Profile of Public Research Activity in Ireland 1998-2006

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Executive Summary

In order to have a complete picture of the research outputs of the public research sector which includes the higher education institutions (HEIs) and other public research organisations (PROs), it is necessary to collate a number of different research activity indicators gathered from multiple agency sources. This report represents the first comprehensive profile of Irish research activity in the public sector to date, and provides a valuable baseline from which to assess future research activity data.

The output of this study is a data summary which provides a valuable resource for stakeholders wishing to have a comprehensive reference and an overall picture of the fields of science in which the Irish public research base is active. It is critical that the data capturing the outputs of the public research base are fully available and can best be utilised by policy makers and enterprise to maximise the potential for innovation and economic growth. It must be noted that there is a time lag between research investment and subsequent impact. This means that the impact of the investment and outputs being profiled in this statement may not be felt until a later period. The information and data contained in this report will also assist further analysis by stakeholders in subsequent phases of national research policy development and implementation. In particular, this report is a complement to the joint Forfás /HEA report, 'Research and Development Activity of Irish Based Enterprise' and will be used as an input to the 'National Research Prioritisation Exercise' currently ongoing in Forfás.

This report covers the period 1998-2006 and uses a number of data sources including the Higher Education Authority (HEA) enrolment and graduate student data, Forfás Higher Education Research and Development (HERD) and Government Research and Development (GOVERD) data, and an independent national Bibliometric assessment (for which there is data up to 2007). Although there is more recent data available from some sources, this statement focuses on the period 1998-2006, as 2006 was the last year for which all data sets were available in a comparable format. For the purposes of this study, the public research base was understood to comprise higher education institutions (HEIs) and other public research organisations (PROs). This statement presents a series of detailed research activity profiles for 19 modified fields of Science (mFOS)[1] as follows:

- Clinical Medicine
- Pre-Clinical & Health
- Biological Sciences
- Biotechnology
- Agricultural Biotechnology & Engineering (including Food)
- Agricultural Sciences
- Earth & Environment Sciences
- Mathematics
- Physics & Materials Sciences

[1] The 19 mFOS were taken from the customised 'project' research areas used in the Forfás/HEA Bibliometric report 'Research Strengths in Ireland'. These project research areas were based on the revised Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS). The OECD system was constructed primarily to serve an economic purpose. Knowledge exploitation is cross-disciplinary and therefore OECD FOS maps only partially to the structure of knowledge innovation in public sector research and some customisation was needed.

- Chemical Sciences
- Nanotechnology
- Computer & Information Sciences
- Civil Engineering
- Electrical Engineering, Electronic Engineering, Information Engineering
- Mechanical Engineering
- Social Sciences
- Economics & Business
- Psychology
- Humanities

Starting from a low base in many of the research areas profiled, Ireland demonstrated growth across all research indicators for the period 1998-2006. Overall, there has been an increase in research activity and research output in Ireland for the period. However, the growth profiled in this report must be considered in light of how far behind Ireland was, in regards historical research activity on the international stage. It is to be expected that starting from such a low base, the percentage of growth demonstrated for the period may appear large, but in real terms, Ireland still lags behind the majority of key research players internationally.

In 2006, Agricultural Sciences, Pre-Clinical & Health, Social Sciences and Biotechnology accounted for the highest proportion of public sector research-active staff. The undergraduate student pipeline was, and still is, concentrated in the Humanities, Social Sciences and Economics & Business fields. Postgraduate activity in 2006 was highest in the Biological Sciences, Humanities, and Social Sciences for both enrolled and graduating PhD and Masters students. For Masters students, Computer & Information Sciences also accounted for a high % of enrolled and graduating students.

The Bibliometric report (for which there is data up to 2007) indicated that although volume was small, Ireland's output was cited more than average and the impact or quality of the research was good. In 2007, Ireland was ranked 18th out of 20 comparator countries by published volume. By citation impact, Ireland was ranked 8th out of 20 comparator countries in 2007.

In order to realise the vision of Ireland as an Innovation Hub as outlined in the 'Innovation Ireland report'[2], a continued focus on furthering Irish research needs to be maintained. Thus it is critical that the growth and outputs for the period 1998-2006 outlined in this report be considered as a positive step in the right direction and an indication of how far Ireland has come from a very low base. This report provides a valuable baseline from which to assess future research activity data.

[2] Innovation Ireland – Report of the Innovation Taskforce, March 2010

1. Introduction

The focus of the report 'Innovation Ireland' is on "building the innovation or 'ideas' component of the economy through the utilisation of human capital – the knowledge, skills and creativity of people – and the ability and effectiveness of that human capital to translate ideas into valuable processes, products and services." In order to do this Ireland must deliver innovative people with world-class education, ideas, and knowledge.

The public research base, consisting of the higher education institutions (HEIs) and other public research organisations (PROs), plays a critical role in the innovation agenda for the future. Through the provision of high quality teaching and learning and research, the public research base stimulates the generation and exploitation of new knowledge and provides the capacity to address the changing needs and challenges in our society. It is critical that the data capturing the outputs of the public research base are fully available and can best be utilised by policy makers and enterprise to maximise the potential for innovation and economic growth.

The purpose of this study was to collect and present a comprehensive profile of the research and development activity in the public sector from 1998 to 2006. Although there is more recent data available, this statement focuses on the period 1998-2006, as 2006 was the last year for which all data sets were available in a comparable format. This report represents the first comprehensive profile of Irish research activity in the public sector to date, and provides a valuable resource from which to assess future research activity data.

The output of this study is a data summary which provides a valuable resource for stakeholders wishing to have a reference and an overall picture of the fields of science in which the Irish public research base is active. It must be noted that there is a time lag between research investment and subsequent impact. This means that the impact of the investment and outputs being profiled in this statement will not be felt until a later period. The information and data contained in this report will also assist further analysis by stakeholders in subsequent phases of national research policy development and implementation. In particular, this report is a complement to the joint Forfás /HEA report, 'Research and Development Activity of Irish Based Enterprise' and will be used as an input to the 'National Research Prioritisation Exercise' currently ongoing in Forfás.

In Chapter 2, the 19 modified Fields of Science (mFoS) as defined for this report are presented, and the content and sources of data used to develop each of the profiles are also discussed. Chapter 3 presents a summary of the overall level and change in public sector research activity for the period 1998-2006. In Chapter 4, the data for each of the research activity indicators is summarised across the 19 modified fields of Science (mFOS) profiled. A detailed profile for each mFOS is then provided in Chapters 5 through to 23.

2. Methodology[3]

In this part of the report an explanatory note is provided by way of background as to how the 19 modified Fields of Science (mFOS) were defined and selected for profiling. An outline of the content that is provided in each Field of Science profile is discussed briefly. The data sources used in developing the 19 mFOS profiles are indicated within the content outline and any caveats or deviation from these sources are referenced within the specific mFOS profiles. A more detailed analysis of the methodology is provided in Annex 1.

2.1 Defining the 19 Modified Fields of Science Used to Profile Public Research Activity in Ireland

The 19 mFOS were taken from the 20 customised[4] 'project' research areas used in the Forfás/HEA Bibliometric report 'Research Strengths in Ireland'[5]. These 20 project research areas were based on the revised Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS)[6] and are an aggregation of the 42 revised minor OECD fields.

For the purposes of this review, the 'Biological Sciences: Organismal Biology' and 'Biological Sciences: Molecular & Cellular Biology' used in the Bibliometric study were condensed into one mFOS giving a total of 19 mFOS to profile as follows[7]:

- Clinical Medicine
- Pre-Clinical & Health
- Biological Sciences
- Biotechnology
- Agricultural Biotechnology & Engineering (including Food)
- Agricultural Sciences
- Earth & Environment Sciences
- Mathematics
- Physics & Materials Sciences
- Chemical Sciences
- Nanotechnology
- Computer & Information Sciences

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[3] See Annex 1 for more detail on the methodology

[4] The OECD system was constructed primarily to serve an economic purpose. Knowledge exploitation is cross-disciplinary and therefore OECD FOS maps only partially to the structure of knowledge innovation in public sector research and some customisation was needed.

