



Mapping Organizational Capabilities for Innovation and Competitiveness: Research Performance and Patenting in Small Open Economies

Technical Report 2

Study on Productivity, Innovation and Competitiveness
in Small Open Economies

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Preface

Mapping Organizational Capabilities for Innovation and Competitiveness: Research Performance and Patenting in Small Open Economies is the second of four reports produced by the study on *Productivity, Innovation and Competitiveness in Small Open Economies (PIC SOE)*. The PIC SOE project is a research study commissioned by the Department of Enterprise, Trade and Investment (DETI) in 2009 to investigate approaches and strategies for advancing productivity, innovation and competitiveness in the three leading small open economies of Singapore, New Zealand, and the Republic of Ireland so as to draw insights for Northern Ireland.

The PIC SOE project is undertaking economic performance, industry, and policy analyses of these small open economies and of key sectors within them, including emerging technology industries, chemicals, processed food, and advanced services. Three technical reports are being delivered: 1. *A Comparison of Northern Ireland's Productivity and Efficiency across Services and Manufacturing*; 2. *Mapping Organizational Capabilities for Innovation and Competitiveness: Research Performance and Patenting in Small Open Economies* (this report); and 3. *Competitiveness and Innovation Profiles of Three Small Open Economies: New Zealand, Singapore, and Republic of Ireland*. A final report, *Productivity, Innovation and Competitiveness in Small Open Economies*, will provide an overview of the findings of these earlier reports and assesses the applicability, comparability, and significance of the findings for policy development in Northern Ireland to support the region's prosperity, innovativeness, and industrial productivity.

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This report maps the profiles of research, development, and innovation to determine the key players, themes (and changes in the themes) in research and patenting and identify emerging topics in knowledge production and patenting. This report was written by Philip Shapira and Luciano Kay. Any opinions, findings, and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of DETI. Some information and analyses included in this report have been updated prior to use in the PIC SOE final study report.

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Executive Summary

Performance in scientific research and patenting, the scientific and technological fields of emphasis, and the relationships between organizations involved in research and in patenting are important contributors to national innovation and competitiveness. In this report, we examine publication and patent data over the last ten years to map the profiles of research, development, and innovation in Northern Ireland, New Zealand, the Republic of Ireland, and Singapore and to identify key actors engaged in knowledge-driven innovation in these small open economies (countries). We also determine key themes (and changes in the themes) in research and patenting in the countries and identify emerging topics in knowledge production and patenting. Our analysis finds that:

- Singapore and the Republic of Ireland have seen more rapid growth in scientific publication activity over the last decade activity than Northern Ireland and New Zealand
- Scientific research is concentrated, particularly to large universities or government-related institutions. Both Northern Ireland and Singapore each have two large universities which dominate the scientific research landscape and lead in scientific collaborations and publications. In New Zealand, large Crown-owned companies with commercial operations also are active in scientific research. In Singapore, a large proportion of research is undertaken by government agencies in strong collaboration with leading universities.
- Scientific research is diversified, although to a smaller extent in Singapore. Topical areas are broadly stable, *but* there has been change in the order of specializations. In Northern Ireland, thrusts have shifted from broader Medicine or veterinary-related areas to more specialized areas like Oncology, Biotechnology, or Materials Science. Singapore has shifted from traditional engineering areas to more multidisciplinary and high-technology areas like Nanotechnology or Biotechnology.
- Research in the corporate sector has grown particularly in the Republic of Ireland and Singapore, with 50 percent or higher increase rates in number of companies between the time periods 1999-2003 and 2004-2008. The growth rate was only about 26 percent for the same period in Northern Ireland.
- Research in the corporate sector is concentrated in fewer scientific areas than the overall scientific profile of each economy. With the exception of New Zealand, corporate research was generally more focused on areas like Engineering and Materials Science. In Northern Ireland, this was focused on Chemistry and Veterinary Sciences; in the Republic of Ireland, on Chemistry, Biotechnology, and Computer Science; and, in Singapore, on Physics and

Nanotechnology. Corporate research in New Zealand, dominated primarily by large Crown-owned companies, focused and specialized in areas like Ecology, Marine Studies, Plant Sciences, Geosciences, and Agriculture.

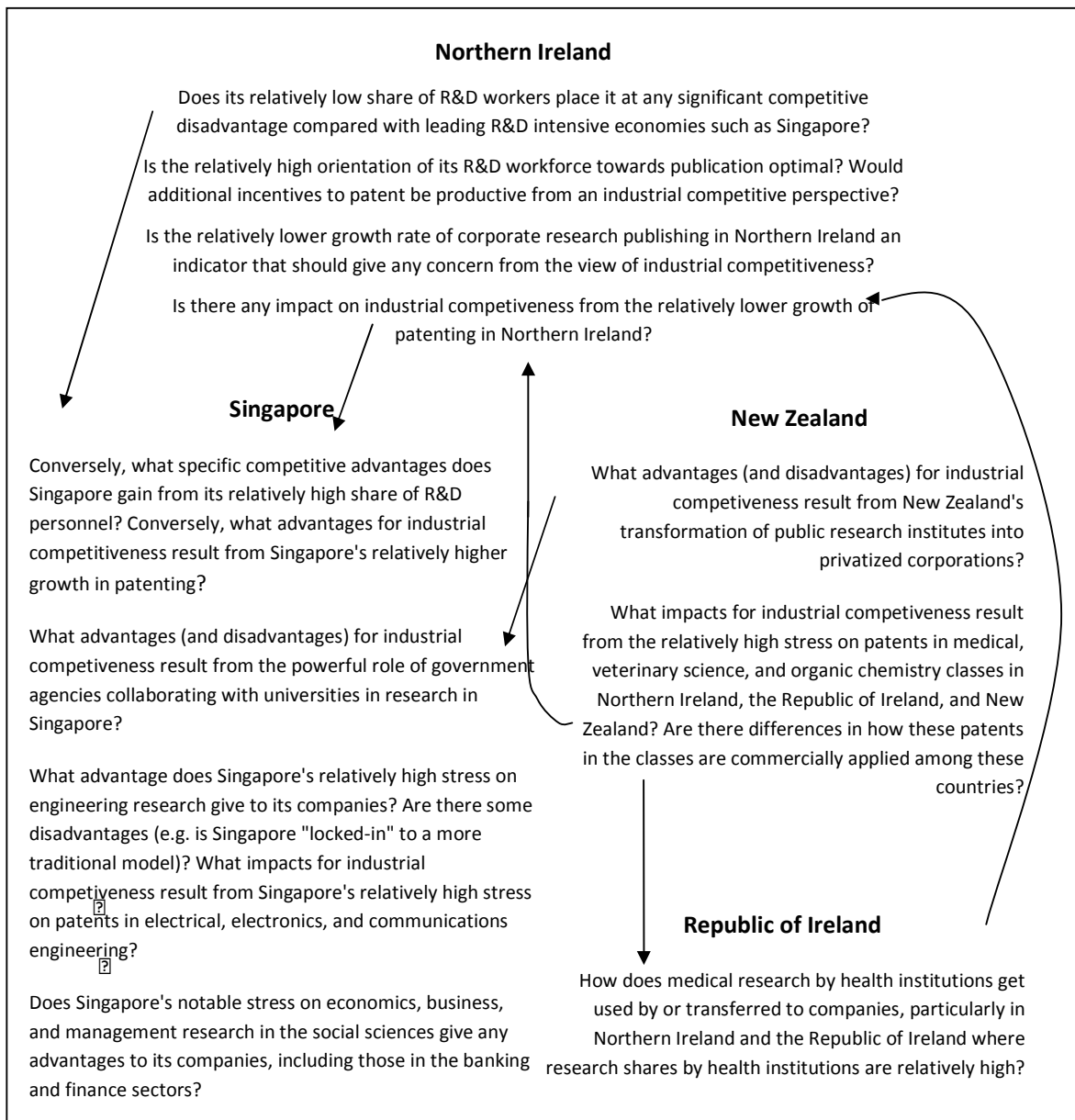
- Companies do collaborate to pursue scientific research. At least 62 percent of the companies undertaking scientific research did so in collaboration with other organizations. In Singapore and New Zealand this share reached a high 70 percent.
- International research collaborations are significant and maintained primarily with proximate countries, the USA, or leading European countries.
- For Northern Ireland and New Zealand, social sciences publication output relative to all publications was twice as important as that of Singapore, while Republic of Ireland was in intermediate levels. Still, social sciences publications represented less than one-fifth of all publications in the four countries. More than 40 percent of social sciences publications were related to areas like Psychology, Psychiatry, Environmental & Occupational Health, and Economics, except for Singapore which was rather more focused in Economics, Business, Management, and Psychology.
- Singapore led in patenting, followed by New Zealand and the Republic of Ireland, and then Northern Ireland. Patented technologies are diverse, yet there are some trends. At least one-fourth of the technologies patented by Northern Ireland, Republic of Ireland, and New Zealand are related to medical or veterinary science and organic chemistry. Singapore's patents are more strongly related to electric, electronic, and communications engineering.
- Collaborations in patents are less frequent than in scientific research. Singapore had the highest proportion of patent grants (about 8 percent) with both local and foreign co-assignees. In Northern Ireland, the share of foreign assignees of patents is high. Foreign assignees of country patents (typically, multinational corporations) were primarily from USA and, with a lower share, from the UK.

We also examine prominent knowledge and technology clusters in the four countries. This shows how research orientation evolves and aligns (more or less) to patented technologies. Over the last 10 years, research on Chemistry and Biotechnology grew in Singapore, research on Food Science & Technology decreased in the Republic of Ireland while it increased in New Zealand, and Northern Ireland experienced relative growth in Chemistry. While research activity was more or less distributed among these clusters, patenting was more related to Engineering in the four countries. The data suggest that Northern Ireland and Singapore may have undertaken research

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more related to new technologies developed or owned by local organizations, including primarily Engineering and, to some extent, Chemistry and Biotechnology.

While the analyses included in this report offer a series of key insights, it would be premature to suggest any specific policy recommendations. The patterns of research organization and patenting, including patterns of concentration, ownership, and networking, have evolved over time and no doubt each has its relative advantages and disadvantages. However, now that we have detailed the organizational patterns and trajectories of research and patenting performance, we are in a position to probe, in the next phase of analysis (including field work) whether any particular aspects or features of an economy result in enduring and significant advantages from the view of industrial and national competitiveness. Some specific and interrelated questions for the next phase of the study are indicated in the box (below).



1. Introduction

The competitiveness of an economy is determined to a significant extent by its ability to innovate, including by the generation, acquisition, and deployment of new knowledge, products, processes, organizational methods, business models, and institutional relationships. Performance in scientific research, the development of intellectual property (including through patenting), the scientific and technological fields of emphasis, and the relationships between organizations involved is fundamental to understanding several of the key underlying capabilities and frameworks contributing to a country's innovation outcomes.

This report examines the landscape of scientific performance and technological patenting for Northern Ireland, New Zealand, the Republic of Ireland, and Singapore. For each of these countries, we examine the creation of new scientific knowledge within the economy and characterize research and corporate organisations and their interactions. We also explore new knowledge creation in the social sciences, focusing particularly on management, economics and finance (since these provide a knowledge base for advanced services, one of the sectors of interest in the PIC SOE study). Finally, we analyze performance in the four countries in applying knowledge through patenting to secure protectable intellectual property in inventions and innovations.

Our assessment of scientific performance (in sciences, engineering, medicine, social sciences, and other areas) is based on large-scale analyses of journal publications. This approach is also known as bibliometric assessment. It is based on the expectation that scientific breakthroughs, discoveries, and research results are rapidly published in journals. We are able to analyze the number and type of scientific articles published by a researchers in the public and private sectors and assess the connections between articles (through co-authorship) and by authoring organizations. In this report, we do not apply bibliometrics to explore the impact (for example, through citations or publications in high impact journals) of a particular field or author, but rather to understand the patterns of scientific emphasis; the concentration of research activities; the main actors and their collaborations; and the trajectories of scientific knowledge in each country.

Our assessment also draws on the analysis of patents and patenting in the four countries. Patents measure invention disclosures, but they can also be used (making some reasonable assumptions) as an indicator of innovation capability. A patent award signifies that an invention is novel, non-obvious and has utility. Data on patent applications and grants can be used to assess innovation performance, assess technological trajectories, understand how R&D is translated into protectable intellectual property and measure the value and quality of innovation, identify which organizations are contributing to the development of new technologies, and analyze the competitiveness of technology-oriented organizations and innovation systems. Patent analysis is most useful in sectors (such as high technology) where competitive advantage can be obtained from possessing protectable intellectual property.

In this report, our analyses are based on 119,000 Science Citation Index and 6,800 Social Science Citation Index records for publications and on 50,200 Patstat records corresponding to

patents for inventions in Northern Ireland, the Republic of Ireland, New Zealand, and Singapore granted during the ten-year period between 1999 and mid-2008.

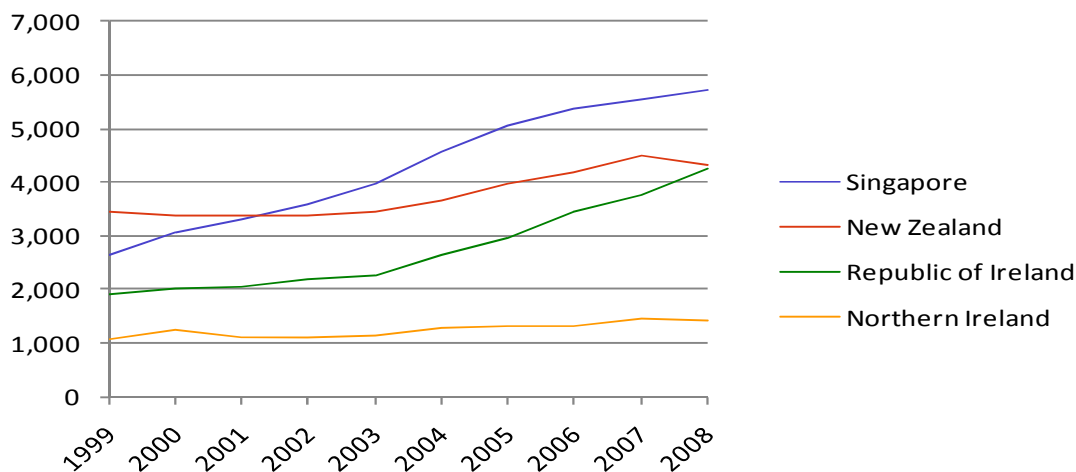
The report is organised as follows: Section Two presents the research landscape in the four economies, and examines performance in scientific research, including identifying the institutions responsible for creating new knowledge through scientific research and publications. Section Three focuses on research activities in the social sciences, especially in management, economics and finance. Section Four examines performance and patterns in patenting. Section Five analyzes knowledge and technology clusters and relationships between publications and patenting. Finally, Section Six provides concluding observations and sets out a series of questions for further examination in the next phase of the study.

2. Knowledge Creation through Scientific Research

This section presents an overview of scientific research activity in Small Open Economies (countries) of Northern Ireland, the Republic of Ireland, New Zealand, and Singapore. The data is based on the ISI-WoS database - Science Citation Index Expanded (SCI-EXPANDED) – consisting of more than 119,000 records for scientific publications (articles) with at least one author with affiliation in those countries.

Over the period 1999 to 2008, Singapore is the leading generator of new scientific knowledge, with almost 43,000 scientific articles published. New Zealand and the Republic of Ireland published 37,648 articles and 27,483 articles respectively. In the same period, Northern Ireland published 12,414 articles, which is less than a third of the scientific articles of New Zealand and less than a half of the articles published by the Republic of Ireland. The overall trend in scientific publications in the countries is illustrated in Figure 2.1. The Republic of Ireland and Singapore are the economies that grew the most in scientific publication in the period. These countries have shown a steady growth in scientific publication, at annual rates of 9.4 percent and 9.0 percent respectively (Table 2.1).

Figure 2.1 Scientific publication trends, publications per year (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Table 2.1 Scientific publications trend, publications per year (1999-2008)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Avg. growth rate/ yr
Northern Ireland	1,075	1,235	1,114	1,104	1,128	1,283	1,295	1,311	1,445	1,405	12,395	3.3%
Rep of Ireland	1,908	2,021	2,029	2,183	2,263	2,657	2,964	3,444	3,766	4,238	27,473	9.4%
New Zealand	3,452	3,363	3,364	3,386	3,434	3,667	3,984	4,172	4,492	4,325	37,639	2.6%
Singapore	2,648	3,061	3,318	3,600	3,973	4,563	5,053	5,354	5,535	5,727	42,832	9.0%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

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Northern Ireland and New Zealand saw overall publication annual growth rates of only 3.3 percent and 2.6 percent for the period, respectively. Publication levels in both these countries dipped slightly in the early 2000s before resuming growth. It is important to normalize research activities, since the four countries vary by economic scale and population size. The largest economy in terms of population and Gross Domestic Product (GDP) is Singapore.

Table 2.2 shows that Singapore has the largest number of R&D workers (all sectors, including industry as well as higher education and government). New Zealand and Singapore lead in publications per million population. By publications per billion GDP, New Zealand is the lead, followed by Northern Ireland and Singapore. Singapore has the highest R&D intensity: Gross Expenditure on R&D (GERD) as a percentage of GDP is 2.2% in Singapore compared with 1.2% in Northern Ireland. However, Northern Ireland leads Singapore (and is similar to New Zealand) by publications per \$ million GERD and appears to lead in the publications per 1000 R&D workers (based on estimated R&D personnel for Northern Ireland; reported data from UNESCO for the other countries). This does not mean that researchers in Northern Ireland are more productive in overall terms than their colleagues elsewhere; rather, it suggests that researchers in Northern Ireland (and also New Zealand) are more oriented towards producing publications than in Singapore and the Republic of Ireland.

Table 2.2 Population, economy, and R&D statistics for selected countries (2006)

Statistics	Northern Ireland	Republic of Ireland	New Zealand	Singapore
Total Population (thousands) ^a	1,742	4,253	4,142	4,401
Gross Domestic Product – GDP (million current PPP\$)	50,542 ^b	173,179	108,607	207,153
Gross Domestic Expenditure on R&D - GERD (million current \$)	602	2,030	1,826 ^c	4,582
GERD as a Percentage of GDP	1.2	1.2	1.7	2.2
Total R&D personnel (FTE)	4,725 ^d	17,647	23,178 ^c	30,129
Researchers (FTE) per million population	2,712	2,882	4,207 ^c	5,713
Publications (1999-2008)	12,395	27,473	37,639	42,832
Publications (1999-2008) per million population	7,115	6,460	9,087	9,732
Publications per \$ billion GDP	245	159	347	207
Publications per \$ million GERD	20.6	13.5	20.6 ^c	9.3
Publications per 1000 R&D workers	2,623	1,557	1,624 ^c	1,422

Notes: all figures in US dollars except as indicated. ^aPopulation, GDP, GERD, and their relation to publications are based on values for year 2006, except as indicated. ^bGross Value Added (GVA) by component of income at current basic prices by region. ^cAs of 2005. ^dEstimated from NISRA, Research & Development Statistics 2007. Sources: GDP data: OECD Main Science and Technology Indicators (MSTI): 2008/2 edition; R&D personnel: UNESCO Institute for Statistics S&T database; Northern Ireland data: Northern Ireland Statistics and Research Agency (NISRA); UK Office for National Statistics. Publications: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED).

2.1 Scientific Research Organizations

The analysis of scientific publications allows the characterisation of research organisations and units (known as research organisations) into distinctive types in order to understand the nature and type of the top performing organisation in each economy.¹ In this study, research organizations are classified as Government (including quasi-governmental organizations), Academic, Hospital, Corporate, and Others. During the period 1999-2008, more than 1,550 organizations from New Zealand published at least one scientific article (Table 2.3), which is the highest amongst the four countries under study. The Republic of Ireland and Singapore had 960 and 885 research organizations, respectively, publishing in the same period. Northern Ireland is the economy with the lowest number of research organizations publishing during this period among the countries, with only 361 unique organisations.

Table 2.3 Percentage of each type of organization (and total number) publishing scientific articles (1999-2008)

	Government	Academic	Hospital	Corporate	Other ^a	Total
Northern Ireland	23.5%	12.7%	28.3%	25.2%	10.2%	361
Republic of Ireland	21.1%	10.5%	20.1%	42.4%	5.8%	960
New Zealand	22.1%	9.1%	18.3%	41.5%	9.0%	1,551
Singapore	21.9%	11.6%	7.9%	56.2%	2.4%	885

Note: (a) Other types of organizations include organizations like: foundations, zoos, botanical gardens, and sports organizations.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

New Zealand has the highest proportion of government organizations (22.2 percent) and Northern Ireland the highest proportion of academic organizations (almost 13 percent) publishing scientific articles between 1999 and 2008. In relative terms, New Zealand has relatively lower academic organizational participation in the publication of scientific research (only 9 percent of the organizations are universities). Slightly more than 28 percent of Northern Ireland research organizations are hospitals or clinics, a noticeable difference considering that in the Republic of Ireland, the second country in terms of this type of organization, the proportion of hospitals and clinics is only 20 percent. This proportion is even lower in New Zealand and Singapore, about 18 percent and 8 percent, respectively. On the other hand, Singapore is the country with the largest share of companies undertaking scientific research. More than 56 percent of the organizations that published at least one article between 1999 and 2008 in that country were companies. In the case of New Zealand and the Republic of Ireland, only about 42 percent of research organizations are companies, while in Northern Ireland this proportion is even lower—almost 28 percent.

¹ Research organisations analysis is based on the analysis of the organisation names reported in publications and patents. As far as possible, duplicate organisational titles are consolidated. However, some organisational duplicates may remain, especially where there have been name changes or mergers. Additionally, in several cases, public research organisations have been privatized and these are now included in the corporate sector. In all cases, organisations' names are reported as they appear in publication and patent databases.

Table 2.4 shows the top-20 research organizations in Northern Ireland. Half of these are hospitals, three are universities, and only three are companies. The Queens University of Belfast and the University of Ulster are the top research organizations, with a share of publications of about 62 and 19.5 percent, respectively. The third research organization is the Belfast City Hospital, with slightly more than 7 percent of publications. These top-3 organizations account for almost 83 percent of all scientific publications in Northern Ireland, while 341 organizations below the top-20 co-authored 5.3 percent of publications.

The top-20 research organizations in the Republic of Ireland are shown in Table 2.5, they consist of 13 academic organizations, 5 health care organizations, and the TEAGASC (Irish Agriculture and Food Development Authority). Among those academic organizations, there are four constituents of the National University of Ireland system: University College Dublin, University College Cork, University College Galway, and National University of Ireland-Maynooth. These organizations have been among the top-10 in the period 1999-2008, co-authoring 13,558 publications or 49.3 percent of Republic of Ireland scientific

Table 2.4 Top 20 research organizations in Northern Ireland (1999-2008)

Rank	Pub(s)	Share	Top research organizations, by publications
1	7,683	62.0%	Queens Univ Belfast
2	2,414	19.5%	Univ Ulster
3	903	7.3%	Belfast City Hosp, Antrim
4	809	6.5%	Royal Victoria Hosp Trust, Antrim
5	710	5.7%	Dept Agr & Rural Dev No Ireland
6	472	3.8%	Royal Belfast Hosp Sick Children
7	364	2.9%	Agri Food & Biosci Inst No Ireland
8	292	2.4%	Armagh Observ
9	138	1.1%	Ulster Hosp
10	118	1.0%	Musgrave Pk Hosp, Antrim
11	101	0.8%	Royal Matern Hosp, Antrim
12	100	0.8%	Craigavon Area Hosp
13	95	0.8%	Altnagelvin Hosp
14	73	0.6%	Antrim Area Hosp, Antrim
15	17	0.1%	Forens Sci No Ireland
16	14	0.1%	Erne Hosp
17	14	0.1%	Seagate Technol
18	13	0.1%	Andor Technol Ltd, Antrim
19	13	0.1%	Bombardier Aerosp UK, Antrim
20	12	0.1%	College of Agriculture, Food and Rural Enterprise
	663	5.3%	Other 341 research organizations
Total	12,395		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Table 2.5 Top 20 research organizations in the Republic of Ireland (1999-2008)

Rank	Pub(s)	Share	Top research organizations, by publications
1	6,027	21.9%	University College Dublin - National University of Ireland
2	4,785	17.4%	Trinity Coll Dublin
3	4,455	16.2%	University College Cork - National University of Ireland
4	2,462	9.0%	University College Galway - National University of Ireland
5	1,679	6.1%	Dublin City Univ
6	1,260	4.6%	Univ Limerick
7	1,209	4.4%	TEAGASC
8	988	3.6%	Nalt Univ Ireland Maynooth
9	987	3.6%	Royal Coll Surgeons Ireland
10	972	3.5%	St James Hosp, Dublin
11	871	3.2%	Beaumont Hosp, Dublin
12	772	2.8%	St Vincents Univ Hosp
13	653	2.4%	Dublin Inst Technol, Dublin
14	596	2.2%	Adelaide & Meath Hosp
15	494	1.8%	Our Ladys Hosp Sick Children, Crumlin
16	447	1.6%	Mater Misericordiae Hosp Grp, Dublin
17	444	1.6%	Dublin Inst Adv Studies
18	206	0.7%	Cork Inst Technol
19	110	0.4%	Galway Mayo Inst Technol, Galway
20	105	0.4%	Central Veterinary Research Laboratory
	4,048	14.7%	Other 940 research organizations
Total	27,473		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

research publications. The top-20 research organizations of Republic of Ireland co-authored almost 92 percent of all publications, with the remaining 940 organizations only co-authored 14.7 percent of them. Several health care organizations are among the top-20 in the case of Republic of Ireland for the period 1999-2008. The five organizations of this type that published the most contributed 14 percent of all scientific publications in this period

Among the top-20 research organizations of New Zealand there are 7 universities, which co-authored 69.7 percent of all scientific publications in the period 1999-2008 (Table 2.6). The top-4 organizations are the University of Auckland, the University of Otago, Massey University, and the University of Canterbury. These four universities co-authored 60 percent of all scientific publications in the study period.

A major role in scientific research in New Zealand is performed by independent, Crown-owned research and development companies. These are limited liability companies that generate revenue streams. For example, AgResearch Ltd., a company undertaking research in Agriculture & Environment, Applied Biotechnologies, and Food & Textiles, is in the fifth position of New Zealand's top-20 research organization, with a 5 percent share of all publications. The National Institute of Water and Atmospheric Research, Landcare Research, and HortResearch, similar type of companies in the corporate sector, are in the sixth, eighth, and eleventh positions, with 4.9 percent, 3.8 percent, and 2.4 percent of publications, respectively.

Table 2.6 Top 20 research organizations in New Zealand (1999-2008)

Rank	Pub(s)	Share	Top research organizations, by publications
1	8,513	22.6%	Univ Auckland
2	7,480	19.9%	Univ Otago
3	3,972	10.6%	Massey Univ
4	3,407	9.1%	Univ Canterbury
5	1,901	5.1%	AgResearch Ltd
6	1,860	4.9%	Natl Inst Water & Atmospher Res NIWA
7	1,712	4.5%	Victoria Univ Wellington
8	1,413	3.8%	Landcare Res New Zealand Ltd
9	1,400	3.7%	Univ Waikato
10	1,043	2.8%	Lincoln Univ
11	897	2.4%	HortResearch
12	876	2.3%	Inst Geol & Nucl Sci
13	845	2.2%	Ind Res Ltd
14	694	1.8%	Christchurch Hosp
15	623	1.7%	New Zealand Inst Crop & Food Res Ltd
16	443	1.2%	Auckland Hosp, Auckland
17	416	1.1%	Adis Int Ltd, Auckland
18	387	1.0%	New Zealand Forest Res Inst Ltd
19	358	1.0%	Green Lane Hosp, Auckland
20	357	0.9%	Dept Conservat Res Dev & Improvement
	7,491	19.9%	Other 1,531 research organizations
Total	37,639		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Government-led scientific research is also undertaken by government agencies in New Zealand, yet these only contributed in a minor way to published output. For example, the New Zealand Department of Conservation, Development and Improvement Division, is the top government organization undertaking research with slightly less than 1 percent of publications.

Scientific research in Singapore is concentrated in two academic organizations (Table 2.7). These are the National University of Singapore and Nanyang Technology University, which co-authored 80 percent of all research publications in the period 1999-2008, with shares of 51.5% and 31% respectively. A prominent third organization in Singapore's top-20 list is A*STAR, a network of public research institutes that conduct research in specific niche areas in science and engineering and in biomedical science. This government organization contributed with 14.4 percent of all scientific publications between 1999 and 2008. Among Singapore's top-20 research organizations, there are at least 8 related to

health care and medicine, contributing about 8 percent of all publications. The remaining 865 research organizations of Singapore co-authored only 9 percent of publications in this period.

