry.

The government Bill on research, *Research for a Better Life* (Swedish Government, 2005), that followed this sets out R&D priorities and investments for the 2005-8 period. It takes a holistic view of innovation, stating that while R&D is a necessary pre-condition for innovation in Sweden, it will not be sufficient in itself. Further improvements will be brought about through

- increased co-operation between the academic and the business sectors
- changed intellectual property rights for R&D conducted at the universities
- action plans to increase technology transfer and research commercialisation

- increased mobility of the higher educated and skilled personnel
- strategic long-term financing of the industrial institutes.

Collaboration between industry and academia is clearly a continuing priority, although results are mixed. While the business sector is very R&D active (75% of total R&D activity in Sweden is funded by industry), it accounts for less than 6% of funding for research conducted at universities (European Commission, 2006).

In terms of support schemes, public funding of in-company research is an exception (European Commission, 2001). Swedish programmes are primarily aimed at fostering collaboration between industry and academia: focusing on increasing the competence level of research within the universities in potential areas of future interest to companies. This means that Swedish public sector R&D financing has, to date, been heavily focused on curiosity-driven research (increasing the level of mission-oriented research is one of the identified future policy challenges).

Public sector schemes include:

- AIS (research consortia comprising HEIs, research institutes and enterprises)
- TUFF (enhancing absorptive capacity of SMEs and fostering their interaction with HEIs and research institutes)
- Innovation Bridge (launched in 2005 to support high-tech start-ups across the regions)
- competence centres.

(European Commission, 2006)

Policy initiatives aimed at SMEs have traditionally been modest, although it would not be surprising to see a shift in coming years given the growing importance being attached to SMEs and start-ups. Indeed, this can already be seen in the creation of the Innovation Bridge in 2005 and recent discussions on the introduction of preferential public procurement procedures for SMEs to increase their research capability.

4.2 Competence centres

Competence centres are a key element of Swedish public support for industry-academia collaboration. They aim to create excellent academic research environments in which companies participate actively and persistently in order to derive long-term benefits (European Commission, 2002). The importance attached to them by the Swedish government is demonstrated by

- the level of investment in them (approximately €20m per annum by Vinnova, matched by a further €40m split between the universities and enterprise)
- the fact that a fresh round of centres (branded as VINN excellence centres) has recently been initiated.

4.2.1 Establishment

Launched in 1995, the successful centres were selected on the basis of

- 1 effect of renewal in the Swedish R&D system (enhancing inter-disciplinarity)
- 2 sufficient academic relevance/a firm scientific base
- 3 direct industrial relevance, participation of a number of companies
- 4 a sustained (5-10 years) concentration of resources at one university
- 5 attractive partners for international collaboration.

There was no thematic prioritisation. With regard to industry participation, written commitments from the relevant companies had to be included in the final proposals submitted to NUTEK (now VINNOVA).

NUTEK had overall responsibility for the design of the programme. In doing this, it drew up what it viewed as the ten key characteristics of a successful competence centre:

- 1 offers commerce an attractive and concentrated research environment for collaboration, problem-solving and long-term competence development: the centre has a clear home within the contracting University
- 2 has enduring participation from commerce in management, implementation and financing of a

- research programme of common interest and attracts resources from industrial partners of at least the same extent as NUTEK's financing (now VINNOVA's role)
- 3 has a clear competence profile within which the centre is internationally competitive and capable of adapting and reinforcing this having regard to the needs of interested parties and technological-scientific development
 - 4 renews and extends its scope of interests within commerce (including SMEs)
 - 5 is well anchored within the university and the university's own work in the form of base organisation and other resources in order for the activities of the centre to increase successively
 - 6 is characterised by mutual person mobility between the university and corporate R&D environments by
 - i research students and researchers within the university conducting research in active collaboration with and within enterprises
 - ii R&D staff from the enterprise are active within the centre's university environment
 - 7 collaborates with the university's basic and research education work
 - 8 has increased external funding for activities that reinforce the centre's competence profile and base
 - 9 achieves results that enterprise may use and that lead to scientific qualifications
 - 10 collaborates with other research groups and has an increasing element of international research collaboration in line with the industrial partners' wishes.

(VINNOVA, 2005)

There was intense competition in response to the initial call for proposals. Only 10% of applicants were funded following review by panels of over 40 national and international experts.

4.2.2 Operation

The 28 centres supported (for details please refer to Appendix B) each enjoy a network of somewhere between 60 and 100 individuals, with an average of 6 research groups and 11 research

partners. Each centre implements a research programme in which there can be between 5 and 15 research projects underway. Senior staff are employed by the centre and PhD students can undertake their study there. Of the approximate 250 industrial partners, somewhere between 20% and 30% are SMEs. Technology areas include energy, environmental technology and IT.

Clear (yet somewhat flexible) guidelines for governance of the centres were laid down through a principal agreement that had to be signed by all partners covering issues such as

- organisation
- operations and operating plan
- financing
- exit mechanisms
- reporting, evaluation and audit
- dispute resolution.

Under this agreement (which is re-visited in phased stages in line with the evaluation process), each centre is managed within a university and is normally connected to a department that acts as its host and provides administrative support (thus a competence centre is not a legal entity on its own). Under the agreement, the centre must have its own accounting system and be governed by a board. The university in consultation with VINNOVA and the industrial partners appoints the chairman and other board members (De Jager et al, 2002). In the majority of centres, the chairman and most board members come from industry. In addition, most centres have appointed an international advisory board. A centre director, who is appointed by and employed at the university, manages the centre. There have been efforts to support the centre directors with handbooks and training courses.

Also under the principal agreement, the centre partners decide on the rules for industrial partners' contributions. This is usually a central part of the discussions when the research programme for the next stage is being formalised. Overall funding for the centres is split equally three ways between VINNOVA (or in some cases STEM, the Swedish energy agency), the university and the industrial partners. VINNOVA/STEM provides up to €0.7m per centre per annum, with a view to supporting the centres for up to 10 years (De Jager et al, 2002). Their contribution is approved on a

staged basis, in line with the regular evaluations. The overall combined budget from the three partners for each centre is therefore approximately €2.1m.

VINNOVA manages the centre programme in co-operation with STEM. It is organised on a matrix basis with a small central management group for co-ordination and policy issues and about 15 programme managers for the different technology areas.

4.2.3 *Evaluation*

The evaluations of each of the centres have been based on NUTEK's 10 success criteria (listed above) and have taken place at the 2, 5 and 8-year marks. The first focused mainly on establishment and management of the centres. The next concentrated on scientific and industrial 'performance' while the last continued this focus and also considered the centres' ability to sustain themselves after 10 years of funding. One centre was closed based on the outcome of the first evaluation but, for the most part, the evaluations were primarily used as a means for learning and feedback. This was facilitated by the fact that a core group of international 'generalists' have taken part in all three evaluation rounds so they were able to follow up on what had happened in the light of their recommendations.

Technopolis conducted an overall impact assessment of the programme in 2004 (Technopolis, 2004a). Going through the rounds of evaluations, Technopolis concluded that substantial progress could be seen between the fifth and eighth years when the performance of many of the centres shifted from being 'adequate' to 'very good', demonstrating the need for long-term support for this type of initiative.

Other interesting conclusions reached by Technopolis included the following.

- Participating **companies preferred competence centres** to other types of collaborative arrangements with academia because: they give better access to academic networks; they provide greater access to knowledge from other companies; they train PhDs who are more quickly useful to industry; they produce results that are more immediately usable in R&D and production.
- **Industry participation** at both board level and project level is essential to minimising 'mission drift' into topics

that are of less interest to firms. There has been a rising trend in industrial participation through the life of the competence centre programme.

- The **SMEs** involved are typically either small, young, high-tech firms or, in a smaller number of cases, forward-looking but less technologically capable. Technopolis found that the main surprise about their participation in centres was the similarity of their interests to those of larger companies, e.g. to gain access to people with doctorates in research fields relevant to them, to obtain important research results. Key differences identified were that they are more concerned than bigger firms about building up university links. They also care more about the cost of R&D and are thus more attracted to competence centres as a means to control those costs. Building up their own R&D capacity through the centres is also more important to them.
- With regard to the **universities**, the centres have provided a new opportunity to learn new ways in which to manage research. They are also an important source of new relationships and allow academics working in industry-relevant fields to pursue typical university research goals.
- While strongly emphasising the dangers inherent in estimation of the programme's **monetary value**, Technopolis estimated crudely the ten-year return at €540m.
- The most important impact of the state's investment was on the **people**: the centres typically include a significant proportion of PhD education, producing PhDs who are more used to, and interested in, working with industrial problems than many, and who are more quickly absorbed into companies.
- Overall, Technopolis identified five important **outputs** from the centres:
 - 1 knowledge, both that directly useful in design and development and more fundamental understanding beneficial to Swedish industry in the longer term
 - 2 research-trained people, particularly adapted to working in industry

- 3 extended networks of people and organisations that work with a common set of knowledge in universities and industry
- 4 direct inputs to innovation generating money and employment
- 5 increased attractiveness of the Swedish innovation infrastructure, influencing the location of R&D and production for certain firms.

As the 10-year funding period finishes, the 23 centres that have been supported by VINNOVA will receive no further aid, while those funded by STEM will have some level of financial support over the next 4 to 8 years.

Sweden continues to be committed to the competence centre model as is evidenced in their next generation launch: the VINN Excellence Centres for which there will be approximately €160m available for 25 new centres over a period of 10 years. Almost all the academic and industrial partners in the previously funded centres are applying again for support under this programme. The centres are being established through 3 consecutive calls over the 2004 to 2007 period. The first 4 centres selected (within the working life and transport research areas) are in their start-up phase. The second call resulted in the selection of 15 new centres in June 2006 and, finally, it is envisaged that a third call for 6 more centres will take place.

International practice II: Austria

5.1 The Austrian landscape

Austria also presents its own paradox: high levels of growth (albeit slowing recently) and living standards despite historically low levels of investment, relative to its GDP, in R&D.

5.1.1 *The Austrian innovation system*

Austrian economic growth has fallen behind fast-growing smaller European economies that have been investing consistently in growth drivers. While in the 1980s Austria's GDP per capita growth rate was in line with other small high-income European countries, it has performed less favourably since the second half of the 1990s (OECD, 2004a).

Up to recently, Austrian industry has been concentrated in several 'traditional' areas of technology such as construction, lighting and heating. This corresponds to relatively less focus on high-tech areas such as instruments, electronics and communications (OECD, 2005). There are significant numbers of firms, many of them SMEs, operating in niche markets with strong competitive positions. However, only a relatively small number of research-intensive enterprises are seen to be capable of 'breakthrough' technological innovation (OECD, 2004a).

Efforts are currently underway to increase the level of higher-tech industrial activity. In tandem with its entry to the European Union, Austria's R&D investment levels increased significantly, reaching 2.37% of GDP in 2003 (European Commission, 2005a). In recognition of the need to shift from physical capital formation to greater knowledge investment, the government aims to drive this to 2.5% by the end of 2006, with the use of increased financing for R&D (additional monies were made available through 'exceptional funds' which designated an additional €1.1bn over the 2000-2006 period for R&D: European Commission, 2005c).

In the public research sector, the twelve main universities are the primary R&D performers, accounting for nearly 80% of total R&D

expenditure in public science. The University Act 2002 has brought about notable change to the governance of the university system by broadening the degree of autonomy enjoyed by the universities. Other public research organisations include the polytechnics, which were established in 1994 as an alternative to classical university education, and a range of public sector research establishments (PSREs).

Overall, the extent of industry-science linkages has been low, as demonstrated by the low share of funding of higher education R&D by the business enterprise sector (OECD, 2004a). In its 2001 study, the European Commission concluded that the most prevalent form of industry-science linkages was graduate employment. It found that contract research was more important to PSREs than universities (though this may have moved since). It also found that researcher mobility is relatively low in Austria, and what does take place is due to informal linkages. Evidence of low activity has led to government initiatives to foster greater collaboration (discussed in more detail below).