[5] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[6] See Annex 2 for a comparison of the OECD original Foes versus OECD revised FOS classification in the Frascati Manual. The original FOS classification was updated in 2007 to reflect the emergence of new technology fields in particular ICT, biotechnology and nanotechnology.

[7] See Annex 2 for tables listing the OECD revised minor FOS that were aggregated into the 19 mFOS and showing how the OECD original minor FOS categories were mapped onto the 19mFOS.

- Civil Engineering
- Electrical Engineering, Electronic Engineering, Information Engineering
- Mechanical Engineering
- Social Sciences[8]
- Economics & Business
- Psychology
- Humanities[9]

It is recognised that there will be an element of overlap between these categories and for the purposes of clarification, where relevant, this has been indicated on mFOS profiles.

2.2 Content Provided in each of the 19 mFOS Profiles[10]

The following information is provided within the profile of each mFOS[11]:

1. A snapshot of public research activity for the year 2006 (Activity Fact File - 2006).
   - 1.1. Inputs (Financial)[12]
   - 1.2. Staff[13]
   - 1.3. Students enrolled[14]
   - 1.4. % National[15] activity
2. A trend analysis of public research activity for the period 1998-2006 (Activity-Emerging Trends 1998-2006).
   - 2.1. Growth/decline in activity?
   - 2.2. Distribution of activity

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[8] The mFOS 'Social Sciences' covers a vast range of diverse subject areas, however for the purposes of the 'Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007)', they were collated under one heading due to the use of faculties and schools as the broad basis for deciding on the project categories.

[9] The mFOS 'Humanities' covers a vast range of diverse subject areas, however for the purposes of the 'Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007)', they were collated under one heading due to the use of faculties and schools as the broad basis for deciding on the project categories.

[10] See Annex 1 for methodology and source data details

[11] A Glossary of Terms is provided in Annex 3 and a list of acronyms is provided in Annex 4.

[12] This represents reported Higher Education Research and Development (HERD) and Government Research and Development (GOVERD) 'research-related' income in a given year and is not used as a primary direct measure of research activity for that year as it includes income associated with capital infrastructure. Research-related income is not directly linked to the number of 'research-active' staff.

[13] This represents the number of reported GOVERD and HERD full-time equivalent (FTE) 'research-active' staff and does not reflect the total number of staff employed in a specific year

[14] This was the total number of students enrolled in an academic year (i.e. 2005/06 = students enrolled as at 1st March 2006) and included all students (e.g. those in their 1st, 2nd, 3rd … years of study). See Annex 4 for mapping of Level 3 ISCED codes onto the 19mFoS.

[15] National Activity for research-related income and research-active staff was calculated as the sum of the 2006 GOVERD and HERD data for each mFOS.

3. An indication of the number of undergraduate students (Underpinning Factors)
   - 3.1. Undergraduate pipeline - students enrolled in system 1998/9 and 2005/06
   - 3.2. Undergraduate graduates for 2006[16]
4. Bibliometric analysis (Outputs and Outcomes)
   - 4.1. Volume
   - 4.2. Citation Impact
5. An indication of the number of Master's and PhD graduates (Outputs and Outcomes)
   - 5.1. Master's Graduates for 2006[17]
   - 5.2. PhD Graduates for 1998 & 2006
6. Other relevant information
   - 6.1. An overview of relevant physical and supporting infrastructure
   - 6.2. A summary of Strategic developments since 2006
   - 6.3. A summary of the key data for each mFOS.

[16] This was the number of undergraduate students graduating in the calendar year 2006 (i.e. number of students that graduated as at December 2006)

[17] Comprehensive data not available for 1998. See Annex 12.

3. Summary of Level and Change in Public Sector Research Activity

Drawing on multiple sources of data collected historically for different purposes, this statement gives a broad indication of the level and change in public sector research activity in 19 mFOS for the period 1998-2006. This is the first time that this data has been brought together to present an overall picture of the Irish research environment.

Starting from a low base in many of the research areas profiled, Ireland demonstrated growth across all research indicators for the period 1998-2006. Overall, there has been an increase in research activity and research output in Ireland for the period. However, the growth profiled in this report must be considered in light of how far behind Ireland was, in regards historical research activity on the international stage. It is to be expected that starting from such a low base, the percentage of growth demonstrated for the period is large.

With respect to the overall numbers of staff engaged in research activity in Ireland, there was an increase for the period 1998-2006. There was large variation in the initial numbers of research-active staff across the 19mFOS, resulting in a large range of % change over the period. In 2006, Agricultural Sciences, Pre-Clinical & Health, Social Sciences and Biotechnology accounted for the highest proportion of public sector research-active staff.

The overall amount of research funding available at the start of the period was relatively low. This increased over the period 1998-2006, with the mFOS median amount of reported research-related income more than doubling for the period (252%). The research-related income reported for a given year includes capital infrastructure and research-related income and should not be confused with expenditure. For this reason, the number of staff engaged in research was used as the primary measure of research activity in a given year.

With respect to students, there has been a large overall increase in the numbers of students engaging in higher education in Ireland during the period 1998-2006. The undergraduate student pipeline was, and still is, concentrated in the Humanities, Social Sciences and Economics & Business fields. Postgraduate activity (including enrolled research Masters and PhD students and the numbers of PhD students graduating) for the period 1998-2006 has increased by 80% on average, across the 19mFOS. Postgraduate activity in 2006 was highest in the Biological Sciences, Humanities and Social Sciences for both enrolled and graduating PhD and Masters students. For Masters students, Computer & Information Sciences also accounted for a high % of enrolled and graduating students.

Ireland more than doubled its published output between 1998 and 2007. The Forfás/HEA Bibliometric report 'Research Strengths in Ireland'[18] published in November 2009, reported this as 'an impressive increase relative to the comparator countries used in the study', but also stated that 'this occurred from a very low starting base'. In 2007, Ireland was ranked 18th out of 20 comparator countries by published volume. By citation impact, Ireland was ranked 8th out of 20 comparator countries in 2007. The

[18] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007). An international comparator group of 20 geographical entities was used for this study including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

Bibliometric report indicated that although volume was small, Ireland's output was cited more than average and the impact or quality of the research was good. In the Bibliometric report, the fields of science where Ireland consistently demonstrated a good citation impact relative to the world average included Pre-Clinical & Health, Mechanical Engineering and Chemical Engineering. International competition in Biological Sciences was noted as a constraint to relative performance, while performance in Agricultural Biotechnology was cited as stronger. The recent upward trend in Nanotechnology was highlighted as above average.

In order to realise the vision of Ireland as an Innovation Hub as outlined in the 'Innovation Ireland report'[19], a continued focus on furthering Irish research needs to be maintained. Thus it is critical that the growth and outputs for the period 1998-2006 outlined in this report be considered as a positive step in the right direction and an indication of how far Ireland has come from a very low base. This report provides a valuable baseline from which to assess future research activity data.

[19] Innovation Ireland – Report of the Innovation Taskforce, March 2010

4. Summary of Data Across the 19 mFOS Profiled

4.1 Activity Fact File (2006) - Using Revised OECD FOS Categorisation

Table 1: Percentage of Total Public Research Activity that each of the 19 mFOS Represented in 2006

mFOS[20]	% of National[21] Research-Active Staff	% of National PhD enrolled Students	% of National Masters enrolled Students	% of National Research-Related Income
Clinical Medicine	4.6%	5.1%	2.4%	4.1%
Pre-Clinical & Health	10.5%	1.8%	5.0%	11.4%
Biological Sciences	6.8%	11.8%	8.8%	6.6%
Biotechnology	8.2%	1.1%	0.4%	4.8%
Agricultural Biotechnology & Engineering	0.7%	0.4%	0.6%	1.2%
Agricultural Sciences[22]	12.7%	2.0%	2.3%	12.2%
Earth & Environment Sciences	4.3%	2.1%	0.9%	5.7%
Mathematics	2.7%	2.3%	1.2%	2.6%
Physics & Materials Sciences	6.2%	4.2%	3.9%	5.1 %
Chemical Sciences	3.4%	4.9%	3.1%	3.1 %
Nano-technology	2.7%	N/A	N/A	4.3 %
Computer & Information Sciences	5.2%	9.0%	8.3%	4.3%
Civil Engineering	1.6%	2.1%	3.7%	1.0%
Electrical, Electronic, Information Engineering	4.4%	3.6%	4.3%	4.4 %
Mechanical Engineering	1.8%	0.5%	0.8%	2.1%
Social Sciences	9.0%	8.5%	9.3%	8.2 %
Economics and Business	5.8%	5.1%	15.4%	5.1 %
Psychology	1.2%	3.9%	1.4%	1.2 %
Humanities	7.6%	18.3%	18.0%	5.5 %

[20] Throughout this report the mFOS are presented in the same random order as the published 'Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007)' to aid cross-referencing.