Table 2.7 Top 20 research organizations in Singapore (1999-2008)

Rank	Pub(s)	Share	Top research organizations, by publications
1	22,065	51.5%	Natl Univ Singapore
2	13,265	31.0%	Nanyang Technol Univ
3	6,161	14.4%	ASTAR
4	1,769	4.1%	Singapore Gen Hosp
5	1,146	2.7%	Natl Univ Singapore Hosp
6	732	1.7%	Tan Tock Seng Hosp
7	553	1.3%	Natl Canc Ctr
8	407	1.0%	DSO Natl Labs
9	403	0.9%	Singapore Natl Eye Ctr & Eye Res Inst
10	335	0.8%	KK Womens & Childrens Hosp
11	320	0.7%	Chartered Semicond Mfg Ltd
12	316	0.7%	Natl Inst Neurosci
13	314	0.7%	Changi Gen Hosp
14	312	0.7%	Singapore MIT Alliance Program
15	291	0.7%	Genome Inst Singapore
16	207	0.5%	Natl Skin Ctr
17	171	0.4%	Minist Hlth
18	170	0.4%	Singapore Managment Univ
19	152	0.4%	Alexandra Hosp
20	143	0.3%	Natl Heart Ctr Singapore
	3,848	9.0%	Other 865 research organizations
Total	42,832		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Table 2.8 Share of top research publishing organizations (1999-2008)

Group	Northern Ireland	Republic of Ireland	New Zealand	Singapore
Top-3	83.1%	54.1%	51.5%	86.5%
Top-10	95.8%	81.5%	79.5%	94.0%
Top-20	97.5%	91.9%	89.9%	96.1%
Total organizations	361	960	1,551	885

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Overall, the concentration of research activity is high in Northern Ireland and Singapore, where the top-3 organizations co-authored 83.1 and 86.5 percent of all publications, respectively (Table 2.8). In the Republic of Ireland and New Zealand, scientific research is less concentrated in the top-three. However, in all four countries, the top-20 research organizations co-author 90% or more of all publications.

Table 2.9 Share of publications of each type of research organization participating in scientific research (1999-2008)

	Government	Academic	Hospital	Corporate	Other ^a
Northern Ireland	7.2%	80.4%	21.0%	1.6%	2.9%
Republic of Ireland	12.0%	81.1%	16.4%	3.3%	0.5%
New Zealand	7.8%	71.2%	8.1%	28.1%	1.3%
Singapore	22.6%	83.1%	7.8%	4.0%	0.1%

Note: totals exceed 100 percent due to collaborations. (a) Other category includes foundations, zoological gardens, sport organizations. (b) Several leading research organizations in New Zealand are limited liability companies (Ltd.) with government ownership and commercial operations.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Although Government research organizations and corporations are most prevalent in terms of the sheer number of publishing organizations in the four countries, the bulk of publishing by number of papers occurs in universities (Table 2.9). Universities concentrate more than 70 percent of publications in the four countries, with Singapore as the country with the largest share of academic research (slightly more than 83 percent of scientific publications), followed by Republic of Ireland (81 percent). On the other hand, 71 percent of scientific publications were co-authored by academic organizations in New Zealand between 1999 and 2008, which is the smallest share comparing with the other countries.

Table 2.10 Share of publications for each type of research organization as first authors in scientific research (1999-2008)

	Government	Academic	Hospital	Corporate	Other	Out-of country first author
Northern Ireland	2.7%	50.7%	13.0%	0.4%	1.5%	31.7%
Republic of Ireland	6.6%	52.3%	10.1%	1.2%	0.2%	29.6%
New Zealand	3.9%	47.4%	4.4%	17.4%	0.4%	26.4%
Singapore	11.3%	62.1%	5.1%	1.3%	0.0%	20.2%

Note: (a) Other category includes foundations, zoological gardens, sport organizations. (b) Several leading research organizations in New Zealand are limited liability companies (Ltd.) with government ownership and commercial operations.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Singapore is also the country with the largest share of publications by government organizations in the period 1999-2008, a share of 22.6 percent. New Zealand and Northern Ireland are the countries with the smallest share of government research, less than 8 percent, while Republic of Ireland has an intermediate level of government involvement, with 14.7 percent of publications co-authored by this type of organizations. Northern Ireland has the largest share of scientific research co-authored by hospitals or other health care centers (21 percent), a share significantly higher than the case of Singapore or New Zealand, for example, both with an 8 percent share of hospital co-authorships.

Although more than 56 percent of the organizations undertaking scientific research in Singapore are companies, this type of organization co-authored only 4 percent of the country's publications in the period 1999-2008. The largest share of scientific research by companies is observed in New Zealand, where this type of organizations co-authored 28.1 percent of all publications. This outstanding share is the result of the dominant role of those independent, Crown-owned research and development companies, like AgResearch Ltd. In the Republic of Ireland and Northern Ireland the shares of corporate scientific research are similar or smaller to Singapore's, 3.3 percent and 1.6 percent, respectively.

In the case of Northern Ireland, other types of research organizations have a share of scientific research noticeably higher than the other three countries. This is particularly due to the research activity of the Armagh Observatory, which has co-authored about 2.4 percent of all publications in the period 1999-2008. For the Republic of Ireland and New Zealand, respectively 30% and 26% of their articles have first authors outside of the country. Northern Ireland has the highest level of out-of-country first-authorships (bearing in mind that some of these may be with colleagues in the rest of the United Kingdom as well as in the Republic of Ireland and in other foreign countries). Singapore has the lowest role (20%) of foreign first authors.

2.2 Research areas in Sciences

This section probes the scientific profile of the countries by examining the top subject areas of research. The ISI-WoS SCI database provides subject areas or areas of research for each scientific publication. Scientific articles may be related to more than one subject area out of more than 150 different areas in which research in sciences are undertaken. In general, research activity during the period 1999-2008 was distributed fairly broadly among different subject areas, yet the countries analyzed here show different science profiles (Table 2.11).

Singapore presents a higher concentration in two areas, Engineering (28.7 percent) and Physics (15.9 percent of publications), with an important share (11.8 percent) in Materials Science as well. Chemistry and Computer Science complete the top-5 subject areas in Singapore, with 11 and 8.7 percent, respectively. Interestingly, scientific research in this country has been related to emerging technologies like nanotechnology (3.1 percent of publications), something absent for the other countries.

Physics and Engineering were also among the top-3 research areas for Northern Ireland and the Republic of Ireland, but with shares of less than 10 percent. Chemistry is also among the top-3 research areas for these two countries, with shares of 9.3 and 10.2 percent, respectively. This makes the two countries relatively similar in relation to the main subject areas. However, their profiles differ to some extent when comparing the rest of the top-15 areas.

Table 2.11 Top-15 subject areas of scientific research for selected countries according to shares of publications in each subject area (1999-2008)

Northern Ireland		Republic of Ireland	
Subject area	Share	Subject area	Share
Physics	9.9%	Chemistry	10.2%
Engineering	9.8%	Physics	9.7%
Chemistry	9.3%	Engineering	9.4%
Astronomy & Astrophysics	5.4%	Food Science & Technology	5.3%
Medicine	4.1%	Biochemistry & Molecular Biology	5.1%
Optics	3.9%	Materials Science	4.4%
Materials Science	3.8%	Mathematics	4.1%
Computer Science	3.3%	Medicine	3.6%
Biochemistry & Molecular Biology	3.3%	Microbiology	3.6%
Biotechnology & Applied Microbiology	3.3%	Biotechnology & Applied Microbiology	3.4%
Pharmacology & Pharmacy	3.0%	Computer Science	3.2%
Microbiology	3.0%	Neurosciences	3.0%
Veterinary Sciences	2.6%	Surgery	3.0%
Oncology	2.5%	Agriculture	2.7%
Surgery	2.5%	Pharmacology & Pharmacy	2.6%

New Zealand		Singapore	
Subject area	Share	Subject area	Share
Chemistry	7.5%	Engineering	28.7%
Engineering	6.3%	Physics	15.9%
Ecology	4.8%	Materials Science	11.8%
Biochemistry & Molecular Biology	4.4%	Chemistry	11.0%
Marine & Freshwater Biology	4.4%	Computer Science	8.7%
Plant Sciences	4.3%	Optics	4.7%
Physics	4.0%	Mathematics	4.4%
Geosciences	4.0%	Biochemistry & Molecular Biology	4.3%
Pharmacology & Pharmacy	3.6%	Mechanics	3.6%
Medicine	3.4%	Nanoscience & Nanotechnology	3.1%
Agriculture	3.4%	Medicine	2.8%
Food Science & Technology	3.2%	Telecommunications	2.8%
Environmental Sciences	3.2%	Polymer Science	2.6%
Zoology	3.0%	Automation & Control Systems	2.6%
Mathematics	2.9%	Cell Biology	2.2%

Note: the sum of individual shares exceeds 100 percent since scientific publications may be related to more than one subject area.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

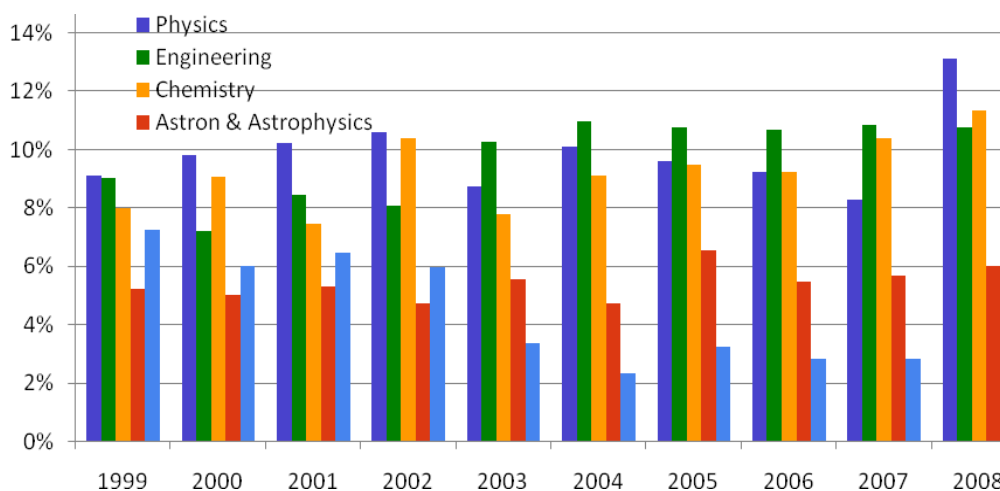
In Northern Ireland, Astronomy & Astrophysics is prominent – a research area not highly ranked in the other three countries. In the Republic of Ireland, more than 5 percent of publications are in the Food Science & Technology area (which is not present in the Northern Ireland profile). Both countries have done research in Medicine and related areas, like Surgery and Pharmacology.

The science research profile of New Zealand is diversified, with Chemistry and Engineering as the main subject areas but with smaller shares (7.5 and 6.3 percent, respectively) compared to the other countries. New Zealand places more stress on research related to natural resources, in areas like Ecology, Marine & Freshwater Biology, Plant Sciences, and Geosciences, all areas with 4 percent or larger shares of publication. Medicine- and Physics-related research is also present, although with smaller shares, particularly for the latter (Physics only contributed 4 percent in the period 1999-2008).

Emerging Trends

The analysis of scientific research publication in different years allows understanding the broad trends taking place in each country in terms of science profile. In recent years, the science profiles remain relatively stable over the time, with some exceptions. The following four figures (2.2, 2.3, 2.4 and 2.5) show the year-by-year trend for the top-5 research areas in each country. Tables 2.12 and 2.13 show the emerging and declining (or least growing) subject areas among the top-20 for each country.

Figure 2.2 Trend in top-5 subject areas of scientific research publication in Northern Ireland (1999-2008)

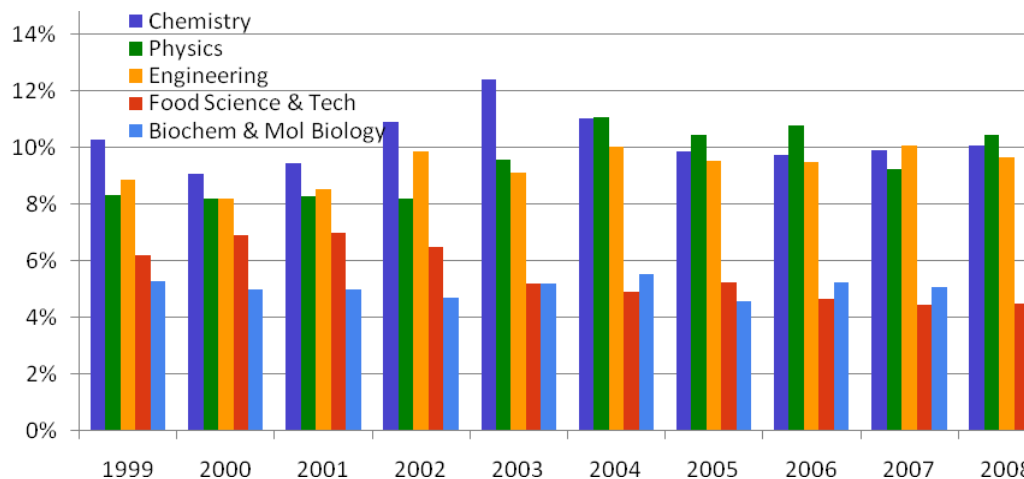


Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Northern Ireland has increased its concentration of scientific research in Physics and Chemistry, subject areas that reached 13.1 and 11.3 percent of all published articles in 2008 (Figure 2.2). Engineering, the most important research area between 2003 and 2007, was the third

subject area in 2008 with 10.8 percent of all publications. Still, Engineering has been one of the research areas that grew the most among the top-20 (although not enough to stay at the top), increasing the number of publications about 50 percent between the periods 1999-2003 and 2004-2008 (Table 2.12). The fact that Physics was not among the subject areas that grew the most between those 5-year periods indicates that the sudden growth in the year 2008 is not necessarily a future trend. Astronomy & Astrophysics remained among the top-5 research areas of Northern Ireland with an average share of 5.4 percent during the period 1999-2008, while Medicine, the fifth subject area, has decreased its share over this period (Table 2.13). Indeed, when considering the top-20 research areas, Medicine has been for Northern Ireland the area that lost the largest share between the periods of 1999-2003 and 2004-2008. Other medicine-related areas like Clinical Neurology and Surgery were also among the group that grew the least between those periods.

Figure 2.3 Trend in top-5 subject areas of scientific research publication in the Republic of Ireland (1999-2008)



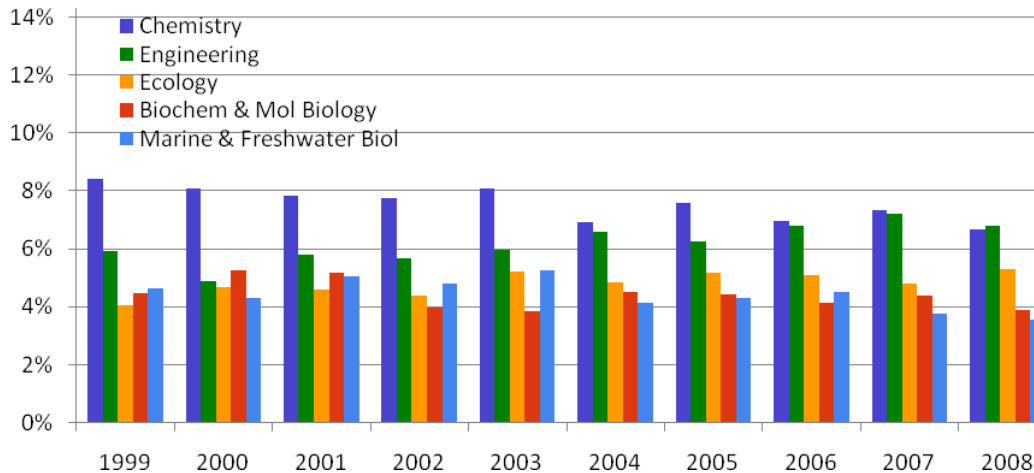
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In the case of the **Republic of Ireland** there have been three subject categories that remained as the top-3 during the period 1999-2008, yet with some changes in their relative importance. In particular, Physics has increased its share to become the main focus of scientific research (10.5 percent of publications in 2008), yet Chemistry and Engineering have had similar shares in recent years (10.1 and 9.7 percent, respectively). These top-3 areas have concentrated at least 30 percent of publications since 2003 and two of them, Chemistry and Physics, were among the top-20 research areas that grew the most between the periods 1999-2003 and 2004-2008. Still, the top emerging areas among the top-20 and between those 5-year periods were Genetics & Heredity (127 percent), Computer Science (119 percent), Optics (119 percent), and Astronomy & Astrophysics (117 percent) (Table 2.12).

Food Science & Technology was among the top-20 research areas that grew the least between those 5-year periods (Table 2.13), losing its relative share to reach only 4.5 percent of all publications in 2008. Biochemistry & Molecular Biology remained relatively stable in terms of

share of publications, becoming the fourth research area with 5.1 percent in 2008. It is interesting to observe that Medicine, an area that is among the top-20 of Republic of Ireland for the period 1999-2008, was the subject area that grew the least in that group between the periods 1999-2003 and 2004-2008 (although with other magnitude, this trend is also noticed for New Zealand and Northern Ireland).

Figure 2.4 Trend in top-5 subject areas of scientific research publication in New Zealand (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The overall comparison for the period 1999-2008 showed that Chemistry and Engineering are the top subject areas for **New Zealand** (Figure 2.4). However, the year-by-year analysis reveals that Chemistry decreased its share from 8.4 to 6.7 percent in ten years, while Engineering, the second area until 2006, has increased steadily to become the top subject by a small difference in 2008. Effectively, Engineering was among the areas that grew the most in the group of top-20 between the periods 1999-2003 and 2004-2008 (45 percent increase in publications).

Scientific research in New Zealand looks more diversified. With publications in as many subject areas as the other three Countries, New Zealand's science shows a more evenly distributed share among, at least, the top-5 areas. Besides Engineering, Environmental Sciences and Physics were among the fastest growers between the periods 1999-2003 and 2004-2008, with an increase of 50 and 46 percent, respectively. Still, these subject areas are not part of the top-5 group (Table 2.12). Both Biochemistry & Molecular Biology and Marine & Freshwater Biology have decreased their shares to less than 4 percent of all publications (only the top-3 subject areas have shares larger than 4 percent). Indeed, when considering the top-20, Marine & Freshwater Biology was among the research areas that grew the least between the periods 1999-2003 and 2004-2008 (Table 2.13). The subject area that decreased the most between those periods was Medicine (38 percent less publications in the second period).

Table 2.12 Fastest growing subject areas among top-20 subject areas

Singapore				New Zealand				Republic of Ireland				Northern Ireland			
Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.
Nanoscience & Nanotechnology	2.0%	3.8%	205%	Environmental Sciences	2.8%	3.4%	50%	Genetics & Heredity	2.0%	2.7%	127%	Oncology	2.0%	3.0%	79%
Biotechnology & Applied Microbiology	1.6%	2.4%	139%	Physics	3.6%	4.4%	46%	Computer Science	2.6%	3.5%	119%	Biochemistry & Molecular Biology	2.8%	3.7%	59%
Oncology	1.3%	2.0%	137%	Engineering	5.7%	6.7%	45%	Optics	2.0%	2.7%	119%	Engineering	8.6%	10.8%	50%
Cell Biology	1.8%	2.6%	129%	Food Science & Technology	3.0%	3.4%	38%	Astronomy & Astrophysics	2.2%	2.8%	117%	Materials Science	3.4%	4.1%	44%
Medicine	2.4%	3.1%	105%	Ecology	4.6%	5.0%	34%	Materials Science	3.9%	4.7%	99%	Computer Science	3.1%	3.6%	39%

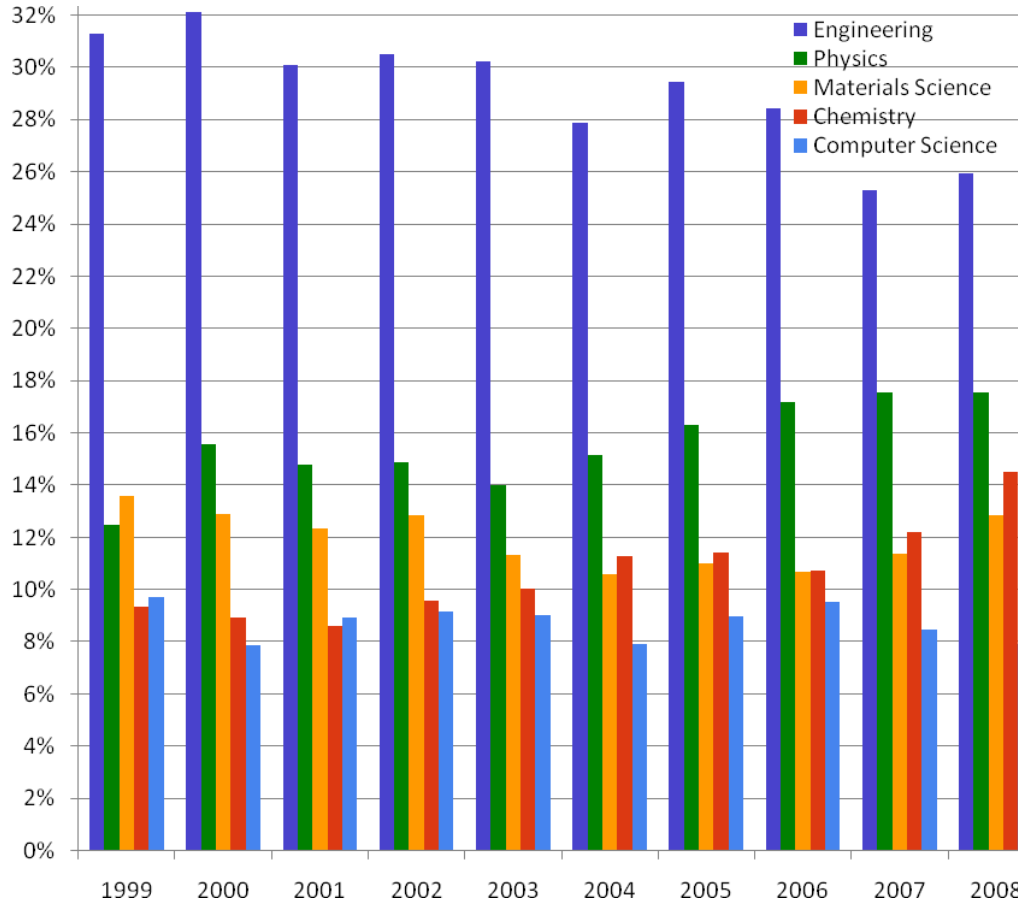
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Table 2.13 Fastest declining (or slowest growing) subject areas among top-20 subject areas

Singapore				New Zealand				Republic of Ireland				Northern Ireland			
Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.
Automation & Control Systems	3.3%	2.2%	5%	Medicine	4.7%	2.4%	-38%	Medicine	4.5%	3.1%	16%	Medicine	5.8%	2.8%	-12%
Mathematics	5.5%	3.7%	7%	Fisheries	2.8%	1.9%	-20%	Pharmacology & Pharmacy	3.1%	2.3%	21%	Veterinary Sciences	3.1%	2.3%	-8%
Mechanics	4.4%	3.2%	14%	Plant Sciences	5.0%	3.8%	-7%	Food Science & Tech	6.3%	4.7%	22%	Optics	4.4%	3.4%	-1%
Polymer Science	3.1%	2.3%	20%	Oceanography	3.1%	2.4%	-6%	Immunology	2.5%	1.9%	30%	Microbiology	3.3%	2.8%	3%
Engineering	30.8%	27.3%	40%	Marine & FreshwaterBio	4.8%	4.0%	2%	Agriculture	3.0%	2.4%	34%	Clinical Neurology	2.2%	1.9%	3%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Figure 2.5 Trend in top-5 subject areas of scientific research publication in Singapore (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

It was already pointed out that the top subject areas of **Singapore** have been Engineering and Physics, something that applies to the whole period 1999-2008 (Figure 2.5). Engineering has always represented more than 25 percent of Singapore's scientific publications, yet it decreased about 5 percentage points in the last 10 years. However, there are other faster growing areas that are reducing the relative importance of Engineering. For example, Physics has increased its share to reach about 17 percent of all publications in 2008, growing almost 85 percent in number of publications between the periods 1999-2003 and 2004-2008. Still, the fastest growing subject areas among the top-20 for this country were Nanoscience & Nanotechnology, Biotechnology & Applied Microbiology, and Oncology (with growth rates of 205 percent, 139 percent, and 137 percent, respectively) (Table 2.12). In particular, Nanoscience & Nanotechnology, has increased its share from only 1.5 percent in 1999 to almost 5 percent in 2008, becoming the seventh subject category in Singapore science. Materials Science and Chemistry, which are among the overall top-5 areas for Singapore, have had a steady increase to reach shares of 13 and 14.5 percent in 2008, respectively.

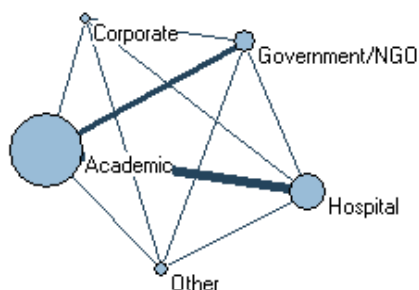
The top-20 subject areas in science in Singapore continue growing in terms of articles, although some of them have growth relatively slowly between the periods 1999-2003 and 2004-2008. Automation & Control Systems, Mathematics, and Mechanics were those that grew the least between those periods in terms of publications—only 5 percent, 7 percent, and 14 percent, respectively (Table 2.13).

2.3 Scientific research collaborations

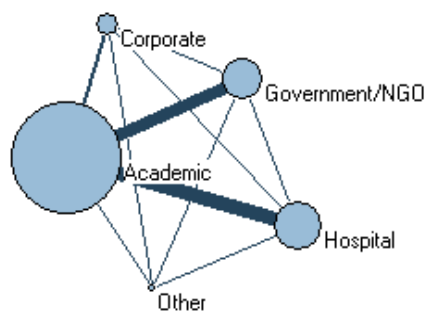
This section examines scientific collaborations between different research organizations within each economy. Although many research collaborations take place within or between universities, they also collaborate with other types of organizations and these other organizations collaborate between them as well. Co-authorships between different organizations in scientific publication are considered research collaborations, although, certainly, these collaborations may be of very different nature in practice depending on the type of organization, research project, or subject area. For each country, we show both the visual of collaborations between types of organizations (using Pajek software) and total shares of publications co-authored between them (in tables). We next analyze the collaborations at the level of individual research organizations within each economy, depicting the nature of collaborations of the top 15 organizations.

Figure 2.6 Collaboration between different types of research organizations in Northern Ireland and the Republic of Ireland (1999-2008)

a) Northern Ireland



b) Republic of Ireland



	Acad	Hosp	Gov	Other	Corp
Acad	80.4%	7.6%	4.1%	0.4%	0.8%
Hosp	7.6%	21.0%	0.4%	0.1%	-
Gov	4.1%	0.4%	7.2%	0.1%	0.1%
Other	0.4%	0.1%	0.1%	2.9%	-
Corp	0.8%	-	0.1%	-	1.6%

	Acad	Hosp	Gov	Corp	Other
Acad	81.1%	5.8%	5.4%	1.6%	0.2%
Hosp	5.8%	16.4%	0.6%	0.1%	0.1%
Gov	5.4%	0.6%	12.0%	0.3%	-
Corp	1.6%	0.1%	0.3%	3.3%	-
Other	0.2%	0.1%	-	-	0.5%

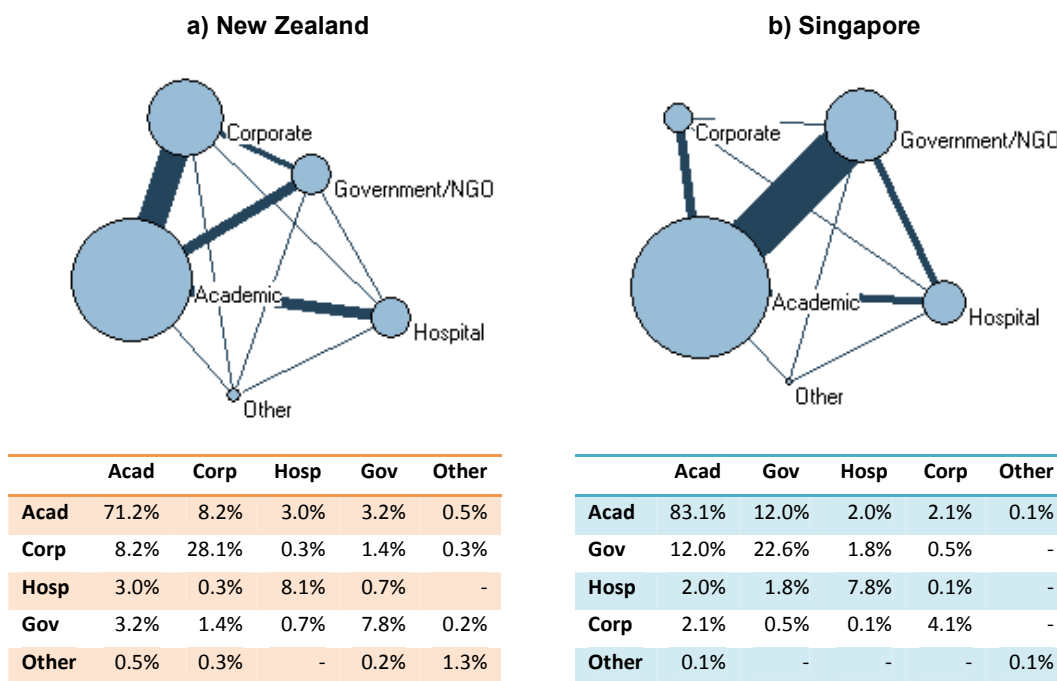
Note: nodes represent research organizations, lines represent co-authorships, the size of lines represent number of co-authored publications, and the size of nodes represents number of publications for that research organization.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In **Northern Ireland**, 80.4 percent of scientific publications are the result of co-authorships between (or within) universities (Figure 2.6a). Collaborations between universities and health organizations represent 7.6 percent of all publications, between universities and Government 4.1 percent, and between universities and companies less than 1 percent. An important share of publications is the result of collaborations between hospitals (21 percent). Collaborations between other types of research organizations are only marginal, as shown by links between nodes (thinner lines) and shares in the respective table (between 0.1 and 0.4 percent).