5.1.2 Recent policy developments

Over the last ten years, changes have taken place that may deliver a longer-term impact on industry-academia collaboration:

- 1 the performance and international competitiveness of the science base have improved
- 2 there has been a considerable structural change in R&D expenditure by industries, away from sectors characterised by incremental innovations towards those implementing more science-based innovations
- 3 innovating firms are co-operating more with higher education institutes.

(OECD, 2004a)

With regard to framework conditions, a notable feature of the Austrian system is its generous fiscal incentives for R&D. In other areas, its venture capital market and competition policy have both been criticised as weak (OECD, 2005).

Support for industrial clusters has been a key tool in Austrian regional development especially in regions where traditional industry seemed to be eroding, for example the automotive clusters in Styria and Upper Austria. The decision as to which technologies

should be the thematic centre of a cluster was usually based on the strengths of the regional economy (European Commission, 2005c).

In 2000, innovation policy and governance in Austria underwent a transformation with the re-organisation of ministry responsibilities and affiliation of research promotion agencies. One of the major developments was the establishment of a Council for Research and Technology Development to advise all ministries involved in science and R&D and to comment on all major projects before a final decision is taken (European Commission, 2004b). In 2002, the Council published its *National Research and Innovation Plan* in which efforts to strengthen industry-academia linkages are a theme throughout. The plan assessed key indicators and looked at the institutional system. Based on this, proposals were made for achieving the national 2.5% target (Austrian Council for Research and Technology Development, 2002).

In December 2003, the Council presented follow-up recommendations (with implications for funding allocations). It recommended prioritisation of the following issues:

- support for human resources
- extension of co-operation between science and economy
- extension of research capacities in science
- enhanced internationalisation
- dialogue between science and society.

There are a number of initiatives operating in Austria to tackle these issues, including:

PROKISO4	Started in 2004 to improve the ability of research institutions to collaborate, especially when supporting SMEs in innovative projects.
Protec 2002+	Programme for technology transfer including network building and innovation management training.
AplusB	Aims to increase the number of innovative technology-oriented spin-offs from the academic sector.
Christian Doppler	Through a network of research laboratories, the CDG provides affiliated companies with early

	and direct access to new scientific and technical knowledge.
REGplus	Supports technology centres, competence building and networking activities in the regions.
Kplus and Kind/ Knet	See below.

A number of these initiatives are relatively new and the range of initiatives now in operation has led to calls for a consolidation of existing structures. Some institutional progress was made on this with the creation of FFG (Austrian research promotion agency) and AWS (Austrian Economic Services Ltd) to amalgamate previous bodies. Accompanying simplification of promotion schemes could help actors such as SMEs to access support (European Commission, 2005c).

5.2 Competence centres

Like Sweden, competence centres are a significant element in Austria's support for collaborative activity. There are two types of competence centre in Austria: the Kplus centre and the Kind centre. The former is the one usually put forward as Austria's competence centre model (although some examination of the Kind centres may help to inform Irish developments).

5.2.1 Establishment

First piloted in 1998, the Kplus centres fall within the remit of the Ministry for Transport, Innovation and Technology. Their objectives include:

- development of co-operation between science and industry
- more efficient use of existing competences and resources
- stimulation of pre-competitive R&D co-operation
- performing long-term research programmes
- pronounced strategic orientation of research
- improving Austria's quality as a business and scientific location
- generation of competences and critical masses at national level

- improved integration of Austria in international research initiatives
 - development of human resources.
- (Forschungszentrum Telekommunikation Wien, 2004)

Before the start of the Kplus programme, an ex ante evaluation took place. This comprised an examination of the status quo and a needs analysis, a study of the most important models and the definition of the key parameters of the programme. The approach taken included expert interviews, workshops, a steering group, in-depth studies of successful foreign models and a project report by the then Ministry of Science and Transport – now the Ministry of Transport, Innovation and Technology (Ohler and Stampfer, 1999).

The Kplus centres were chosen through a competitive process, an important new departure for Austrian funding schemes (European Commission, 2002). There was no pre-selection of technological/scientific areas.

There are eighteen centres (for more details please refer to appendix C) that were selected through three calls for tender. Each call comprised a two-step process and applications were judged on their

- scientific and technological quality
- ability to ‘cluster’ existing scientific and economic competence into critical masses
- estimated economic benefit for Austrian companies
- quality of their business plans.

As well as Austrian scrutiny, those proposals reaching the second stage were examined by six international auditors and considered by a visiting committee. An independent jury then drew up a ranking based on the results and made recommendations on which centres were to be funded. These recommendations were subject to the approval of the Minister for Transport, Innovation and Technology.

5.2.2 Operation

Each centre is tailored to meet the particular needs of the partners involved and it is important to recognise that they vary significantly to reflect the technology area (as is also the case in Sweden). Nevertheless, there are some general characteristics:

- €2-4m total budget per centre per annum
- 5-15 leading scientific staff
- 20-40 scientific staff (FTE)
- minimum 5 companies
- 7 year funding period (4+3 years).

The general guideline for starting out is that a centre should commence operations with at least 3-7 key people, 10-20 scientific/technical personnel as well as the management and administration function. They usually reach full capacity after 2 to 3 years (FFG, 2005).

In total, collaborative research is currently underway with about 270 industrial partners (of which up about 25-30% are SMEs) and 150 partners from the research sector.

On the matter of finance, a Kplus centre may receive public funding for up to 7 years. Once approved, it receives funding for 4 years. During the fourth year, the centre undergoes a mid-term evaluation that will determine whether or not it receives funding for a further 3 years. FFG provides c. 35% of funding, other public sponsors 20%, industry 40% and the research institutions 5%. A maximum of 50% of the contributions by partners may be provided in kind (OECD, 2004a).

There is a standard funding contract between FFG and the centres in addition to a centre-specific general agreement between all partners (including the funding organisations). The latter is the 'constitution' of the centre and includes all general rules. After an initial phase during which the partners can organise themselves as an association, they are expected to set up a limited company. Centres are mostly free to define their internal relations themselves.

With regard to intellectual property rights, in the case of basic research they belong to the centre and each partner has the right to use the results. The same goes for industrial research with partner companies. For those, the participating company must define an area of interest for each project. Within this it may give sub-licences to connected companies. Outside this area of interest of the partner companies, the centre may use the results for further research, also with third parties (OECD, 2004a).

The centres are regularly monitored by way of annual reports to FFG. The mid-term evaluation mentioned earlier looks at the results of the research in the first period as well as at plans for years

5 to 7. It will determine whether funding for the remaining 3 years is to be approved and, if appropriate, certain conditions are to be applied.

Managed by the Ministry of Economic Affairs and Labour, Kind centres are more industry-driven than their Kplus counterparts.

Aim	Building upon existing networks of enterprises with similar R&D interests, the aim is to concentrate the R&D activities of a number of enterprises and research institutions working in the same field. This is intended to build up and develop application-oriented technical expertise which can then be disseminated to existing and new companies.
Participants	All research institutions and industrial enterprises with their own R&D departments may participate. SMEs without their own R&D capability may become involved as 'associate' partners at the level of individual projects.
Funding	As with the Kplus centres, funding is allocated on a 4+3 year basis. Grants are provided up to a maximum of 60% of total (eligible) costs. Enterprises must assume at least 40% of the costs.
Agreement	The co-operation agreement may take various forms, ranging from relatively loose associations to the establishment of a limited company. In practice, the majority of them take the latter form.
Activities	Joint R&D.
IPR	No standard regulations. IPR issues are addressed on an ad hoc basis in side letters or articles of association.
Evaluation	A standardised procedure was put in place in 2002 based on experiences in evaluation of Kplus. (European Commission, 2001; OECD, 2004a)

The Ministry also operates Knet: a related networking initiative to co-ordinate geographically dispersed research competences that possess similar themes. There are currently 17 Kind/Knet activities in operation (OECD, 2004a).

The Kplus and Kind/Knet programmes were established more or less simultaneously, both with intentions to

- raise R&D expenditure
- accelerate innovation
- alter 'R&D culture'.

At the same time, there are notable differences between the programmes – not in their main goals – but rather in their research emphasis and implementation procedures, i.e. the degree of formalisation of such procedures, the organisation of the selection process, the role of evaluation and the balance of power in internal relations.

- While Kplus centres are primarily knowledge-driven and the programme itself is based on highly structured, formalised processes of decision-making, Kind/Knet is mainly industry-driven and in many respects much less formalised.
- Kind/Knet has the stimulation of private R&D as a key aim, while Kplus puts stronger emphasis on additionality in both the private and public sectors.
- Kplus seeks to promote excellence in research, while the Kind/Knet programme focuses more on the combination of (existing) capacities and technology transfer.
- Kind/Knet includes virtual centres/networks, while the Kplus programme requires that the majority of researchers are assembled at one physical location.
- A major goal of Kind/Knet is the creation and establishment of industrial/ technological clusters. In this context, Kind/Knet takes local conditions into account and therefore has a stronger regional dimension than Kplus.

(OECD, 2004a)

5.2.3 *Evaluation*

The Austrian Institute for SME Research and the Fraunhofer Institute for Systems and Innovation Research carried out an assessment of the Kplus and Kind/Knet programmes in early 2004. The main findings were the following.

- The programmes share a similar basic understanding of the role of the state in competence centre programmes: impulse generator (in establishing centre); enabler (financing joint R&D activities in the centre); moderator; and controller.
- They provided answers to obvious problems in the Austrian innovation system in the late 1990s with systematic approaches.
- The funding for the Kplus programme seemed justified by the orientation, the stringent programme design and the concept realisation. The development of a new co-operative culture was seen as one of the main successes of the programme.
- With the Kind/Knet initiatives, the Ministry of Economic Affairs and Labour succeeded in bundling industry-oriented research capacities and activities and achieving concrete results from research co-operation. However, it also found that the initiatives had some weaknesses in design and implementation. Among these was the insufficient change culture within academic research and industry and the fact that the benefits are mainly going to a limited number of large enterprises who dominate the centres and the networks.
- It was recommended that both programmes continue their work with some improvements. The Kplus programmes should remain unambiguously science-driven while the Kind/Knet programme should be unambiguously innovation-driven.

(European Commission, 2005c).

Around the same time, the OECD also recommended that future support for the K programmes should

- maintain the demand from, and commitment of, industry
- preserve the contribution that the K programmes make to the efficiency of the overall funding system in Austria by adding to its flexibility
- question the 'one size fits all' approach to financing
- ensure that the portfolio of centres will be managed in a

way which gives due consideration to the need to scale up promising centres and to emphasise more interdisciplinary research when consolidating existing centres or creating new ones

- improve their interfaces with European programmes and regional innovation policy, especially cluster initiatives.

(OECD, 2004a)

OECD also concluded that there is no compelling need to run the Kplus and Kind/Knet programmes separately. Indeed, 'it is hardly conceivable that there would have been two programmes if competencies in S&T policy were concentrated in one ministry'.

Planning for a new round of competence centre investments in Austria is currently underway.

6

Ireland

6.1 Irish economic performance and policy development

6.1.1 The health of the economy

When economic historians come to tell the story of the Celtic Tiger, they will not treat it as a single, cohesive era. Not one, but two such animals roamed our land in those times, they will say ... As globalisation intensifies, the challenge for our economy is to re-discover the lean and agile qualities of the 1990s. More Tiger, less Garfield.

Marc Coleman, *The Irish Times*, 4 November 2005

Ireland's economic health has witnessed nothing short of a phenomenal turnaround since the start of the 1990s. From a position of high unemployment and relatively low levels of GNP per capita, we have moved to quite the opposite.