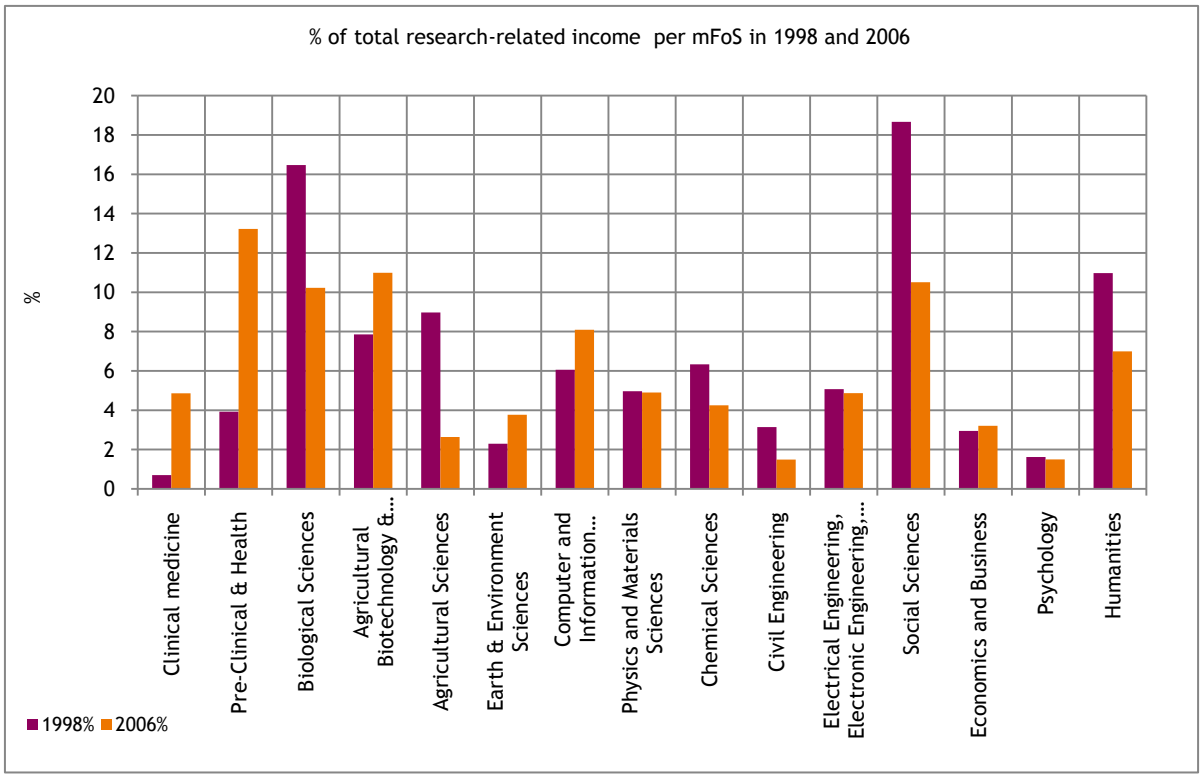
[21] National Activity for research-related income and research-active staff was calculated as the sum of the 2006 GOVERD and HERD data for each mFOS

[22] Teagasc represented circa 70% of the 2006 national research-active staff cohort and 65% of the 2006 national research-related income in Agricultural Sciences.

4.2 Activity (1998 versus 2006) – Using Original OECD FOS Categorisation

The percentage of total research-related income[23] that each of the 19 mFOS represented in 1998 and 2006 is shown in Figure 1. Figure 2 shows the percentage of total research-active staff[24] that each of the 19mFOS represented in 1998 and 2006. The absolute numbers for each mFOS have all increased as will be summarised in the following sections.

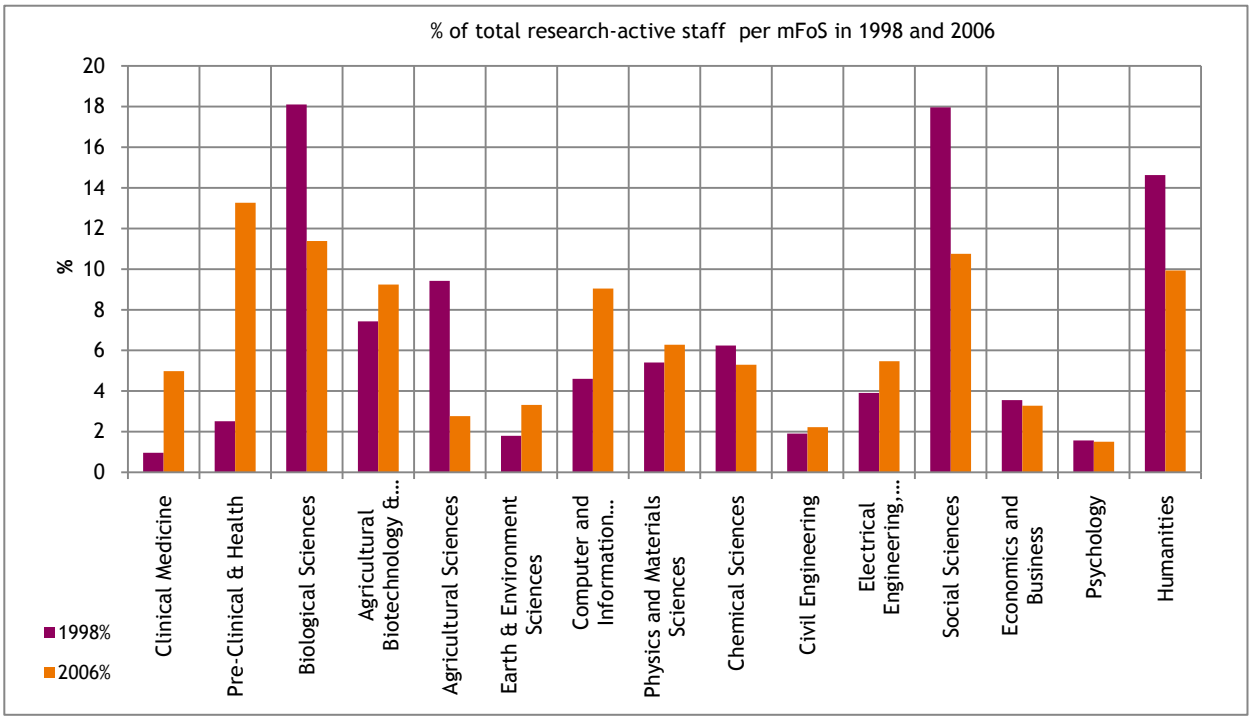
Figure 1 Percentage of Total Research-related Income that each of the mFOS Represented in 1998 and 2006



[23] This represents the percentage of total HERD reported research-related income. It does not include GOVERD data.

[24] This represents the percentage of total HERD reported research-active staff. It does not include GOVERD data.

Figure 2 Percentage of Total Research-active Staff that each of the 19mFOS Represented in 1998 and 2006



4.3 Outputs and Outcomes - Results from the Forfás/HEA Bibliometric Study[25]

The Forfás/HEA Bibliometric Study stated that the total research capacity in Ireland is relatively small and is centred in the higher education institutions and a small number of research performing organisations. The volume of published output (numbers of papers in Thompson Reuters' indexed journals) has increased 33%[26] across all disciplines. The report stated that this was an impressive increase that far exceeded the majority of 20 comparator countries[27] (bar China with 59% growth). Across all disciplines, the study ranked Ireland 18th by volume with a 0.50% share of world papers. Ireland's citation impact (citations per paper rebased to relevant world averages for year and field) was reported to have increased 9% across all disciplines. The study ranked Ireland 8th by citation impact with a 0.64% share of world citations. This indicates that although volume is small, Ireland's output is cited more than average and the impact or quality of the research is good.