In the **Republic of Ireland**, there is a similar pattern of scientific collaborations (Figure 2.6b). Most of the research is the result of collaborations within or between universities (more than 81 percent) with a lower share of collaborations between universities and hospitals (5.8 percent), between universities and government organizations (5.4 percent), and between universities and companies (1.6 percent). However, in this country collaborations between government organizations have a somewhat higher share, 12 percent of all publications. Collaborations between companies represent more than 3 percent of all publications, and collaborations between hospitals more than 16 percent. Other collaborations (for example, government-hospitals, companies-hospitals, or between other types of organizations) represent marginal shares.

Figure 2.7 Collaboration between different types of research organizations in New Zealand and Singapore (1999-2008)



Note: nodes represent research organizations, lines represent co-authorships, the size of lines represent number of co-authored publications, and the size of nodes represents number of publications for that research organization.
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In the case of **New Zealand**, a more active corporate sector (which includes crown-owned companies) appears as a larger node with stronger collaborations with universities (Figure 2.7a). About 8.2 percent of all scientific publications in this country are the result of collaboration between these two types of organizations. Meanwhile, collaborations between universities government organizations are 3.2 percent and others (hospitals or other) are 3 percent or less.

In **Singapore**, the academic sector concentrates most of the research activity and collaborates more actively with government organizations, more than the other three countries (Figure 2.7b). Twelve percent of Singapore’s publications are the result of those collaborations (something reflected by the thicker link in the network). In this case, government research organizations have a more active role than in the other countries. More than 22 percent of publications are collaborations within or between government organizations. Collaborations between government and companies are more relevant than in the other three countries, yet they still represent less than 1.5 percent of all collaborations.

Table 2.14 Average and normalized degree for groups of top research organizations according to scientific publications (1999-2008)

	Northern Ireland		Rep. of Ireland		New Zealand		Singapore	
	Degree	Norm degree	Degree	Norm degree	Degree	Norm degree	Degree	Norm degree
Top-3	91	0.25	187	0.19	334	0.21	264	0.30
Top-4 to 10	23	0.06	75	0.08	110	0.07	54	0.06
Top-11 to 20	12	0.03	45	0.05	58	0.04	26	0.03

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The analysis of research collaborations is next undertaken at the level of individual research organizations. Network analysis and visualization is more useful in this case considering the complexity emerging from the large number of research organizations and co-authorships. The degree analysis in networks provides a measure of connectivity of each node within its network. Two measures are used here: 1) the absolute value of degree, which indicates the number of connections of each node, and, 2) the relative value or normalized degree, which indicates, for each node, the proportion of the total nodes of the network connected to that node. For the purpose of this analysis, the degree measure indicates the number of different research organizations that collaborated with each organization in the analyzed period, and the normalized degree indicates what proportion of the network has collaborated with each organization in the analyzed period.

Since the distribution of the degree measure in networks is frequently concealed, we also look at the average degree for groups of top organizations in each country and not global averages (Table 2.14). The data show that, in average, the top-3 research organizations of Northern Ireland have collaborated with 91 other organizations in the period 1999-2008. That represents collaborations with 25 percent of all organizations in the economy. The following group

(organizations 4th to 10th in the rank of publications) has, in average, collaborated with 23 other research organizations in the same period, or about 6 percent of the network. The group of organizations of top-11 to 20 collaborated with only 12 other organizations in average.

Certainly, as science becomes increasingly collaborative, research collaborations are positively correlated with overall publication activity in top organizations. Those that published the most collaborated the most as well. This is typical of this type of networks, yet there is some variation between the countries.

Referring to Table 2.14, the top-3 research organizations in the **Republic of Ireland** collaborated in average with 19 percent of all organizations during the period 1999-2008, 6 percentage points less than Northern Ireland. However, the other two groups we are comparing within the top-20 organizations have been, in average, more connected to the rest of the network than Northern Ireland. **New Zealand** presents a pattern of connectivity similar to that of the Republic of Ireland, with slightly more average collaborations in the top-3 research organizations. In this case, however, although it was shown that research activity is relatively less concentrated in the top-20 organizations, collaborations are still more likely to occur within this group. **Singapore** is, within the group of four countries, the one with the highest average normalized degree. The top-3 organizations collaborated in average with 264 research organizations or about 30 percent of the rest of Singapore organizations in the period 1999-2008.

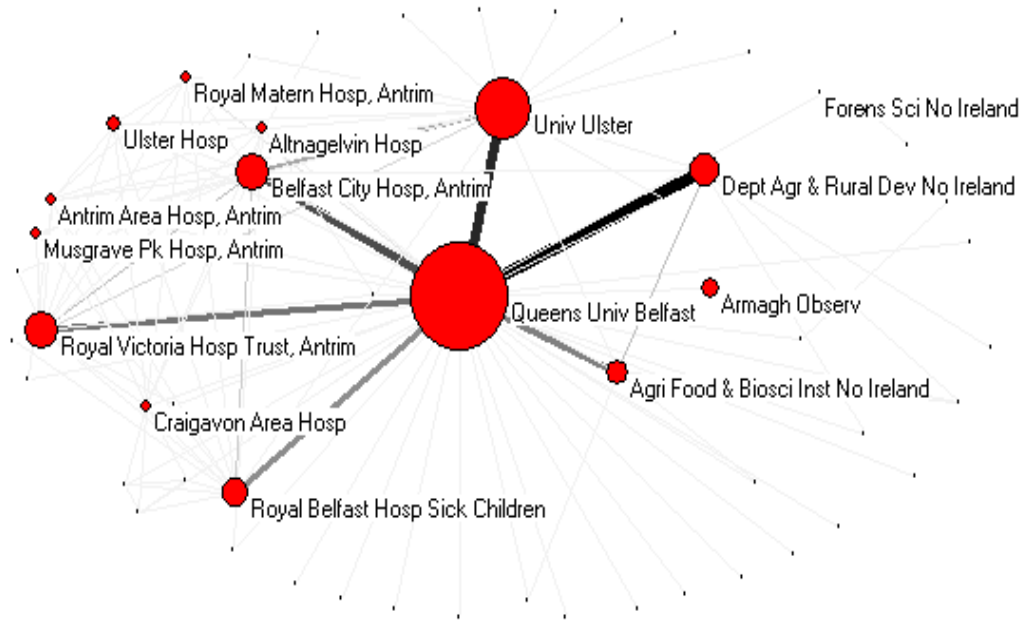
Strength and Network of Collaboration

To demonstrate graphically the complexity of the research networks developed in the period 1999-2008, we visualized the research collaboration networks in the countries (Figures 2.8, 2.9, 2.10 and 2.11). These graphics reveal to some extent the role of top organizations in the research network system (the top-15 research organizations are labelled), their high number of connections or co-authorships with other organizations, and the complete set of collaborations for the rest of organizations as well.²

In Northern Ireland, 114 research organizations or 31 percent of all organizations have undertaken research without collaborations in the period 1999-2008; for the Republic of Ireland those figures are 305 or 32 percent; for New Zealand, 319 or 21 percent; and, for Singapore, 225 or 25 percent. This implies that, relatively, New Zealand research organizations have been more open to collaborations than the rest of the countries’.

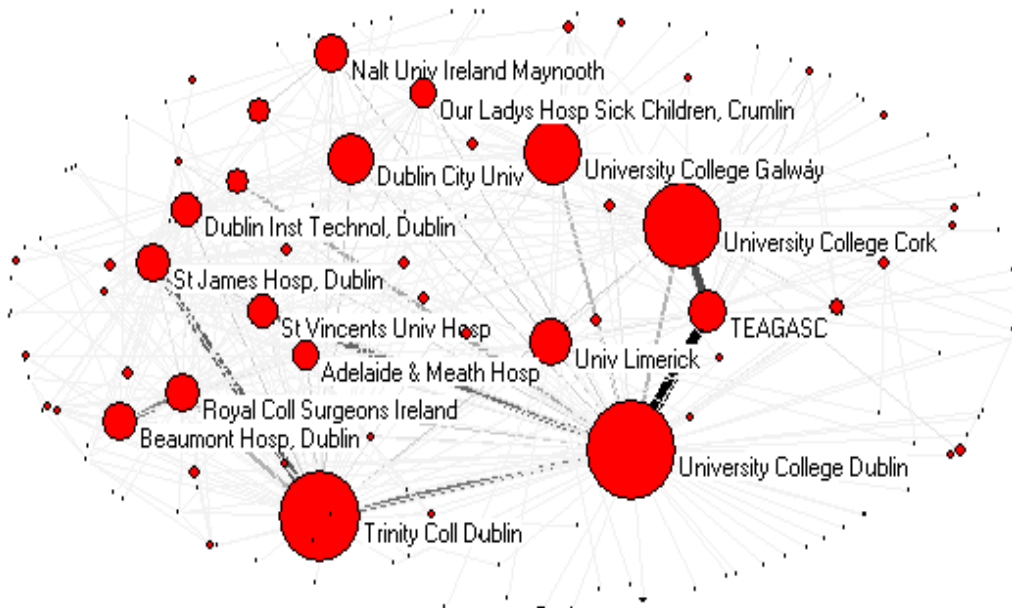
² For all network figures in this section: nodes represent research organizations and their size the number of publications; lines represent co-authorships and their size and color represent the strength of collaborations (i.e. the wider and the darker the line, the higher the number of co-authorships for the linked research organizations); only organizations with three or more co-authorships are shown; labels are displayed for only top-15 research organizations in terms of publications.

Figure 2.8 Research collaboration networks in Northern Ireland (1999-2008)



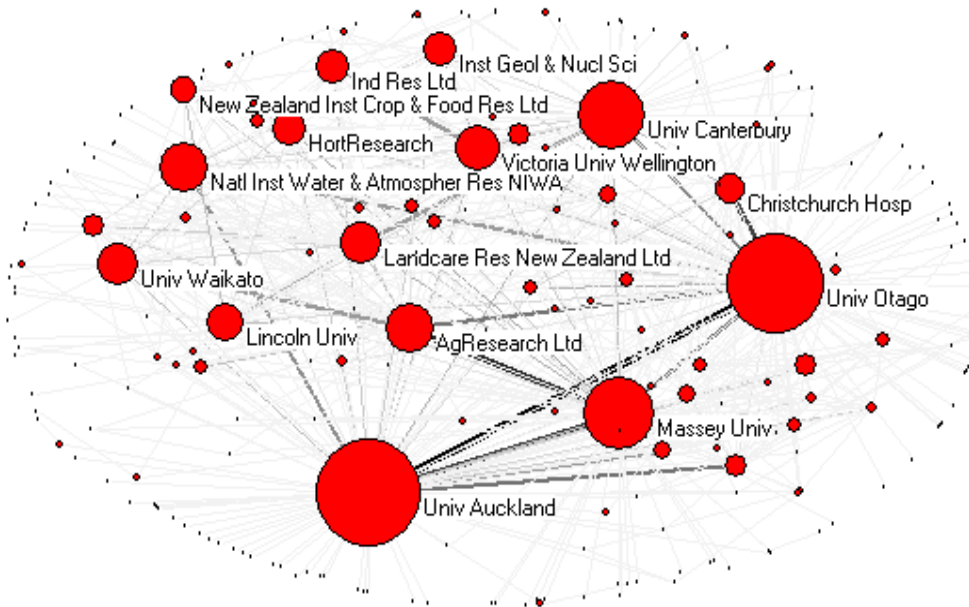
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.9 Research collaboration networks in the Republic of Ireland (1999-2008)



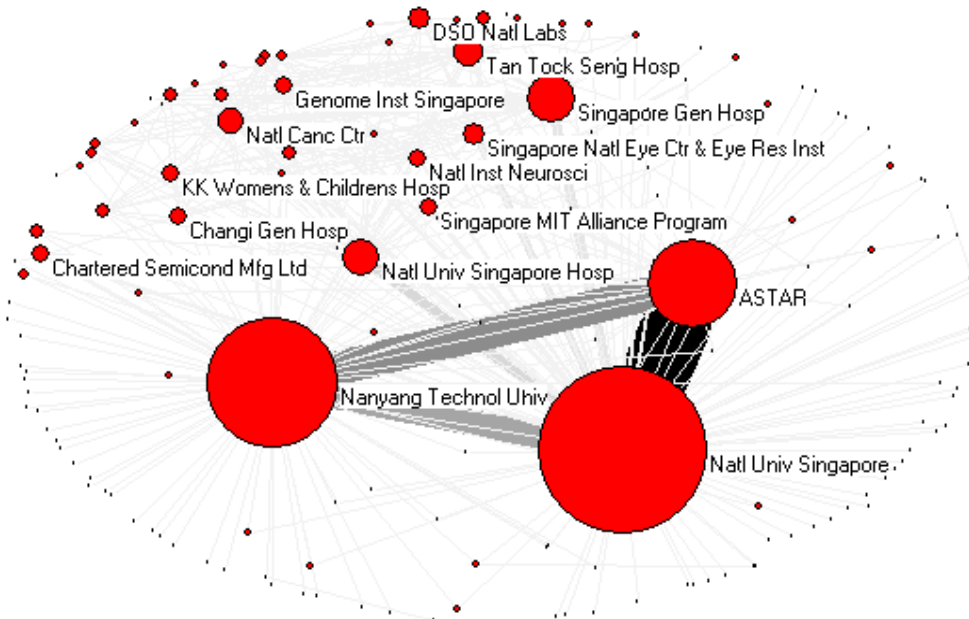
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.10 Research collaboration networks in New Zealand (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.11 Research collaboration networks in Singapore (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

2.4 Industry Collaborations in Sciences

The analysis of corporate research is undertaken in this section. Although private corporations undertake a relatively small share of research publication output, this output is measurable, and indicates the innovation and competitiveness landscape of the economy that is not necessary driven by pure state funding but perhaps promoted by government support.

Table 2.15 Corporate publications trend, total, and average annual growth rate (1999-2008)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Annual growth rate
Northern Ireland	13	12	16	11	21	20	21	25	33	17	189	9.8%
Republic of Ireland	53	70	74	83	85	93	91	95	115	157	916	13.5%
New Zealand	1,082	945	1,015	1,074	1,060	1,078	1,099	1,113	1,077	1,051	10,594	-0.2%
Singapore	94	119	134	152	165	174	203	216	227	221	1,705	10.2%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The share of corporate research is relatively low in Northern Ireland (1.6 percent), Republic of Ireland (3.3 percent), and Singapore (4.1 percent), while in New Zealand it is more important than government and hospital research (with a 28.1 percent of all publications) (Table 2.9). However, it should be noted that a major role is played in scientific research in New Zealand by a series of independent, Crown-owned research and development companies that also generate revenue streams from commercial clients. In spite of their share of publications, the scientific activity of these New Zealand companies in terms of published articles has not shown appreciable change in the period 1999-2008 (Table 2.15). In contrast, corporate research has shown average annual growth rates of 8 percent or more in Northern Ireland (9.8 percent), Republic of Ireland (13.5 percent), and Singapore (10.2 percent). Still, these three countries have levels of corporate scientific publication well below of New Zealand's, particularly Northern Ireland, with only 189 research articles published by companies in the period 1999-2008 (Table 2.15).

The number of companies publishing scientific articles varies each year (Table 2.16). Still, the average number of companies has increased in the four countries, including New Zealand where the number of articles published between 1999 and 2008 remained constant. Between the five-year periods 1999-2003 and 2004-2008, the average number of companies publishing has grown 26.5 percent in Northern Ireland, 54.3 percent in the Republic of Ireland, 40.2 percent in New Zealand, and 50.3 percent in Singapore.

Table 2.16 Number of companies publishing articles (1999-2008)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total firms ^a	Chg. of avg. firms ^b
Northern Ireland	13	12	15	10	18	13	15	20	24	14	91	26.5%
Republic of Ireland	43	48	52	63	63	64	60	76	84	131	407	54.3%
New Zealand	92	88	113	106	114	121	128	142	163	165	643	40.2%
Singapore	48	63	82	84	87	92	106	108	123	118	497	50.3%

Note: (a) Count of unique companies does not contemplate mergers or company split-ups;
 (b) change in average number of unique companies compares period 1999-2003 to 2004-2008.
 Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Top Companies in Corporate Research

Tables 2.17, 2.18, 2.19 and 2.20 show the top-20 companies in terms of scientific publications for the period 1999-2008. The share of overall publications for corporate research organizations is low in Northern Ireland, the Republic of Ireland, and Singapore, with all companies contributing individually with 0.7 percent or less of all publications (most of the companies contribute individually with 0.1 percent or less). In New Zealand, some crown-owned companies are among the top research organizations of the country based on their share of publications. The contribution of companies to scientific publication in each country is relatively low but more evenly distributed among companies than in other types of research organizations.

Table 2.17 Top-20 companies in Northern Ireland

Rank	Pub(s)	Share of all research	Share of corp. research	Top companies
1	14	0.1%	7.4%	Seagate Technol
2	13	0.1%	6.9%	Andor Technol Ltd
3	13	0.1%	6.9%	Bombardier Aerosp UK
4	12	0.1%	6.3%	Randox Labs Ltd
5	10	0.1%	5.3%	Devenish Nutr Ltd
6	9	0.1%	4.8%	Xenosense Ltd
7	6	0.0%	3.2%	Norbrook Labs Ltd
8	5	0.0%	2.6%	Avalon Instruments Ltd
9	4	0.0%	2.1%	Amphion Semicond Ltd
10	4	0.0%	2.1%	Fus Antibodies Ltd
11	4	0.0%	2.1%	McFarland Associates
12	3	0.0%	1.6%	BCO Technol NI Ltd
13	3	0.0%	1.6%	EFMB Ltd
14	3	0.0%	1.6%	Irish Fertilizer Ind Ltd
15	3	0.0%	1.6%	MDS Pharma Serv
16	3	0.0%	1.6%	Vetpar Serv
17	2	0.0%	1.1%	Aerosp Short Bros PLC
18	2	0.0%	1.1%	AI Serv NI Ltd
19	2	0.0%	1.1%	Almac Diagnost Ltd
20	2	0.0%	1.1%	Analog Devices Belfast Ltd
	82	0.7%	43.4%	Other 71 companies
Total	189			

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In **Northern Ireland**, academic publications are strongly concentrated in two universities (Queens University Belfast and University of Ulster, with 62 percent and 19.5 percent), while the top-3 companies co-author only about 7 percent of corporate publications each (Table 2.17). Still, these companies are among the top-20 research organizations of the country. These top-3 companies are Seagate Technologies (a US manufacturer of digital storage solutions with worldwide operations), Andor Technology Ltd (a Queen's University of Belfast's spin out that manufactures high performance light measuring solutions), and Bombardier Aerospace UK (a Canadian manufacturer of aircrafts and trains). The rest of the top-20 companies in this list have shares between 1.1 and 6.3 percent of corporate publications, while the remaining 71 companies in the country co-authored about 43 percent of Northern Ireland corporate publications.

Table 2.18 Top-20 companies in the Republic of Ireland

Rank	Pub(s)	Share of all research	Share of corp. research	Top companies
1	49	0.2%	5.3%	Analog Devices Inc
2	25	0.1%	2.7%	Coillte Res & Dev
3	23	0.1%	2.5%	Alltech Ireland Ltd
4	18	0.1%	2.0%	Intel Ireland Ltd
5	14	0.1%	1.5%	Stryker Howmedica Osteon
6	13	0.0%	1.4%	Biomed Res Ltd
7	13	0.0%	1.4%	Elan Corp Plc
8	11	0.0%	1.2%	Trident Bioanalyt Ltd
9	10	0.0%	1.1%	Denis Wood Associates
10	10	0.0%	1.1%	Farran Technol Ltd
11	10	0.0%	1.1%	Guinness R&D
12	10	0.0%	1.1%	Luxcel Biosci Inc
13	10	0.0%	1.1%	Megazyme Int Ireland Ltd
14	9	0.0%	1.0%	Loctite Ireland Ltd
15	9	0.0%	1.0%	Media Lab Europe
16	8	0.0%	0.9%	Glebe Sci Ltd
17	8	0.0%	0.9%	Littelfuse Ireland Ltd
18	8	0.0%	0.9%	Medtron AVE Ireland Ltd
19	8	0.0%	0.9%	Ultrason Sci Ltd
20	7	0.0%	0.8%	CSA Grp
	648	2.4%	70.7%	Other 387 companies
Total	916			

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

No company is among the top-20 research organizations in the **Republic of Ireland**, and the average contribution of each company to publications is even lower than in Northern Ireland. The top-3 companies in this country are Analog Devices Inc. (a US manufacturer of integrated circuits for a wide array of electronic equipment), Coillte Teoranta (an Irish State owned company operating in forestry, land based businesses, and added-value processing operations), and Alltech Ireland Ltd (an Irish biotechnology company providing natural solutions to the feed and food industries) (Table 2.18). They have shares of 5.3 percent, 2.7 percent, and 2.5 percent of corporate publications, respectively. The rest of the top-20 companies have shares of 2 percent or less, while other 387 companies publishing in the Republic of Ireland share about 70 percent of corporate publications.

Table 2.19 Top-20 companies in New Zealand

Rank	Pub(s)	Share of all research	Share of corp. research	Top companies
1	1,901	5.1%	17.9%	AgResearch Ltd
2	1,860	4.9%	17.6%	Natl Inst Water & Atmospher Res NIWA
3	1,413	3.8%	13.3%	Landcare Res New Zealand Ltd
4	897	2.4%	8.5%	HortResearch
5	876	2.3%	8.3%	Inst Geol & Nucl Sci
6	845	2.2%	8.0%	Ind Research Ltd
7	623	1.7%	5.9%	New Zealand Inst Crop & Food Res Ltd
8	416	1.1%	3.9%	Adis Int Ltd
9	387	1.0%	3.7%	New Zealand Forest Res Inst Ltd
10	330	0.9%	3.1%	Inst Environm Sci & Res Ltd
11	186	0.5%	1.8%	Dexcel Ltd
12	167	0.4%	1.6%	Fonterra Cooper Grp Ltd
13	45	0.1%	0.4%	AgriQual New Zealand Ltd
14	37	0.1%	0.3%	Livestock Improvement Corp
15	36	0.1%	0.3%	Genesis Res & Dev Corp Ltd
16	32	0.1%	0.3%	Bldg Res Assoc New Zealand Ltd
17	28	0.1%	0.3%	Canesis Network Ltd
18	25	0.1%	0.2%	Mat Performance Technol Ltd
19	25	0.1%	0.2%	Microfossil Res Ltd
20	24	0.1%	0.2%	Carina Chem Labs Ltd
	1,354	3.6%	12.8%	Other 623 companies
Total	10,594			

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In **New Zealand**, there are eight Crown-owned companies and research institutes among the top-20 corporate publishers (Table 2.19). As shown before, the overall contribution of companies to publications in this country (28.1 percent) is noticeable higher than in the rest of the countries analyzed here. Those Crown-owned organizations also concentrate publications among companies. The top-7 companies in terms of publications, all Crown-owned research companies, co-authored more than 75 percent of all corporate publications and more than 21 percent of all publications of New Zealand in the period 1999-2008. The top-3 are AgResearch Ltd (a research services company in the areas of Agriculture & Environment, Applied Biotechnologies, and Food & Textiles), National Institute of Water and Atmospheric Research Ltd (NIWA) (research and consultancy company conduct environmental science), and Landcare Resesearch Ltd (a provider of solutions and advice for sustainable development and the management of land-based natural resources) (Table 2.19). They have shares of 17.9 percent, 17.6 percent, and 13.3 percent of

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corporate publications, respectively. The rest of the top-20 companies have shares of 8.5 percent or less (several of them are Crown-owned companies as well), while other 623 companies co-authored only 12.8 percent of the corporate publications of that period.

Table 2.20 Top-20 companies in Singapore

Rank	Pub(s)	Share of all research	Share of corp. research	Top companies
1	320	0.7%	18.8%	Chartered Semicond Mfg Ltd
2	48	0.1%	2.8%	Novartis Singapore Pte Ltd
3	42	0.1%	2.5%	Singapore Util Int Pte Ltd
4	39	0.1%	2.3%	GlaxoSmithKline Pharmaceut
5	36	0.1%	2.1%	Seagate Technologies
6	33	0.1%	1.9%	NanoMat Technol Private Ltd
7	31	0.1%	1.8%	Motorola Elect Co Ltd
8	25	0.1%	1.5%	Union Carbide Asia Pacific Inc
9	22	0.1%	1.3%	ASM Technol Pvt Ltd
10	21	0.0%	1.2%	STMicroelect Asia Pacific Pte Ltd
11	19	0.0%	1.1%	Dow Chem Pacific Ltd
12	19	0.0%	1.1%	Philips Elect Singapore Pte Ltd
13	18	0.0%	1.1%	Agilent Technol Singapore Pte Ltd
14	17	0.0%	1.0%	ES Cell Int Pte Ltd
15	17	0.0%	1.0%	MerLion Pharmaceut
16	16	0.0%	0.9%	Microfine Mat Technol Pte Ltd
17	16	0.0%	0.9%	Novo Nordisk AS
18	15	0.0%	0.9%	Hewlett Packard Corp
19	15	0.0%	0.9%	Infineon Technol Asia Pacific Pte Ltd
20	13	0.0%	0.8%	Eli Lilly Company
	947	2.2%	55.5%	Other 477 companies
Total	1,705			

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In **Singapore**, Chartered Semiconductor Mfg Ltd (a dedicated semiconductor foundry) has concentrated almost one-fifth of all corporate publications during the period 1999-2008. It is the only company among the top-20 research organizations of this country, with a share of 18.8 percent of corporate publications and only 0.7 percent of all scientific publications (Table 2.20). Novartis Singapore Pte Ltd (a Swiss pharmaceutical company with global presence) and Singapore Utilities International Pte Ltd (an R&D and consultancy company in the sector of water supply management and recycling which is a wholly owned registered subsidiary of the Public Utilities Board of Singapore) are among the top-3 companies as well, with 2.8 percent and 2.5 percent of Singapore corporate publications. The rest of the top-20 companies have shares of 2.3 percent or less, while other 477 companies co-authored 55.5 percent of the corporate publications of the time period 1999-2008.

Top Subject Areas in Corporate Research

The bibliometric analysis allows looking at the top subject areas of corporate research (Table 2.21) and compare them with the top subject areas of the overall profile of scientific publication in each country (Figures 2.12 and 2.13). One of the most noticeable differences is the higher relevance of Engineering research in corporate publications, particularly for Northern Ireland, Republic of Ireland, and Singapore. Materials Science is an area more addressed by corporate research as well, particularly in Northern Ireland and the Republic of Ireland. Moreover, except for New Zealand, the top subject areas of corporate research contribute more publications than the top areas for the overall research publication activity for these countries in the period 1999-2008 (discussed in following paragraphs.)