	1994	2003	2004
GNP	€41.7bn	€111.7bn	€122.6bn
GNP per capita	€11,640	€28,065	€30,305
GNP growth	6.3%	2.8%	5.5%
Population	3.6m	4.0m	4.0m
Labour force	1.4m	1.9m	2.0m
Unemployment	14.7%	4.7%	4.5%
Inflation	2.4%	3.5%	2.2%
Balance of payments	€1.3bn	-€1.9bn	-€0.6bn
- as % of GDP	2.7%	-1.4%	-0.4%

(Central Bank, 2005)

The Enterprise Strategy Group (2004) highlighted a number of reasons for this economic transformation, including the following:

- membership of the European Union enabled Ireland to benefit from significant regional aid and access to sizeable markets
- consistent long-term partnership and policies created a favourable corporate tax, fiscal and wage-setting environment and a well-qualified workforce
- global trade expanded at an exponential rate; in particular, sectors such as ICT and life sciences grew rapidly through the latter half of the last decade
- Ireland's demographic profile facilitated the fast pace of economic growth.

In its review of industrial policy, the Enterprise Strategy Group also noted that a range of challenges now face Ireland as it tries to remain competitive and to continue to grow in an ever-changing international environment:

- the phenomenal scale of globalisation and the competition it presents in the form of countries such as India and China
- the Irish cost base has increased substantially
- Ireland's low corporation tax base is being emulated by competitors
- overall, not many of our indigenous industry sectors have achieved strong growth in exports over the past ten years
- imminent changes in EU state-aid limits will place new restrictions on state aid for enterprise after 2006.

Ireland's current competitive position can be summarised as follows:

Strengths

- existing base of high performing firms and a growing internationally trading services sector
- business friendly operating environment
- membership of the EU and the only English speaking member of Euro zone

Weaknesses

- increasing cost base, particularly for property, utilities and locally traded services
- weak productivity growth in locally trading, mainly services, sectors
- congested transport infrastructure and under-developed ICT infrastructure

*Strengths**Weaknesses*

-
- | | |
|---|--|
| <ul style="list-style-type: none"> • an adaptable labour force • an expanding labour force, reflecting both natural demographic growth and immigration • competitive personal and corporate tax rates • an international reputation for flexibility and responsiveness • a culture of openness – to trade, investment, ideas and people. | <ul style="list-style-type: none"> • a small domestic market • limited management expertise in innovation and international sales and marketing • underdeveloped national scientific research system • vulnerability to global demand swings and exchange rate volatility • high dependency on imported fossil fuels. |
|---|--|
-

(National Competitiveness Council, 2007)

In terms of how we deal with these challenges, policy discussions have focused on the need to change radically the economic model through which we deliver growth. Ireland can no longer depend on marketing itself as a low-cost environment for production: our own cost base has grown significantly and other countries have emerged as attractive lower-cost locations for foreign direct investment.

6.1.2 Policy evolution: the drive for knowledge-intensive industrial development

It is thus widely recognised that Ireland needs to find new ways to deliver and sustain economic growth in the future. It is also broadly accepted that the opportunities primarily lie in the development of knowledge-intensive industry here, both in terms of indigenous activity and in what element(s) of foreign direct investment Ireland seeks to attract and embed. It also means greater use of technology in more traditional sectors to improve productivity and competitiveness.

This planned shift will only happen if the national innovation system is radically strengthened: both the actors themselves and the relationships between them (not forgetting also international relationships). This is discussed in some detail in subsequent sections.

Ireland has taken significant steps towards knowledge-intensive industrial development in recent years. While deeper thinking on Irish science, technology and innovation (STI) policy commenced around the 1970s, it was only in 2000 that matters took a decisive turn with the very significant increase in funding for research, technological development and innovation (RTDI) under the 2000-2006 National Development Plan (NDP). Of the €51.5bn available, an unprecedented €2.48bn was allocated to RTDI (€0.5bn was provided for it under the 1994-1999 Plan). Within this, the NDP's objectives included:

- strengthening the research capability in the third-level education and state research institutes to meet the RTDI and skills needs of the economy
- increasing RTDI linkages between institutions and companies
- helping companies to develop innovative products, services and processes
- encouraging firms to access and exploit international sources of R&D and technology.

(Government of Ireland, 1999)

The importance being attached to R&D and innovation was again picked up in the 2004 review of industrial development policy undertaken by the Enterprise Strategy Group which identified two key priorities for Irish growth:

- 1 developing expertise in international markets, to promote sales growth
- 2 building technological and applied R&D capability, to support the development of high-value products and services.

In the same year, further focus was directed at the issue of R&D and its contribution in Ireland's economy. In addition to the work of the Enterprise Strategy Group, what is commonly referred to as Ireland's R&D Action Plan (*Building Ireland's Knowledge Economy: the Irish Action Plan for Promoting Investment in R&D to 2010*) was published. This report to the Inter Departmental Committee for Science, Technology and Innovation was the output of a high-level

steering group, established by then Tánaiste Mary Harney, to determine the implications of policy initiatives at European level for Ireland and to identify actions required to develop Ireland as a knowledge economy.

The report put forward the following vision: 'Ireland by 2010 will be internationally recognised for the excellence of its research and be at the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture'. To realise this, it set a range of targets and identified outline actions necessary to achieve these.

At the same time, new governance structures were created to strengthen the oversight and review framework for national STI policy. These new structures include:

- establishment of a cabinet sub-committee on STI
- establishment of an inter-departmental committee (IDC) on STI of senior officials to support the cabinet sub-committee
- appointment of a chief science adviser (CSA) to government
- establishment of the Advisory Science Council to act as the primary interface between stakeholders and policymakers in the STI arena.

Building on the R&D Action Plan and other developments above, the pivotal national Strategy for Science, Technology and Innovation 2006-2013 was launched recently. The Strategy for STI (Government of Ireland, 2006) highlights a number of key priorities to transform Ireland's research base into a competitive advantage:

- increased participation in the sciences by young people
- significant increase in the numbers of people with advanced qualifications in science and engineering
- enhanced contribution of research to economic and social development across all relevant areas of public policy including agriculture, health, environment and the marine and natural resources
- transformational change in the quality and quantity of research undertaken by enterprise – both directly and in co-operation with third-level institutions

- increased output of economically relevant knowledge, know-how and patents from those institutions
- increased participation in international S&T co-operation and transnational research activity
- an established international profile for Ireland as a premier location for carrying out world-class research and development
- greater coherence and exploitation of synergies to mutual advantage in the developing of STI policy on the island of Ireland.

The IDC for STI, reporting to the cabinet sub-committee, has overall responsibility for the implementation of the Strategy, for which total planned spend over the period to 2013 is in the region of €8.75bn. In addition to the inputs of the Advisory Science Council and the chief science advisor, it is supported by two implementation groups composed of representatives from the relevant departments and related agencies. The Higher Education Research Group is responsible for ensuring coherence among key funding initiatives such as PRTL and the funding awards schemes of the relevant agencies and councils. Technology Ireland is responsible for enterprise R&D activity and collaborative initiatives. The IDC and implementation groups will be backed up by a joint secretariat comprised of representatives from the Department of Enterprise, Trade and Employment, the Department of Education and Science, Forfás and the Higher Education Authority.

The Strategy for STI is reflected in the 2007-2013 National Development Plan with its objective under the Enterprise, Science and Innovation Priority to 'fully implement the Strategy for Science, Technology and Innovation in the period to 2013, thereby achieving a transformational change in the quantity and quality of research and enhancing the contribution of research to economic and social development and increasing the numbers of people with advanced qualifications' (Government of Ireland, 2007).

6.2 The Irish national innovation system

6.2.1 Overview of current R&D performance

National innovation systems are often crudely measured by the level of investment in R&D. In Ireland, progress has been made in

increasing gross expenditure on R&D (GERD) in recent years.

In 2006, GERD in Ireland stood at an estimated €2.3bn (1.56% of GNP), up from 1.48% in 2004 (Forfás, 2007a). Nevertheless, some distance remains between us and international comparators.

*GERD as % of GDP/GNP: Ireland and international comparators
1998-2006*

	1998	2002	2004	2006
OECD	2.15%	2.24%	2.25%	2.26%*
EU 25	1.7%	1.79%	1.77%	1.77%*
Sweden				3.86%
GERD/GNP Ireland	1.41%	1.36%	1.48%	1.56%
GERD/GDP Ireland	1.24%	1.11%	1.25%	1.34%

(Forfás, 2007a)

* (Figures are for 2004/5)

During the same time, the public sector was an increasing source of funding for GERD.

Funding sources of GERD in Ireland 2000-2006

	2000	2006
% GERD financed by industry	71.7%	65.5%
% GERD financed by public sector (including EU)	26.9%	32.8%
% GERD financed by other sources	1.4%	1.7%

(Forfás, 2007a)

The latest figures released show that business expenditure on R&D (BERD) rose to €1.33bn in 2005, representing an average annual increase of 9.7% between 2003 and 2005. Preliminary estimates for 2006 indicate further growth to €1.56bn. As a ratio of GNP, it increased to 0.95% and is estimated at 1.05% in 2006 (Forfás, 2007b).

In 2004, expenditure on R&D in the higher education sector (HERD) continued its steady upward trend to €492m, up 0.1% of GNP on 2002. This moves us much closer to international averages.

*HERD as % of GDP/GNP: Ireland and international comparators
1994-2004*

	1994	1998	2002	2004
OECD	0.37	0.37	0.41	0.43
EU-25	0.36	0.37	0.41	0.43
Sweden				0.83
Austria				0.57
HERD/GNP Ireland	0.29	0.3	0.3	0.4
HERD/GDP Ireland	0.26	0.26	0.25	0.33

(Forfás, 2005b)

Government intramural expenditure increased to €169m in 2006 (0.11% of GNP), well below the EU-25 and OECD averages of 0.27% and 0.24% respectively (Forfás, 2007a).

In terms of researchers (FTE) per 1,000 total employment, Ireland grew from 5.7 to 6.0 between 2004 and 2006. Most R&D personnel (researchers plus support staff) were employed in business (62%), with 31% in the third-level sector and 8% in the public sector (Forfás, 2007a).

6.2.2 Features of the system

The diagram featured in Section 3.1.1 provides a useful framework to consider the main features of the Irish national innovation system.

The following three subsections consider Ireland's innovation system today with regard to

- framework conditions
- industry in Ireland
- the higher education sector.

In the subsequent section, the current status of collaborative relations between industry and higher education and the role that the state has played are explored.

6.2.2.1 A favourable framework environment

As noted in chapter 2, a conducive environment is essential for greater levels of R&D activity and collaboration between actors. Ireland's track record in this regard is mixed. Its strong economic performance in recent times is a result of a number of positive factors including:

- taxation
- a strong entrepreneurial culture: we rank second in the EU and seventh among OECD countries for entrepreneurial activity
- labour market regulations are perceived to facilitate business activity
- openness to trade and investment.

(National Competitiveness Council, 2005)

Challenges can be seen in issues such as

- infrastructure: despite recent high levels of investment, transport infrastructure is under strain
- non-pay business costs (National Competitiveness Council, 2007)
- the structure of indigenous industry: many small firms, few medium to large-sized ones
- the youth of the research system in Ireland.

While always cognisant of the crucial contribution of framework conditions, the OECD cites three primary factors in the effectiveness of industry-science relations:

- the need of business firms for the outputs of the research base and their ability to absorb and exploit them
- the orientation of universities and PROs to the needs of business
- the links between universities/PROs and business firms.

(OECD, 2005)

6.2.2.2 Industry in Ireland

In 2003, there were nearly 9,000 agency-supported firms in Ireland in manufacturing and internationally traded services. Employment and direct expenditure in the economy were fairly evenly split between indigenous and foreign-owned yet their average size and turnover levels were very different, as demonstrated in the following figures.

Agency-supported firms in manufacturing and internationally traded services, 2003

	<i>Total</i>	<i>Indigenous</i>	<i>Foreign-owned</i>
Number of firms	8,663	7,390	1,273
Number of full-time employees	297,549	147,895	149,654
Average number of employees	34	20	118
Sales (€m) (2002)	99,341	23,588	75,753
Direct expenditure in the economy (payroll, procurement of Irish raw materials and services, €m) (2002)	34,170	16,677	17,493
Exports (€m) (2002)	78,803	8,785	70,018

(Enterprise Strategy Group, 2004)

While many of the multinationals are in high-value sectors (increasingly concentrated in chemicals/pharmaceuticals and the computer/electronics sector), their operations here are strongly production-oriented.