[25] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[26] Current value (as at 2007) compared to recent average (2002-2006).

[27] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

Table 2: Summary of Forfás/HEA Bibliometric Study Results for the Public Research Base by mFOS

	Volume Output[28]		Citation Impact	
mFOS	% change in numbers of papers (and 2007 ranking in comparator group of 20 countries)	% change in share of world papers (and 2007 % share of world papers)	% change in citation impact over period	Irish 2007 rank within comparator group for citation impact
Clinical Medicine	+30% (ranked 14)	+18% (0.52)	+19%	9
Pre-Clinical & Health	+39% (ranked 16)	+24% (0.47)	+2%	2
Biological Sciences – Organismal	+43% (ranked 18)	+32% (0.53)	+25%	7
Biological Sciences – Molecular & Cellular	+41% (ranked 17)	+35% (0.56)	-8%	11
Biotechnology	+41% (ranked 17)	+23% (0.62)	-32%	15
Agricultural Biotechnology & Engineering (incl Food)	+13% (ranked 12)	-5% (1.39)	+20%	5
Agricultural Sciences	+33% (ranked 17)	+19% (0.70)	+51%	6
Earth & Environment Sciences	+22% (ranked 17)	+7% (0.39)	+6%	11
Mathematics	+38% (ranked 17)	+22% (0.51)	+42%	6
Physics and Material Sciences	+25% (ranked 17)	+16% (0.45)	+3%	7
Chemical Sciences	+31% (ranked 17)	+17% (0.38)	+24%	3
Nano-technology	+139% (ranked 13)	+27% (0.61)	-5%	7
Computer & Information Sciences	-18% (ranked 16)	+10% (0.67)	-17%	16
Civil Engineering	+144% (ranked 17)	+104% (0.48)	+104%	5
Electrical, Electronic, Information Engineering	+66% (ranked 15)	+40% (0.57)	-19%	12
Mechanical Engineering	-8% (ranked 18)	-17% (0.24)	+22%	3
Social Sciences	+57% (ranked 15)	+37% (0.58)	+51%	4
Economics and Business	+68% (ranked 17)	+38% (0.56)	+25%	8
Psychology	+66% (ranked 14)	+43% (0.46)	+130%	2
Humanities	+1% (ranked 11)	-1% (0.49)	-47%	15

[28] Numbers of papers in Thompson Reuters' indexed journals

4.4 Outputs and Outcomes – Masters and PhD Output

Table 3: Percentage of the Total Masters and PhD Graduates that each of the mFOS Represented in 2006.

mFOS	% of Total Masters Graduates in 2006	% of Total PhD Graduates in 2006
Clinical Medicine	12.0	10.3
Pre-Clinical & Health	3.3	1.2
Biological Sciences	5.3	15.0
Biotechnology	2.9	1.1
Agricultural Biotechnology & Engineering (including Food)	2.4	1.3
Agricultural Sciences	5.6	2.5
Earth & Environment Sciences	1.1	1.6
Mathematics	2.0	2.1
Physics & Materials Sciences	4.0	3.2
Chemical Sciences	2.9	7.9
Nano-technology	N/A	N/A
Computer & Information Sciences	9.1	7.0
Civil Engineering	7.3	1.1
Electrical, Electronic, Information Engineering	7.8	6.3
Mechanical Engineering	1.6	0.7
Social Sciences	6.0	8.6
Economics and Business	3.3	4.1
Psychology	1.8	2.9
Humanities	10.9	13.3

5. Clinical Medicine

5.1 Activity Fact File 2006

Inputs

Total Research Income €29,729,720

- Government Dector (GOVERD) €0[29]
- Higher Education Sector (HERD) €29,729,720
  - Direct Irish Exchequer Funding €16,703,260
  - Non-Irish Exchequer Funding
    - European Union (public) €1,375,000
    - Foreign Sources €341,000
    - Irish Private Funded €2,415,000

Research- active Staff

- HERD (FTEs) – 292
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 77
- PhD students (# in system) - 214

% National activity

- Clinical Medicine 2006 research-related income was 4.1% of national total
- Clinical Medicine 2006 research-active staff made up 4.6 % of national total
- Clinical Medicine 2006 research students represented 2.4% of the Masters and 5.1% of the PhD national total

5.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- The large growth in Clinical Medicine activity stands out when compared to other fields but was from a very low starting base.
- Growth in research-related income (€) from 1998 - 2006 was 2,410%. This was the largest reported increase of all the mFOS. The median of the 19 mFOS was 252%. The majority of this growth occurred 2000-2004. Growth from 2004 - 2006 was 31%. The median increase for the 19 mFOS was 19%.
- There was a significant 1,071% increase in number of reported research-active staff (FTEs) 1998-2006. This was the 2nd largest % increase across all the mFOS. The median increase was 163% for the 19mFOS for this period. From 2004 - 2006 the reported 15% increase was in line with the 19 mFOS median increase of 17%.
- There was a slow increase in the numbers of PhD and Masters students from 2005 onwards[30].

Distribution of Activity

- Activity was distributed across HEIs for the period 1998-2006. In 2006, there appeared to be a rapid increase in activity for a number of HEIs.
- TCD and UCC consistently reported the highest absolute numbers of research-active staff and appear to have consistently grown this, year on year 1998-2006. The staff from these HEIs represented circa 33% and 25% of the national cohort respectively in 2006.

[29] Agency-funded clinical research in the hospital sector was reported under HERD

[30] Data unavailable for this mFOS 1999/2004 for PhDs and Masters but this was the trend 2005-2008. See Annex A8, Table 4 & 5.

5.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 1,028 (2% of national total)[31]
- Students (# enrolled in system in 2006): 4,742 (4.0 % of national total)

Undergraduate graduates (2006): 714 (4.5 % of national total)[32]

The enrolment of undergraduate students in Clinical Medicine over this period was subject to Government guidelines. The pattern for other mFOS was overall growth in numbers over the period.

5.4 Outputs and Outcomes

5.4.1 Results from the Forfás/HEA Bibliometric Study[33] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	740	1,007	1,309	+30%
Group Average Papers	6,897	8,187	9,404	+15%
Ireland / Group Average	0.11	0.12	0.14	+13%
Ireland rank within Group	15	14	14	stable
Ireland share of world (%)	0.37	0.44	0.52	+18%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.01 Number of Clinical Medicine Papers

The rate at which Clinical Medicine outputs from Ireland are increasing (30%) is only exceeded (from our comparator group for this study[34]) by China, South Korea, India, the Czech Republic and Brazil. This is an impressive increase in comparison with increases in Northern Ireland (8%), Scotland (5%) and the UK as a whole (10%). Ireland's ranking within the comparator group, in terms of volume of published clinical research, has moved up one position since 1998, having overtaken New Zealand. Ireland's share of world papers is small set against the other nations, but there is good growth against a low baseline, especially in the period 2003- 2007.

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[31] No data available for this mFOS for the IoTs.

[32] No data available for this mFOS for the IoTs.

[33] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[34] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

5.4.2 Results from the Forfás/HEA Bibliometric Study[35] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.97	1.14	1.36	+19%
Group average citation impact	1.11	1.14	1.24	+9%
Ireland / Group average	0.87	1.00	1.09	+9%
Ireland rank within Group	13	12	9	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.01 Citation Impact of Clinical Medicine Papers

Clinical Medicine research published by Irish authors in 2007 has been cited 19% more frequently than papers published in the previous five years. This rate of increase is well ahead of the average increase achieved by the comparator nations. Ireland is ranked 9th amongst the comparator group utilised for this study –almost on a par with the USA and Australia, and ahead of the UK (including Northern Ireland) and New Zealand. Combined with the 30% increase in research volume over the same period, this suggests that Clinical Medicine research in Ireland is performing well.