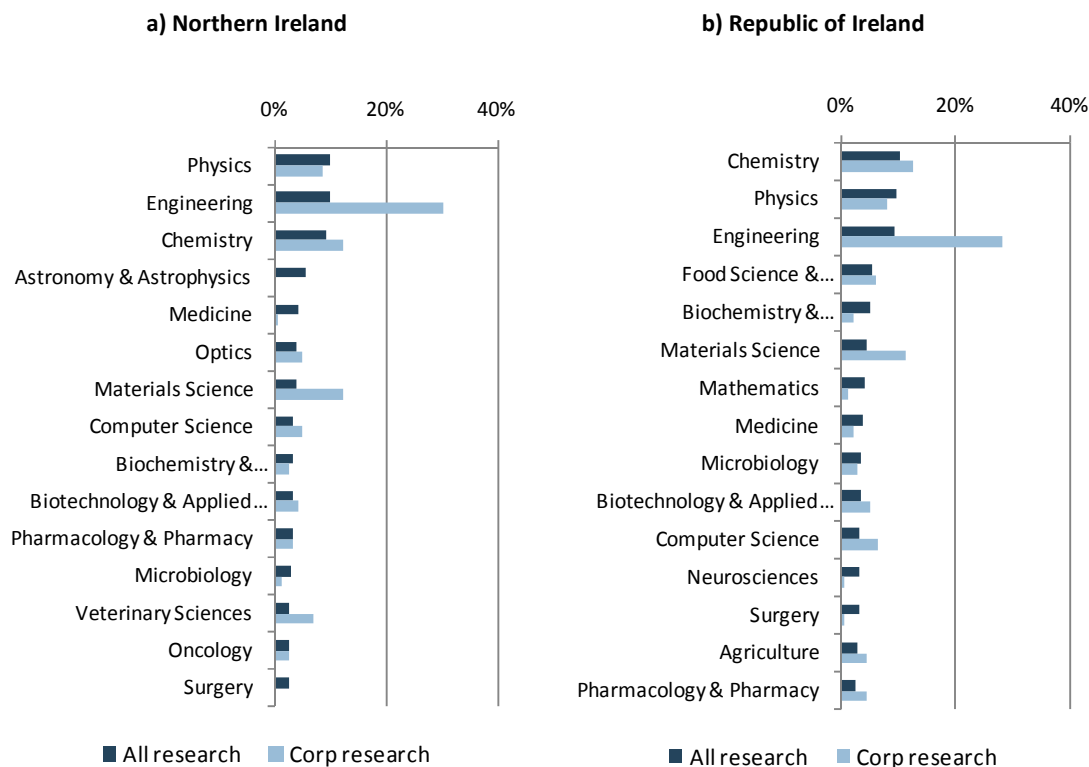
Table 2.21 Top-15 subject areas for corporate research (1999-2008)

Northern Ireland		Republic of Ireland		New Zealand		Singapore	
Subject area	Share	Subject area	Share	Subject area	Share	Subject area	Share
Engineering	30.2%	Engineering	28.1%	Plant Sciences	9.1%	Engineering	42.3%
Chemistry	12.2%	Chemistry	12.6%	Agriculture	7.7%	Physics	21.6%
Materials Science	12.2%	Materials Science	11.4%	Marine & Freshwater Biology	7.7%	Materials Science	15.7%
Physics	8.5%	Physics	7.9%	Ecology	6.9%	Chemistry	9.3%
Veterinary Sciences	6.9%	Computer Science	6.2%	Geosciences	6.9%	Computer Science	6.7%
Food Science & Technology	5.3%	Food Science & Technology	5.9%	Food Science & Technology	6.4%	Nanoscience & Nanotechnology	5.8%
Computer Science	4.8%	Veterinary Sciences	5.7%	Chemistry	5.9%	Optics	4.2%
Optics	4.8%	Biotechnology & Applied Microbiology	5.0%	Oceanography	5.5%	Pharmacology & Pharmacy	3.6%
Biotechnology & Applied Microbiology	4.2%	Pharmacology & Pharmacy	4.4%	Environmental Sciences	5.4%	Telecommunications	3.2%
Agriculture	4.2%	Agriculture	4.3%	Pharmacology & Pharmacy	5.1%	Polymer Science	3.0%
Operations Research & Mgmt Science	3.7%	Telecommunications	3.7%	Agronomy	5.0%	Electrochemistry	2.6%
Pharmacology & Pharmacy	3.2%	Optics	2.9%	Engineering	4.9%	Construction & Building Technology	2.6%
Construction & Building Technology	3.2%	Marine & Freshwater Biology	2.7%	Fisheries	4.8%	Biochemistry & Molecular Biology	2.6%
Biochemistry & Molecular Biology	2.6%	Environmental Sciences	2.7%	Horticulture	3.9%	Biochemical Research Methods	2.4%
Oncology	2.6%	Microbiology	2.6%	Soil Science	3.9%	Energy & Fuels	2.2%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Corporate research in **Northern Ireland** is particularly concentrated in Engineering (30.2 percent), Chemistry, and Materials Sciences (both with 12.2 percent shares) (Table 2.21). These top-3 subject areas respond for almost 50 percent of all corporate research, while the top-3 overall research areas for this country (Physics and, here again, Engineering and Chemistry) share only 27 percent of all publications. In particular, Engineering and Materials Science are more prevalent in corporate research than in the overall scientific profile of Northern Ireland (Figure 2.12a). Chemistry and Veterinary Sciences are also relatively more prevalent in corporate publication. On the other hand, the examination of the top subject areas reveals that there are no corporate publications in the areas of Astronomy & Astrophysics, Medicine, and Surgery.

Figure 2.12 Shares of top-15 subject areas for all scientific research vs. share of corporate research (1999-2008)

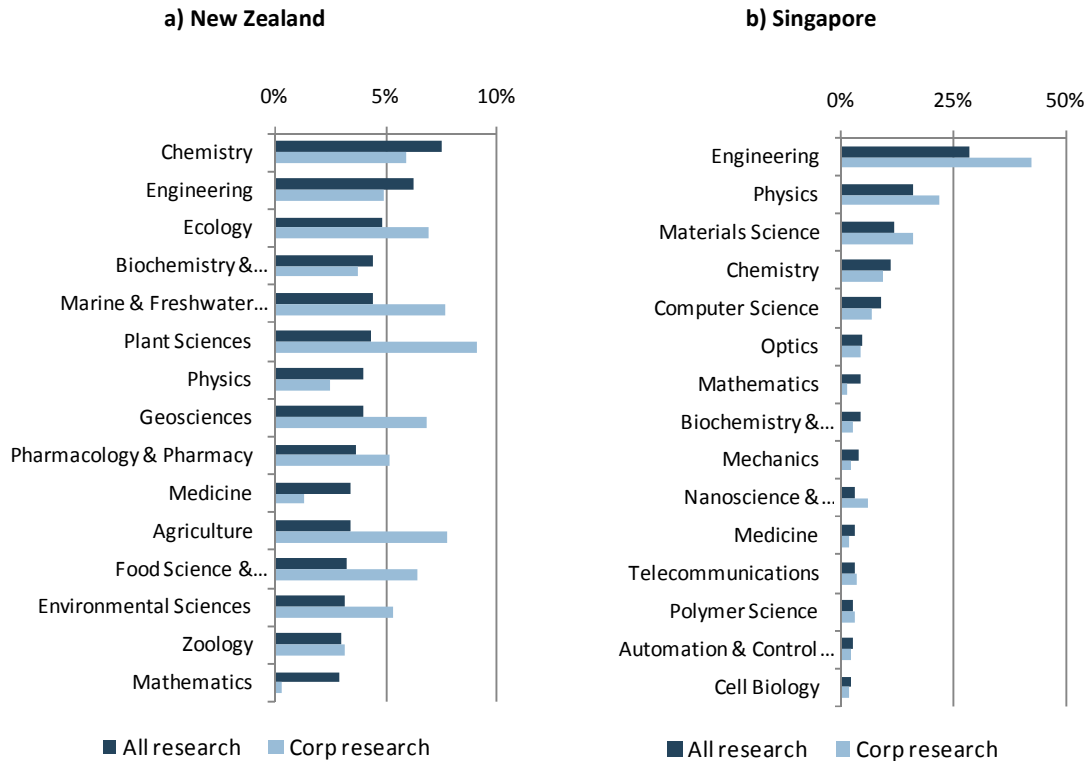


Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Corporate research in the **Republic of Ireland** is concentrated in Engineering (28.1 percent), Chemistry (12.6 percent), and Materials Science (11.4 percent), similarly to Northern Ireland (Table 2.21). These top-3 subject areas of corporate research are also more prevalent in this case, concentrating 45 percent of all corporate research (while Chemistry, Physics, and Engineering contribute about 27 percent of all scientific publications in the country). In particular, Engineering and Materials Science are more prevalent in corporate research than in the overall

scientific profile of Republic of Ireland (Figure 2.12b). Chemistry, Biotechnology & Applied Microbiology, Computer Science are also among the subject areas of corporate publication that are more prevalent than the overall scientific publication profile of Republic of Ireland for the period 1999-2008. On the other hand, the relative shares of Mathematics, Neurosciences, and Surgery are very low in corporate publications compared to the overall profile of scientific publications for the country.

Figure 2.13 Shares of top-15 subject areas for all scientific research vs. share of corporate research (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In the case of **New Zealand**, corporate publication is more evenly distributed between several subject areas, although it is still relatively more prevalent in several of the top-15 subject areas for the country in the period 1999-2008 (Figure 2.13a). Plant Sciences, Agriculture, and Marine & Freshwater Biology are the main corporate subject areas, with shares of 9.1 percent, 7.7 percent, and 7.7 percent, respectively. These subject areas are among the most important differences with the overall profile of publications in this country. Also Ecology, Geosciences, Agriculture, Food Science & Technology, and Environmental Sciences are more prevalent subject areas in corporate research. On the other hand, corporate publication in areas like Chemistry, Engineering, and Physics is relatively less important, while subject areas like Medicine and Mathematics have very low shares of corporate publication.

For **Singapore**, the top-3 subject areas of corporate publication (Engineering, Physics, and Materials Science) coincide with the top-3 areas of the overall publication profile of the country, yet they have higher shares in corporate publication (Figure 2.13b). About 42 percent of corporate publications are in Engineering, 21.6 percent in Physics, and 15.7 percent in Materials Science (Table 2.21). Nanoscience & Nanotechnology, Telecommunications, Polymer Science are relatively more prevalent in corporate research as well, with shares of 5.8 percent, 3.2 percent, and 3 percent, respectively. For the rest of the top-15 subject areas of this country, corporate publication is less important, yet still represents low shares.

Areas of Growth and Decline

The fastest growing areas of corporate publication coincide only in few cases with the fastest growing areas of the overall publication profiles of the countries (Table 2.22a and 2.22b). On the other hand, in general, the fastest growing areas in corporate publication have grown relatively faster than their counterparts in the overall picture of scientific publication (with the exception of New Zealand). Among the top-20 subject areas of corporate publication, Biotechnology & Applied Microbiology is the fastest growing in Singapore and Northern Ireland (271 percent and 600 percent between the 5-year periods 1999-2003 and 2004-2008) and is among the top-5 fastest growing areas in New Zealand as well (with 23 percent growth between those periods). Chemistry is among the top-5 emerging corporate subject areas of Singapore, Republic of Ireland, and Northern Ireland as well, with growth rates between 80 percent and 260 percent. For the fastest declining or slowest growing corporate subject areas there is no common pattern for these countries. Only Construction & Building Technology (in Singapore and Northern Ireland) and Materials Science (in New Zealand and Northern Ireland) are common declining corporate areas of publication.

In **Singapore**, the top-3 emerging subject areas in corporate publication among the top-20 are Biotechnology & Applied Microbiology, Pharmacology & Pharmacy, and Biochemical Research Methods, with growth rates of 271 percent, 243 percent, and 210 percent between the 5-year periods 1999-2003 and 2004-2008 (Table 2.22a). Still, these three subject areas represent relatively low shares (2.5 percent, 4.6 percent, and 3 percent, respectively, in the 5-year period 2004-2008). On the other hand, among the top-20 corporate subject areas, there are at least three areas that have declined in terms of publication share. They are Construction & Building Technology, Geosciences, and Metallurgy & Metallurgical Engineering, which reduced their shares 20 percent, 20 percent, and 13 percent between the 5-year periods 1999-2003 and 2004-2008. These subject areas are not among the top-20 subject areas of the country and, except for Construction & Building Technology, they have grown in the overall profile.

In **New Zealand**, four of the top-5 emerging corporate subject areas are also among the top-20 subject areas for the country (Table 2.22a). In particular, Environmental Sciences and Food Science & Technology are the fastest growing corporate subject areas, yet they have growth rates similar to the overall profile of research publication for the country. This similarity is the result of the important contribution of corporate publications to the total. Still, the top-5 fastest growing corporate subject areas have grown at lower rates between the 5-year periods 1999-2003 and

2004-2008. As shown before, the number of corporate publications has remained stable between 1999 and 2008 (Table 2.15) and, therefore, it is expected for this type of research organizations to reduce its relative contribution in most of its subject areas. The fastest declining subject areas in corporate publication between those 5-year periods have been Toxicology, Fisheries, and Horticulture (Table 2.22b). Moreover, contrary to the case of Singapore and the Republic of Ireland, corporate publications in Materials Science have declined in this country (23 percent between 1999-2003 and 2004-2008).

In the **Republic of Ireland**, Agriculture, Materials Science, and Environmental Sciences are the fastest growing corporate subject areas (Table 2.22a). In particular, Agriculture, the fastest growing for corporate research, is among the slowest growing in general. And, although Materials Science is also among the fastest growing for all publications in this country, the growth rate for corporate publications is even higher for corporate publications. Similarly to Singapore and Northern Ireland, Chemistry is also among the fastest growing areas for corporate publication in this case, yet the growth rate is lower in the Republic of Ireland. On the other hand, while there are no declining subject areas among the overall top-20, Forestry, Microbiology, and Food Science & Technology are declining areas in corporate publication (Table 2.22b).

Northern Ireland shares with other countries some of the emerging areas of corporate publication, although in this case the growth rates are substantially higher (Table 2.22a). For example, Biotechnology & Applied Microbiology, Food Science & Technology, and Medical Laboratory Technology are the fastest growing corporate subject areas, with growth rates between 300 percent and 600 percent between 1999-2003 and 2004-2008). As a consequence, these subject areas have increased notably their participation in corporate publication. Another example is Chemistry, also among the top-5 emerging in corporate publication, now with a 15.5 percent share (260 percent growth compared to the 5-year period 1999-2003). On the other hand, Electrochemistry and Water Resources have been among the fastest declining corporate areas, both with practically no corporate publications in the last five years (while growing at a 30 percent rate in the same period for the overall research activity of the country) (Table 2.22b).

Table 2.22a Fastest growing subject areas in corporate research

Singapore				New Zealand				Republic of Ireland				Northern Ireland			
Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.
Biotechnology & Applied Microbiology	1.1%	2.5%	271%	Environmental Sciences	4.5%	6.2%	44%	Agriculture	2.5%	5.4%	233%	Biotechnology & Applied Microbiology	1.4%	6.0%	600%
Pharmacology & Pharmacy	2.1%	4.6%	243%	Food Science & Technology	5.5%	7.2%	37%	Materials Science	7.9%	13.6%	159%	Food Science & Technology	2.7%	6.9%	300%
Biochemical Research Methods	1.5%	3.0%	210%	Biochemistry & Molecular Biology	3.4%	4.1%	28%	Environ. Sciences	1.9%	3.3%	157%	Medical Laboratory Technology	1.4%	3.4%	300%
Chemistry	7.8%	10.3%	106%	Biotechnology & Applied Microbiology	3.1%	3.6%	23%	Veterinary Sciences	4.9%	6.2%	89%	Chemistry	6.8%	15.5%	260%
Nanoscience & Nanotechnology	5.1%	6.2%	91%	Ecology	6.4%	7.4%	22%	Chemistry	11.2%	13.4%	80%	Energy & Fuels	1.4%	2.6%	200%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Table 2.22b Fastest declining subject areas in corporate research

Singapore				New Zealand				Republic of Ireland				Northern Ireland			
Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.	Subject area	Share 1999-2003	Share 2004-2008	Var.
Construction & Bldg Tech	3.8%	1.9%	-20%	Toxicology	4.7%	3.0%	-32%	Forestry	4.4%	0.9%	-69%	Electrochemistry	5.5%	0.0%	-100%
Geosciences	3.0%	1.5%	-20%	Fisheries	5.7%	3.9%	-28%	Microbiology	3.6%	2.0%	-15%	Water Resources	5.5%	0.9%	-75%
Metallurgy & Metallurgical Engineering	2.4%	1.3%	-13%	Horticulture	4.7%	3.2%	-27%	Food Science & Technology	7.7%	4.7%	-7%	Materials Science	17.8%	8.6%	-23%
Computer Science	8.3%	5.7%	7%	Pharmacology & Pharmacy	5.9%	4.3%	-23%	Physics	9.0%	7.1%	18%	Engineering	43.8%	21.6%	-22%
Polymer Science	3.8%	2.6%	8%	Materials Science	3.7%	2.8%	-23%	Immunology	2.5%	2.0%	22%	Construction & Bldg Tech	4.1%	2.6%	0%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Strength and Network of Industry Collaboration

Research collaborations can be analyzed specifically for the corporate sector, within the country and with foreign research organizations. Similarly to the analysis of research collaborations for all research organizations, we look at co-authorships in publications. In this case, the analysis comprises publications with at least one author with corporate affiliation. Not all scientific publications are the result of research collaborations between organizations. For example, almost 33 percent of all corporate publications in New Zealand between 1999 and 2008 had authors from only one company (that is, one or more authors, all from the same company) (Table 2.23). For the rest of the countries included in the analysis, that share is lower, 16.3 percent in the Republic of Ireland, 12 percent in Singapore, and only 10.1 percent in Northern Ireland.

Table 2.23 Percentages of corporate publications co-authored with different types and groups of research organizations (1999-2008)

	No collab.	Corp.	Acad.	Gov / NGO	Hosp.	Other	Top-3	Top-10	Top-20
Northern Ireland	10.1%	37.6%	49.7%	4.8%	3.2%	1.1%	48.7%	51.3%	62.4%
Republic of Ireland	16.3%	33.4%	46.8%	8.0%	2.5%	0.3%	28.7%	46.1%	47.8%
New Zealand	32.9%	34.0%	29.2%	5.1%	1.0%	1.0%	17.6%	63.8%	90.3%
Singapore	12.0%	28.0%	53.8%	13.7%	1.7%	0.0%	56.6%	58.2%	61.0%

Note: percentages in the three right-side columns show shares of corporate publications co-authored with top-3, top-10, and top-20 research organizations of the country.

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The companies that collaborated with other organizations in the period 1999-2008, did that with different types of organizations. For example, while about 38 percent of corporate publications in Northern Ireland had corporate co-authors (i.e. companies collaborating with each other), in Singapore only 28 percent of corporate publications were co-authored by more than one company. However, companies in Singapore were more likely to collaborate with universities and other academic organizations. Almost 54 percent of corporate publications in this country were co-authored by at least one company and one university. On the other extreme, New Zealand companies co-authored only 29.2 percent of their publications with universities. In the case of Northern Ireland and the Republic of Ireland, corporate publications co-authored with universities in this period had a share of 49.7 percent and 46.8 percent, respectively.

Collaborations with other types of research organizations are less important in terms of publications (Table 2.23). Only in Singapore companies co-authored a significant share of publications with government organizations (13.7 percent). Collaborations with government have a share of 8 percent in the Republic of Ireland, and 5 percent or less in New Zealand and Northern

Ireland. Collaborations with hospitals represented 3.2 percent in the case of Northern Ireland, but less than that in the rest of the countries.

The earlier analysis allows examining whether companies collaborated with top research organizations in each economy (Table 2.23). For example, in Singapore, 56.6 percent of corporate publications had at least one author from the top-3 research organizations of the country in the time period 1999-2008. In the case of Republic of Ireland and New Zealand that share drops to 28.7 percent and 17.6 percent, respectively. Furthermore, looking at collaborations with the top-10 and top-20 groups, it is possible to observe how concentrated were collaborations in corporate publications for some countries. In the case of New Zealand, more than 90 percent of corporate publications had co-authors among the top-20 organizations (this high share is in part explained by the fact that several large companies are among the top-20 organizations). In Northern Ireland and Singapore, slightly more than 60 percent of corporate publications were co-authored with at least one top-20 research organization.

Table 2.24 Shares of corporate publications co-authored with other countries (1999-2008).

	Northern Ireland	Republic of Ireland	New Zealand	Singapore	Other countries	All foreign collab.
Northern Ireland	100.0%	10.1%	0.5%	0.5%	47.1%	55.0%
Republic of Ireland	3.3%	100.0%	0.5%	0.2%	47.5%	50.1%
New Zealand	0.2%	0.6%	100.0%	0.3%	39.0%	39.5%
Singapore	0.0%	0.1%	0.8%	100.0%	41.5%	42.2%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Corporate collaborations within this set of four economies were not significant, although in the case of Northern Ireland about 10 percent of corporate publications were co-authored with research partners of Republic of Ireland (Table 2.24). International collaborations were in general maintained with other countries not included in this analysis. In all the countries, corporate publications with at least one foreign co-author represented at least 40 percent. Northern Ireland is the most internationalized in corporate collaborations (with a 55 percent share). In the following section, a more detailed analysis of international collaborations is provided.

The visualization of corporate collaborations helps in understanding their nature and characteristics. Figures 2.14, 2.15, 2.16 and 2.17 show collaboration networks developed by companies in the period 1999-2008.³ These figures only show companies that maintained collaborations in the form of co-authorships of publications. For these selected countries, only 57

³ For the network graphs shown in this section, nodes represent research organizations (companies in blue) and lines represent co-authorships. Companies that did not collaborated with other organizations during the period 1999-2008 are not shown. Companies are represented by blue nodes and other organizations by red nodes. The width of lines represent the strength of collaborations (in other words, number of co-authored articles).

companies in Northern Ireland (63 percent), 264 in the Republic of Ireland (65 percent), 504 in New Zealand (78 percent), and 354 in Singapore (71 percent) maintained collaborations in the period (Table 2.25). On the other hand, for those companies that maintained collaborations for publications, a large proportion did that with only one research partner, generating the pattern that gives the concentric shape to the collaboration networks shown in this section.

Table 2.25 Measures of corporate collaboration for selected countries (1999-2008)

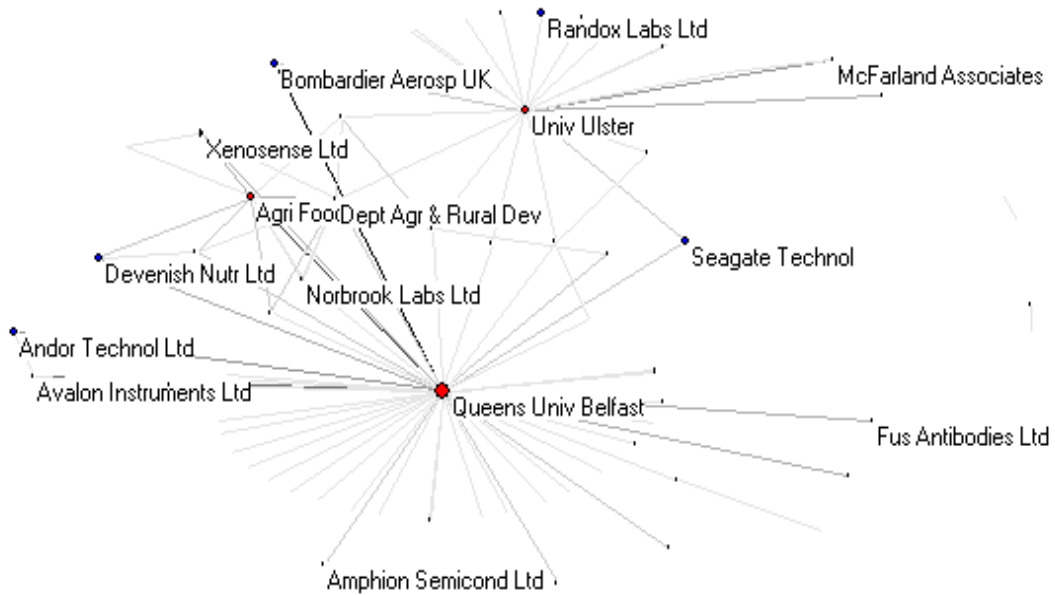
Measures of collaboration	Northern Ireland	Republic of Ireland	New Zealand	Singapore
Companies publishing scientific articles	91	407	643	497
Companies with one or more research collaborators (percentage of companies)	57 (62.6%)	264 (64.9%)	504 (78.4%)	354 (71.2%)
Companies with only one research collaborator (percentage of companies with collaboration)	39 (68.4%)	148 (56.1%)	295 (58.5%)	227 (64.1%)
Companies with no collaborations (percentage of companies)	34 (37.4%)	143 (35.1%)	139 (21.6%)	143 (28.8%)
Number of collaborating non-corporate organizations	13	78	268	68

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The network size varies, with New Zealand and Singapore as the largest networks for this 10-year period. In particular, in the case of New Zealand there is a larger share of companies collaborating with other organizations, and there are many more research organizations of other types (university, government, etc.) that collaborated with those companies (Figure 2.16). This relatively important participation of other types of research organizations in corporate collaboration networks can be better appreciated by looking at Singapore corporate networks (Figure 2.17). While these countries have similar number of companies publishing scientific articles (497 in Singapore and 643 in New Zealand), New Zealand more than triples the number of collaborating organizations of other types (268 versus 68 organizations of other types in Singapore) (Table 2.25). Moreover, in Singapore a larger proportion of companies only maintained collaborations with one research partner.

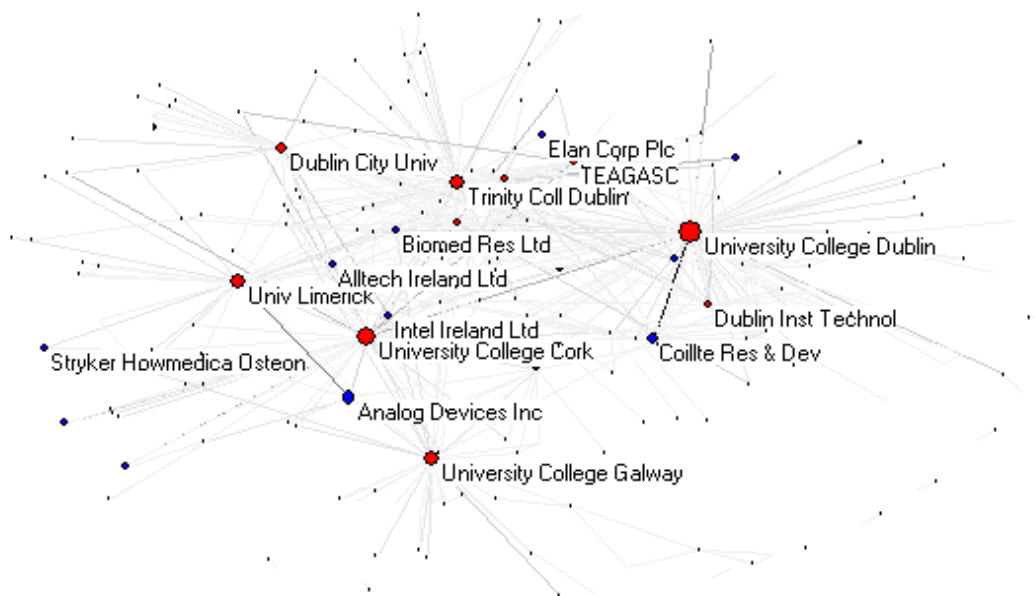
In the case of Northern Ireland only about 6 out of 10 companies maintained collaborations in publication of scientific articles (Figure 2.14 and Table 2.25). Still, most of these companies (68.4 percent) collaborated with only one research partner over the 10-year period. In particular, the main co-authors for these companies have been Queen's University of Belfast and University of Ulster, plus a handful of other organizations. Meanwhile, the proportion of companies that maintained collaborations in the Republic of Ireland between 1999 and 2008 was slightly higher than in Northern Ireland (Figure 2.15 and Table 2.25). However, in the case of Republic of Ireland there were almost five times more companies maintaining collaborations. Still, a large proportion of these companies (56 percent) had only one research partner during that period.

Figure 2.14 Corporate research collaboration networks in Northern Ireland



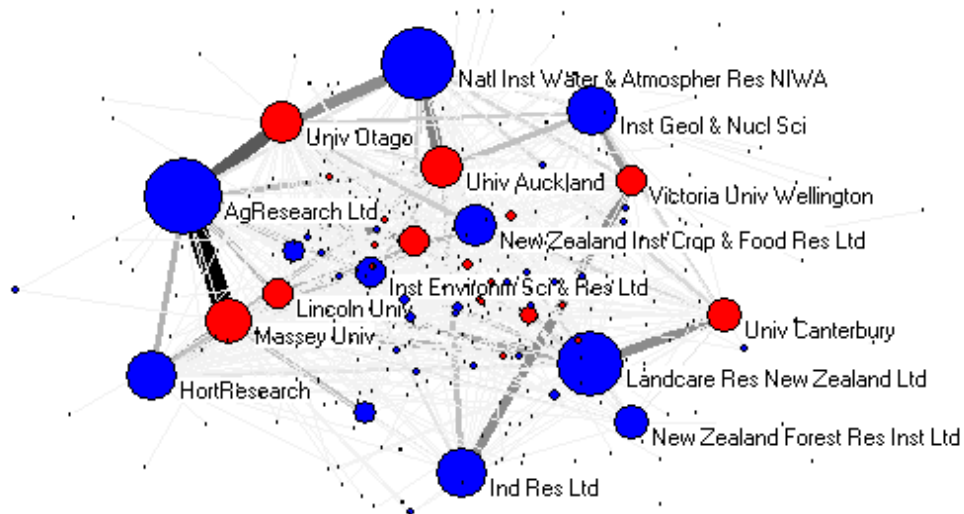
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.15 Corporate research collaboration networks in the Republic of Ireland



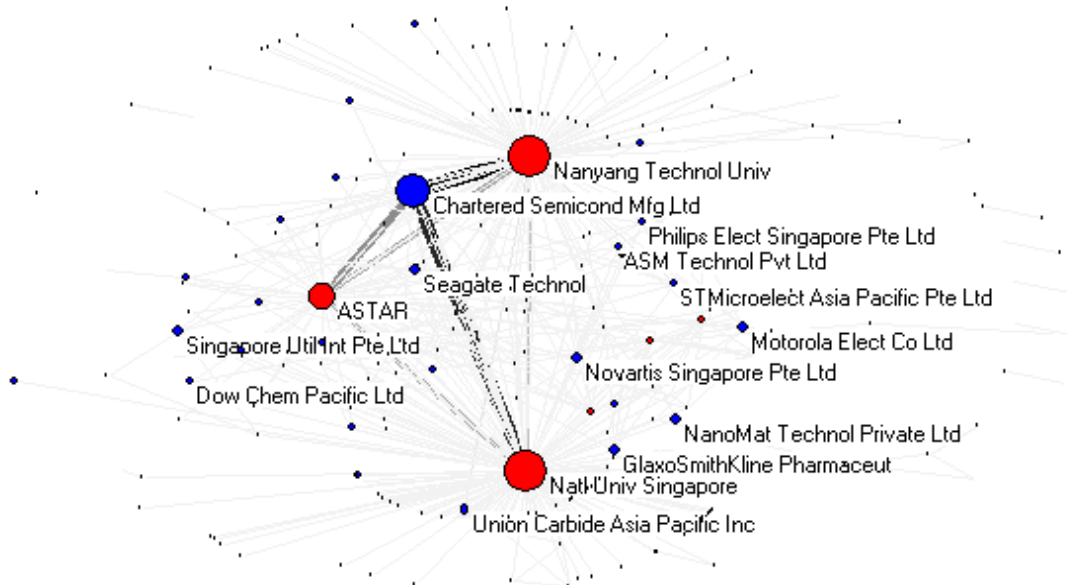
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.16 Corporate research collaboration networks in New Zealand (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

Figure 2.17 Corporate research collaboration networks in Singapore (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED), using Pajek software.