Over 80% of the €1.33bn in BERD in 2005 was concentrated in four sectors:

- software/computer related (31%)
- electrical/electronic equipment (21%)
- pharmaceuticals (20%)
- instruments (9%).

And a further 9% was split between Food, Drink & Tobacco and other services (Forfás, 2007b).

With regard to ownership, indigenous industry rose to €390m invested by 1,025 firms, representing 29.4% of total BERD. R&D expenditure by 345 foreign-owned firms increased to €939m, i.e. 70.6% of total BERD in 2005.

Number of R&D-active firms by ownership, 1995-2005

<i>R&D Active</i>	<i>1995</i>	<i>1999</i>	<i>2001</i>	<i>2003</i>	<i>2005</i>
Irish-owned	806	905	978	873	1025
Foreign-owned	363	248	286	252	345
Total	1169	1153	1264	1125	1370

(Forfás, 2007b)

When it comes to devising appropriate state supports, perhaps the critical split is along the lines of companies' varying stages of development (to be discussed further in Section 7.1.3). In general, SMEs face a range of obstacles to development, including scale, management capability, productivity levels and international experience. Larger firms, while obviously more developed, encounter ongoing challenges such as competitiveness and success in international markets.

The future of industry in Ireland

Looking ahead, suggestions have been put forward regarding areas with overall potential for industrial development in Ireland.

High-value manufacturing:

<i>Sector</i>	<i>Sub-sectors/activities</i>
Pharmaceutical/ biotechnology	Process development Ethical pharmaceuticals Bio-pharmaceuticals
Food	Prepared consumer foods Functional foods Food ingredients Speciality foods

ICT	Supply chain management, hardware and systems Software development Infocomms – eLearning, wireless, digital media Integrated circuit design Customer technical support
Medical technologies	Cardiovascular – cardio-rhythm management
Diagnostics Engineering	Proprietary products in niche areas such as automotives and telematics
Consumer goods	High-margin goods, enhanced by use of strategic design

Services:

Sectors	Education, financial services, healthcare, tourism, creative services, maritime services, aviation, professional and consultancy services, agricultural and bloodstock services.
Activities	European headquarters, franchising, intellectual property, sales and marketing, shared and outsourced business processes, supply chain management, services delivered electronically, e.g. data management.

(Enterprise Strategy Group, 2004)

Further analysis/development of these areas would help inform policy making and investment decisions (this will be discussed further in Section 7.1).

Under the Strategy for STI, clear targets have been set for the numbers of firms in Ireland involved in R&D activity and for their level of spend over the period to 2013.

	2003	2013
Business investment in R&D (constant prices)	€1.076bn	€2.5bn
Indigenous firms with meaningful R&D activity (> €100,000)	462	1050
Indigenous firms with significant R&D (>€2m)	21	100
Foreign affiliate companies with meaningful R&D activity	213	520
Foreign affiliate companies with significant R&D activity	60	150

(Government of Ireland, 2006)

6.2.2.3 The higher education sector

The higher education sector in Ireland primarily comprises seven universities and fourteen Institutes of Technology. In 2004, expenditure on higher education R&D increased to €492m, up 0.1% of GNP on 2002, the majority of which was performed by the universities.

Research expenditure by performer (1998-2004), current prices (€m)

<i>Higher education institution</i>	1998	2000	2002	2004	<i>% change 2002–2004</i>
Institutes of Technology	13.49	23.98	25.27	30.4	20.3%
Universities	169.2	191.64	286.7	461.3	61%

(Source: Forfás, 2005b)

Share of total higher education R&D expenditure by field of science, 2004

Natural sciences	39%
Medical sciences	18%
Engineering	17%
Social sciences	17%
Humanities	8%
Agricultural sciences	2%

(Forfás, 2005b)

The two primary funders of research activity in the third-level sector are the Higher Education Authority (HEA) through the Programme for Third-Level Research in Ireland (PRTLTI) and Science Foundation Ireland (SFI).

The PRTLTI was launched in 1998 and provides integrated financial support for institutional strategies, programmes and infrastructure. It aims to ensure that institutions have the capacity and incentives to formulate and implement research strategies that will give them critical mass and world-level capacity in key areas of research (www.heai.ie). It has invested €605m under its first three cycles (details of the 47 projects are summarised in Appendix E). The fourth cycle is currently in the process of evaluating proposals and a budget of €190m is to be provided for investment over the period 2007-2010.

SFI was established in 2000 to support research in areas of strategic importance to Ireland. It was allocated €646m under the NDP 2000-2006 and funding is granted competitively (with research excellence as the primary criterion) to researchers working in the fields of biotechnology and information and communications technology. By June 2006, approximately €622m had been invested in these broad areas.

An international panel, reporting on SFI in 2005, identified the growing need to provide greater support to the mission of linking more firms into the research base: 'The panel is aware of the gap in the Irish research support system related to applied research which was identified by the Enterprise Strategy Group. This gap makes it more difficult to link industry, particularly SMEs, to the research funded through SFI. The panel supports the suggestion of establishing "competence centres" in research and innovation which would be closely tied to industry needs and which would help to strengthen industry links to SFI' (Forfás, 2005c).

Other funders of research in higher education institutions include Enterprise Ireland, the Irish Research Council for Science, Engineering and Technology, the Irish Research Council for Humanities and Social Sciences and the Health Research Board.

Future developments

The Irish academic research landscape has undergone dramatic changes over the last number of years as is evidenced in the closing gap with international averages and in evaluations.

Doubling the number of PhDs over the forthcoming period, as recommended by the OECD (OECD, 2004b) and targeted in the Strategy for STI (Government of Ireland, 2006), is central to the future success of Ireland as a knowledge society. Progress on sustainable career structures for academic researchers would help this pursuit. Identification of areas where postgraduate numbers should be grown is also important in this context.

In parallel with skills enhancement, the management and use of intellectual property will require significant strengthening. The technology transfer offices in the colleges are a vital element in the system and will require additional funding, expertise and profile within their institutions and more widely if the state's investment in the research base is to be optimised. The recent launch of a fund with this objective at its heart is welcomed.

At international level, the commencement of the EU's Seventh Framework Programme in 2007 provides further impetus to the development of the research base.

In terms of domestic research partners for industry, one must also take into account research institutes in the public sector. According to the 2004 report to the IDC for STI, the principal R&D performers in this context were Teagasc and the Department of Agriculture and Food (their combined performance accounting for more than half of the total R&D performed in the public sector that year). At the same time, the Department of Communications, Marine and Natural Resources and the Marine Institute are enhancing measures in the marine sector. Relative to other countries, the state sector is engaged in a relatively low level of R&D, standing at 0.11% of GNP in 2006, less than half the EU-25 and OECD averages. This will be important as one looks at suitable partners for Irish enterprise when developing their R&D collaborative activities.

In addition, research undertaken in hospital settings is an emerging important aspect of the national innovation system. Work is currently underway by a number of actors, including the Advisory Science Council, to explore how best this can be supported and leveraged to deliver returns to the economy and society.

6.3 Industry-Academia collaboration

6.3.1 Parameters

Chapter 3 outlined the theoretical case for industry-academia collaboration. There are numerous activities – for example informal networking, consultancy, personnel mobility, collaborative research – in which companies and colleges can engage, that can result in a range of benefits to the innovation system including:

- trained researchers and qualified scientists and engineers
- knowledge
- some discrete technologies
- problem-solving
- research methods
- equipment prototypes.

(OECD, 2005)

While it is hard to quantify the returns on industry-academia collaboration, there is widespread agreement that they are sufficient to warrant greater encouragement and support.

That said, it is important to remember that encouraging firms to collaborate with a higher education institution is not necessarily the appropriate next step in the development of all firms. Many require substantial further strengthening of their internal R&D capabilities before they are in a position to make the most of such interactions. In addition, a clear case needs to be made for the benefits gained from devoting resources to this activity, particularly in the case of smaller companies. If there is not some clear potential gain in it for those getting involved, the appetite for investing time and/or money in engagement naturally lessens.

Similarly on the academic side, active collaboration with industry is not for all. Nevertheless it is a role that third-level institutions, in the light of the growing knowledge intensity of economic development, are being asked to assume more strongly.

Collaborative relationships with other actors are also vital, for example with other firms and internationally. New structures to encourage firms to engage with the third-level sector would do well to take in these dimensions as well.

6.3.2 Current levels of collaborative activity

In 2005, 231 of the total 1,370 R&D-active firms were involved in collaborative R&D work with a higher education institution in Ireland (i.e. 16.9%) and 116 with a higher education institution outside Ireland (i.e. 8.5%) (Forfás, 2007b)³.

With regard to sectoral variations, the instruments and pharmaceutical sectors had the highest degree of collaboration with higher education institutions in Ireland, followed by the electrical/electronic equipment sector.

<i>Sector</i>	<i>%</i>
Instruments	32.7
Pharmaceuticals	27.3
Electrical/Electronics	21.2
Food, Drink & Tobacco	16.5
Other Sectors	13.6
Software/Computing	13.1

(Forfás, 2007b)

The barriers to collaboration in Ireland appear to be pretty much consistent with those cited in the literature. For companies, resources are usually directed to other priorities and their in-house technology capability and strategy do not position academic engagement at the top of the 'to do' list. For colleges, levels of interest in industrial interactions and related resources are limited. Differing cultures, timelines and expectations constitute challenges for all. A number of those consulted in both enterprise and academia highlighted the issue of communication and the importance of building up trust between parties.

In several consultations, the question was raised as to what is the optimal level of collaboration. There is no straightforward formula for this, or at least none that this author could devise. The European Commission (2002) indeed advises that it is not possible to identify an optimal level of interaction.

³ Note: these are not mutually exclusive. The BERD survey questionnaire asked the respondent whether it had engaged in joint research projects with any of the following parties: other firms in Ireland, other firms outside Ireland, higher education or other institutes in Ireland, higher education institutes outside Ireland (and to tick yes or no accordingly).

One potential way of looking at this – which will be discussed in more detail later – is to approach it from the angle of building a clear picture of what companies' needs are at their particular stage of development and their area(s) of focus. This would help to ensure that their needs – whatever they are – are being met. For example, collaboration may not necessarily be about joint R&D projects to be carried out on a college campus, it may concern access to a piece of specialised equipment or the placement of graduates in companies for a specified period of time. Indeed, collaboration with a higher education institution in Ireland may well not be the most suitable action. Depending on the stage the company is at, they could be best served by being supported to link in with other firms or by being introduced to relevant technology acquisition opportunities; in other words in terms of future economic development, industry-academia collaboration is not an end in itself. It is one – significant – means to drive economic progress.

In order to move forward, it would be very helpful to have a more detailed understanding of the level and types of interactions between companies and colleges in Ireland. The work of the Advisory Science Council Taskforce on Industry-Academia Collaboration may help in this regard.

What can be broadly accepted is that greater levels of collaboration could be taking place and that state support should be improved to deliver on this. Between 1998 and 2002, funding of HERD by the business sector fell significantly and remained static between 2002 and 2004, against a backdrop in increases in BERD over the same period.

6.3.3 The role of the state

State activity to date in this area is underpinned by recent policy developments as set out in Section 6.1.2 and will be primarily driven in coming years by the Strategy for STI. As the latter and the latest National Development Plan roll out, enhanced ways to support greater industry-academia collaboration will be explored and tested.

Policy actors

While STI policy is increasingly viewed as a cross-government priority as demonstrated by the co-operation of eight government departments in the development of the Strategy for STI, primary responsibility for it lies with the Office of Science, Technology and

Innovation (OSTI) in the Department of Enterprise, Trade and Employment.