5.4.3 Masters and PhD Output[36]

- Masters Graduates (2006): 54 (12% of national total)
- PhD Graduates (1998/9): 62 (12.1% of national total)
- PhD Graduates (2006): 95 (10.3% of national total)

5.5. Other Relevant Information

Physical and supporting infrastructure

The requirement for appropriate resources has been recognised and steps have been undertaken to redress this. The 2007 HEA/Forfás report - 'Research Infrastructure in Ireland – Building for Tomorrow'[37] – noted that a number of clinical research facilities were in various stages of development. There has been the creation of a network of clinical research facilities across the island, funded by the HRB, HSE and the Wellcome Trust.

Furthermore, the lack of PhD clinician researchers in Ireland was highlighted in the aforementioned 2007 HEA/Forfás report and this deficiency in the Irish system is currently being addressed through targeted Clinician-Scientist PhD training programmes supported by Molecular Medicine Ireland (MMI) and the HRB, and through the joint HRB/HSE NSAFP.

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[35] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[36] No data available for this mFOS for the IoTs.

[37] HEA/Forfas report - 'Research Infrastructure in Ireland – Building for Tomorrow', 2007

Other investment in supporting research infrastructure to facilitate researchers nationally and also to facilitate participation in pan-European research and in pan-European infrastructure ESFRI projects include the establishment of MMI (a consortium of HEIs), HRB support for the establishment of the Irish Clinical Research Infrastructure Network and the All-Ireland Cooperative Oncology Research Group.

Strategic developments since 2006

Since 2006, this area has been consistently highlighted as a strategic priority nationally. A number of reports emerged in the period 2006 to 2009 from the private sector and the Advisory Science Council recommending ways to enhance health and medical research in Ireland. The Health Research Action Plan[38] was published in June 2009 and amongst its objectives is the implementation of a strategy to exploit opportunities for stronger linkages between our health sector, the health sciences and related FDI and indigenous sectors such as medical devices and biopharma. By 2013, the Health Research Action Plan, with the support of all key stakeholders, aims to deliver a high performing health research system that will be characterised by a significantly enhanced infrastructure for health research including fully functional and networked clinical research facilities in our main academic teaching hospitals, a streamlined clinical trials and ethical approval system, with a focus on accelerating research advances into benefits for patients and the population.

Key Data

- Clinical Medicine 2006 research-related income was 4.1 % of national total
- Clinical Medicine 2006 research-active staff made up 4.6 % of national total
- Clinical Medicine 2006 research students represented 2.4% of the Masters and 5.1% of the PhD national total
- The large growth in Clinical Medicine activity stands out when compared to other fields but was from a very low starting base.
- Activity was distributed across HEIs for the period 1998-2006, but in 2006 there appeared to be a rapid increase in activity for a number of HEIs.
- The rate at which Clinical Medicine outputs from Ireland are increasing (30%) is only exceeded (from our comparator group) by China, South Korea, India, the Czech Republic and Brazil. Ireland's share of world papers is small set against these comparator nations, but there is good growth against this low baseline, especially in the period 2003 - 2007.
- Clinical Medicine research published by Irish authors in 2007 has been cited 19% more frequently than papers published in the previous five years. This rate of increase is well ahead of the average increase achieved by comparator nations. Combined with the 30% increase in research volume over the same period, this suggests that Clinical Medicine research in Ireland is performing well.
- Clinical Medicine 2006 research graduates represented 12% of the Masters and 10.3% of the PhD national total

[38] Health Research Action Plan 2009-13, prepared by the Health Research Group, June 2009.

6. Pre-Clinical & Health

6.1 Activity Fact File – 2006

Inputs

Total Research Income €82,439,670

- Government Sector (GOVERD) €3,516,000
- Higher Education Sector (HERD) €78,923,670
  - Direct Irish Exchequer Funding €34,946,000
  - Non-Irish Exchequer Funding
    - European Union (public) €1,219,000
    - Foreign Sources €2,491,000
    - Irish Private Funded €2,539,000

Research-active Staff

- HERD (FTEs) – 638
- GOVERD (FTEs) – 32

Students enrolled

- Masters Students (# in system) - 160
- PhD students (# in system) - 74

% National activity

- Pre-Clinical & Health 2006 research-related income was 11.4 % of national total
- Pre-Clinical & Health 2006 research-active staff made up 10.5% of national total
- Pre-Clinical & Health 2006 research students represented 5% of the Masters and 1.8% of the PhD national totals

6.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- The overall trend for the period was an increase in research activity across the indicators, particularly post 2004.
- There was slow growth in research-related income (€) up to 2002, but a dramatic increase followed in 2004. Growth 1998 - 2006 was 1,116%, which is very large relative to the median of 252% for the 19 mFOS. Growth from 2004 - 2006 was 23%, compared the 19% median for the 19 mFOS.
- The numbers of reported research-active staff (FTE) increased by a massive 1095%. This was the largest increase of the mFOS. The mFOS median was 163%. From 2004 to 2006 the increase for this field was 10%, in line with the 17% median increase for the 19mFOS.
- Absolute numbers of enrolled PhDs and Masters students were variable for the period.

Distribution of Activity

- Activity was distributed across HEIs for the period 1998-2006. From 2004, a number of HEIs reported a rapid increase in activity.
- From 2002, UCD grew research activity in this area at a significantly faster rate than other HEIs with a circa 500% increase in research-active staff for the period 1998-2006. In 2006, UCD research-active staff represented circa 36% of the national cohort.
- In 2006, RCSI represented circa 20% of the national cohort of research-active staff in this area.

6.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 5,496 (4.7% of national total)
- Students (# enrolled in system in 2006): 12,952(11% of national total)

Undergraduate graduates (2006): 1403 (8.9% of national total)

6.4 Outputs and Outcomes

6.4.1 Results from the Forfás/HEA Bibliometric Study[39] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	395	639	887	+39%
Group Average Papers	5,601	6,566	7,645	+16%
Ireland / Group Average	0.07	0.10	0.12	+19%
Ireland rank within Group	16	17	16	increase
Ireland share of world (%)	0.27	0.38	0.47	+24%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.02 Number of Pre-Clinical & Health Papers

Over the last five years, in terms of the volume of Pre-Clinical & Health publications, Ireland has moved one place up the rankings within the comparator group[40] utilised for this study (i.e. from 17th to 16th position) by overtaking Portugal. The growth in Irish research volume (39%) is impressive relative to the comparator group, exceeded only by China (79%), and matched by the Czech Republic (also 39%). The Czech Republic is an interesting comparator nation, as the overall volume of research there is similar to that produced by Ireland.

Ireland's share of world papers in Pre-Clinical & Health-related papers is small set against the comparator nations. While the nearest world comparator nations in terms of world share (New Zealand, Finland, Belgium and Denmark) are maintaining their percentage position, Ireland shows a consistent and steady growth in terms of the percentage share of total world outputs.

[39] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[40] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

6.4.2 Results from the Forfás/HEA Bibliometric Study[41] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.13	1.20	1.23	+2%
Group average citation impact	0.90	0.97	0.98	+0%
Ireland / Group average	1.26	1.23	1.26	+2%
Ireland rank within Group	5	3	2	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.02 Citation Impact of Pre-Clinical & Health Papers

Ireland is ranked 2nd out of 19 within the comparator group utilised for this study in terms of the rate at which Pre-Clinical & Health papers are being cited, beaten only by the USA. This is a particularly good result given that the volume of papers produced has increased by 39% over the last six years.

6.4.3 Masters and PhD output[42]

- Masters Graduates (2006):15 (3% of national total)
- PhD Graduates (1998/9): There is no comparable data available for this field.
- PhD Graduates (2006): 11 (1.2% of national total)

6.5 Other Relevant Information

Physical and supporting infrastructure

Since 1998 there has been the development of several new buildings and/or facilities accommodating researchers in this area (PRTLI Cycles 1 – 3) and a concerted investment in state-of-the-art equipment from a variety of sources (e.g. HEA, HRB, SFI, EU & others). The exchequer investment has also been leveraged to attract significant private investment in the area by means of (i) philanthropy, (ii) industry investment & (iii) EU framework funding.