2.5 International Collaborations in Sciences

Based on the analysis of the affiliation of the authors that collaborate in scientific publications, it is possible to map the pattern of collaboration between the four countries analyzed here and other countries.⁴ In Table 2.26 are shown the top-10 collaborating countries for Northern Ireland, Republic of Ireland, New Zealand, and Singapore.

Table 2.26 Shares of publications co-authored with top-10 collaborating countries

Northern Ireland		Republic of Ireland		New Zealand		Singapore	
Country	Share	Country	Share	Country	Share	Country	Share
England	20.4%	England	14.3%	USA	14.9%	USA	12.1%
USA	11.7%	USA	12.9%	Australia	10.9%	Peoples R China	12.0%
Republic of Ireland	6.8%	Germany	7.4%	England	8.2%	Australia	4.2%
Scotland	5.2%	France	5.4%	Germany	3.7%	England	3.8%
Germany	4.6%	Italy	4.1%	Canada	3.7%	Japan	2.1%
France	4.5%	Netherlands	3.9%	France	2.3%	Canada	2.1%
Italy	2.9%	Spain	3.3%	Japan	2.2%	Germany	1.8%
Peoples R China	2.7%	Northern Ireland	3.1%	Peoples R China	2.0%	India	1.4%
Netherlands	2.6%	Canada	3.1%	Scotland	1.5%	Taiwan	1.3%
Spain	2.5%	Scotland	3.0%	Netherlands	1.5%	France	1.1%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

For both Northern Ireland and the Republic of Ireland, the main collaborating countries for the period 1999-2008 were England and the USA, yet in different magnitudes. The proportion of scientific publications co-authored with England was more than 20 percent for Northern Ireland and about 14 percent for the Republic of Ireland. Co-authorships with USA authors were present in almost 13 percent of Republic of Ireland scientific publications and less than 12 percent of Northern Ireland articles.

Northern Ireland and the Republic of Ireland share other international partners as well, like Germany, The Netherlands, France, and Italy. In fact, most of the top-10 international collaborators of these two countries are European counterparts. In the case of Northern Ireland, the exception is China which co-authored about 2.7 percent of the publications in the period 1999-2008. In the case of the Republic of Ireland the exception is Canada, which co-authored about 3 percent of the publications. In the region, both Northern Ireland and the Republic of Ireland have maintained collaborations with Scotland, in 5 and 3 percent of the publications, respectively. These two countries also collaborated between them, yet for the Republic of Ireland

⁴ England, Scotland, Wales, and Northern Ireland are considered separated countries for the purpose of this research to provide more detail of regional collaborations.

this collaboration was less than half of important than for Northern Ireland in terms of co-authorship share.

The USA was the main international partner in scientific research for both New Zealand and Singapore, representing about 15 and 12 percent, respectively, of the total publications for the period 1999-2008. The geographic proximity of Singapore to China is reflected in scientific collaboration as well, representing 12 percent of Singapore research articles for that period. New Zealand has also collaborated in science with China, yet the latter is not as important as partner as it is for Singapore. Besides the USA, the top partners in science for New Zealand between 1999 and 2008 were Australia and England, with 11 and 8 percent of publications co-authored, respectively. These two countries were also partners of Singapore for scientific research, yet their importance was less than half of that for New Zealand in terms of share of co-authorships. Neither Australia nor Japan (another partner of New Zealand and Singapore) were top-10 partners for Northern Ireland and the Republic of Ireland. There were no significant scientific collaborations between New Zealand and Singapore in the period 1999-2008, or between these two countries and Northern Ireland or Republic of Ireland.

Table 2.27 Shares of corporate publications co-authored with top-10 collaborating countries (1999- 2008)

Northern Ireland		Republic of Ireland		New Zealand		Singapore	
Country	Share	Country	Share	Country	Share	Country	Share
England	20.1%	USA	13.8%	USA	14.1%	USA	13.5%
Ireland	10.6%	England	13.6%	Australia	8.3%	Peoples R China	10.3%
Scotland	8.5%	Germany	5.3%	England	6.2%	England	4.5%
USA	6.9%	France	3.8%	Germany	3.5%	Australia	3.3%
France	4.2%	Northern Ireland	3.4%	Canada	3.2%	Japan	3.0%
Canada	3.2%	Netherlands	3.2%	Japan	2.3%	Switzerland	2.0%
Spain	2.6%	Canada	3.1%	France	2.2%	India	2.0%
Germany	2.1%	Scotland	2.8%	Peoples R China	1.6%	Malaysia	1.9%
Italy	2.1%	Spain	2.1%	Netherlands	1.3%	Canada	1.7%
Japan	1.6%	Italy	1.9%	Scotland	1.2%	South Korea	1.6%

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

The patterns of corporate collaborations with foreign research organizations show that collaborations of companies are maintained with similar countries, with some exceptions. For example, in Northern Ireland companies were less likely to collaborate with the USA and Germany, but more with Republic of Ireland and Scotland between 1999 and 2008 (Table 2.27). Slightly more than 20 percent of corporate publications are co-authored with organizations from England, as described for all Northern Ireland scientific publications. The second and third collaborating countries for this country are the Republic of Ireland and Scotland, with 10.6 and 8.5 percent of corporate publications.

In the case of Republic of Ireland, corporate publications followed the overall pattern of collaborating countries, with small differences in shares. The USA, England, and Germany were the top-3 collaborating countries for companies between 1999 and 2008, with 13.8 percent, 13.6 percent, and 5.3 percent of corporate publications, respectively (Table 2.27). However, Italy was not among the top-10 collaborating countries in this period (while this country was co-author of 4.1 percent of all Republic of Ireland publications).

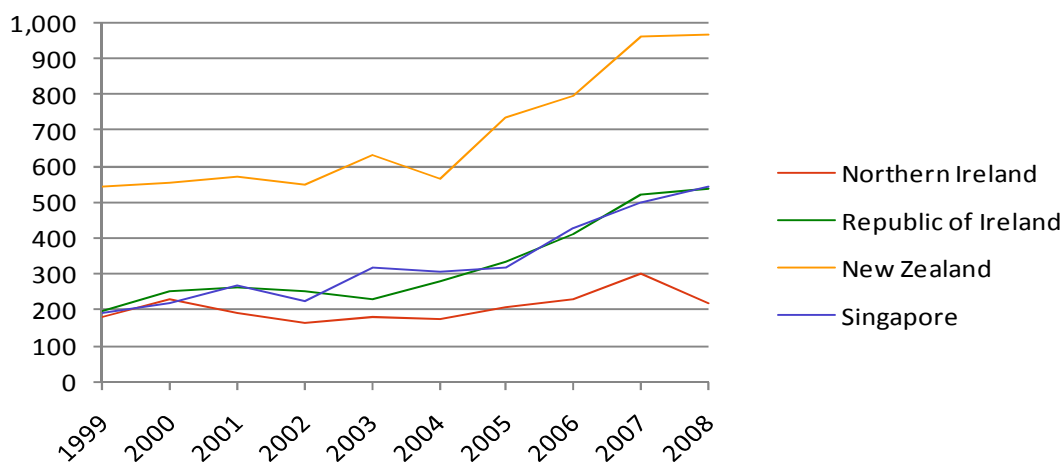
The USA has been the top collaborating country for New Zealand and Singapore as well, with similar proportion of co-authored corporate publications (about 14 percent) between 1999 and 2008. England is also among the top-10 collaborating countries, yet with shares lower than in the Republic of Ireland. While New Zealand companies have had the same collaborating countries than the rest of research organizations in the country, companies in Singapore have had Switzerland, Malaysia, and South Korea among the top-10 collaborating countries instead of Taiwan, Germany, and France.

3. Performance and Patterns in Social Sciences

This section presents the analysis of activity in the Social Sciences. This analysis is based on the database Social Sciences Citation Index (SSCI), which comprises more than 15,200 records of scientific publications (articles) in social sciences with at least one author with affiliation in the four countries during the ten-year period between 1999 and 2008.

Figure 3.1 shows the overall trend in publications in social sciences for the Republic of Ireland, New Zealand, Northern Ireland, and Singapore in the period 1999-2008. The data underlying this figure are shown in Table 3.1. In this period, New Zealand was the country that published the most, with more than 6,800 social sciences articles. Meanwhile, Singapore and the Republic of Ireland maintained similar publication levels, with 3,309 and 3,286 social sciences articles published in that period. Northern Ireland started that period with levels of publication similar to Singapore and the Republic of Ireland, but its activity in social sciences did not grow as other countries. For the whole period, Northern Ireland published 2,080 articles.

Figure 3.1 Trend of scientific publication in Social Sciences, publications per year (1999-2008)



Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

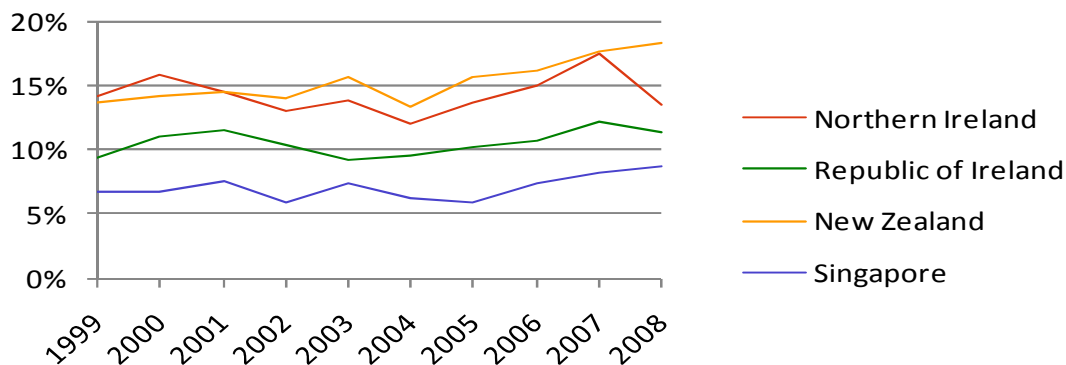
Table 3.1 Social Sciences publications trend, publications per year (1999-2008)

Country	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total	Avg. annual growth rate
Northern Ireland	178	231	189	166	180	176	206	231	304	219	2,080	4.3%
Republic of Ireland	196	252	264	252	231	282	336	410	523	540	3,286	12.7%
New Zealand	542	553	571	551	633	563	735	798	960	966	6,872	7.3%
Singapore	190	219	268	227	316	306	319	425	498	541	3,309	13.5%

Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

While New Zealand has been the country with the highest levels of publication in social sciences for the time period 1999-2008, Singapore saw the highest average annual rate of growth (13.5 percent) (Table 3.1). The Republic of Ireland maintained similar growth levels (12.7 percent), while New Zealand and Northern Ireland had more moderate average growth rates (7.3 percent and 4.3 percent, respectively).

Figure 3.2 Share of publication activity in social sciences within the total publications output (1999-2008)



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI)

Typically, social research is less prominent than other scientific disciplines, yet not less important. In the case of the selected countries, the number of publications in social sciences has been less than one-fifth of the total scientific publications during the 10-year period started in 1999 (Figure 3.2). Interestingly, social science research for Northern Ireland is almost as much important as New Zealand in relation to research in other scientific disciplines. For the latter, social sciences articles represented slightly more than 15 percent of the total publication output of the country for that period (with an increasing share after 2004), while for Northern Ireland that share was 14.3 percent. On the other hand, social sciences articles represented only 7 percent in the total publication output of Singapore.

3.1 Research areas in Social Sciences

The ISI-WoS SSCI database distinguishes subject areas in each social science article. Each article may be related to more than one subject area out of more than 160 different areas in which these four countries undertake research. Table 3.2 shows the top subject areas in social science research for each country. Compared to other scientific disciplines, social science research is somewhat more concentrated in few top areas (Table 3.2). Except for Singapore, Psychology is the top social research area for these economies, with 18.5 percent of publications in Northern Ireland and the Republic of Ireland and almost 27 percent in New Zealand. Psychology is rather important in Singapore as well, yet Economics, Business, and Management have larger shares (around 15 percent each). In the Republic of Ireland, Psychiatry and Economics are also within the range of the 10 to 15 percent share. The rest of the top-15 social sciences subject areas have all between the 2 and 10 percent shares for the four countries.

Table 3.2 Top-15 subject areas in Social Sciences (1999-2008)

Northern Ireland		Republic of Ireland		New Zealand		Singapore	
Subject area	Share	Subject area	Share	Subject area	Share	Subject area	Share
Psychology	18.5%	Psychology	18.5%	Psychology	26.8%	Economics	15.8%
Nursing	9.7%	Psychiatry	12.4%	Psychiatry	9.1%	Business	15.2%
Economics	6.9%	Economics	12.0%	Public, Environmental & Occupational Health	8.9%	Management	14.6%
Public, Environmental & Occupational Health	5.9%	Nursing	6.7%	Economics	8.4%	Psychology	13.0%
Political Science	5.7%	Public, Environmental & Occupational Health	5.7%	Social Sciences	6.2%	Computer Science	9.1%
Psychiatry	5.7%	Management	5.5%	Management	5.6%	Operations Res. & Mgmt. Science	6.9%
Management	5.5%	Political Science	5.0%	Education & Educ. Res.	5.3%	Information Science & Library Science	6.3%
Social Sciences	5.5%	Social Sciences	4.5%	Business	5.1%	Social Sciences	5.4%
Environmental Studies	5.4%	Environmental Studies	4.4%	Environmental Studies	3.6%	Education & Educ. Res.	5.1%
Geography	5.1%	Education & Educ. Res.	4.0%	Geography	3.5%	Engineering	5.0%
Education & Educ. Res.	4.6%	Business	4.0%	Sociology	3.1%	Environmental Studies	4.3%
Sociology	4.5%	Geography	3.7%	Neurosciences	2.9%	Geography	4.0%
Public Administration	4.0%	Rehabilitation	3.7%	Behavioral Sciences	2.7%	Psychiatry	3.8%
Rehabilitation	3.3%	Sociology	3.3%	Political Science	2.6%	Urban Studies	3.5%
Social Work	3.3%	Neurosciences	3.3%	Rehabilitation	2.4%	Planning & Development	2.9%

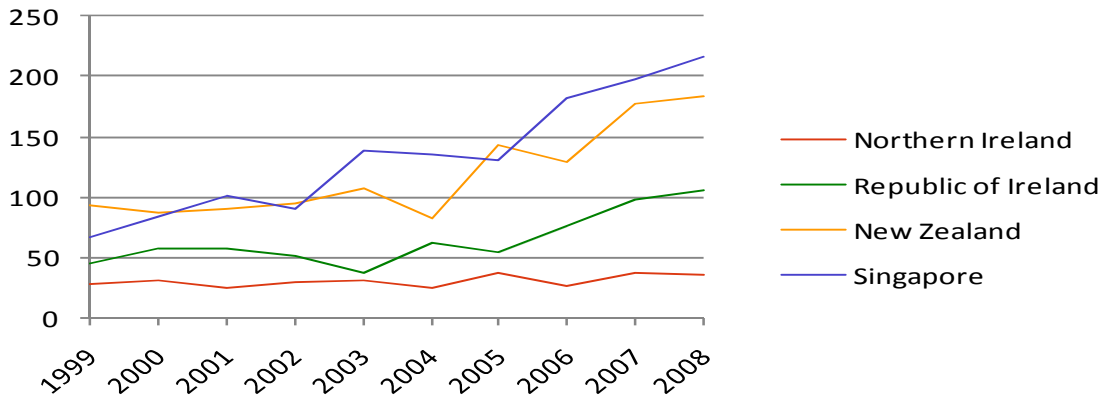
Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

Some specific areas of the social sciences are of special interest since they are related to the study of aspects of innovation and competitiveness probed elsewhere in this study. The following parts of the analysis focus on five of those subject areas, for which a specific subdataset was created and analyzed. These five categories were re-grouped into two broader areas: Economics/Finance (comprising Economics and Finance subject categories) and Business/Management (comprising Management, Business, and Operations Research & Management Science).

The relative importance of research in Economics/Finance and Business/Management is different for the four countries. In Singapore, these research areas represented about 40 percent of all social science research in the period 1999-2008, in the Republic of Ireland 20 percent, in New Zealand 17 percent, and in Northern Ireland only 15 percent. Such difference in relative importance makes Singapore the country with the highest number of publications in Economics/Finance and Business/Management during this time period. Furthermore, this country

was the one that grew the most compared to the other three. Republic of Ireland had also moderate growth rates in these subject areas, while Northern Ireland remained relatively stable in absolute number of publications for this time period.

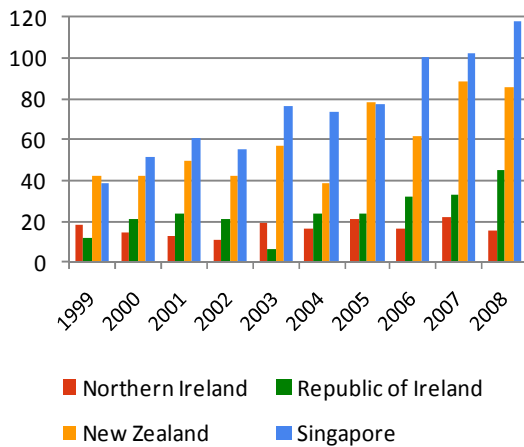
Figure 3.3 Overall trends in subject areas related to Economics/Finance and Business/Management (1999-2008)



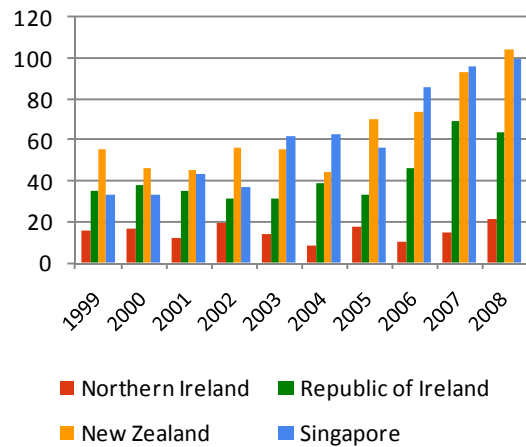
Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

Figure 3.4 Trend in Social Sciences research related to Business/Management and Economics/Finance (1999-2008)

a) Business/Management



b) Economics/Finance



Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

The four countries perform differently in those two broad categories, Business/Management and Economics/Finance (Figure 3.4). While Singapore has been the country with the largest number of publications in Business/Management during most of the period 1999-

2008, it shared that position with New Zealand in terms of Economics/Finance publications. Overall, both countries had had increasing number of publications on these areas (about 15 percent average annual growth) yet New Zealand experienced lower growth rates in Economics/Finance (only about 10 percent). Both Republic of Ireland and Northern Ireland present lower levels of publication and varying average growth. For example, while Economics/Finance publications grew at an average 10 percent rate in the Republic of Ireland, Business/Management did that at more than 40 percent annually, closing the gap with New Zealand and Singapore. On the other hand, Northern Ireland, as shown in the overall trends for Business/Management and Economics/Finance, presented relatively low (and relatively stable) levels of publication in those areas.

3.2 Social Science Research Organizations

The total number of organizations involved in Economics/Finance and Business/Management research varies within this group of four countries. In Northern Ireland, only 13 organizations published scientific articles in those areas during the time period 1999-2008, with similar shares of participation of different types of organizations (universities, companies, and government agencies) (Table 3.3). Meanwhile, more than a hundred research organizations published in those areas in New Zealand. In relative terms, more companies and fewer universities participated in this type of social science research in this country. The country with the largest relative number of companies doing research in these areas was Singapore, with a total of 74 research organizations, 51.4 percent of which were companies. On the other hand, 58 organizations participated in the Republic of Ireland, almost half of them universities.

Table 3.3 Share of organizations publishing in Economics/Finance and Business/Management areas (1999-2008)

	Academic	Corporate	Hospital	Gov / NGO	Other	Total
Northern Ireland	38.5%	30.8%	0.0%	30.8%	0.0%	13
Republic of Ireland	46.6%	32.8%	1.7%	19.0%	0.0%	58
New Zealand	26.5%	37.3%	1.0%	34.3%	1.0%	102
Singapore	29.7%	51.4%	1.4%	17.6%	0.0%	74

Note: (a) Other types of organizations include organizations like: foundations, zoos, botanical gardens, and sports organizations. Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

In spite of the varying numbers of research organizations, most of the scientific articles are published by universities, particularly in the case of Singapore with 98.7 percent of all articles in Economics/Finance and Business/Management published by universities (Table 3.4). Publications by companies have shares of 5.4 percent (New Zealand) or less, while Government/NGO shares vary. In the Republic of Ireland, almost 15 percent of the articles in those social sciences areas were published by Government agencies, while for the other countries this share is 7 percent or less. Meanwhile, hospital and other types of research organizations have null or very low shares.

Table 3.4 Share of publications for research organization in Economics/Finance and Business/Management areas (1999-2008)

	Academic	Gov / NGO	Corporate	Hospital	Other ^a
Northern Ireland	96.8%	7.1%	2.9%	0.0%	0.0%
Republic of Ireland	92.7%	14.7%	3.7%	0.2%	0.0%
New Zealand	95.3%	6.9%	5.4%	0.2%	0.2%
Singapore	98.7%	3.1%	4.6%	0.4%	0.0%

Note: totals exceed 100 percent due to collaborations. (a) Other category includes foundations, zoological gardens, sport organizations. Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

In line with the data shown of organizational participation, the examination of the top research organizations shows how important are universities in Economics/Finance and Business/Management research in each country. Table 3.5, Table 3.6, Table 3.7, and Table 3.8 show the top-10 research organizations in those areas of social science research for the four countries. As these lists of organizations show, the participation of companies in those areas of social sciences research is not significant. The few companies that appear within the top-10 lists have shares of 0.6 percent (the global consulting firm PriceWaterhouseCoopers in Northern Ireland) or lower.

In **Northern Ireland** almost all research in Economics/Finance and Business/Management is concentrated in the top-2 research organizations of the country, the Queens University of Belfast and the University of Ulster, although in this case the University of Ulster has a higher share compared to its own participation in overall research (45.5 percent share in these social sciences versus only 19.5 percent share in other scientific disciplines) (Table 3.5). The Economic Research Institute of Northern Ireland (ERINI), an executive non-departmental public body, appears as the third organization with a relatively low share (3.6 percent).

Table 3.5 Top-10 research organizations in Economics / Finance and Business / Management areas, in Northern Ireland (1999-2008)

Rank	Pub(s)	Share	Organization
1	176	57.1%	Queens University Belfast
2	140	45.5%	University of Ulster
3	11	3.6%	Econ Res Inst No Ireland
4	3	1.0%	Agri Food & Biosci Inst No Ireland
5	3	1.0%	Dept Agr & Rural Dev No Ireland
6	2	0.6%	PriceWaterhouseCoopers
7	1	0.3%	Coves Consulting, Bushmills
8	1	0.3%	Dept Environm Rd Serv
9	1	0.3%	Dept Reg Dev
10	1	0.3%	Dream Ireland Ltd
	2	0.6%	Other 3 organizations
Total	308		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

In the **Republic of Ireland**, research in Economics/Finance and Business/Management is less concentrated but still undertaken within a small group of top-universities. Both the University College Dublin (NUI) and the Trinity College Dublin concentrate more than half of the publications of the period 1999-2008, with shares of 34.3 percent and 19.6 percent, respectively (Table 3.6). Other 5 universities that are also among the top research organizations of the country are within this list for Economics/Finance and Business/Management. The University of Limerick and the National University of Ireland Maynooth show more focused research in these social sciences areas than in other scientific disciplines (they contribute 8 percent and 7 percent of these social sciences articles, respectively, but only 4.6 percent and 3.6 percent in other scientific disciplines, respectively, as shown in the previous section of this report).

Table 3.6 Top-10 research organizations in Economics / Finance and Business / Management areas, in the Republic of Ireland (1999-2008)

Rank	Pub(s)	Share	Organization
1	222	34.3%	University College Dublin - National University of Ireland
2	127	19.6%	Trinity Coll Dublin
3	63	9.7%	University College Galway - National University of Ireland
4	52	8.0%	Univ Limerick
5	45	7.0%	Nalt Univ Ireland Maynooth
6	40	6.2%	University College Cork - National University of Ireland
7	36	5.6%	Econ & Social Res Inst, Dublin
8	28	4.3%	Dublin City Univ
9	22	3.4%	Central Bank Ireland, Dublin
10	12	1.9%	TEAGASC
	65	10.0%	Other 48 organizations
Total	647		

Note: the sum of individual shares exceeds 100 percent due to collaborations.

Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

There are 8 universities within the top-10 research organizations in Economics/Finance and Business/Management in **New Zealand** (Table 3.7). Although they are still the same leader universities as in other disciplines, the Massey University and the Victoria University of Wellington rank higher in those social sciences areas, contributing about 15 percent of total publications each. The University of Auckland is still the top research organization within this list. Overall, the top-7 research organizations (universities) in New Zealand published more than 90 percent of Economics/Finance and Business/Management in New Zealand between 1999 and 2008.

In **Singapore**, social sciences research in Economics/Finance and Business/Management is dominated by the National University of Singapore and the Nanyang Technology University as well (Table 3.8). However, two other universities, Singapore Management University and INSEAD Singapore, have significant contribution to publications in these science areas (with shares of 14.1 percent and 4.2 percent, respectively). The rest of the organizations of this list are of Government / NGO type, except for DBS Bank Ltd, a large banking group established in Singapore and Hong Kong which has only a marginal share of publications.

Table 3.7 Top-10 research organizations in Economics / Finance and Business / Management areas, in New Zealand (1999-2008)

Rank	Pub(s)	Share	Organization
1	343	28.8%	Univ Auckland
2	180	15.1%	Massey Univ
3	179	15.0%	Victoria Univ Wellington
4	175	14.7%	Univ Waikato
5	131	11.0%	Univ Otago
6	92	7.7%	Univ Canterbury
7	47	3.9%	Lincoln Univ
8	20	1.7%	Reserve Bank New Zealand
9	6	0.5%	Auckland Univ Technol
10	6	0.5%	Inst Environm Sci & Res Ltd
	115	9.6%	Other 92 organizations
Total	1,192		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

Table 3.8 Top-10 research organizations in Economics / Finance and Business / Management areas, in Singapore (1999-2008)

Rank	Pub(s)	Share	Organization
1	761	56.7%	Natl Univ Singapore
2	312	23.2%	Nanyang Technol Univ
3	189	14.1%	Singapore Managment Univ
4	57	4.2%	INSEAD Singapore
5	9	0.7%	Inst Southeast Asian Studies
6	8	0.6%	Monetary Author Singapore
7	5	0.4%	Minist Defense
8	3	0.2%	ASTAR
9	3	0.2%	DBS Bank Ltd
10	3	0.2%	IMF Inst Singapore
	76	5.7%	Other 64 organizations
Total	1,342		

Note: the sum of individual shares exceeds 100 percent due to collaborations.
Source: ISI-WoS database, Social Sciences Citation Index (SSCI)

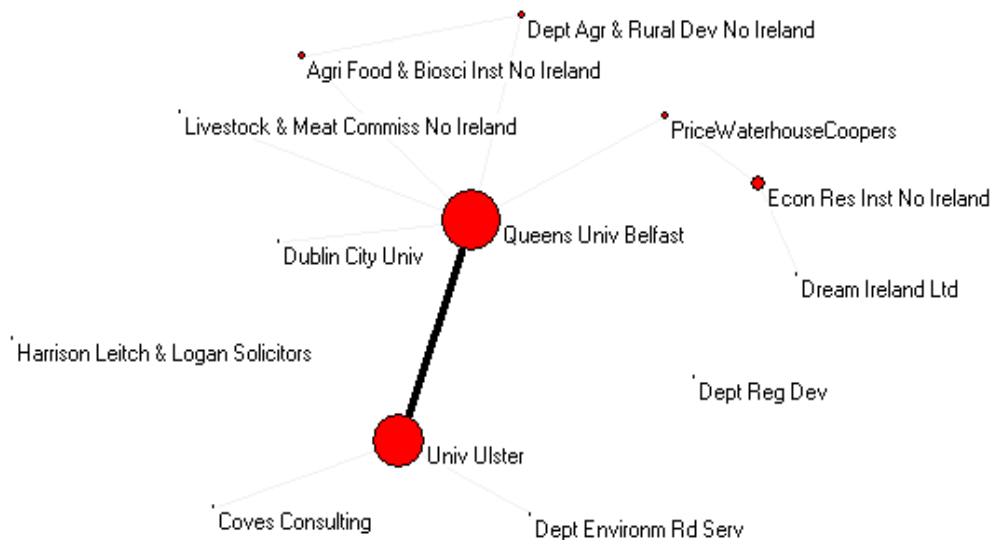
3.3 Scientific collaborations in Social Science

To demonstrate the complexity of the research networks developed in the period 1999-2008 in the Economics/Finance and Business/Management areas, we visualized the research collaboration networks of Northern Ireland, Republic of Ireland, New Zealand, and Singapore (Figures 3.5, 3.6, 3.7 and 3.8). These graphics reveal to some extent the role of top organizations in the whole research network (the top-15 research organizations for each country are labeled),

their relatively low number of connections or co-authorships with other organizations, and the complete set of collaborations for the rest of organizations as well.⁵

In general, collaborations (co-authorships) in Economics/Finance and Business/Management go along with the organizational concentration in publication activity. However, there are some differences between the four countries analyzed here. For example, in Northern Ireland (Figure 3.5) and to some extent in Singapore (Figure 3.8) there are stronger collaborations between the leading universities, while in the Republic of Ireland (Figure 3.6) and New Zealand (Figure 3.7) there is many more “weak” links between organizations. In relative terms, the latter two countries show more equally distributed shares of publication between higher numbers of organizations, which is noticed in the graphs by larger numbers of vertices of similar size. While most of those “weak” links may be the result of sporadic co-authorships, the strongest links represent collaboration relations that were built through most of the studied period.