OSTI is advised by Forfás, the national policy advisory board for science and enterprise. Forfás is also the body through which powers are delegated to Enterprise Ireland for the promotion of indigenous industry and to IDA Ireland for the promotion of inward investment. As mentioned above, Science Foundation Ireland (Department of Enterprise, Trade and Employment) and the Higher Education Authority (Department of Education and Science) are pivotal to the building up of the science base in Ireland.

The governance structures created in 2004 and currently being enhanced will be aimed at ensuring coherence and co-ordination in research funding over the period of the Strategy. This will involve maintaining the freedom of government departments and funding agencies to meet their policy objectives, while at the same time reducing the fragmentation of the national innovation system and increasing the productivity and efficiency of research expenditure.

Under the Strategy for STI, Enterprise Ireland, working with IDA Ireland, is charged with the development of competence centres as well as the development of industry-higher education linkages more generally.

Policy initiatives: an evolving landscape

Under the 2000-2006 NDP, support for collaboration between companies and higher education institutes was detailed under the RTDI for Collaboration section of the Industry chapter of the RTDI Priority. In this, €232m in co-financed expenditure (with a contribution of €76m from the ERDF) was earmarked to support

- building partnerships that enhance company capability and competitiveness in firms, particularly SMEs, through collaboration networks nationally
- helping firms, particularly SMEs, to exploit technology effectively by improving access to appropriate technology available internationally.

The measures, administered by Enterprise Ireland, included:

- Innovation Partnerships
- Commercialisation Fund
- Programmes in Advanced Technologies

plus some smaller levels of support for the intellectual property assistance scheme, networking initiatives, technology transfer and international collaboration.

Technopolis undertook an evaluation of this NDP RTDI for the Collaboration chapter in 2004 (Technopolis, 2004b). While there were a number of positives in some of the programmes, overall the consultants concluded that the schemes do not meet the objectives for partnership within the national innovation system. They called for a 'radical re-design' of the programme with differentiated instruments to address the different needs of sub-populations, including a mechanism that links the research sector with active research performers in industry. They see such instruments comprising

- major network schemes (technology programmes, competence centres)
- focused/bilateral schemes
- 'first-time' user linkage schemes
- innovation supports for non-R&D performers.

With regard to the first, the consultants argue that mechanisms are needed to create genuine partnerships among and between companies and HEIs, involving active engagement from multiple participants. These should include supports that foster networking between MNCS and indigenous firms as well as encouraging the development of strong inter-disciplinary environments in the HEIs. They suggest that a competence centre programme may be a useful way to achieve this. It can be adapted to work both at very high levels of technological ambition (Sweden, USA) and at lower ones (Estonia, Hungary). They differentiate competence centres from SFI's CSETs in that they

- are long-term,
- involve industry actively in research projects
- tackle a range of company capabilities
- have goals set by the consortium rather than being academically led.

Technopolis also put forward technology programmes (as employed by Tekes in Finland) as a possible approach. The main

criterion for choosing between the two – competence centres and technology programmes – is the extent to which the university and research institute system already has strong clusters of critical mass in relevant technologies. Competence centres aim to build such mass, while technology programmes are better suited to exploiting them (Technopolis, 2004b).

In reality, public support for industry-science linkages in Ireland today has not been limited to those under the 2000-2006 NDP's RTDI for Collaboration chapter. A number of initiatives (summary details provided in Appendix F) have emerged as state agencies seek to address the increasing need to build linkages between companies and colleges in Ireland.

Their broad objectives could perhaps be summarised as efforts to

- 1 build industry-relevant research competence, and/or
- 2 help more firms to access and apply research competence in Ireland.

They include centres such as

- the Tyndall Institute (Cork)
- Centres for Science, Technology and Engineering (various universities)
- National Digital Research Centre (Digital Hub, Dublin)
- Dublin Molecular Medicine Centre (Dublin)
- National Institute for Bioprocessing Research and Training (based in UCD)
- Applied Research Enhancement (across the Institutes of Technology).

Other initiatives primarily provide support for more project-specific activity, for example

- Innovation Partnerships
- use of existing company R&D supports, such as R&D capability funding, to support firms to link in with colleges
- Industry Supplements
- Commercialisation Fund
- Programmes in Advanced Technologies.

Enterprise Ireland's new industry-led research networks provide fresh assistance for more medium-term to longer-term enterprise-driven research programmes.

Deeper consideration of how these initiatives fit with each other would be useful. What matters is not just the form of the initiative, e.g. centre versus programme, but rather the key driver, i.e. whether it is enterprise-led or academic-led, and – critically – what identified need it is seeking to address.

Overall, it can be seen that aspirations for improving applied research capability in Ireland has been a common theme of policy makers in Ireland in recent years. From the Enterprise Strategy Group, through the R&D Action Plan and the Strategy for STI, the state's plans have now evolved under the 2007-2013 NDP to measures that include one for competence centres (within the enterprise STI sub-programme).

This planned roll out of 'Irish-style' competence centres is predicated on

- the desire to enhance industry-science relations with a view to increasing returns to the Irish economy
- recognition that this centre model is a noteworthy policy tool in other countries like Sweden and Austria and that such an approach, provided that it is adapted appropriately to the specificities of the Irish environment, can lead to the sought-after increased linkages.

Planning for the future

In order to achieve this it is important, as highlighted at the start of this paper, that such future state investments should be planned in the context of clarity on

- the present environment
- how Ireland sees itself in the future, and
- what steps should be taken now to deliver on this transition.

In addition to the merit in developing a clearer understanding of the present situation (both activities and relevant initiatives) as discussed in the previous chapter, investment in future industry-academia collaborative supports may be enhanced by

- (i) consideration of an overall strategic framework
- (ii) deeper examination of the ‘umbrella objective’ of accessing and applying research competence to industry needs, before proceeding to
- (iii) the formulation of specific initiatives within this objective such as competence centres.

7.1 Developing a (flexible) framework

In order to optimally

- (a) build industrially-relevant research competence
- (b) access and apply existing research competence to industry needs in Ireland,

it would be helpful to be clearer on

- 1 what types of support companies at different stages of development need in order to be in a position to engage in the most suitable way possible with academia
- 2 what are the areas of strategic focus that Ireland should be concentrating on for future industrial development
- 3 what research activity on these exists already.

7.1.1 Companies: developing in stages

Just as investments in research in the third-level and fourth-level sectors do not take place homogeneously, companies run into different issues often reflecting their stage of development. (This is relevant for all aspects of state support, not just in the context of industry-academia collaboration.) A broad 'stage of development' categorisation frequently employed in relation to R&D is that of

- a. non R&D-performers
- b. existing 'adequate' performers
- c. more sophisticated performers.

a. Non-R&D performers

In the 2005/6 *Survey of Business Expenditure on R&D* (Forfás, 2007b), 546 firms (470 Irish-owned, 76 foreign-owned) were identified as having some expenditure on R&D but less than €100,000. While these companies all had in common their negligible R&D activity, they did not necessarily all have the same needs with regard to getting on the first rung of the R&D ladder. For example, awareness for SMEs involves understanding the importance of R&D to competitive advantage. For MNCs, it revolves around how attractive Ireland is as a research location.

b. 'Adequate' performers

The same survey identified 453 firms (361 Irish-owned, 92 foreign-owned) spending between €100,000 and €500,000 on R&D, and 253 firms (161 Irish-owned and 92 foreign-owned) spending between €0.5m and €2m.

What threshold constitutes 'adequate' has varied in discussions. Some view the €100,000 mark as appropriate, others hold that the €500,000 level represents an R&D unit of reasonable scale within a company. Possible areas for support for this broad range of companies could include:

- the development of technology strategies and planning
- a move towards a programmatic rather than project-based approach to R&D
- related to the above, increasing formalisation of R&D operations within the firm

- access to other actors, e.g. the third-level sector, other firms with similar strategic interests, the EU's Framework Programme.

c. Sophisticated performers

More sophisticated R&D performers are typically identified as those firms spending in excess of €2m on R&D, of which there were 118 in the BERD 2005/6 survey. There may be a need to support their further development in Ireland through significant R&D expansions (facilities and staff) and deeper linkages with other actors.

7.1.2 Prioritising areas for future investment

With the benefit of the Technology Foresight process, SFI invests in research across the spectrums of biotechnology and ICT. The HEA, through the PRTLII, is making huge strides in building up the research system, based on higher education institutions' research strategies. Other agencies are investing in public research: some industry-driven, a good deal academic-driven.

As Ireland's investment in research continues and matures, it is vital that its outputs are optimised. This holds true from a number of perspectives: industry, labour force participant, taxpayer and citizen.

With regard to industrial development, two inter-linked key outputs are

- people skilled in industry-relevant technologies and practices, and
- knowledge/research capability in these areas, including critical mass of research activity and appropriate facilities.

Company access to skilled workers and knowledge can only take place to any great extent if the research system and relevant funders are cognisant of what industry needs are.

Finding answers to this will entail consultation with industry on future growth opportunities leading to a view on investment priorities. This is not necessarily straightforward because many firms have not been in a position to devote resources to the articulation of medium-term to longer-term strategies for market development, including within that research/technological needs.

This situation is evidenced in the time taken to build up Enterprise Ireland's industry-driven research networks. Analysis of wider global technology roadmaps to assess where currently unexplored opportunities for Ireland lie would also be useful in this context.

These are not easy issues to address and the processes through which they are explored are critical. They must be credible, meaningful and, at the same time, sufficiently flexible to enable support for future emerging opportunities and reduced investment in areas that are seen to demonstrate reduced potential over time.

The Strategy for STI notes the central role of the development agencies, working with Technology Ireland, in managing this process.

7.1.3 Existing research competence

Also extremely pertinent is an enhanced understanding of the research competence that exists already. This matters for a variety of reasons:

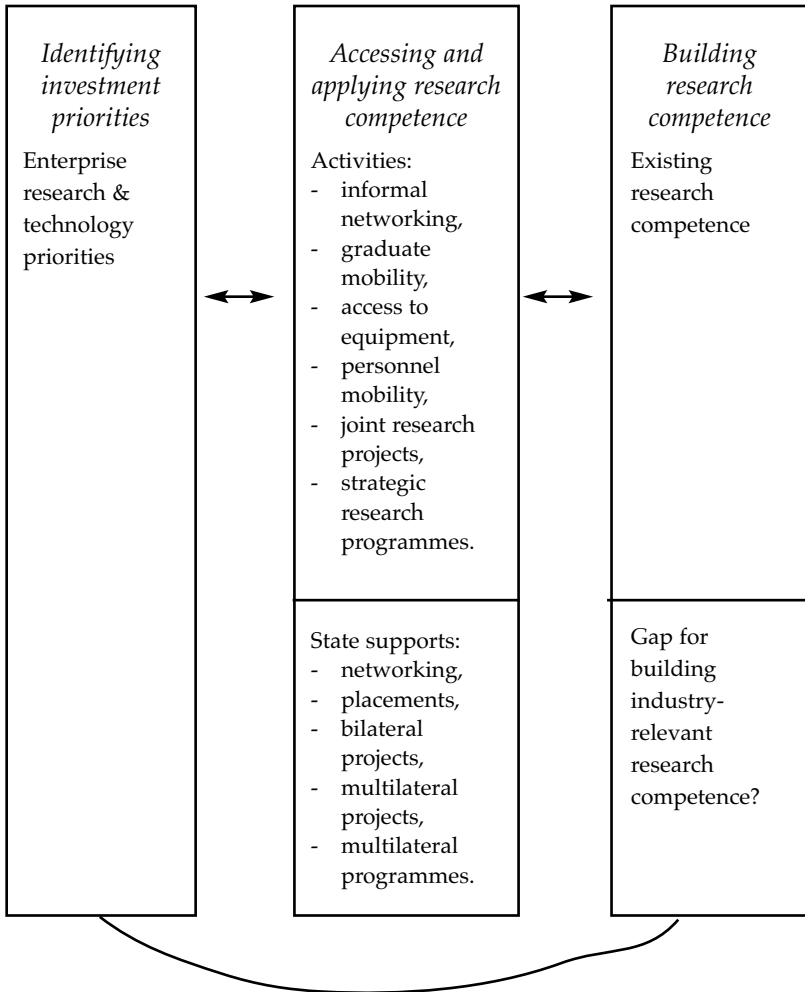
- 1 it aids understanding of the alignment between the academic research base and the enterprise base
- 2 it is not possible to access what one does not know exists
- 3 in order to minimise duplication of resources
- 4 it would help to enhance the profile of Ireland overseas.