The 2007 HEA/Forfás Research Infrastructures Report[43] notes that there continues to be a serious deficit in the provision of specialized capabilities – e.g. transgenic facilities, small/large animal facilities & others. More recent investment initiatives have sought, and will seek (PRTLI cycle 5) to address these deficits at a national level.

[41] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[42] No data available for this mFOS for the IoTs.

[43] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow 2007 Report

Strategic developments since 2006

Since 2006, this area has been consistently highlighted as a strategic priority nationally. Strategic reports by the HRB in particular have identified particular areas of for attention. The Health Research Action Plan[44] published in 2009, sets out strategic objectives which reflect the needs of this field of science.

With respect to this particular mFOS, the Health Research Action Plan aims to deliver by 2013 a high performing health research system that is characterised by:

- Enhanced partnerships between the health system, academia and enterprise for mutual benefit and to contribute to the 'smart economy' including strategic clusters of academics, healthcare professionals and industry in experimental and translational medicine.
- An expanded capacity to conduct high quality population science and health services research which can inform the delivery and organisation of health services
- Research partnerships to assist the health service delivery system in accelerating progress in key reform areas such as health/business intelligence, ICT and e-health, process improvement and resources management
- Impacting on this and other mFOS, a key priority is to develop a small number of centres of world significance in translational health research, each with strong foundations in both the health services and academia.

Key Data

- Pre-Clinical & Health 2006 research-related income was 11.4% of national total
- Pre-Clinical &Health 2006 research-active staff made up 10.5% of national total
- Pre-Clinical & Health 2006 research students represented 5% of the Masters and 1.8% of the PhD national totals
- The overall trend for the period was an increase in research activity across the indicators, particularly post 2004.
- Activity was distributed for the period 1998-2006. From 2004 a number of HEIs reported a rapid increase in activity.
- Growth in Irish research volume (39%) is impressive relative to the comparator group. Although Ireland's share of world papers in Pre-Clinical & Health is small, there has been consistent and steady growth in terms of world share, while nearest comparators have been maintaining their percentage position.
- Ireland was ranked 2nd within our comparator group in terms of the rate at which Pre-Clinical & Health papers were being cited in 2007, beaten only by the USA. Combined with the increase in volume over the last six years, Pre-Clinical & Health appears to be performing well.
- Pre-Clinical & Health 2006 research graduates represented 3.3% of the Masters and 1.2% of the PhD national total

[44] Health Research Action Plan 2009-13, prepared by the Health Research Group, June 2009

7. Biological Sciences

7.1 Activity Fact File – 2006

Inputs

Total Research Income €47,475,130

- Government Sector (GOVERD) €6,575,000
- Higher Education Sector (HERD) €40,900,130
  - Direct Irish Exchequer Funding €22,324,000
  - Non-Irish Exchequer funding
    - European Union (public) €2,433,000
    - Foreign Sources €103,000
    - Irish Private Funded €615,000

Research-active Staff

- HERD (FTEs) – 352
- GOVERD (FTEs) – 78

Students Enrolled

- Masters Students (# in system) - 278
- PhD students (# in system) - 498

% National Activity

- Biological Sciences 2006 research-related income was 6.6% of national total
- Biological Sciences 2006 research-active staff made up 6.8 % of national total
- Biological Sciences 2006 research students represented 8.8% of the Masters and 11.8% of the PhD national total[45]

7.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- There was a consistent trend of high research activity across the indicators for Biological Sciences 1998-2006.
- There was a modest 124% growth in research-related income from 1998 to 2006 relative to the 252% median increase for the 19 mFOS. However, Biological Sciences had the 2nd highest reported research-related income in 1998 so it started from a relatively high base. Research-related income fell by 20% from 2004 to 2006 compared to the median 19% increase for the 19 mFOS. This reflected a peak year in 2004 for many of the HEIs in this field.
- There was a 42% increase in the number of research-active staff (FTEs) from 1998 to 2006 relative to the median 163% increase for the 19 mFOS. Biological Sciences had the 2nd highest absolute number of research-active staff in 1998 so started from a higher base than the other mFOS. From 2004 - 2006 the number of research-active staff fell by 11% compared to the median 17% increase for the 19 mFOS.
- The numbers of Masters and PhD students remained fairly constant from 2005 onwards[46].

Distribution of Activity

- Activity was distributed across HEIs.
- A substantial increase in research-active staff was reported by UCD (circa 325%) and NUIG (circa 150%).
- In 2006, UCD, TCD and UCC each represented approximately 20% of the national research-active FTE cohort in this area.

[45] This is a relatively high compared to the average of 6.2% across all the mFOS

[46] No Masters or PhD data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08. See Annex A5, Table 4 & 5.

7.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): There was no comparable data available for this mFOS
- Students (# enrolled in system in 2006): 3539 (3% of national total)

Undergraduate graduates (2006): 378 (2.4% of national total)[47]

7.4 Outputs and Outcomes

Note: In order to disaggregate the considerable volume of output in Biological Sciences and to better align activity with industry NACE codes, the Bibliometric analysis was conducted in two subfields – Organismal Biology, and Molecular & Cellular Biology.

7.4.1 Results from the Forfás/HEA Bibliometric Study[48] (Volume)

Organismal Biology (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	505	776	1,108	+43%
Group Average Papers	6,339	7,658	8,575	+12%
Ireland / Group Average	0.08	0.10	0.13	+27%
Ireland rank within Group	17	18	18	stable
Ireland share of world (%)	0.30	0.40	0.53	+32%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.03 Number of Biological Sciences: Organismal Biology Papers

Ireland shows very strong growth in the number of papers published in organismal biology (43%), second only to China (65%) in the comparator group for this study[49]. Despite this, Ireland's ranking within the group remains 18th as the nearest competitor nations (Singapore and Portugal) also have high rates of increase. Ireland's share of world papers in organismal biology is small set against the comparator nations. However Ireland shows strong and significant growth in terms of world share over the last five years (32% increase). Australia, New Zealand and the Netherlands show modest increases in world share over the same period (3-6%) while other comparators show a decrease in world share.

[47] Data from the IoTs not available

[48] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[49] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

Molecular & Cellular Biology (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	361	513	724	+41%
Group Average Papers	4,140	4,860	5,307	+9%
Ireland / Group Average	0.09	0.11	0.14	+29%
Ireland rank within Group	16	18	17	Increase
Ireland share of world (%)	0.32	0.41	0.56	+35%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.04 Number of Biological Sciences: Molecular and Cellular Biology Papers

Ireland shows very strong growth in the number of papers published in molecular and cellular biology (41%), second only to China (65%) and Singapore (44%) in the comparator group. Ireland improved its ranking within the group by one position (to 17th) having overtaken New Zealand. Ireland's share of world papers in molecular and cellular biology is small set against the comparator nations. Ireland showed strong and significant growth in terms of world share over the last five years (35% increase). Australia, New Zealand and the Netherlands show modest increases in world share over the same period (3-6%) while other comparators show a decrease in world share. Ireland's growth in world share in molecular and cellular biology is particularly impressive given the intense activity in this field on the international stage.

7.4.2 Results from the Forfás/HEA Bibliometric Study[50] (Citation Impact)

Organismal Biology (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.92	1.06	1.32	+25%
Group average citation impact	0.94	1.04	1.13	+8%
Ireland / Group average	0.98	1.02	1.17	+15%
Ireland rank within Group	11	10	7	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.03 Citation Impact of Biological Sciences: Organismal Biology Papers

Citation rates for organismal biology papers from Ireland have improved by 25% over the last six years. Citation rates for Irish research are now better than rates achieved by research published by workers in the USA. Combined with the 43% increase in research volume over the same period this suggests that organismal biology research in Ireland is performing well.

[50] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

Molecular & Cellular Biology (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.68	1.16	1.07	-8%
Group average citation impact	0.89	0.95	0.98	+3%
Ireland / Group average	1.89	1.22	1.09	-11%
Ireland rank within Group	1	5	11	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.04 Citation Impact of Biological Sciences: Molecular and Cellular Biology Papers

Citation rates for molecular & cellular biology papers publicised by Irish authors in 1998 and 2001 were high (1.68 and 1.66 – well above world average) but more recently papers in this subject have had much less impact, meaning Ireland is now ranked 11th out of 19 amongst our comparator group, well behind both the USA and most of the European comparator nations. Volume of Irish papers in this subject has greatly increased by 43%, but these data suggest fewer papers might have achieved a greater impact.