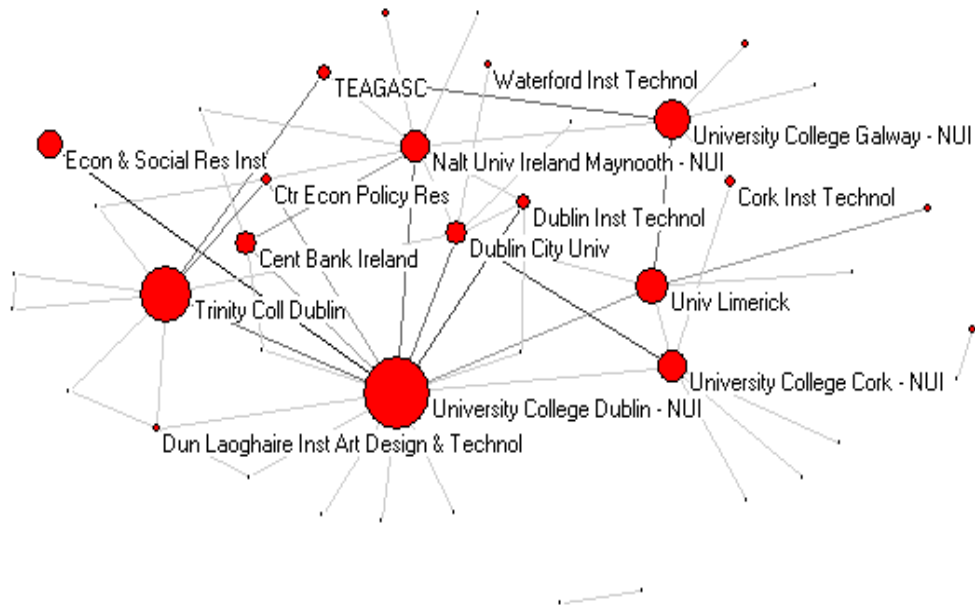
Figure 3.5 Research collaboration networks in Economics/Finance and Business/Management areas in Northern Ireland (1999-2008)



Source: ISI-WoS database, Social Sciences Citation Index (SSCI), using Pajek software.

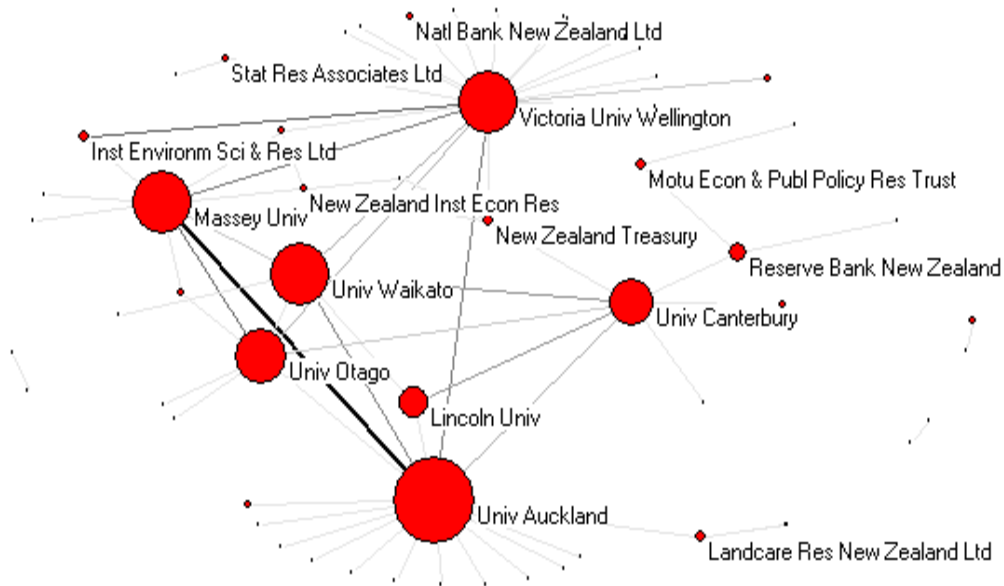
⁵ For all network figures in this section: nodes represent research organizations and their size the number of publications; lines represent co-authorships and their size and color represent the strength of collaborations (i.e. the wider and the darker the line, the higher the number of co-authorships for the linked research organizations); only organizations with at least one co-authorship are shown; labels are displayed for only top-15 research organizations in terms of publications.

Figure 3.6 Research collaboration networks in Economics/Finance and Business/Management areas in the Republic of Ireland (1999-2008)



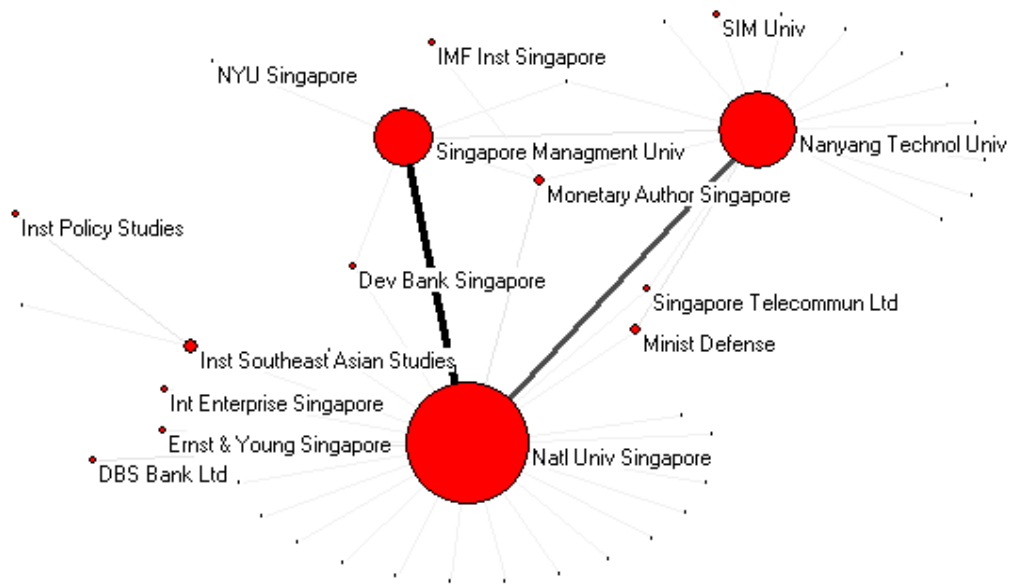
Source: ISI-WoS database, Social Sciences Citation Index (SSCI), using Pajek software.

Figure 3.7 Research collaboration networks in Economics/Finance and Business/Management areas in New Zealand (1999-2008)



Source: ISI-WoS database, Social Sciences Citation Index (SSCI), using Pajek software.

Figure 3.8 Research collaboration networks in Economics/Finance and Business/Management areas in Singapore (1999-2008)



Source: ISI-WoS database, Social Sciences Citation Index (SSCI), using Pajek software.

4. Patent Analysis

In this section, the analysis of overall patenting activity for the selected countries is based on data from the Patstat database. This database is developed by the European Patent Office (EPO) in conjunction with other patent authorities around the world. Patstat allows extracting and comparing patent data for more than 160 countries and patent authorities, including important patent offices such as the United States Patent and Trademark Office (USPTO), the Japanese Patent Office (JPO) and EPO. This analysis is based on more than 50,200 patent records corresponding to patents for inventions with at least one inventor or assignee in Northern Ireland, Republic of Ireland, New Zealand, and Singapore (hereafter, country patents) and granted during the ten-year period between 1999 and 2008.⁶

Inventors and organizations based in Northern Ireland can file patent applications with, for example, the UK Intellectual Property Office (formerly the UK Patent Office) and the European Patent Office. Because there is no specific “country code” for Northern Ireland in Patstat or other available patent databases, they may appear in patent records with the country code of either GB (Great Britain) or IE (Ireland, i.e. with the Republic of Ireland). We thus developed a customized allocation method to identify patent records emanating from Northern Ireland. This allocation method is based on inventors and assignees’ addresses (when available) and also uses a Fame⁷ list of companies in Northern Ireland.

Patent records include both patent applications and grants, among other type of records (e.g. re-issue certificates or translations). While the total number of records is an expression of the overall patenting activity of any country or organization, only the total number of grants reveals the success in obtaining patent protection for new inventions. For this reason, the analysis is based primarily on patent grants rather than applications for the countries concerned. Although this approach provides a clearer picture of the technological capabilities of countries and organizations, it does not provide data related to patents granted before the period of analysis (total owned patents) nor does it account for applications filed during this period that may become granted patents in following years. Patent applications may take several months to several years before ultimately becoming a patent grant (or receiving a decline), depending on the relevant patent office among other factors.

As shown in Figure 4.1, the overall patent activity in each country varies considerably. This overall activity assessment is based on the data reported by patent offices where inventors and assignees of each country file for patents.⁸ Within the four countries, Singapore has the largest

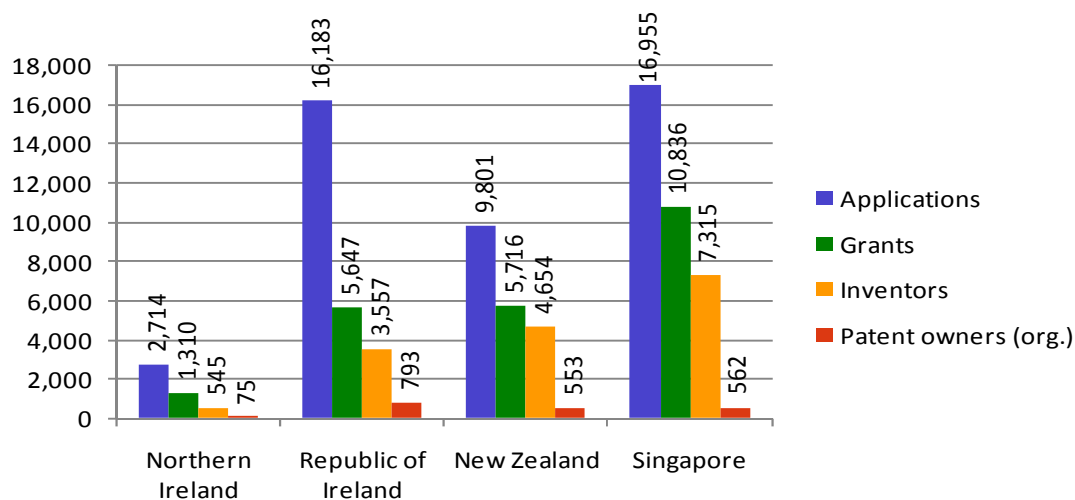
⁶ The latest update of Patstat is as of July 2008. Estimates of values for year 2008 are used for the purpose of this analysis, calculated based on the average annual growth in the number of patent grants for each country in previous four years.

⁷ FAME is a database that contains information for companies in the UK and Ireland. More information available on <http://www.bvdep.com/en/fame.html>

⁸ As it will be discussed in the following sections, inventors and assignees from each country apply for patents before different patent authorities, which leads to different grants-to-applications ratios and overall patenting process wait periods, among others. Such differences affect the data available for country patents.

number of patent applications and grants during the period 1999-2008 (almost 17,000 patent applications and 10,836 patent grants). Singapore has also the largest number of unique inventors in that period, more than 7,300. However, the largest number of organizations seeking to protect inventions is in the Republic of Ireland. During that 10-year period, 793 unique organizations from the Republic of Ireland applied for more than 16,000 patents and obtained 5,647 patent grants. In New Zealand, between 1999 and 2008, 553 unique organizations applied for 9,800 patents and obtained 5,716 patent grants (Figure 4.1). The number of unique inventors in New Zealand exceeds that of Republic of Ireland, yet it has fewer unique organizations seeking IP protection with patents. In the case of Northern Ireland, there were even fewer patenting organizations. Only 75 unique organizations were identified in Northern Ireland as patent assignees for the period 1999-2008. These organizations applied for more than 2,700 patents and obtained 1,310 patent grants. On the other hand, only 545 unique inventors were matched to Northern Ireland organizations for that time period, a number considerably lower than in the other three countries. The vast majority of assignees of patents are companies, although some universities, government agencies, and other types of organizations and individuals may be assignees as well. Inventors, usually more than one per patent, are individuals working for different organizations.

Figure 4.1 Total applications, grants, inventors, and patent owners (1999-2008)



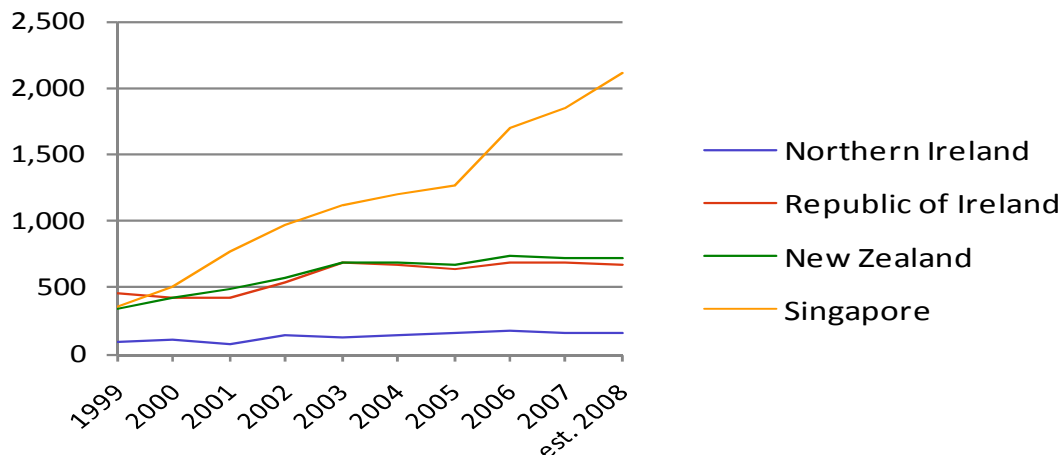
Notes: data labels are shown only for total number of inventors and patents owners; inventors refer to the number of unique local inventors in country granted patents; patent owners refer to local organizations of different types that own country granted patents.

Source: Patstat patents database

Although the number of patent applications indicates how many inventions are trying to patent organizations from each country, it does not reveal how successful these organizations are when seeking patent protection. For example, between 1999 and 2008, the ratio of grants-to-applications varies from 0.26 to 0.44 in the countries (in the cases of Republic of Ireland and Singapore, respectively; 0.32 is the ratio for Northern Ireland and 0.37 is the ratio for New Zealand). These ratios are only valid for patent records included in Patstat at the point in time of

our analysis and do not consider patents filed during this period that are granted after July 2008. On the other hand, the number of grants received by each country has varied within the analyzed time period, demonstrating different growth rates.⁹

Figure 4.2 Trends in total patent grants for country inventors or assignees (1999-2008)



Source: Patstat patents database

Table 4.1. Total patent grants for country inventors or assignees (1999-2008)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008 (est.)	Avg. annual growth
Northern Ireland	100	103	79	138	131	150	163	175	154	161	8.5%
Republic of Ireland	464	422	430	545	694	670	636	694	682	680	5.7%
New Zealand	338	424	485	579	686	681	678	732	719	728	10.3%
Singapore	353	504	774	973	1,126	1,200	1,272	1,692	1,855	2,111	24.1%

Source: Patstat patents database

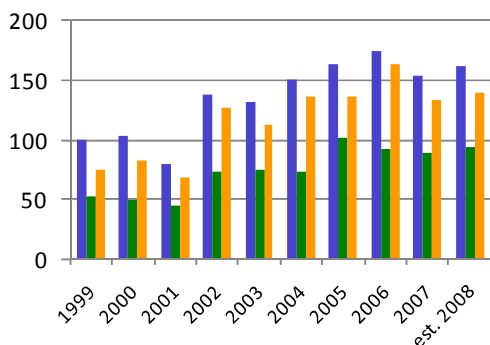
Figure 4.2 shows the trends in patent grants for Northern Ireland, Republic of Ireland, New Zealand, and Singapore for the period 1999-2008, which are all growing. The data underlying this figure are shown in Table 4.1. Singapore obtained the largest number of patent grants, 10,836 patents, and had the highest average growth rate in grants (about 24 percent annually) for that time period. In particular, Singapore has increased substantially the number of patents after 2005. That average growth rate exceeds substantially the rates observed for the other three countries. For example, the rate growth in grants for New Zealand inventors and assignees was only 10.3

⁹ Singapore's patent regulations have gone through changes in the last 15 years. Particularly important modifications were introduced in 1995 and 2004 in relation to the overall scheme of IP protection and the requirements for examination and grant of applications, which may have affected the general trends in patent granted by the Singapore's patent office. The same applies for New Zealand's patent regulations. In 2008, a new patents bill imposed stricter requirements on the grant of patents and brings New Zealand legislation into line with other countries.

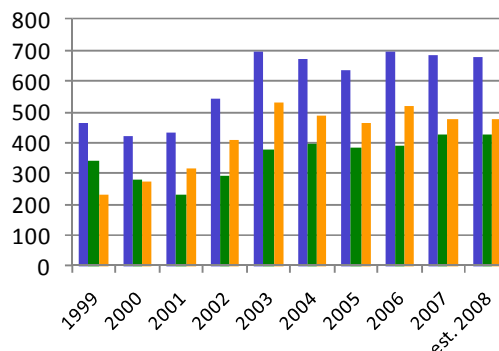
percent annually during that period, while for Northern Ireland and the Republic of Ireland was 8.5 percent and 5.7 percent, respectively. In particular, the highest growth rates for these three countries were seen until 2003, while for Singapore the most important growth has occurred in the last four years. Since only seven months of data for year 2008 are included in the latest available Patstat database, an estimate for the complete year 2008 is provided (Table 4.1).

Figure 4.3 Trends in granted patents in selected countries (1999-2008)

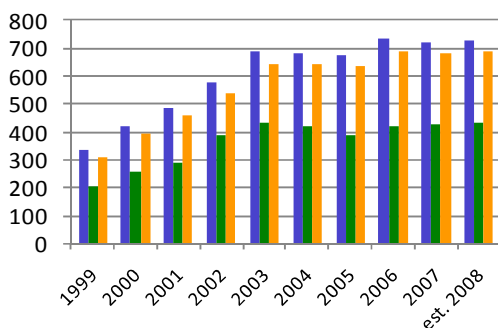
a) Northern Ireland



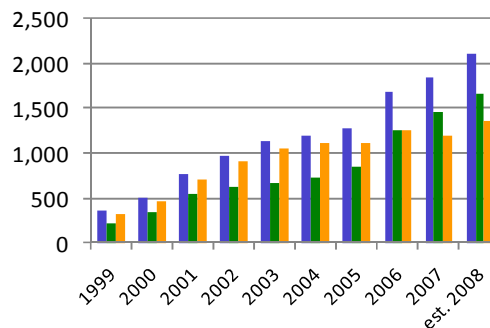
b) Republic of Ireland



c) New Zealand



d) Singapore



■ Total grants ■ Grants for country assignees ■ Grants for country inventors

Source: Patstat patents database

As mentioned before, each patent dataset includes patents with inventors or assignees reporting addresses in each country. However, there may be cases of patents for technologies

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invented in a specific economy but assigned to a foreign organization. On the other hand, there may be technologies invented by foreign inventors which are assigned to local organizations. While more granted patents for local inventors may be considered a proxy describing more creativity in the economy, more granted patents for local assignees are more likely to reflect potential commercialization and exploitation of new technologies. Although this analysis look at these situations in more detail in the following sections, the overall trends in granted patents for inventors and assignees are presented here (Figure 4.3).

Generally speaking, the number of patents for country inventors and assignees follows the general trend of granted patents for the country. In each country, the number of patents for inventors tends to be higher than the number for assignees, with few exceptions. For example, In Northern Ireland and New Zealand, the number of patents for inventors has been always higher than the number for assignees (Figure 4.3.a and Figure 4.3.c) which indicates to some extent that a share of local patent inventions are assigned to foreign entities. For the Republic of Ireland, the numbers of granted patents for assignees and for inventors are more similar (Figure 4.3.b), while in the case of Singapore, the relation between granted patents for local inventors and assignees has varied, to reach recently a number of granted patents for assignees that exceeds the number of patents for local inventors (Figure 4.3.d).

There are more than 160 patent authorities worldwide, yet patents granted by the United States Patent Office (USPTO), European Patent Office (EPO), and Japan Patent Office (JPO) are usually considered of particular value. The Patstat database contains data related to the patent authorities used by inventors from different countries to apply for patents for new technologies. In the analysis of patent grants, applications for patents in the World Intellectual Property Organization (WIPO) via the Patent Cooperation Treaty (PCT) are not shown, yet granted patents following that path are reflected in patent counts for each national authority (WIPO only publishes applications and not patent grants).

Table 4.2 Share of granted patents in top-10 patent authorities (1999-2008)

Rank	Northern Ireland		Republic of Ireland		New Zealand		Singapore	
	Patent Authority	Share	Patent Authority	Share	Patent Authority	Share	Patent Authority	Share
1	USA (USPTO)	54.6%	USA (USPTO)	42.0%	New Zealand	44.9%	USA (USPTO)	51.0%
2	European Patent Office (EPO)	25.8%	European Patent Office (EPO)	19.1%	USA (USPTO)	31.5%	Singapore	26.9%
3	Great Britain (IPO UK)	6.7%	Great Britain (IPO UK)	14.2%	European Patent Office (EPO)	7.0%	Taiwan (TIPO)	6.4%
4	Canada	3.7%	Taiwan (TIPO)	4.1%	Great Britain (IPO UK)	3.5%	European Patent Office (EPO)	6.3%
5	Taiwan (TIPO)	1.5%	Irish Patent Office	3.8%	Canada	3.2%	Great Britain (IPO UK)	2.8%
6	France	1.2%	Canada	2.7%	China	2.4%	China	2.3%
7	Hong Kong	1.2%	China	2.3%	Taiwan (TIPO)	1.6%	Germany	1.0%
8	China	1.1%	Japan (JPO)	1.9%	Japan (JPO)	1.5%	Japan (JPO)	0.8%
9	Republic of Korea	0.9%	Russian Federation	1.5%	Hong Kong	1.1%	Hong Kong	0.7%
10	Germany	0.5%	Hong Kong	1.0%	Russian Federation	0.8%	Canada	0.4%

Source: Patstat patents database

Table 4.2 shows the top-10 patent authorities where organizations from Northern Ireland, Republic of Ireland, New Zealand, and Singapore obtained patent grants between 1999 and 2008. Most of the patents for the four countries were granted by the USPTO and the EPO, while minor shares of patents were granted by several other (still, practically the same set of) patent offices (Table 4.2). Significant shares of granted patents were obtained in the local patent offices in the case of New Zealand and Singapore. It should be noted that Northern Ireland and the Republic of Ireland can use the EPO route to obtain IP protection in their own territories.

With the exception of New Zealand, other countries had obtained patent grants primarily from USPTO during that time period (Table 4.2). In particular, more than 54 percent of Northern Ireland's patents were granted by USPTO. The figures for the other three countries are lower than that. For example, 51 percent of Singapore's patents and 42 percent of Republic of Ireland's were granted by USPTO. In the case of New Zealand, most of the country patent grants were obtained in the local patent authority (IPONZ), which represents almost 45 percent of all grants. For Northern Ireland and the Republic of Ireland, EPO is the second most important patent office, with shares of almost 26 percent and slightly more than 19 percent, respectively (Table 4.2). In the case of New Zealand and Singapore, that share is only 7 percent and 6.3 percent, respectively. For Singapore, the second most important office was the local office (IPOS), with almost 27 percent of granted patents, and the third was the Taiwanese Patent Office (TIPO), with 6.4 percent of grants. The third most important patent office for Northern Ireland and the Republic of Ireland was IPO UK, with shares of granted patents of 6.7 percent and 14.2 percent, respectively.

4.1 Patent Assignees

In general, patent records allow identifying the organizations and individuals that applied for and own the patents for each country. Patents may have one or more inventors, individuals that created the technology and, when the patent legislation allows that, applied for the patent. Patents may have one or more assignees as well, which are typically organizations of different kind that own the patent and have the exclusive right to exploit or commercialize the technology.

Table 4.3, Table 4.4, Table 4.5, and Table 4.6 present the names and shares of granted patents for the top-20 national patent assignees for Northern Ireland, Republic of Ireland, New Zealand, and Singapore. Foreign organizations that own patents of technologies invented locally are excluded from these lists, but mentioned in the following sections of this report. On the other hand, all organizations that reported addresses in the selected countries are shown, including foreign subsidiaries operating locally.

In **Northern Ireland**, most of the top-20 assignees are companies, with only two universities within the top-20 lists (Table 4.3). The top assignee is Randox Laboratories Ltd, a privately owned diagnostic reagent and equipment manufacturing company. The second assignee is one of those two universities, The Queen’s University of Belfast, with slightly more than 10 percent of the country grants. Short Brothers Plc, aircraft components and engines company, is the third most important assignee with 9 percent of the granted patents. These top-20 organizations concentrate 64 percent of the country patent grants in Northern Ireland, while other 142 assignees contributed less than 39 percent of all grants obtained in the period 1999-2008.

Table 4.3 Top-20 patent assignees from Northern Ireland (1999-2008)

Rank	Patents	Share	Organization
1	85	11.5%	Randox Laboratories Ltd
2	74	10.1%	The Queen's University Of Belfast
3	66	9.0%	Short Brothers Plc
4	33	4.5%	Norbrook Laboratories Limited
5	32	4.3%	Camco Drilling Group Limited
6	28	3.8%	Uutech Limited
7	24	3.3%	Valpar Industrial Limited
8	18	2.4%	Munster Simms Engineering Limited
9	12	1.6%	European Components Co Limited
10	12	1.6%	Morphy Richards Limited
11	10	1.4%	Giltspur Scientific Limited
12	10	1.4%	Sepha Pharmaceuticals Limited
13	9	1.2%	Heartsine Technologies Limited
14	9	1.2%	University of Ulster
15	8	1.1%	E.D.Medical Ltd
16	8	1.1%	Expotech Limited
17	8	1.1%	F.G. Wilson
18	8	1.1%	T.G. Eakin Limited
19	8	1.1%	Ulster Carpet Mills
20	7	1.0%	Denroy Group Limited
	284	38.6%	Other 142 assignees

Notes: the share of patents is from granted patents for all country assignees; percentages may exceed 100 percent due to patents with more than one assignee.

Source: Patstat patents database

In the **Republic of Ireland**, patent grants are more evenly distributed between many more assignees (Table 4.4). The share of the top-20 organizations in this economy is 30.4 percent of all granted patents, while other 1,236 assignees contributed 70.3 percent of all patents between 1999 and 2008. The top assignee was Pfizer Research & Development Ltd, the US global pharmaceutical company with R&D labs in Ringaskiddy, Cork, with 6.2 percent of patent grants. Another US pharmaceutical company with local presence, Elan Pharma International Limited, was the second assignee in this time period, with slightly more than 4 percent of patent grants. On the other hand, two universities are among this top-20 list. The Trinity College of Dublin and the National University of Ireland – Cork contributed one percent of patent grants each during the period 1999-2008.