A more detailed picture of the research activity that is taking place in higher education institutions across Ireland and of the institutions' plans would be informative in this regard and the recent HEA/Forfás Review of National Research Infrastructure is a key input to this.

7.1.4 Mapping out a framework

Further exploration of Section 7.1.1 would help to deliver supports that are appropriate to the companies' particular needs (discussed further in Section 7.2.3).

Using Sections 7.1.2 and 7.1.3 above could aid understanding of where there are gaps and opportunities for greater industry-academia collaboration.



7.1.5 State interventions

State interventions to enhance industry-academia collaboration could be looked at as follows.

- Where enterprise priorities are identified and research competence is deemed to exist:
 - look at ways to access and apply that research competence to industry development needs.

- Where enterprise priorities are identified and research competence is not deemed to exist:
 - build research competence
 - and/or access it internationally?

It is important to note that where research competence exists and is not deemed industrially relevant does not necessarily point to a weakness. Research and indeed knowledge are of course not all about economic growth.

7.2 Accessing and applying research competence to industry needs

7.2.1 Objective

Focusing on the matter of accessing and applying research competence to industry needs, the aim could perhaps be summarised as connecting more companies ‘more’ into the third-level and fourth-level sectors. This is grounded in the understanding that wider and deeper connections will increase returns to the local economy.

As outlined in Section 7.1, a clear understanding of industry needs and of what relevant research competence exists will prove helpful in achieving this objective.

7.2.2 Activities

There is a wide range of increasingly structured collaborative linkages that can deliver two-way benefits to the innovation system:

- informal networking/communications
- mobility: graduate; academic researchers; company researchers
- consultancy/expert support
- access to specialised equipment/facilities
- training (for both company and college personnel)
- joint research projects
- joint research programmes.

The first two – networking and mobility – came up often both in consultations and papers as fundamental to enhancing synergies

between industry and academia. As well as the possibility of intertwining support for these activities into longer-term collaborative structures, they are critical means by which firms can start to become involved with the academic research base and consequently deserve considerable attention. It should be noted that even such engagement at the less structured end of the scale is predicated on the need for a potential return to the parties involved to exist for it to be realistic to expect them to engage.

7.2.3 *Role of the state*

In Ireland, current state initiatives (please refer to Appendix F) support a variety of activities both to build industry-relevant research competence and to access and apply that competence to industry needs.

Ensuring that the range of support for connections between enterprise and academia is coherent and progressive would help to strengthen Ireland's innovation system. The spectrum of activities identified above would benefit from a corresponding spectrum of increasingly structured supports and the role and activities of the state in this regard deserves further consideration by policy-makers.

The success of the plan to invest at the more structured end would be helped by enhanced support for less formal linkages (in line with the 2004 Technopolis review findings) such as networking and placements since natural tendencies favour initial relationship-building in advance of longer-term commitments. If the ultimate aim is to have more companies 'more' engaged, one must build a pipeline and assist firms to become increasingly involved with the academic research base, taking into account their starting point.

Delivery of state supports to firms in tune with their developmental stages should help to enhance the impact of state support, for example

- for those areas that demonstrate significant potential for industrial engagement but only low levels of existing activity, initial relationship-building such as informal networking and/or bilateral R&D projects would be useful
- where industry is active and there are some signs of longer-term strategic needs emerging, the involvement of firms in an industry-driven research network with a

- view to clarifying their agenda and testing the stability of the consortium may be most appropriate
- where it is apparent that industry has a clear view of its longer-term requirements and is willing to collaborate, and where research expertise is available, a proposal for a competence centre may be the option best explored.

In line with this 'spectrum approach', Enterprise Ireland's planned centres for technology collaboration can be seen not as alternatives to industry-driven research networks, but rather as being suitable for groups of companies that are more developed in their longer-term technology strategies. The challenge is therefore to grow that cohort of firms in a sustainable fashion.

Furthermore, in addition to investing in new structures, it would be useful to see what potential exists to 'tweak' existing initiatives in order to increase industry engagement with them (in such a way that does not upset their original purpose). If the purpose of 'centres for technology collaboration' is to access research competence, the way in which they connect with the present research base is critical.

7.3 Plans for centres

Zoning in further to consider some details of such centres, the broad aim is to establish longer-term more structured forms of support that will support industrial development and that will help companies, including smaller ones, to push out their R&D 'horizons'.

A summary comparison of Swedish and Austrian competence centres is set out in Appendix D. According to Technopolis (2004b), competence centres aim to build critical mass in relevant technologies, while technology programmes (such as those operated by Tekes in Finland) seek to exploit this mass for economic reward. Whether, using that distinction, what is planned here is a typical competence centre is not the overriding issue. Regardless of the label attached, there are lessons to be learned from other countries' initiatives. By concentrating on what Ireland's needs are at this stage in its development and employing relevant insights from others, there will be greater potential for positive outputs and outcomes.

As discussed above, increased interaction requires a certain degree of alignment between academic research competence and

industry agendas. It also of course means strengthening the enterprise and academic capabilities and appetites to engage with each other – all formidable challenges in their own right.

7.3.1 Establishment

Before the start of the Austrian Kplus programme, an *ex ante* evaluation took place. This comprised an analysis of the status quo and a needs analysis, a study of the most important models and the definition of the key parameters of the programme. The approach taken included expert interviews, workshops, a steering group, in-depth studies of successful foreign models and a project report by the then Ministry of Science and Transport (now the Ministry of Transport, Innovation and Technology). Such an exercise for the Irish situation could prove helpful.

A logical starting point, as outlined above, is to identify where industry needs for, and interest in, this new initiative or structure arise. In order to decide to make an investment based on such an agenda, it is important to decide whether those companies involved plus the potential for future economic performance constitute sufficient critical mass to warrant the investment of state funds.

On the academic side, it is important to assess whether a satisfactory level of research competence exists to merit investment in structures to build links between it and industry. If not, the gap between industrial STI investment priorities and the existing research base may be addressed through building up research competence in Ireland (under SFI or the PRTL) and/or considering accessing capability overseas.

With regard to the centres themselves, initiatives such as the Programmes in Advanced Technology (PAT) centres were seen to run into difficulty partly because of a lack of critical mass. Fresh efforts to develop intermediary structures will need to avoid this.

If the substantial investments in collaborative structures are to be justified, decisions will need to be reached – as best possible in the uncertain world of R&D – on a sufficiently strong basis. That is not in any way to suggest, for example, that one can forecast definitively the number of licences to come out of such an arrangement. It is an unpredictable and complex environment and different models will need to be tried. Nevertheless, due processes are vital. These centres or focal points will be in receipt of substantial public monies and it is essential to be satisfied with the

case being made for investment. Moreover, the resources available are not unlimited and choices will have to be made accordingly.

Linked to this and as mentioned previously, the development of any framework for such investment requires flexibility in the form of entry and exit mechanisms to allow for new opportunities and to cut back state support in areas that demonstrate reduced levels of potential return.

Scale/Scope/Location

The size and number of these centres is not possible to quantify at the outset. The latter should depend on the investment priorities identified and on available resources.

The size will differ according to needs and interest. In Sweden, a competence centre engages an average of 6 research groups and 11 research partners. Each centre implements a research programme in which there can be between 5 and 15 research projects underway at any one time. In Austria, the general guideline for starting out is that a centre should commence operations with at least 3-7 key people, 10-20 scientific/technical personnel as well as the management and admin function. Centres usually reach full capacity after two to three years.

One generally agreed view is that the centres need to be of sufficient scale. This is important for the researchers that they attract, the activities that they can undertake and for their profile (nationally and internationally).

Location is also not possible to specify at the outset. It depends on a number of factors, for example academic competence, location of companies. Indeed, whether or not such centres have to be physical structures may need to be assessed according to the requirements of particular cases.

Industry participation

A central issue will be the likelihood of companies, particularly smaller ones even if they are deemed to be 'R&D-capable', to become involved in such a venture. Time and again in consultations the issue of the short-term focus of smaller firms arose. This is evidenced in the substantial period of time taken to engage firms in Enterprise Ireland's industry-driven research networks (time notably recognised as well spent).

In Sweden and Austria, somewhere between 20% and 30% of industrial partners in their centres are SMEs.

The approach discussed above – based on companies’ stages of development – could usefully stratify the most likely industry participants.

Academic Participation

Just as with companies, participation in this model is not for all academics. The general view that emerged from the consultations nevertheless was that there is a sufficient cadre of academic researchers who are interested in working in this space.

One of the issues raised as a barrier to this is the short-term nature of contracts for academic research staff. If researcher numbers are to grow to the levels being talked about, research careers must become more attractive and more sustainable. Structures such as those with longer timeframes being proposed may assist in this, as will the work to be undertaken by the Advisory Science Council.

Selection process

A logical route is for a group of firms to agree a shared strategic research agenda and to issue a call for academic engagement based on this. Again the issue of critical mass – linked to quality – comes up. If the response from academic researchers is not deemed to address sufficiently the enterprise agenda, it is not likely that desired returns in the form of key skills and knowledge transfer will take place. As mentioned already, it then may be a case of considering whether to build up that research capability in Ireland.

Linking into the issue of ensuring that investment is being made in the right area, a suggestion was made that a progressive competitive call be issued – so that funded activities can be bolstered if they are seen to be succeeding or terminated if not.

Some of the criteria used in the Swedish and Austrian processes may be useful here to develop a flexible and sustainable model, bearing in mind that not all of them are applicable in this particular situation.

7.3.2 *Operation*

Activities

Ideally, any significant structures will encompass a range of activities and of relationships. With regard to the latter, while the

relationship of primary interest in this paper is that between a company and a higher education institution, it is also recognised that investments in collaborative structures could also help linkages between firms themselves, for example between an SME and a multinational. Care must be taken therefore that opportunities for these linkages are not lost if SMEs were to be supported through one mechanism and large multinationals through another. International relations (with the centre as a portal for international research competence) and relations with the general public (through outreach activities) are also to be encouraged.

The development and use of key skills and knowledge are the underlying drivers of activity. A frequent point made in consultations was that it is the training and mingling of people that is critical. This is consistent with the literature reviewed. According to Technopolis (Technopolis, 2004a), the most important impact of Sweden's investment was on the people: the centres typically include a significant proportion of PhD education, producing PhDs who are more used to, and interested in, working with industrial problems than many, and who are more quickly absorbed into companies.

Postgraduate development in these environments would help companies to access potential recruits with important skills and knowledge. It could help postgraduates to engage in strategically relevant research work. The development of company researchers in this environment would help their understanding and skill set. There is room therefore to consider weaving in greater state support for placements for

- academic researchers into companies
- company researchers into colleges
- undergraduates.

Underpinning all this of course lies the collaborative research activity that is conducted based on enterprise priorities. It is through such work that people will gain training, knowledge and contacts. The encouragement of inter-disciplinarity will aid teams of researchers to combine their particular expertises and to learn from each other.

Funding

Funding for these structures will need to be long-term – yet finite – in order to foster the types of activity and sustainable behaviour that are sought.

In its impact assessment of the Swedish competence centre programme, Technopolis concluded that substantial progress could be seen between the fifth and eighth years when the performance of many of the centres shifted from being ‘adequate to ‘very good’, demonstrating the need for long-term support for this type of initiative.