The table indicates a general downward trend in citation rates, to the point where papers published in 2007 achieve a citation impact of only 1.07 and leaving Ireland with a ranking of 11th in the comparator group.

7.4.3 Masters and PhD Output

- Masters Graduates (2006): 24 (5 % of national total)
- PhD Graduates (1998/9): There is no comparable data available for this mFOS
- PhD Graduates (2006): 138 (15% of national total)

7.5 Other Relevant Information

Physical and supporting infrastructure

There has been significant and wide ranging exchequer investment in physical infrastructure supporting this area of research. Within this mFOS, capital facilities have largely been developed to support, *inter alia*, the broad biosciences (molecular and cellular biology), immunology, neuroscience, biomedical and cancer research.

Strategic developments since 2006

This field has been viewed as a key underpinning area within science and medicine. Acknowledging that there are strong areas of performance within this field, and that Ireland has an historical track record in this area, increasingly the policy emphasis is on harnessing the outputs so as to enhance economic and societal impact both directly and indirectly, in addition to enhancing education and research. National policy and funding programmes across all agencies are increasingly focusing on knowledge transfer and translation in their widest sense.

Key Data

- Biological Sciences 2006 research-related income was 6.6% of national total
- Biological Sciences 2006 research-active staff made up 6.8% of national total
- Biological Sciences 2006 research students represented 8.8% of the Masters and 11.8% of the PhD national total. This was a relatively high compared to the average of 6.2% across all 19 mFOS.
- There was a consistent trend of high research activity across the indicators for Biological Sciences 1998-2006.
- Activity was distributed across HEIs for the period 1998-2006.
- Ireland shows very strong growth in the number of papers published in organismal biology (43%) and molecular & cellular biology (41%). Although Ireland's share of world papers in these subjects is small set against comparator nations, Ireland shows strong and significant growth in terms of world share over the last five years for both organismal biology and molecular & cellular biology.
- Citation rates for Irish research in organismal biology are now better than rates achieved by research published by workers in the USA. Combined with the large increase in research volume over the same period this suggests that organismal biology research in Ireland is performing well.
- Citation rates for Irish papers in molecular & cellular biology were high in 1998 but have not been maintained. Ireland has dropped from 1st to 11th in the comparator group in terms of citation impact for 2007.
- Biological Sciences 2006 research graduates represented 5.3% of the Masters and 15% of the PhD national total

8. Biotechnology

8.1 Activity Fact File – 2006

Inputs

- Total Research Income €34,750,982
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €34,750,982
  - Direct Irish Exchequer Funding €20,151,000
  - Non-Irish Exchequer Funding
    - European Union (public) €2,520,000
    - Foreign Sources €202,937
    - Irish Private Funded €856,405

Research-active Staff

- HERD (FTEs) – 502
- GOVERD (FTEs) – 19

Students enrolled

- Masters Students (# in system) - 14
- PhD students (# in system) - 47

% National activity

- Biotechnology 2006 research-related income was 4.8% of national total
- Biotechnology 2006 research-active staff made up 8.2% of national total
- Biotechnology 2006 research students represented 0.4% of the Masters and 1.1% of the PhD national total)

8.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

There was no data collected prior to 2006 for Biotechnology, hence it is not possible to do a trend analysis

8.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): No data available
- Students (# enrolled in system in 2006): 643 (0.5% of national total)

Undergraduate graduates (2006): 154 (1.0% of national total)[51]

[51] No data available for this mFOS for the IoTs.

8.4 Outputs and Outcomes

8.4.1 Results from the Forfás/HEA Bibliometric Study[52] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	106	207	291	+41%
Group Average Papers	1,038	1,374	1,640	+19%
Ireland / Group Average	0.10	0.15	0.18	+18%
Ireland rank within Group	18	17	17	stable
Ireland share of world (%)	0.33	0.51	0.62	+23%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.05 Number of Biotechnology Papers

Ireland shows very strong growth in the number of papers published in biotechnology (41%), third only to China (77%) and New Zealand (43%) in the comparator group utilised for this study[53]. Ireland's share of world outputs has almost doubled, from 0.33% in 1998 to 0.62% in 2007. Biotechnology is one of Ireland's strongest subjects in terms of percentage share of total world output. Despite this Ireland remains at 17th position in terms of volume ranking within the comparator group for this study, ahead of New Zealand and Northern Ireland. If trajectories continue as at present, Irish outputs might be expected to exceed those of Czech Republic and Scotland within the next 5-10 years.

8.4.2 Results from the Forfás/HEA Bibliometric Study[54] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.47	1.19	0.81	-32%
Group average citation impact	1.04	1.12	1.20	+7%
Ireland / Group average	1.42	1.06	0.68	-36%
Ireland rank within Group	1	9	15	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.05 Citation Impact of Biotechnology Papers

Irish biotechnology papers produced in 1998 were well cited with a citation impact of 1.47. This placed Ireland ahead of all the comparator nations in the group utilised in this study. Subsequently citation rates dropped steadily, and papers published in 2007 achieved a citation impact of only 0.81 – well below world average. Ireland is now at the bottom of the rankings except in relation to the Asian nations which receive only low impact for their research.

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[52] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[53] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[54] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

8.4.3 Masters and PhD output[55]

- Masters Graduates (2006): 13 (3% of national total)
- PhD Graduates (1998/9): There is no data available for this field
- PhD Graduates (2006): 10 (1.1% of national total)

8.5 Other Relevant Information

Physical and supporting infrastructure

There is significant variation in the standard of infrastructure available to support this discipline ranging from new, state-of-the-art facilities (e.g. National Institute for Bioprocesssing Research and Training i.e. NIBRT- physically under construction in the UCD Business Park), the viral vector & GMP facilities at the National Centre for Bioengineering Science and REMEDI – physically based at NUIG), food processing facilities (by DAFF, EI and HEA), to other facilities which are, on occasions, not fit-for-purpose. The need for larger & better resourced GMP facilities, post incubation start up space and the exploitation of food processing facilities were highlighted in the 2007 HEA/Forfás Research Infrastructures Report[56].

Strategic developments since 2006

With the establishment of Science Foundation Ireland (SFI) in 2001/2, biotechnology, and its underpinning areas, were clearly set down as a national priority for funding and for enterprise, and economic, development. Biotechnology and the underpinning sciences are one of the three strategic areas of focus for SFI. In addition in the area of natural resources, biotechnology and the underpinning areas have become a focus. For example, it has been clearly signalled in 'Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland, 2006' (Marine Institute)[57] that leading edge research in marine biotechnology/biodiscovery is to be a priority with the aim that by 2020 Ireland will have leading capability in the utilisation of marine organisms and materials for the production of drugs, advanced biomaterials and nutraceuticals.

More recently, Innovation Ireland (Government of Ireland 2010)[58] has among its key recommendations the need to take advantage of convergence opportunities – biotechnology is a key convergence interface. In this regard Innovation Ireland highlights the need to establish an industry-led convergent technologies network to facilitate collaboration between companies, academics and medical practitioners across the formerly discrete sectors of pharma, bio, medtech, ICT and engineering.