Table 4.4 Top-20 patent assignees from Republic of Ireland (1999-2008)

Rank	Patents	Share	Organization
1	208	6.2%	Pfizer Research & Development Ltd
2	138	4.1%	Elan Pharma International Limited
3	71	2.1%	Loctite R&D Limited
4	59	1.7%	Vasogen Ireland Limited
5	52	1.5%	Kingspan Holdings
6	50	1.5%	Activcard Ireland Limited
7	47	1.4%	Flooring Industries Ltd
8	42	1.2%	Sylmark Holdings Limited
9	39	1.2%	Tibotec Pharmaceuticals Ltd
10	37	1.1%	Abbott Laboratories Vascular Enterprises Ltd
11	35	1.0%	Trinity College Of Dublin
12	33	1.0%	National University of Ireland Cork
13	30	0.9%	Salviac Limited
14	29	0.9%	Howmedica International Inc
15	29	0.9%	KUM Limited
16	29	0.9%	Xsil Technology Limited
17	28	0.8%	Hp-Chemie Pelzer Research & Development Ltd
18	26	0.8%	Adiseo Ireland Ltd
19	26	0.8%	Atropos Ltd
20	20	0.6%	Kinerton Ltd
	2,375	70.3%	Other 1,236 assignees

Notes: the share of patents is from granted patents for all country assignees; percentages may exceed 100 percent due to patents with more than one assignee.

Source: Patstat patents database

In **New Zealand**, the list of top-20 patent assignees includes several private companies, a few crown-owned companies, and only two universities (one of them represented by a company) (Table 4.5). Fisher & Paykel Appliances Limited, a large manufacturer of home appliances, is the leading assignee with 8.1 percent of all patent grants. The second assignee is Auckland UniServices Limited, the commercial research and knowledge transfer company for the University of Auckland, with 3.5 percent of patent grants. Among the Crown-owned companies are Industrial Research Ltd, AgResearch Ltd, and Horticulture and Food Research Institute of New Zealand Ltd. Massey University, the only academic institution within the top-20 list, obtained less than 1 percent of the grants. Overall, these top-20 organizations contributed almost 40 percent of all patent grants for this economy between 1999 and 2008.

Table 4.5 Top-20 patent assignees from New Zealand (1999-2008)

Rank	Patents	Share	Organization
1	280	8.1%	Fisher & Paykel Appliances Limited
2	121	3.5%	Auckland Uniservices Ltd
3	116	3.3%	Industrial Research Ltd
4	107	3.1%	Fonterra Corporate Research and Development Ltd
5	92	2.7%	AgResearch Limited
6	90	2.6%	Fisher & Paykel Healthcare Limited ^a
7	78	2.2%	Genesis Research & Development Corporation Limited
8	65	1.9%	Formway Furniture Limited
9	65	1.9%	Horticulture and Food Research Institute Limited
10	64	1.8%	Carter Holt Harvey Limited
11	48	1.4%	Fletcher Challenge Building Limited
12	40	1.2%	Gallagher Group, Ltd
13	40	1.2%	Sealed Air New Zealand
14	37	1.1%	Tait Electronics Limited
15	29	0.8%	Massey University
16	28	0.8%	Tru-Test Corporation Limited
17	27	0.8%	University Of Otago
18	25	0.7%	Compudigm International Limited
19	25	0.7%	Deep Video Imaging Limited
20	23	0.7%	Interag
	2,156	62.2%	Other 1,003 assignees

Notes: the share of patents is from granted patents for all country assignees; percentages may exceed 100 percent due to patents with more than one assignee. (a) Fisher & Paykel Healthcare Limited is a separate, different company from Industries Fisher & Paykel Appliances Limited; in the past, these two companies were part of the same industrial group.

Source: Patstat patents database

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In **Singapore**, the top-20 patent assignees concentrate the major part of the grants, a 70 percent share (Table 4.6). More than a thousand remaining assignees contributed only about 31 percent of patent grants in the same time period. The top assignee in this list is Chartered Semiconductor Manufacturing Ltd., one of the world's top dedicated semiconductor foundries, which held 22 percent of the Singapore's granted patent for the period 1999-2008 (more than 1,600 patents). This leader more than doubles the share of the second assignee, Avago Technology Ltd, another semiconductor company that was part of Agilent Technologies (also in this list) until 2005. The third assignee is the Agency for Science Technology and Research (A*Star), a governmental organization comprising a network of public research institutes which conduct cutting-edge research in specific niche areas. There also two universities in this list, including the largest National University of Singapore, with a 6.6 percent share of grants between 1999 and 2008.

Table 4.6 Top-20 patent assignees from Singapore (1999-2008)

Rank	Patents	Share	Organization
1	1,662	22.0%	Chartered Semiconductor Manufacturing Company Ltd
2	785	10.4%	Avago Technology Ltd
3	708	9.4%	Agency for Science Technology and Research (A*Star)
4	502	6.6%	National University of Singapore
5	252	3.3%	Lenovo Singapore Ltd
6	218	2.9%	Creative Technology Ltd
7	201	2.7%	Nanyang Technological University
8	152	2.0%	STMicroelectronics Asia Pacific Pte Ltd
9	145	1.9%	Agilent Technologies Singapore Pte Ltd
10	131	1.7%	ASM Technology Singapore Pte Ltd
11	127	1.7%	St Assembly Test Service Ltd
12	110	1.5%	Stats Chippac Ltd
13	78	1.0%	Oki Techno Centre Pte Ltd
14	73	1.0%	Verigy Pte Ltd
15	61	0.8%	Advaced Systems Automation Ltd
16	59	0.8%	Trek 2000 International Ltd
17	52	0.7%	FCI Asia Technology Pte Ltd
18	47	0.6%	Shimano (Singapore) Pte. Ltd
19	43	0.6%	Tritech Microelectronics Ltd
20	39	0.5%	Singapore Technologies Aerospace Ltd
	2,371	31.4%	Other 1,121 assignees

Notes: the share of patents is from granted patents for all country assignees; percentages may exceed 100 percent due to patents with more than one assignee.

Source: Patstat patents database

4.2 *Patented Technologies*

Using the standard IPC class codes of patents, it is possible to know the type of technology covered by the patent grant. In this case, the top 3-digit IPC codes are reported in Table 4.7. This is a level of aggregation that allows describing the general profile for each countries. For the period 1999-2008, the top 3-digit IPC class in Northern Ireland, Republic of Ireland, and New Zealand is Medical or Veterinary Science, with 20.2 percent, 23.7 percent, and 15.9 percent shares, respectively (Table 4.7). Organic Chemistry is another IPC class shared by these three countries, with a 12.6 percent share in Northern Ireland, 9.7 percent share in the Republic of Ireland, and 8.1 percent in New Zealand.

In **Northern Ireland**, other two IPC classes contribute significantly to patent grants. They are Measuring and Testing (11.7 percent) and Electric Communications (8.5 percent). Together, vehicle and engineering-related technologies contribute almost 10 percent of patent grants in this country. Overall, the top-4 IPC classes represent more than 44 percent of all granted patents for this country in this period.

In the **Republic of Ireland**, Computing and Electric Communications as well contribute almost 10 percent of granted patents each. Electric and Electronic Circuitry also contribute almost 10 percent of patent grants. In this economy, the top-4 IPC classes also concentrate about 44 percent of patent grants.

In **New Zealand**, similar IPC classes are among the top-10, although in this case there is a significant contribution of Agriculture and forestry-related technologies (10.6 percent share). Moreover, an IPC class related to Food or Foodstuff is another particular feature of the technology profile of this economy, with a 4.4 percent share.

On the other hand, as suggested by its list of top assignees, **Singapore's** patent grants are related to Semiconductor, Electronics, and Computing technologies. The top-3 IPC classes (Basic Electric Elements, Computing, and Electric Communications) contribute almost 51 percent of the patent grants. The rest of the top-10 IPC classes for this economy are also related to those industries, yet Medical and Veterinary Services has a minor contribution as well. Optics and Machine Tools are also top-ranked in Singapore, although the relative shares of these two are not large.

Table 4.7 Shares of granted patents for top-10 (3-digit) IPC classes (1999-2008)

Rank	Northern Ireland		Republic of Ireland		New Zealand		Singapore	
	IPC class	Share	IPC class	Share	IPC class	Share	IPC class	Share
1	A61-Medical Or Veterinary Science; Hygiene	20.2%	A61-Medical Or Veterinary Science; Hygiene	23.7%	A61-Medical Or Veterinary Science; Hygiene	15.9%	H01-Basic Electric Elements	32.7%
2	G01-Measuring; Testing	13.2%	G06-Computing; Calculating; Counting	9.9%	A01-Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing	10.6%	G06-Computing; Calculating; Counting	10.8%
3	C07-Organic Chemistry	12.6%	H04-Electric Communication Technique	9.8%	C07-Organic Chemistry	8.1%	H04-Electric Communication Technique	10.2%
4	H04-Electric Communication Technique	8.5%	C07-Organic Chemistry	9.7%	G01-Measuring; Testing	6.6%	G01-Measuring; Testing	6.9%
5	C12-Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation Or Genetic Engineering	7.3%	H01-Basic Electric Elements	6.6%	B65-Conveying; Packing; Storing; Handling Thin Or Filamentary Material	6.5%	G11-Information Storage	5.6%
6	B60-Vehicles In General	5.0%	G01-Measuring; Testing	5.8%	C12-Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation Or Genetic Engineering	6.3%	H03-Basic Electronic Circuitry	4.8%
7	B01-Physical Or Chemical Processes Or Apparatus In General	4.0%	B65-Conveying; Packing; Storing; Handling Thin Or Filamentary Material	3.7%	G06-Computing; Calculating; Counting	4.7%	H05-Electric Techniques Not Otherwise Provided For	3.6%
8	F16-Engineering Elements Or Units; General Measures For Producing And Maintaining Effective Functioning Of Machines Or Installations; Thermal Insulation In General	4.0%	C12-Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation Or Genetic Engineering	3.7%	A23-Foods Or Foodstuffs; Their Treatment, Not Covered By Other Classes	4.4%	A61-Medical Or Veterinary Science; Hygiene	3.2%
9	H01-Basic Electric Elements	3.8%	H03-Basic Electronic Circuitry	3.3%	A47-Furniture; Domestic Articles Or Appliances; Coffee Mills; Spice Mills; Suction Cleaners In General	4.4%	G02-Optics	2.9%
10	E21-Earth Or Rock Drilling; Mining	3.4%	E04-Building	3.0%	H04-Electric Communication Technique	3.9%	B23-Machine Tools; Metal-Working Not Otherwise Provided For	1.8%

Notes: the share of patents is from all granted patents for each country; percentages may exceed 100 percent due to patents with more than one IPC class. Source: Patstat patents database

4.3 Collaborations in Patents

Patent records may be used to analyze collaborations in patenting, yet the nature of these collaborations is not easily revealed (for example, whether it implies co-development of the technology or only co-ownership). For looking at these collaborations, this section examines co-assignees in patents (that is, patents with more than one assignee) for organization-assignees established in the selected countries (the following section looks at international co-assignees). In principle, at the aggregate level, is possible to analyze if different types of organizations share the ownership of granted patents. For this, patent assignees are classified into corporate, academic, government, hospital, and other types of organizations.

Table 4.8 Collaboration in patents for each type of organization and between them (1999-2008).

a) Northern Ireland

	Corp	Acad	Gov	Hosp	Other
Corp	86.2%	-	-	-	-
Acad	-	13.8%	-	-	-
Gov	-	-	-	-	-
Hosp	-	-	-	-	-
Other	-	-	-	-	-

b) Republic of Ireland

	Corp	Acad	Gov	Hosp	Other
Corp	96.4%	0.5%	-	-	-
Acad	0.5%	3.6%	0.1%	-	-
Gov	-	0.1%	0.7%	-	-
Hosp	-	-	-	-	-
Other	-	-	-	-	-

c) New Zealand

	Corp	Acad	Gov	Hosp	Other
Corp	96.8%	0.8%	0.3%	-	0.1%
Acad	0.8%	2.4%	0.2%	-	-
Gov	0.3%	0.2%	1.2%	-	-
Hosp	-	-	-	-	-
Other	0.1%	-	-	-	0.8%

d) Singapore

	Corp	Acad	Gov	Hosp	Other
Corp	81.8%	1.1%	0.7%	-	-
Acad	1.1%	9.7%	0.8%	-	-
Gov	0.7%	0.8%	11.0%	-	0.1%
Hosp	-	-	-	-	-
Other	-	-	0.1%	-	0.1%

Source: Patstat patents database

Table 4.8 shows the shares of patents that have co-assignees of different types in the four countries. The diagonal of each matrix reflects clearly that most of the patents of each economy are owned by companies (between 81 percent and 97 percent shares), with a relatively minor share in universities and, in the case of Singapore, government agencies. Still, collaborations between companies and universities vary between each country. For example, while in Northern Ireland there is at least one university as a leading assignee (Queen's University of Belfast), no patent collaborations with companies are registered in Patstat patent records. The data do reveal

some company-university collaborations for the other three economies, yet they represent very low shares of all patent grants. In the case of Singapore, also with two leading universities among the top assignees, the share of patents co-owned by companies and universities is slightly more than 1 percent of all patent grants. For New Zealand and the Republic of Ireland, this share is 0.8 percent and 0.5 percent, respectively.

Other types of organizations have insignificant or no share of patent grants and, hence, collaborations are less common (Table 4.8). For example, in the cases of Singapore and New Zealand there are small shares of patents with company and government organizations co-ownership (less than 1 percent), yet in Singapore about 11 percent of the grants have government assignee. The share of patents co-owned by universities and government agencies is also negligible, although for Singapore this combination of co-assignees represents 0.8 percent of granted patents.

4.4 International collaborations and technology ownership

As mentioned before, country patents include patents for both inventors and assignees established in that economy. However, not all patents with local inventors are owned by local assignees. Furthermore, not all patents owned by local assignees protect technologies invented locally. This fact has important implications. For instance, although technologies may be created and developed by local inventors, the capability to exploit or commercialize such technologies may be situated in other countries if the patent has foreign assignees. Likewise, local organizations may be able to commercialize technologies developed abroad if they own patents with foreign inventors.

By looking at the data for assignees in patent records, it is possible to examine the extent to which that fact is reflected in patent activity for each country. Generally speaking, one-third or more of granted patents with at least one local inventor were assigned to foreign organizations in these economies between 1999 and 2008 (Table 4.9). In the case of Northern Ireland, this share reached 46.7 percent of all country patents. On the other hand, only about 37 percent of patents with New Zealand or Singapore inventors are owned by foreign organizations. In some cases, these patents with foreign assignees also have at least one local assignee, which can be considered an international collaboration (i.e. co-assignees from different countries). This is the case of at least 3 percent of the granted patents in New Zealand, 5.2 percent in the Republic of Ireland, 6 percent in Northern Ireland, and more than 8 percent in Singapore (Table 4.9).

An important proportion of the granted patents of these four countries reports to have foreign inventors, particularly in the Republic of Ireland and Northern Ireland where that share exceeds the 50 percent (Table 4.9). In the case of New Zealand, only 24.1 percent of granted patents have at least one foreign inventor and local assignees. As mentioned before, these may be patents that allow local organizations to exploit or commercialize technologies that were invented elsewhere in the world yet, in some cases for example, they may reveal only collaborations between inventors with different location within the same global corporation. Indeed, the

percentage of patents that have both local and foreign assignees is significant in all these four countries, ranging from 18.2 percent in New Zealand to 39.5 percent in Northern Ireland.

Table 4.9 Patent grant inventors and ownership for selected countries (1999-2008)

	Local assignee	Foreign assignee	Local / foreign co-assignees	Local inventor	Foreign inventor	Local / foreign co-inventors
Northern Ireland	56.2%	46.7%	6.0%	86.7%	52.8%	39.5%
Republic of Ireland	59.8%	38.9%	5.2%	70.7%	56.8%	28.4%
New Zealand	60.7%	37.6%	3.1%	93.9%	24.1%	18.2%
Singapore	69.7%	37.2%	8.2%	81.8%	44.9%	26.8%

Note: total shares of local and foreign assignees / inventors may exceed 100 percent due to collaborations (co-assignees and co-inventors) or add up to less than 100 percent when no data for assignee countries is available.

Source: Patstat patents database

When looking at foreign assignees, the data shows that USA organizations own (or are co-assignees in) more than 20 percent of all patents from Republic of Ireland and Singapore, and more than 9 percent from Northern Ireland and New Zealand (Table 4.10). The second most important country for foreign assignees is the UK, particularly for Northern Ireland where 10.2 percent of patents have UK assignees (based elsewhere in the UK). The exception is Singapore, where the second most important country of foreign assignees according to patent counts is Japan, yet the share is still relatively small (2.3 percent of Singapore patents). The shares of assignees from other countries are not significant, except for assignees from Republic of Ireland in the case of Northern Ireland, which are assignees or co-assignees of more than 8 percent of the country patents.

At the organizational level, it is possible to examine which foreign organizations are the top owners of patents. As suggested by the assignee country analysis, most of the top foreign assignees are USA companies, yet there are companies from other countries that have important shares of local patents (Table 4.11). Among the top foreign assignees for Northern Ireland patents are Nortel Networks Ltd (the Canadian telecommunications company, 9.8 percent share) and Procter & Gamble (the USA manufacturer of consumer goods, 6.7 percent share). The University of Saskatchewan (Canada) is the eighth ranked foreign patent collaborator with Northern Ireland, including a number of patents co-developed with Queens University, Belfast, in the field of porcine circovirus vaccines and diagnostics reagents. For the Republic of Ireland the leading foreign assignees are 3Com Corp. (USA provider of networking solutions, 7.1 percent share) and Analog Devices Inc (USA manufacturer of integrated circuits, 7.1 percent share). For New Zealand patents, the leading foreign assignees are Trimble Navigation (USA provider of global positioning solutions, 2.5 percent share) and Warner-Lambert Company LLC (the US pharma company acquired by Pfizer, 1.7 percent share). For Singapore patents, the leading foreign assignees are Seagate Technology Inc (the US manufacturer of disk drives and storage devices, 7.1 percent share) and HP Co. (the US computer manufacturer, 6.1 percent share).

Table 4.10 Top-10 foreign assignees countries (1999-2008)

Rank	Northern Ireland			Republic of Ireland			New Zealand			Singapore		
	Country	Patents	Share	Country	Patents	Share	Country	Patents	Share	Country	Patents	Share
1	USA	204	15.6%	USA	1,246	22.1%	USA	516	9.0%	USA	2,231	20.6%
2	UK (excl NI)	133	10.2%	UK	247	4.4%	UK	156	2.7%	Japan	254	2.3%
3	Ireland	107	8.2%	Switzerland	100	1.8%	Australia	74	1.3%	Taiwan	250	2.3%
4	Canada	90	6.9%	Sweden	85	1.5%	Germany	34	0.6%	Germany	227	2.1%
5	France	40	3.1%	Canada	81	1.4%	Sweden	28	0.5%	Netherlands	129	1.2%
6	Netherlands	19	1.5%	Germany	77	1.4%	Netherlands	25	0.4%	Malaysia	103	1.0%
7	Germany	12	0.9%	Netherlands	75	1.3%	Switzerland	25	0.4%	France	81	0.7%
8	Japan	8	0.6%	France	55	1.0%	Japan	16	0.3%	Switzerland	72	0.7%
9	Iran	5	0.4%	Cayman Islands	45	0.8%	Canada	14	0.2%	UK	57	0.5%
10	China	4	0.3%	Japan	44	0.8%	Hong Kong	9	0.2%	Bermuda	40	0.4%

Note: the table shows shares of all country patent grants. Data on assignees country is not available for all patents, varying the range of coverage from 50 to 96 percent in selected countries.
Source: Patstat patents database

Table 4.11 Top-10 foreign corporate assignees (1999-2008)

Rank	Northern Ireland			Republic of Ireland			New Zealand			Singapore		
	Country	Pat(s)	Share	Country	Pat(s)	Share	Country	Pat(s)	Share	Country	Pat(s)	Share
1	Nortel Network Limited (CA)	60	9.8%	Analog Devices, Inc (US)	156	7.1%	Trimble Navigation Limited (US)	54	2.5%	Seagate Technology Inc (US)	287	7.1%
2	Procter & Gamble Company (US)	38	6.2%	3Com Corporation (US)	155	7.1%	Warner-Lambert Company LLC (US)	37	1.7%	Hewlett Packard Company (US)	247	6.1%
3	Merial SAS (FR)	28	4.6%	Telefonaktiebolaget Lm Ericsson (SE)	64	2.9%	Gibbs Technologies Ltd (GB)	28	1.3%	Micron Technology Inc (US)	208	5.2%
4	ECC International Ltd (GB)	22	3.6%	Logitech Europe S.A. (CH)	60	2.7%	Agriculture Victoria Services Pty Ltd (AU)	25	1.2%	Agilent Technologies Inc (US)	137	3.4%
5	Schrader-Bridgeport International, Inc (US)	22	3.6%	Molex Incorporated (US)	47	2.1%	Assa Abloy Financial Services AB (SE)	25	1.2%	Infineon Technologies A.G (DE)	132	3.3%
6	Curozone Ireland Limited (IE)	19	3.1%	Motorola INC (US)	39	1.8%	Genentech, Inc (US)	25	1.2%	Matsushita Electric Industrial Company, Limited (JP)	121	3.0%
7	Seagate Technology Inc (US)	17	2.8%	Koninklijke Philips N.V (NL)	37	1.7%	Xenova Limited (GB)	25	1.2%	Koninklijke Philips Electronics N.V (NL)	105	2.6%
8	University of Saskatchewan (CA)	16	2.6%	Medtronic, Inc (US)	35	1.6%	Weatherford U.S. L.P (US)	24	1.1%	Taiwan Semiconductor Manufacturing cCo. Ltd (TW)	99	2.5%
9	British Telecommunications PLC (GB)	13	2.1%	Logitech Inc (US)	31	1.4%	Albert Einstein College of Medicine of Yesheva University (US)	22	1.0%	IBM (US)	91	2.3%
10	Analog Devices, Inc (US)	11	1.8%	Hewlett Packard Company (US)	30	1.4%	Graham Packaging Company (US)	17	0.8%	Texas Instruments Inc (US)	73	1.8%
	Other 283 foreign assignees	400	65.4%	Other 795 foreign assignees	1,558	70.9%	Other 1,409 foreign assignees	1,904	88.6%	Other 1,396 foreign assignees	2,585	64.1%

Note: the table shows shares of total country patents with foreign assignees; two-letter codes for country assignees are shown as reported by different patent offices.

Source: Patstat patents database

5. Bibliometric Analysis of Clusters

This section focuses on four specific clusters or sectors related to scientific research (SCI-EXPANDED database) and patented technologies: Chemistry, Food Science & Technology, Biotechnology, and Engineering. These clusters represent more or less relevant sectors in terms of publications and patents, yet they help in understanding the science and technology profiles of Northern Ireland, Republic of Ireland, New Zealand, and Singapore.

For the purpose of the analysis, the clusters were defined as shown in Table 5.1. It must be considered that science subject areas relate to disciplines of research and not to specific sectors or technologies. On the other hand, IPC codes classify patents according to technologies and not to specific industry sectors, which may draw upon very different technologies to produce their outputs. For these reasons, this concordance between subject areas and IPC class codes should be taken only as an approximate match for an overall assessment of the research and patenting profiles of the selected countries.

Table 5.1 Concordance between subject areas in scientific research and IPC class codes in patents

Cluster	Subject areas in scientific research ¹⁰	IPC class codes in patents
Chemistry	Chemistry, Physical; Chemistry, Multidisciplinary; Chemistry, Organic; Chemistry, Analytical; Chemistry, Inorganic & Nuclear; and Chemistry, Medicinal	Based on IPC definitions of: Organic fine chemistry, Macromolecular chemistry and polymers, and Basic materials chemistry ¹¹
Biotechnology	Biochemistry & Molecular Biology; Biotechnology & Applied Microbiology; Microbiology; Cell Biology; and Biomedical Engineering (more than half of the publications of the latter are related to biomaterials and biophysics rather than engineering)	Based on Biotechnology definition used by OECD for patented biotechnologies ¹²
Food Science & Technology	Food Science & Technology	Most of IPC class A23 (Foods Or Foodstuffs; Their Treatment, Not Covered By Other Classes) and Food chemistry)
Engineering	Engineering, Electrical & Electronic; Engineering, Chemical; Engineering, Mechanical; Engineering, Civil; Engineering, Manufacturing; Engineering, Multidisciplinary; Computer Science, Software Engineering; Engineering, Industrial; Engineering, Environmental; Metallurgy & Metallurgical Engineering; Engineering, Geological; Engineering, Aerospace; and Engineering, Petroleum	Based on IPC definitions of: Electrical engineering, Mechanical engineering, Chemical engineering.

Based on the analysis of scientific publications, it is possible to assess the contribution of these clusters and their trends for the selected countries. The absolute number of publications varies considerably among these clusters and economies for the period 1999-2008 (Figure 5.1)

¹⁰ According to data available on ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

¹¹ Available online at WIPO website: http://www.wipo.int/classifications/fulltext/new_ipc/ipcen.html

¹² Available online at OECF Patent Statistics website:

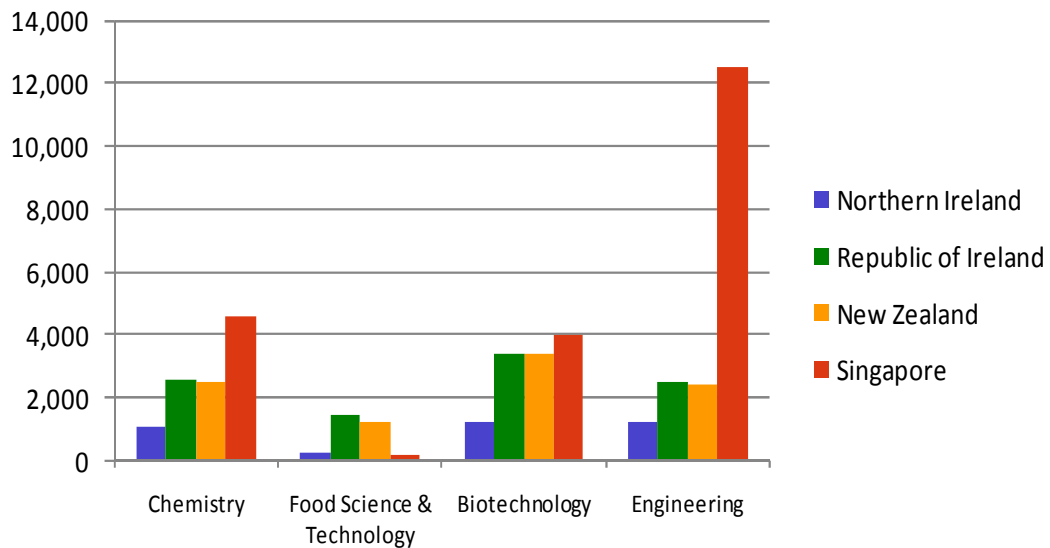
http://www.oecd.org/document/41/0,3343,en_2649_34451_40813225_1_1_1_1,00.html

and, while Northern Ireland, Republic of Ireland, New Zealand, and Singapore increased their number of publications in the four selected clusters, the relative contribution of each cluster varied over that ten-year period.

Engineering is the most active cluster in Singapore in terms of total publications (more than 12,000 for the period 1999-2008), followed by Chemistry and Biotechnology (with about 4,000), and then Food Science & Technology with a minor contribution to the overall research activity of the country (less than 200 scientific articles). However, while Chemistry has increased its share to more than 14 percent of all scientific research, Engineering decreased from 33 percent to 26 percent in the ten-year period (Figure 5.2). As of 2008, Chemistry was more important in terms of publications for Singapore than for the other three countries.

Biotechnology has been already identified as an emerging subject area in Singapore, growing from 7 percent to 10 percent of all publications in ten years (Figure 5.2). Only in the Republic of Ireland this cluster is more representative, with more than 12 percent of all publications or almost 3,400 articles in the period 1999-2008. The Food Science & Technology cluster has also contributed to the Republic of Ireland research more than in any other country, although its share decreased from 6.2 percent to 4.5 percent of all scientific publications of the country (something also already pointed out when identifying this area among the ones that increased the least in this country). Still, compared to the other three clusters, Food Science & Technology makes the lowest contribution in all four countries.