Governance and management

Active ongoing involvement of industry is vital both in the work that is undertaken and in strategic planning. This is consistent with the Swedish experience in which industry participation at both board level and project level is viewed as essential to minimising ‘mission drift’ into topics that are of less interest to firms (Technopolis, 2004a).

On the matter of governance arrangements, guidelines for governance of Swedish competence centres were laid down through a principal agreement that had to be signed by all partners that covered issues including:

- organisation
- operations and operating plan
- financing
- exit mechanisms
- reporting, evaluation and audit
- dispute resolution.

In Austria, there is a standard funding contract between FFG and the centres in addition to a centre-specific general agreement between all partners (including the funding organisations). The latter is the ‘constitution’ of the centre and includes all general rules. After an initial phase during which the partners can organise themselves as an association, they are expected to set up a limited company. Centres are mostly free to define their internal relations themselves.

Possible governance structures for Ireland may be usefully informed by the work being undertaken at present by Forfás on arrangements for multi-party collaborative initiatives.

With regard to management and strategic planning, the centre director is vital to a centre's success. One of the recommendations emerging from the first evaluation of the Vinnova competence centre programmes was to network centre directors with each other so that they could share experiences and lessons. This may be worth pursuing in the Irish context.

Intellectual property

Consistent with the *National Code of Practice for Managing and Commercialising Intellectual Property* (Forfás, 2005d), agreement should be reached at the outset of a centre's establishment on the relevant arrangements. The most commonly held view is that centres should own core intellectual property with options in place for industry partners to license it.

7.3.3 Evaluation

For all similar programmes abroad, regular evaluation according to clear criteria was fundamental to their performance. The evaluation criteria were utilised not simply as a means of checking against targets but also as a learning tool for improving performance.

In Sweden, the evaluations of each of the centres have been based on NUTEK's 10 success criteria (see section 4.2.1) and have taken place at the 2, 5 and 8-year marks. The first focused mainly on establishment and management of the centres. The next concentrated on scientific and industrial 'performance' while the last continued this focus and also considered the centres' ability to sustain themselves after 10 years of funding. In Austria, the Kplus centres were evaluated at the 4-year mark to assess their suitability to receive funding for years 5 to 7. The Knet centres, following an overall assessment of the initiative, enhanced the role of evaluation in their development.

The types of metrics applied will reflect the aims of the initiative. Based on the assertion that the aim is to deliver greater returns to the economy by linking more firms more actively into the third-level and fourth-level sectors, indicators may include:

- level of collaborative research and funding support from industry
- numbers of companies involved and numbers of new companies joining

- number of licence agreements
- level of personnel mobility: graduate/researcher/company (both temporary and longer-term)
- training courses delivered
- number of seminars and technology roadmaps delivered
- number of co-publications
- number of EU Framework Programme participations
- number of spin-offs.

Targets set for centres will naturally reflect the particular areas of focus and the stage of development of industrial participants. As with metrics for any initiative, they must be both meaningful and collectible.

7.4 Some concluding thoughts

References have been made frequently throughout this paper to the issue of the size of the firm and the implications that this has for its readiness to collaborate with others. An SME can vary in size from 10 employees to 249: this is a considerable range.

While organisations such as the OECD may envisage an increasing role for SMEs in the evolving global economic environment, they may be very different size firms to the bulk of SMEs in Ireland. There is a need to support firms in Ireland to grow to sufficient scale so that they are capable of interacting with others, not just in terms of R&D but in other areas. In addition to assisting technology development, state agencies are looking at other intertwined factors such as organisational and management development.

In a similar vein, while R&D activity and collaboration are increasingly important operations within a successful company, they are not an end in themselves. R&D is one means to enhance and sustain enterprise performance. There are others, for example technology acquisition and non-technological innovation, that could benefit from more analysis and support.

Moreover, there are many company needs that are more firmly rooted in the present and these must be addressed if there is to be any 'tomorrow' in which returns on R&D investments can be enjoyed. The application of information technology to operations and the optimisation of supply chain management are just two examples of these.

Taking it from a wider perspective again, enterprise performance is not the final destination either. If one thinks back to the initial discussion in chapter 2 on the importance attached to economic growth, the ultimate aim of a government's interventions is to improve living standards for its citizens. Ireland is a society (not just an economy) in which constructive relationships such as those discussed in this paper will be fostered through clear communication and a building up of mutual trust and respect.

Appendix A

Those consulted

Biomedical Diagnostics Institute
Department of Enterprise, Trade and Employment
Dublin Institute of Technology
Dublin City University
Enterprise Ireland
Forfás
Glanbia
Higher Education Authority
IDA
Industry Research and Development Group
Irish Business and Employers Confederation
Irish Medical Devices Association
Irish Universities Association
National Diagnostics Centre
Dr Ena Prosser
Science Foundation Ireland
Small Firms Association
Trinity College Dublin
Tyndall Institute
VINNOVA

Appendix B

Listing of Swedish competence centres

Catalysis	KCK
Combustion Engines Research	CERC
Environmental Assessment of Product and Material Systems	CPM
High Speed Technology	CHACH
High Temperature Corrosion	HTC
Railway Mechanics	CHARMEC
Research Centre for Radiation Therapy	
Bio- and Chemical Sensor Science and Technology	S-SENCE
Information Systems for Industrial Control and Supervision	ISIS
Noninvasive Medical Measurements	NIMED
Integrated Product Development, Pohlem Laboratory	
Minerals and Metals Recycling	MiMER
Amphiphilic Polymers from Renewable Resources	CAP
BioSeparation	CBioSep
Circuit Design	CCCD
Combustion Processes	
Bioprocess Technology	CBioPT
Customer Driven High Performance Production Systems, Woxencentrum	
Electric Power	EKC
Fluid Mechanics for Process Industry, Faxen Laboratory	
Inorganic Interfacial Engineering, Brinell Centre	BRIIE
Parallel and Scientific Computing Institute	PSCI
Speech Technology	CTT
Surfactants Based on Natural Products	SNAP
User-Oriented IT-Design	CID
Wood Ultrastructure Research Centre	WURC
Advanced Software Technology	ASTEC
Surface and Micro Structure Technology	SUMMIT

(Source: VINNOVA, 2005)

Appendix C

Listing of Austrian Kplus centres

Competence Centre of Applied Biocatalysis	AB
Austrian Bioenergy Centre	ABC
Austrian Centre of Competence for Tribology	AC2T
Advanced Computer Vision	ACV
Centre of Natural Hazard Management	alps
Biomolecular Therapeutics	BMT
Carinthian Tech Research	CTR
Applied Electrochemistry	ECHEM
Forschungszentrum Telekommunikation Wien	FTW
Knowledge Management Centre	KNOW
Linz Centre of Competence in Mechatronics	LCM
Leichtmetall-Kompetenzzentrum Ranshofen	LKR
Materials Centre Leoben	MCL
Polymer Competence Centre Leoben	PCCL
Software Competence Centre Hagenberg	SCCH
Das Virtuelle Fahrzeug	VIF
Zentrum für Virtual Reality und Visualisierung	VRVis
Wood Composites & Chemistry Competence Centre	WOOD

(Source: FFG, 2005)

Appendix D

Summary comparison of Swedish and Austrian competence centre models

	<i>Sweden</i>	<i>Austria (KPlus centres)</i>
Selection criteria	Effect of renewal in Swedish R&D system; Sufficient academic relevance; Direct industrial relevance; Sustained concentration of resources at one university; Attractive partners for international collaboration.	Scientific and technological quality; Ability to 'cluster' existing scientific and economic competence into critical masses; Estimated economic benefit for Austrian companies; Quality of business plans.
Thematic pre-selection	No.	No.
Scale	Currently there are 28 centres, each with a network of 60-100 individuals, with an average of 6 research groups and 11 research partners.	18 centres in operation, with an average of 5-15 leading scientific staff and 20-40 other scientific staff (FTE).
Industry partners	Approximately 250 industrial partners, between 20-30% SMEs.	Around 270 industrial partners, of which 25-30% are SMEs.

	<i>Sweden</i>	<i>Austria (KPlus Centres)</i>
Funding	<p>€2.1m average budget for each centre, split equally three ways between:</p> <ul style="list-style-type: none"> - VINNOVA/STEM - Industry - University 	<p>€2-4m per centre per annum:</p> <ul style="list-style-type: none"> - FFG 35% - Other public sponsors 20% - Industry 40% - Research institutions 5%
Duration	10 years	7 years (4+3)
Governance	<p>A principal agreement sets out:</p> <ul style="list-style-type: none"> - organisation - operating plan - financing - exit mechanisms - reporting, evaluation - dispute resolution 	<p>Standard funding contract between FFG and centres in place plus a centre-specific general agreement between all partners.</p>
Evaluation	<p>Evaluated on the basis of NUTEK's ten success criteria (4.2.1) at 2-, 5- and 8-year marks.</p>	<p>Evaluated at 4-year mark to determine funding for subsequent 3 years.</p>

Appendix E

PRTLTI-funded facilities (with completion dates)

<i>Year</i>	<i>Project</i>	<i>HEI</i>
2001	Geary Institute	UCD
	Institute for the Study of Social Change	UCD
	Biotechnology & Environmental Science	Carlow
	Institute for Advanced Materials Science	TCD
	Ussher Library	TCD
	Institute of Biopharmaceutical Science	RCSI
2002	Centre for the Study of Human Settlement & Historical Change	NUIG
	Nanofabrication facility	UCC
	Biosciences Institute	UCC
	Materials and Surface Science Institute	UL
	National Centre for Plasma Science & Technology	DCU
	Research Institute in Networks & Communications Engineering	DCU
	National Centre for Sensor Research	DCU
	Urban Institute Ireland	UCD
	Institute of Immunology	NUIM
	Institute of Bioengineering & Agroecology	NUIM
	Environmental Research	CIT
	Institute for International Integration Studies	TCD
	2003	Conway Institute for Biomolecular & Biomedical Research
Dublin Molecular Medicine Centre		UCD/TCD

<i>Year</i>	<i>Project</i>	<i>HEI</i>
	Environmental Change Institute	NUIG
	National Centre for Biomedical Engineering Science	NUIG
	Trinity Centre for Bioengineering	TCD
	Humanities Institute of Ireland	UCD
	Centre for Synthesis & Chemical Biology	RCSI
2004	National Institute for Regional & Spatial Analysis	NUIM
	Institute for Information Technology & Advanced Computation	TCD
	Institute of Neuroscience	TCD
	Optical Characterisation & Spectroscopic Facility	DIT
	Biopolymer & Molecular Research	AIT
	Biopharmaceutical Sciences Network	RCSI
	Programme for Human Genomics	RCSI
2005	Environmental Research Institute	UCC
	Centre for Synthesis Chemical Biology	TCD
	Centre for Innovation and Structural Change	NUIG
In progress	Analytical Biological Chemical Research Facility	UCC
	Programme for Human Genomics	Mater
	Programme for Human Genomics	St Vincent's
	Centre for Synthesis & Chemical Biology	UCD
	Biosolids Programme Centre for Sustainability	IT Sligo
	National Institute for Cellular Biotechnology	DCU
	M-Jones	WIT
	Research Library	UCC

<i>Year</i>	<i>Project</i>	<i>HEI</i>
	Cosmo-Grid	DIAS
	Marine Research Programme	NUIG
	Boole Centre for Research in Informatics	UCC
	Eco-Electronics	UCC
	Nanoscale Science	

(Source: Higher Education Authority, 2006)

Appendix F

Irish initiatives relevant to industry-academia collaboration

Applied Research Enhancement

This is an initiative by Enterprise Ireland to help Institutes of Technology improve their capacity to engage with local firms through the strengthening of their research competence in areas relevant to regional enterprise needs.

Centres for science, technology and engineering

These centres aim to support excellent research through clusters of internationally competitive researchers working on areas of potential future strategic importance to industry in Ireland. Their specialisms include:

- therapies for gastrointestinal diseases
- regenerative medicine, e.g. gene therapy
- biomedical diagnostics
- nanotechnology
- digital enterprise (Semantic Web)
- telecommunications value-chain
- software engineering.

The centres are mainly hosted by the universities, with Institute of Technology involvement in some of them. Industrial partners typically comprise a couple of MNCs and in some cases some SMEs. Funding ranges from €1m to €5m per annum for five years with an option to extend for another five. Twenty per cent of costs are to be shared by strategic partners.

Commercialisation Fund

Enterprise Ireland's Commercialisation Fund supports academics to undertake research in areas of potential industrial importance. Support is available across three phases:

- proof of concept
- technology development
- business development.

Dublin Molecular Medicine Centre

The DMMC operates across UCD, TCD and the Royal College of Surgeons. It also has six affiliated teaching hospitals. The Centre focuses on the application of genomics and proteomics to the treatment of commonly acquired diseases.

Industry-led Research Networks

The objectives of this relatively new Enterprise Ireland intervention are to foster multilateral company agreement on a medium-term research agenda and to ensure active industry participation on consequent research work undertaken by selected academic groups. Pilots are currently underway in biotechnology (biodiagnostics, bioprocessing), informatics (wireless, e-learning), and industrial technologies (power electronics). Others are under discussion.

A network typically receives in the region of €2m funding over 2-3 years, with around 5-10 firms engaged in each.

Industry Supplements

This SFI initiative supports collaborative research projects directly related to existing SFI peer-reviewed programmes. Its aim is two-fold: to help inform SFI-funded researchers about industrial research needs and to inform industrial partners of research developments. SFI contributes up to €50,000 per annum for the duration of an existing SFI programme.

Innovation Partnerships

Innovation Partnerships usually involve close-to-market research undertaken by an academic on behalf of an industrial partner. Enterprise Ireland pays 35%-75% of total eligible costs within the third-level institution, subject to a maximum of €190,000. The initiative works to build typically bilateral links between researchers and firms and to solve relevant problems in a 1-2 year timeframe.

Marine Institute

Based in NUI Galway, the Marine Institute supports marine R&D and provides related services, e.g. surveys and monitoring, to promote economic development and protect the environment.

National Digital Research Centre

The NDRC is supported by the HEA and the Department of Communications, Marine and Natural Resources. Its focus is on digital media and related technologies. The funding of €3m per annum over 5 years with possible renewal thereafter was won by the 'Liberty consortium' of UCD, TCD and DCU.

National Institute for Bioprocessing Research & Training

NIBRT is based in UCD and links in with TCD, DCU and IT Sligo. Funded to the tune of €72m over 7 years, it will develop research and training in bioprocessing and biomanufacturing technologies. Its UCD site will comprise a 9,000 square metres facility with substantial scale-up capacity.

Programmes in advanced technologies

Enterprise Ireland's three dedicated technology teams are now streamlined into

- biotechnology
- informatics
- industrial technologies.

Their activities include:

- fostering academic-led industry-oriented research
- support for IP protection and management
- expert assistance on commercialisation (through both start-ups and existing).

Teagasc

Teagasc concentrates on research, advisory and training services for the agriculture and food industry. With approximately 200 research scientists and 300 technicians in nine locations, its research priorities include:

- food processing
- agriculture
- rural economics.

Telecommunications Software & Systems Group

Based in Waterford Institute of Technology, TSSG engages approximately 115 researchers and a range of industrial partners on basic research, as well as more applied work and research commercialisation in the field of communications software services.

Tyndall Institute

Tyndall acts as a national focal point for ICT research and works to provide a bridge between academic research and industry. Its activities range from research, education and services to industry (e.g. failure analysis) in the areas of nanotechnology, photonics, microelectronics and the ICT/Bio interface. Based in Cork, it has in the region of 250 research staff.*Teagasc*

Teagasc concentrates on research, advisory and training services for the agriculture and food industry. With approximately 200 research scientists and 300 technicians in nine locations, its research priorities include:

- Food processing,
- Agriculture,
- Rural economics

Bibliography

- Arnold, E. and S. Kuhlmann (2001), *RCN in the Norwegian Research and Innovation System: Fraunhofer ISI and Technopolis*.
- Austrian Council for Research and Technology Development (2002), *National Research and Innovation Plan*, Vienna: Austrian Council for Research and Technology Development.
- David P. and B. Hall (2000), 'Heart of Darkness: modelling public-private funding interactions inside the R&D black box', *Research Policy* 29 (2000) 1165-1183.
- De Jager D., P. Sowden, F. Ohler and M. Stampfer (2002), *Competence Centre Programme: Estonia Feasibility Study*, Tallinn: Foundation Enterprise Estonia.
- Enterprise Strategy Group (2004), *Ahead of the Curve: Ireland's Place in the Global Economy*, Dublin: Forfás.
- Enterprise Ireland (2005), *Transforming Irish Industry*, Dublin: Enterprise Ireland.
- European Commission (2006), 'European Trend Chart on Innovation: Country Report on Sweden': European Commission.
- European Commission (2005a), *Key Figures 2005 for Science, Technology and Innovation*: European Commission.
- European Commission (2005b), 'European Trend Chart on Innovation: Country Report on Sweden': European Commission.
- European Commission (2005c), 'European Trend Chart on Innovation: Country Report on Austria': European Commission.
- European Commission (2005d), *Competitiveness and Innovation Programme*, available at www.cordis.lu/innovation/en/policy/cip
- European Commission COM (2005) 488, 'More Research and Innovation – Investing for Growth and Employment: a common approach': European Commission.
- European Commission COM (2004) 353, 'Science and Technology: the Key to Europe's Future – Guidelines for Future European Policy to Support Research': European Commission.
- European Commission (2004a), 'European Trend Chart on Innovation: Country Report on Sweden': European Commission.
- European Commission (2004b), 'European Trend Chart on Innovation: Country Report on Austria': European Commission.

- European Commission COM (2003) 226, 'Investing in Research: an Action Plan for Europe': European Commission.
- European Commission COM (2002) 262, 'Productivity: the Key to Competitiveness for European Economies Enterprises': European Commission.
- European Commission (2002), 'Good Practice in Industry-Science Relations', *Benchmarking Papers 5/2002*, Luxembourg: European Communities.
- European Commission (2001), *Benchmarking Industry-Science Relations: the role of framework conditions*, European Commission.
- European Council (2000), Presidency Conclusions, paragraph 5: Lisbon 23-24 March 2000.
- Everett Ehrlich (1997), 'Innovation and Growth: how Governments can help', in OECD Proceedings *Creativity, Innovation and Job Creation*, Paris: Organisation for Economic Co-operation and Development.
- FFG (2005), 'KPlus Programme', available at www.tig.or.at/en/fundingprogramms/Kplus
- Fontana R., A. Geuna and M. Matt (2003), 'Firm Size and Openness: the driving forces of university-industry collaboration', *SPRU Electronic Working Paper Series*, Paper no. 103.
- Forfás (2007a), *Research and Development Statistics in Ireland 2006 at a Glance*, Dublin: Forfás.
- Forfás (2007b), *Survey of Business Expenditure on R&D 2005/6*, Dublin: Forfás.
- Forfás (2005a), *Making Technological Knowledge Work: a study of the absorptive capacity of Irish SMEs*, Dublin: Forfás.
- Forfás (2005b), *Survey of R&D in the Higher Education Sector*, Dublin: Forfás.
- Forfás (2005c), *Science Foundation Ireland: the first years 2001-2005*, Dublin, Forfás.
- Forfás (2005d), *National Code of Practice for Managing and Commercialising Intellectual Property from Public-Private Collaborative Research*, Dublin: Forfás.
- Forfás (2004), *Science and Technology in Ireland*, Dublin: Forfás.
- Forschungszentrum Telekommunikation Wien (2004), *Activity Report*, Vienna: Forschungszentrum Telekommunikation Wien.
- Freeman C. (1997), *The Economics of Industrial Innovation*, London: Continuum.
- Government of Ireland (2007), *National Development Plan 2007-2013: Transforming Ireland*, Dublin.

- Government of Ireland (2006), *Strategy for Science, Technology and Innovation 2006-2013*, Dublin.
- Government of Ireland (1999), *Ireland's National Development Plan 2000-2006*, Dublin: Stationery Office.
- Higher Education Authority (2006), *The Programme for Research in Third-Level Institutions: Transforming the Irish Research Landscape*, Dublin: Higher Education Authority.
- Higher Education Authority (2004), *PRTL I Impact Assessment*, Dublin: Higher Education Authority.
- Howells and Wood (1992), *The Globalisation of Production and Technology*, London: Bellhaven Press.
- Kaufman A. and F. Todtling (2001), 'Science-industry interaction in the process of innovation: the importance of boundary-crossing between systems', *Research Policy* 30 (2001) 791-804.
- Kearns A. (2001), 'Essays on the Consequences of R&D for Manufacturing Firms in Ireland', Dublin: Trinity College Dublin.
- Lundvall B-A. (ed.) (1992), *National Systems of Innovation: towards a theory of innovation and interactive learning*, Oxford: OUP.
- McAleese, D. (2004), *Economics for Business: competition, macrostability and globalisation*, Harlow: Pearson Education Limited.
- National Competitiveness Council (2007), *Annual Competitiveness Report 2006*, Dublin: Forfás.
- National Competitiveness Council (2005), *The Competitiveness Challenge 2005*, Dublin: Forfás.
- Narula R. (2005), 'Globalisation, EU Expansion and Consequences for MNE Location', 2005-003 *MERIT-Infonomics Research Memorandum Series*.
- Narula R. (2004), 'Understanding Absorptive Capacities in an "Innovation Systems" Context: consequences for economic growth and employment growth', 2004-003 *MERIT-Infonomics Research Memorandum Series*.
- OECD (2006), *Economic Survey of Ireland*, Paris: OECD Publications.
- OECD (2005), *Innovation Policy and Performance: a cross-country comparison*, Paris: OECD Publications.
- OECD (2004a), *Public-Private Partnerships for Research and Innovation: an evaluation of the Austrian experience*, Paris: OECD Publications.
- OECD (2004b), *Review of Higher Education in Ireland*, Paris: OECD Publications.
- OECD (2002), *Benchmarking Industry-Science Relationships*, Paris: OECD Publications.

- OECD (1997), *National Innovation Systems*, Paris: OECD Publications.
- Ohler, F. and M. Stampfer (1999), *Evaluation Concept for Kplus Competence Centres: General Rules and Information Base*, Vienna: FFG.
- Porter, M. (1985), *The Competitive Advantage of Nations*, London: MacMillan.
- Report to the Inter Departmental Committee on Science, Technology and Innovation (2004), *Building Ireland's Knowledge Economy: the Irish Action Plan for Promoting Investment in R&D to 2010*, Dublin: Forfás.
- Ricardo, D. (1817), *Principles of Political Economy and Taxation*, New York: Prometheus Books.
- Schwartz P., E. Kelly and N. Boyer (1999), 'The Emerging Knowledge Economy', in *The Future of the Global Economy: towards a long boom?*, Paris: OECD Publications.
- Scott et al (2001), 'The Economic Returns to Basic Research and the Benefits of University-Industry Relationships: a literature review and update of findings', report to the Office for Science and Technology: Crown Stationery Office.
- Swedish Government (2004), *Innovative Sweden: a strategy for growth through renewal*, Stockholm: Ministry of Industry, Employment and Communications.
- Swedish Government (2005), *Research for a Better Life*, Government Bill 2004/05:80, Stockholm: Swedish Government Offices.
- Technopolis (2004a), 'Impact of the Swedish Competence Centres Programme 1995-2003', *VINNOVA Analysis*, VA 2004: 03: VINNOVA.
- Technopolis (2004b), *An Evaluation of RTDI for Collaboration Programme*, Dublin: Forfás.
- VINNOVA (2005), Competence Centre programme available at <http://publiceng.vinnova.se/main.aspx?Id=EBD364CE-EFD5-45AF-BF65-A7BB2D604B80>