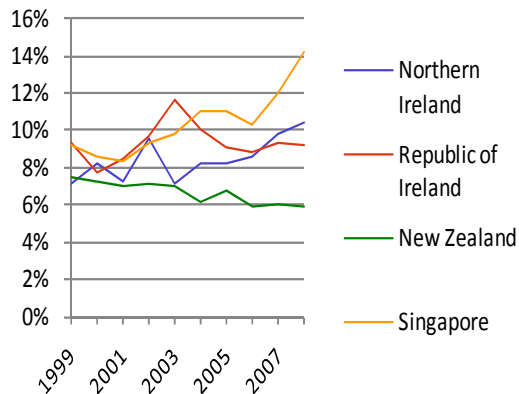
Figure 5.1 Total number of publications in Chemistry, Food Science & Technology, Biotechnology, and Engineering in selected countries (1999-2008)



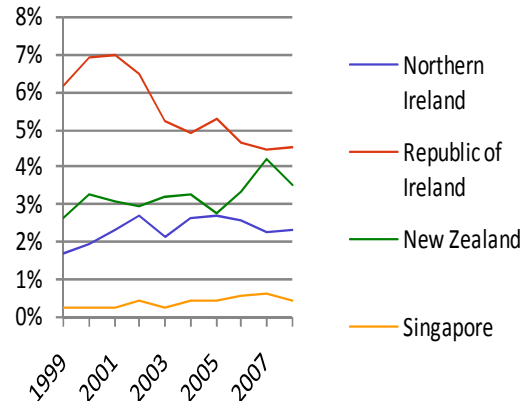
Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

Figure 5.2 Trends in publication shares for Chemistry, Food Science & Technology, Biotechnology, and Engineering clusters (1999-2008)

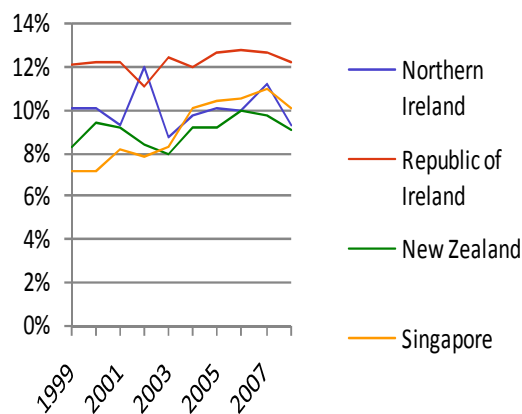
a) Chemistry



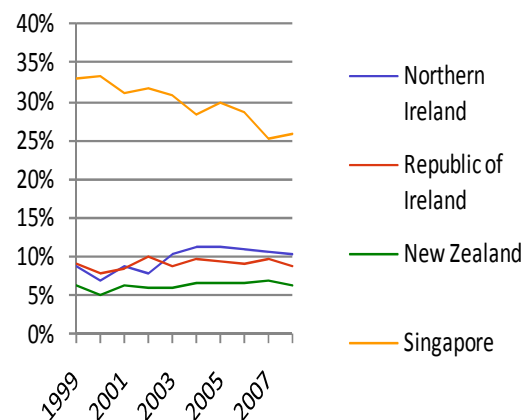
b) Food Science & Technology



c) Biotechnology



d) Engineering



Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED)

In terms of clusters relative contribution, New Zealand has a profile very similar to the Republic of Ireland, although it is changing somewhat differently (Figure 5.1). In the Republic of Ireland, Chemistry remained stable between 1999 and 2008, whilst New Zealand has decreased its share from 7.5 percent to 5.9 percent. Moreover, while Food Science & Technology decreased its share in the Republic of Ireland, in New Zealand it increased from 2.6 percent to 3.5 percent (the subject areas related to this cluster were already identified as emerging areas). Still, among these four clusters, Biotechnology is the most important for New Zealand, yet only increased slightly its share (about 1 percentage point).

In Northern Ireland, the Biotechnology and Engineering clusters have contributed similar numbers of scientific publications (more than 1,200) between 1999 and 2008 (Figure 5.1). Biotechnology has oscillated around a 10 percent contribution to the overall research output of the country, while Engineering increased its share from almost 9 percent to more than 10 percent, with peaks of more than 11 percent within that time period (Figure 5.2). Even more significant was the increase in the Chemistry cluster, from a 7.2 percent share to more than 10 percent of Northern Ireland's scientific articles. Food Science & Technology has a minor, increasing share of 2.3 percent as of 2008.

5.1 Publication and patent profiles

Combining the data on scientific publications and patent, it is possible to compare the countries' profiles in these clusters, from perspectives of their science output and new technologies. In doing this, we compare the shares of publications in each cluster with the shares of patent technologies (in this case, using IPC class codes), as defined in Table 5.1.

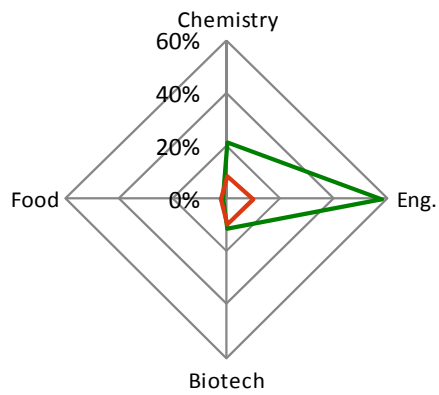
It is important to note that scientific publications can be related to one or more subject areas from a diverse set of more than 160 and, certainly, only some of these subject areas can be related to patented technologies. Scientific research is not aimed at inventing new technologies, yet research may be related to the development of new technologies in some cases for particular disciplines (like Engineering). Still, only a small share of publications can be linked directly to patents when they cite patents among their literature references (only about 2 percent of all scientific publications analyzed here have some reference to existing patents). On the other hand, patents are aimed at protecting legally new technologies or inventions and, according to the class code definitions (IPC), some clusters are more likely to have higher contributions in terms of patent counts, like Engineering.

The purpose of this comparison is to provide a general assessment of the alignment of science with technology in each country, presented graphically in this section. Moreover, for the reasons presented above, this comparison is only aimed at testing the relative 'shape' of each data series (publications versus patents) rather than the percentage of contribution of each cluster.

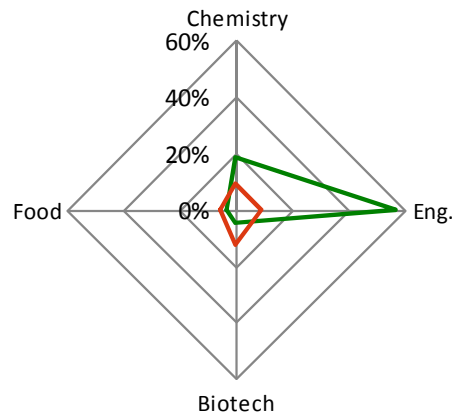
While the shares of publications vary for each cluster and country, most of the patents are typically related to Engineering in all countries (Figure 5.3). The contribution of engineering-related patents ranges from 51 percent in New Zealand to 74 percent in Singapore, with Northern Ireland and the Republic of Ireland having shares of about 57 percent. The second most important cluster in terms of granted patents is Chemistry, with shares between 18 and 21 for Northern Ireland, Republic of Ireland, and New Zealand, yet only slightly more than 5 percent in Singapore. Biotechnology-related patents have their most important contribution in Northern Ireland, with an 11.2 percent share for the period 1999-2008. In Food Science & Technology patents, there is only a significant contribution (of more than 7 percent of patents) in New Zealand.

Figure 5.3 Research and patenting profiles in Chemistry, Food, Biotechnology, and Engineering clusters (1999-2008)

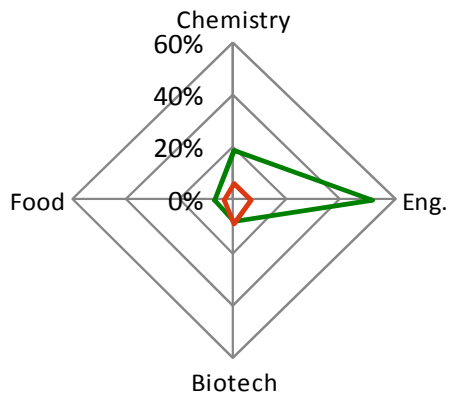
a) Northern Ireland



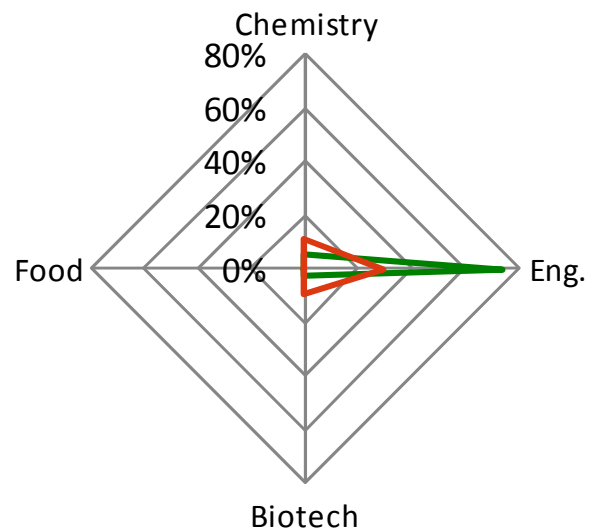
b) Republic of Ireland



c) New Zealand



d) Singapore



— Share of patents — Share of publications

Source: ISI-WoS database, Science Citation Index Expanded (SCI-EXPANDED) and Patstat patents database.

Northern Ireland and, particularly, Singapore display profiles of publications and patents that look more aligned (Figure 5.3). Both are more concentrated in Engineering-related patents and publications, yet Northern Ireland is more diversified in terms of the contribution made by Chemistry and Biotechnology in both patents and publications. Considering *only* these four clusters, Singapore appears much more concentrated in Engineering-related patents than in Engineering-related publications.

Both New Zealand and the Republic of Ireland have very similar research profiles in the four selected clusters, yet they present some differences between publications and patents within each country (Figure 5.3). While in both countries the concentration in Engineering-related patents persists, they still have publication outputs more oriented towards Biotechnology. In New Zealand, Food Science & Technology and Biotechnology patents have a more significant contribution than in the Republic of Ireland yet, overall, they are still similar.

6. Conclusions and Implications

After analyzing the main aspects of scientific research and patenting performance of Northern Ireland, the Republic of Ireland, New Zealand, and Singapore, we are able to draw some conclusions and potential implications about their capabilities for Science & Technology, and innovation performance of these countries. These are discussed in this concluding section. We also highlight questions arising from the analysis in this report that could usefully be addressed in the next stages of the study, including through field interviews.

6.1 Research Performance

The countries that we have examined not only have dissimilar levels of scientific activity but have also evolved differently over the last 10 years. Amongst the four, Singapore has the largest output in terms of scientific publications, followed by New Zealand, and the Republic of Ireland. Compared with Northern Ireland, Singapore has a population about 2.5 times greater *but* produced more than three times as many scientific publications over the last decade. Between 1999 and 2008, Singapore and the Republic of Ireland grew fastest in scientific publications (at about 10 percent annual average rates). Publications outputs differ in relative terms as well. Significantly, although it has relatively fewer R&D workers per million inhabitants, ***Northern Ireland's researchers produce more publications per head than R&D workers in Singapore, the Republic of Ireland and New Zealand.***

As expected, scientific publication is concentrated in universities and other public research institutes. Furthermore, scientific research is concentrated in few organizations in all four economies, particularly large universities or government institutions. Both Northern Ireland and Singapore have two large universities that dominate the scientific research landscape and lead scientific collaborations and publication. Hundreds of companies contribute marginally to scientific publications, sometimes in collaboration with universities, except for New Zealand, where large Crown-owned companies with commercial operations published and collaborated actively in the latest 10 years of scientific research. ***An alternative scheme of government participation in scientific research is seen in Singapore, where a large proportion of research is undertaken by government agencies in strong collaboration with leading universities.*** In addition, Northern Ireland and the Republic of Ireland had relatively important shares of research led by health institutions (21 and 16 percent, respectively) and in collaboration with universities.

Following broader trends in global scientific research publications, these countries undertake a significant share of their research in collaborations between many research organizations. These collaborations have formed ***dense research networks that are typically centered on a few leading and large universities.*** We looked at the top-3 research organizations of each country and found that they co-authored articles with at least 20 percent of all the research organizations of the country. This share reached 25 percent and 30 percent in Northern Ireland and Singapore, respectively, demonstrating the more predominant role of top organizations. ***Growing intensity in collaborations may lead to improvements in*** research

capabilities and preparedness for developing some emerging technologies. For instance, increasing connectedness favors **multidisciplinary and interdisciplinary research**, a key component in the production of knowledge in areas like biotechnology and nanotechnology.

Research topics also provide hints on the potential of these countries for innovation and the development of science-based technology fields. Scientific research in all four countries is diversified, particularly in Northern Ireland, Republic of Ireland, and New Zealand. The exception is Singapore, which has a strong concentration in engineering-related areas. Although topical areas are broadly stable, there has been change in the order of specializations. For example, in **Northern Ireland, research thrusts have shifted from broader Medicine or veterinary-related areas to more specialized areas like Oncology, Biotechnology, or Materials Science**; in the Republic of Ireland, from Food and Medicine to Computer Science, Optics, and Genetics; in New Zealand, from Medicine and marine-related areas to Engineering and Environment; and, in Singapore, from traditional engineering areas to more multidisciplinary and high-technology areas like Nanotechnology or Biotechnology.

Although the involvement of companies in scientific research was less expected than for other types of research organizations, their contribution to science is still relevant and may become even more essential in the future. In these countries, **the number of companies participating in scientific research has grown in the last decade**, yet their relative contribution to publications remains stable or grows at a slow pace. **Particularly the Republic of Ireland and Singapore grew in corporate research, with 50 percent or higher increase rates** in number of publishing companies between the time periods 1999-2003 and 2004-2008. That rate was only about 26 percent in Northern Ireland. The average number of publications per firm varied for each country as well. In Northern Ireland, companies increased slightly their average number of publications per year, while that average remained stable in Singapore and the Republic of Ireland, and decreased almost 50 percent in New Zealand. Indeed, the overall corporate publication output in the latter country decreased slightly as well.

We also found that corporate research is concentrated in fewer science areas than the overall scientific profile of each country. With the exception of New Zealand, corporate research in these countries was generally general more focused on areas like Engineering and Materials Science during the last decade. In Northern Ireland, corporate research was also more significant in Chemistry and Veterinary Sciences; in the Republic of Ireland, in Chemistry, Biotechnology, and Computer Science; and, in Singapore, in Physics and Nanotechnology. Corporate research in New Zealand, dominated primarily by large Crown-owned companies, focused and specialized in areas like Ecology, Marine Studies, Plant Sciences, Geosciences, and Agriculture.

While it is reasonable that companies focus their research thrusts on areas that can potentially contribute to the technologies they develop, it is also logical to question regarding the links between corporate research and the research undertaken by universities and government centers. What is the contribution of these types of organizations to the production of knowledge that can be applied to increase industry innovation capabilities and enhance competitiveness? To answer this question further investigation is required, yet some insights can be obtained from

examining corporate collaborations. The analysis shows that companies do collaborate to pursue scientific research but with few research partners. At least 62 percent of the companies undertaking scientific research in these countries did that in collaboration with other organizations in the last decade. In Singapore and New Zealand, this share reached 70 percent, which has led to denser corporate collaboration networks. However, within this group of **companies that collaborated in research publications, 56 percent or more had only one research partner. And, typically, this partner was a large university or government agency.**

There may be different explanations for that pattern of corporate collaborations. For example, it may indicate the lack of science-based projects, the engagement in collaborations to only access to funding from government programs, the specialization in fewer knowledge areas, or weak absorptive capabilities in companies. Still, large universities play a central role in corporate collaboration networks, which can be understood more as a positive contribution of university research to industry. A closer look at university-industry relations is necessary to understand more clearly the characteristics of the interface science-technology. Indeed, the study of specific cases of collaborative industry-university projects can reveal more details about research collaborations and how they impact technological capabilities of companies.

Research collaborations are not only maintained with local research organizations. Indeed, **international research collaborations are significant for both university and corporate scientific research.** At least 40 percent of scientific publications from these countries were published in collaboration with international organizations. These collaborations were maintained primarily with proximate countries, the USA, or leading European countries. For the time period 1999-2008, besides the USA, the main partners were England, the Republic of Ireland, and Scotland for Northern Ireland; for the Republic of Ireland, they were England, Germany, and France; for New Zealand, they were Australia, England, and Germany; for Singapore, they were China, Australia, and England. Collaborating countries in corporate research were in general the same, although regional collaborations (with England, the Republic of Ireland, or Scotland) were more significant for Northern Ireland. In principle, international collaborations were expected. Yet, further investigation of collaborations with neighboring countries would lead to a better understanding of the science research paths followed by these countries. For example, our data show that Northern Ireland maintains significant research collaborations with England and Scotland, but additional analysis would be required to understand how integrated different research disciplines and organizations are in this region. The same question is valid for example for Singapore, more closely linked to China and Australia besides USA. Furthermore, since corporate publications also show a similar pattern of international collaborations, it would be interesting to investigate more deeply how companies participate in these regional or global partnerships.

Social sciences research activity is less developed compared to other science disciplines in these countries. Moreover, social sciences have different significance and growth rates. New Zealand was the leading country in social sciences research in the last decade, although Singapore's and the Republic of Ireland's growth rates were somewhat higher (about 13 percent opposed to only 7 percent in New Zealand). For Northern Ireland and New Zealand, social sciences publication output relative to all publications was twice as important as that of Singapore, while

the Republic of Ireland was in intermediate levels. Still, social sciences publications **represented less than one-fifth of all publications in the four countries**. More than 40 percent of social sciences publications were related to areas like Psychology, Psychiatry, Environmental & Occupational Health, and Economics, except for **Singapore which was more focused in Economics, Business, Management, and Psychology**.

Specific areas of the social sciences are of special interest since they are related to the study of different aspects of innovation and competitiveness addressed by this project. These are the finance- and business-related research areas, which we re-grouped into Economics/Finance and Business/Management categories to analyze their evolution. Overall, they represent a minor share of all publications in Northern Ireland, Republic of Ireland, New Zealand, and Singapore, yet with increasing shares in some cases. **These research areas are growing in significance for New Zealand and Singapore, where they contributed about 4 percent of the overall publication output** in more recent years (about 50 percent growth in 10 years). The relative significance of these areas for Northern Ireland and the Republic of Ireland was lower, less than a 3 percent share. Singapore is the leader in Business/Management and New Zealand in Economics/Finance. This type of research was led primarily by collaborating universities with weak government or corporate contribution (generally, the same large universities that led publication in other disciplines). Still, these areas of social science research may lead to improvements in business management and innovation if new knowledge is applied to business areas like marketing, human resources, and organizations and operations research.

Several questions arise from our bibliometric analyses which could be worth pursuing in the study's next stage.

- Does Northern Ireland's relatively low share of R&D workers place the country at any significant competitive disadvantage compared with leading R&D intensive economies such as Singapore? Conversely, what specific competitive advantages does Singapore gain from its relatively high share of R&D personnel?
- Is the relatively high orientation of Northern Ireland's R&D workforce towards publication optimal? Would additional incentives to patent (especially for academic personnel) be productive from an industrial competitive perspective, and do the experiences of the other three countries shed further light on the means and value of such strategies?
- What advantages (and disadvantages) for industrial competitiveness result from New Zealand's transformation of public research institutes into privatized corporations?
- What advantages (and disadvantages) for industrial competitiveness result from the powerful role of government agencies collaborating with universities in research in Singapore?
- Do variations in international research collaboration patterns observed among the countries have any significance in terms of industrial competitiveness among the countries?
- How does medical research in health institutions get used by or transferred to companies, particularly in Northern Ireland and the Republic of Ireland where research shares by health institutions are relatively high?
- What advantage does Singapore's relatively high stress on engineering research give to its companies? Are there some disadvantages (e.g. is Singapore "locked-in" to a more traditional model)?

- ❑ How rapidly are the research systems of the four countries able to develop capabilities in critical new areas of science and technology, such as nanotechnology?
- ❑ Is the relatively lower growth rate of corporate research publishing in Northern Ireland an indicator that should give any concern from the view of industrial competitiveness?
- ❑ When companies collaborate in research, it is mostly with universities. But can companies in each of the four countries find good fits with universities and other institutions within the country? If not, can they go offshore, or is this a problem?
- ❑ Does Singapore's notable stress on economics, business, and management research in the social sciences give any advantages to its companies, including those in the banking and finance sectors?

6.2 Patenting Activity

Our analysis has looked at patenting activity in Northern Ireland, the Republic of Ireland, New Zealand, and Singapore. Patents are frequently used as one measure of innovative activity. We found that Singapore is the leader in terms of granted patents in the last decade, followed by New Zealand and the Republic of Ireland, and then Northern Ireland. The growth rates that these countries experienced in patent grants are higher than in publications, except for the Republic of Ireland. The average annual growth rate in Singapore exceeded the 24 percent in the latest 10 years. All four countries obtained patent grants from USPTO and EPO, while in New Zealand and Singapore local offices also granted a significant share of the patents for country assignees.

The technologies patented by these countries are diverse, yet there is some concentration in few areas. At least one-fourth of the technologies patented by Northern Ireland, the Republic of Ireland, and New Zealand are related to Medical or Veterinary Science and Organic Chemistry. Singapore's patents are more strongly related to Electric, Electronic, and Communications Engineering. The other three countries also been granted with patents related to those technologies, but in a less considerable proportion.

When looking at patent co-assignees, collaborations in patents relate to the capability to exploit or commercialize new technologies. Special interest is usually given to collaborations between companies and universities, which can explain how strong industry-university linkages are and, likewise, the capabilities of countries to commercialize new technologies emerging from scientific research. In general, the share of collaborations in patents is less significant than in publications, with varying significance among these four countries. For example, while in Northern Ireland there is at least one university as a leading patent assignee (Queen's University of Belfast), no patent collaborations with companies are registered in patent records. The data do reveal **some company-university collaborations** for the other three countries, yet they represent **very low shares of all patent grants**. In Singapore, with two leading universities among the top assignees, the share of patents co-owned by companies and universities is slightly more than 1 percent of all patent grants. For New Zealand and the Republic of Ireland, this share is 0.8 percent and 0.5 percent, respectively. For collaborations at the international level, Singapore was, within this group, the country with the highest proportion of patent grants (about 8 percent) with both local and foreign co-assignees. This proportion more than doubled that of New Zealand.

Patents with foreign assignees or co-assignees receive special attention as well. There may be cases of patents for technologies invented in a specific country but assigned to a foreign organization. Likewise, there may be technologies invented by foreign inventors which are assigned to local organizations. While more granted patents for local inventors may be considered a proxy describing more creativity in the country, more **granted patents for local assignees are more likely to reflect potential commercialization and exploitation** of new technologies. In this regard, the analysis has shown that at least one-third of the patents granted to these countries between 1999 and 2008 are owned by foreign assignees, as co-assignees or exclusive owners of local inventions. In Northern Ireland that share is even higher. Foreign assignees of country patents were primarily from USA and, with a lower share, from the UK. Assignees from other European countries, and from Asian countries in the case of Singapore, also had minor shares. The top **foreign assignees (primarily multinational corporations from USA, the UK, Canada, and other European countries) are owners of higher shares of patents in Northern Ireland and Singapore** than in New Zealand. In this regard, the Republic of Ireland is in an intermediate level.

These findings may have important implications that deserve further investigation. For instance, although technologies may be created and developed by local inventors, the capability to exploit or commercialize such technologies may be situated in other countries if the patent has foreign assignees. In the same manner, local organizations may be able to commercialize technologies developed abroad if they own patents with foreign inventors. Therefore, the question about the extent to which these countries are capable of leveraging creativity across their innovation systems raises. For sure, patent ownership does not guarantee successful commercialization, yet it is required to be able to exploit new technologies and conquer high technology markets.

To provide additional insights, we looked at certain knowledge/technology clusters to better understand the innovation profiles and capabilities of these countries. In particular, we looked at the Chemistry, Food Science & Technology, Biotechnology, and Engineering clusters. As suggested by the overall scientific research analysis, we found a relative concentration of Singapore in Engineering research and technology and of the Republic of Ireland and New Zealand in Biotechnology. However, within each cluster some variations have occurred during the analyzed ten-year period. **Research on Chemistry and Biotechnology grew in Singapore, research on Food Science & Technology decreased in the Republic of Ireland while increased in New Zealand, and Northern Ireland experienced relative growth in Chemistry.** Patenting activity in each cluster was also examined for these clusters. In principle, while research activity was more or less distributed among different topics, patenting was more related to Engineering in the four countries. On the other hand, the extent of alignment between scientific research and patented technologies was probed. Considering only the clusters' relative contribution within each country, the data suggest that Northern Ireland and Singapore may have undertaken research more related to new technologies developed or owned by local organizations, including primarily Engineering and, to some extent, Chemistry and Biotechnology. Meanwhile, the Republic of Ireland and New Zealand have been more active in Chemistry-related patenting than in research.

Certainly, while scientific research activity and technology development can evolve separately, only their alignment would provide a basis to increase competitiveness by pursuing innovation-driven development. In addition to the overall scientific research trends, our preliminary assessment of four specific clusters demonstrate how the scientific knowledge production changes in the medium term and how technology development can be more or less related to such scientific output. In particular, ***Singapore appears as the country that is changing its Science & Technology profile the most, targeting multidisciplinary areas like biotechnology (one of the analyzed clusters) or nanotechnology (one of the fastest-growing areas identified in the last 10 years).*** Changing its specialization to emerging technologies may be a risky strategy but a very profitable one if successfully implemented. We identified changes in the other three countries as well (including growing high-tech areas), yet the trends are less obvious. Questions arising from the patent analysis which could be worth pursuing in the study's next stage include:

- Is there any impact on industrial competitiveness from the relatively lower growth of patenting in Northern Ireland? Conversely, what advantages for industrial competitiveness result from Singapore's relatively higher growth in patenting?
- What impacts for industrial competitiveness result from Singapore's relatively high stress on patents in electrical, electronics, and communications engineering?
- What impacts for industrial competitiveness result from the relatively high stress on patents in medical, veterinary science, and organic chemistry classes in Northern Ireland, the Republic of Ireland, and New Zealand? Are there differences in how these patents in the classes are commercially applied among these countries?
- How is the propensity to patent influenced by the different patterns of academic-industry collaboration and networking observed in the four countries?
- What is the impact on domestic industrial competitiveness of high levels of foreign assignees in patent classes?
- What are the relative capabilities of companies and innovation systems in the four countries to develop intellectual property in emerging areas of technology, such as nanotechnology?
- What are the relative differences among the four countries in how the acquisition of patents is followed by or associated with commercialization and enterprise development?

6.3 Organizational Patterns and Capabilities

As indicated in the questions posed above, in the next phase of analysis of the innovation capabilities of these countries, a closer look should be taken at the organizational arrangements that are being pursued for scientific research and technology development. While Northern Ireland and the Republic of Ireland display university-centered research systems, New Zealand has pursued a strategy of strong involvement of government-owned companies and cooperatives in scientific research. Meanwhile, Singapore is characterized by the central role of two large universities and a network of government research labs. Private companies, in general, have had a secondary role in scientific research in the last decade. In particular, they do not collaborate extensively with other research organizations, although they do patent new technologies at growing rates, especially in Singapore.

Whether any one of these organizational arrangements offers a significant advantage for industrial competitiveness and the ability to face future competitive challenges depends probably also depends on broader economic, social, and cultural factors and on policy frameworks and incentives. The four countries analyzed here have grown in scientific publications and patenting activity, each one with a unique profile. New Zealand's science & innovation companies are not only leaders in scientific research but also have international presence in related-service and consultancy markets, sometimes by establishing subsidiaries in countries like Australia or USA. While for New Zealand technology transference to private companies is still a concern, the alternative model of science and commercialization pursued by those Crown-owned companies has been, in principle, successful at least for agricultural or environmental areas. On the other hand, Singapore's two largest universities maintain strong collaborations with government laboratories and, to less extent, with private companies. These universities and laboratories have contributed significantly to patenting activity as well. For Singapore, this model has been the appropriate to reach higher growth rates in both engineering-based publications and patents, yet forthcoming changes in research focus and, eventually, in technology development, may require to be flexible enough to keep the same pace.

Northern Ireland and the Republic of Ireland display university-centered research systems, still presenting some differences. Two independent universities govern scientific research in Northern Ireland and are the center in corporate scientific collaborations as well. These universities are very dynamic and well integrated in global scientific collaboration networks, yet they maintain a regional focus and less considerable publication growth rates. Among the four countries, Northern Ireland has had the lower scientific publication and patenting activity. Still, increasing specialization in research and technology niches appears as a path for future science and technology-based development. Universities are the scientific publication drivers in the Republic of Ireland as well, although in this case there are a handful of universities that lead research very actively and a large set of collaborating organizations. Lower growth rates in patents may suggest weaknesses in the application of new knowledge, yet the participation of hundreds of companies as patent assignees suggests, instead, broader applications of developed new technologies. Also for the Republic of Ireland, specialization in research and technology niches will be the challenge, although the starting point in this case is a stronger science and technology foundation.

Other aspects can be analyzed to provide additional insights and complement the findings of this overall assessment of the scientific research and patenting activity in Northern Ireland, the Republic of Ireland, New Zealand, and Singapore. A closer look at the composition of the labor force in each country may explain the relative contribution of the technologies that are currently developed and help in predicting capabilities, training demands, and potential paths of development. Country evolution and shares in high-tech markets can reveal how successful these countries are in commercializing technology developments in global markets. Although patent ownership is a proxy to measure innovation, only successful commercialization of inventions place the country as a technology leader. In addition, interesting insights may emerge from looking at the technology infrastructure available for each country, which may contribute substantially to the

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production, sharing/diffusion, and commercialization of knowledge. Principally, areas like telecommunications (e.g. 3G networks), broadband connectivity, and computing capabilities in R&D organizations can be studied and incorporated into the analysis as factors enabling innovation-driven development.