[55] Data was not available for the IoTs for this mFOS

[56] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow 2007

[57] Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland, 2006

[58] Innovation Ireland – Report of the Innovation Taskforce, March 2010

Key Data

- Biotechnology 2006 research-related income was 4.8% of national total
- Biotechnology 2006 research-active staff made up 8.2 % of national total
- Biotechnology 2006 research students represented 0.4% of the Masters and 1.1% of the PhD national total
- There was no data collected prior to 2006 for Biotechnology, hence it is not possible to do a trend analysis
- Ireland shows very strong growth in the number of papers published in biotechnology (41%) and Ireland's share of world outputs has almost doubled. Biotechnology is one of Ireland's strongest subjects in terms of percentage share of total world output.
- Irish papers in biotechnology produced in 1998 were well cited. Subsequently citation rates dropped alarmingly, and papers published in 2007 achieved a citation impact of only 0.81 – well below world average. Ireland is now at the bottom of the citation impact rankings.
- Biotechnology 2006 research graduates represented 2.9% of the Masters and 1.1% of the PhD national total

9. Agricultural Biotechnology & Engineering (including Food)

9.1 Activity Fact File – 2006

Inputs

- Total Research Income €8,310,000
- Government Sector(GOVERD) €0[59]
- Higher Education Sector (HERD) €8,310,000
  - Direct Irish Exchequer Funding €5,873,000
  - Non-Irish Exchequer Funding
    - European Union (public) €569,031
    - Foreign Sources €25,481
    - Irish Private Funded €107,734

Research-active Staff

- HERD (FTEs) – 46
- GOVERD (FTEs) – 0[60]

Students enrolled

- Masters Students (# in system) - 19
- PhD students (# in system) - 19

% National activity

- Agricultural Biotechnology & Engineering (Including Food) 2006 research-related income was 1.2% of national total
- Agricultural Biotechnology & Engineering (Including Food) 2006 research-active staff made up 0.7% of national total
- Agricultural Biotechnology & Engineering (including Food) 2006 research students represented 0.6% of the Masters and 0.4% of the PhD national total

9.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- In general there was an increase across research activity indicators for the period 1998-2006.
- Growth in research-related income from 1998 to 2006 was 405% with most of the increase occurring 2002-2004. The median for the 19 mFOS was 252%. Research-related income grew by 33% from 2004 to 2006; the median for this time period was 19% for the 19 mFOS.
- The number of of research-active staff (FTEs) increased 181% from 1998 to 2006 with most of the increase occurring 2002-2004. The 19 mFOS median was 163%. From 2004 to 2006 there was a 9% decrease in the number of research-active staff from a peak year in 2004. The median for the 19 mFOS was 17%.
- There was a variable number of Masters students and a decrease in the PhD students for the period 1998-2006.

Distribution of Activity

- Activity was distributed across a number of HEIs.
- UCC reported much larger absolute numbers of research-active staff relative to the other HEIs and accounted for circa 31% of the national cohort in 2006.
- Starting from a low base DCU reported a very large increase (circa 2,000%) in research-active staff over the period.

[59] Research-related income associated with Food has been captured under the 'Agricultural Sciences' mFOS as there was overlap in 'Food Science & Technology' between these categories. See Annex A8 for a description of the mFOS mapping against the Thomson Reuters journal categories.

[60] Research-active staff associated with Food have been captured under the 'Agricultural Sciences' mFOS as there was overlap in 'Food Science & Technology' between these categories. See Annex A8 for a description of the mFOS mapping against the Thomson Reuters journal categories.

9.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 603 (1.2% of national total)
- Students (# enrolled in system in 2006): 1257 (1.1% of national total)

Undergraduate graduates (2006): 118 (0.8% of national total)[61]

9.4 Outputs and Outcomes

9.4.1 Results from the Forfás/HEA Bibliometric Study[62] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	136	177	200	+13%
Group Average Papers	275	361	442	+22%
Ireland / Group Average	0.49	0.49	0.45	-8%
Ireland rank within Group	9	11	12	decrease
Ireland share of world (%)	1.41	1.46	1.39	-5%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.06 Number of Agricultural Biotechnology & Engineering (including Food & Beverage Science) Papers

Ireland had increased its outputs in Agricultural Biotechnology & Engineering (including Food) by 13% in 2007, but this increase was less than the comparator group[63] average and Ireland's overall share of world outputs dropped by 5%. This result may be aberrant however, as in 2007 a comparatively low number of papers were produced, following a particularly high number on 2006. Agricultural Biotechnology & Engineering (including Food) is a field where Ireland usually holds a relatively high percentage share of world outputs compared with other subject areas (around 1.5% of world share each year). The total number of papers produced overall worldwide is quite low however, and Ireland – together with other comparator countries - shows significant year to year variation. Taking the last six years as a whole, Ireland is in the middle of the comparator group utilised for this study, in terms of volume output.

[61] Does not include data from the IoTs

[62] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[63] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

9.4.2 Results from the Forfás/HEA Bibliometric Study[64] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.51	1.18	1.42	+20%
Group average citation impact	1.21	1.16	1.14	-2%
Ireland / Group average	1.25	1.02	1.25	+23%
Ireland rank within Group	6	11	5	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.06 Citation Impact of Agricultural Biotechnology & Engineering (including Food & Beverage Science) Papers

Citation rates for Agricultural Biotechnology & Engineering (including Food) papers produced by Irish authors have improved by 20% over the last six years; over the same period, citation rates for comparator nations utilised for this study as a whole have fallen by 2%. For research published in 2007, Ireland was ranked 5th within the comparator group, ahead of the USA and the UK, and also ahead of most of the other European comparator nations.

9.4.3 Masters and PhD output[65]

- Masters Graduates (2006): 11 (2% of national total)
- PhD Graduates (1998/9): 12 (2.3% of national total)
- PhD Graduates (2006): 12 (1.3% of national total)

9.5 Other Relevant Information

Physical and supporting infrastructure

Teagasc has invested significant capital in the development of physical infrastructure – one example being the Teagasc Biotechnology Food Centre at Moorepark. Within higher education to meet requirements, investment has continued to be expanded & built upon post early cycles of PRTLI cycles (up to 2006) in particular by DAFF, EI and HEA. In 2007, a DAFF award for the purchase of strategic equipment enabled close interaction with industry in the development of new processes and products as well as allowing researchers from other research teams to access strategic equipment to fully develop their areas of research.

[64] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[65] Does not include data from the IoTs

Strategic developments since 2006

The report 'Building Ireland's Smart Economy, 2008'[66] emphasises the need to exploit the potential of an export-led, natural resources based Agri-food sector. Investment in the food processing sector, supporting innovation, marketing and research and development are highlighted as areas of focus. In addition, the DAFF 2020 Strategy[67] has analysed the outlook for the Agri-food industry and developed appropriate strategies with the aim of delivering sustainable growth to build on the successful Agri-Vision 2015 Action Plan. The Strategy recognises the importance of innovation in supporting the sector.

Furthermore, envisaged impacts 2007-2013 in 'Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland, 2006'[68] include new interdisciplinary expertise and competencies developed in a wide range of areas including functional foods and a knowledge base that will support food companies to produce novel and innovative marine based functional foods.

Key Data

- Agricultural Biotechnology and Engineering (Including Food) 2006 research-related income was 1.2% of national total
- Agricultural Biotechnology and Engineering (Including Food) 2006 research-active staff made up 0.7% of national total
- Agricultural Biotechnology and Engineering (Including Food) 2006 research students represented 0.6% of the Masters and 0.4% of the PhD national total
- In general there was an increase across research activity indicators for the period 1998-2006.
- Activity was distributed across a number of HEIs.
- Agricultural Biotechnology & Engineering (including Food) is a field where Ireland holds a relatively high percentage share of world outputs compared with other mFOS (around 1.5% of world share each year). The total number of papers produced overall worldwide is quite low however, and Ireland – together with other comparator countries - shows significant year to year variation. Taking the last six years as a whole, Ireland is in the middle of the comparator group in terms of volume output.
- The upward trend in recent years means that by citation impact, Ireland is now ranked 5th within our comparator group, ahead of the USA and the UK, and also ahead of most of the other European comparator nations. Over the same period, citation rates for comparator nations as a whole have fallen.
- Agricultural Biotechnology and Engineering (Including Food) 2006 research graduates represented 2.4% of the Masters and 1.3% of the PhD national total

[66] Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal, 2008

[67] http://www.agriculture.gov.ie/media/migration/agri-foodindustry/agri-foodindustrypublications/2020Foodharvest190710.pdf

[68] Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland, 2006

10. Agricultural Sciences

10.1 Activity Fact File – 2006

Inputs

- Total Income €88,070,533
- Government Sector (GOVERD) €72,219,000[69]
- Higher Education Sector (HERD) €15,851,533
  - Direct Irish Exchequer Funding €6,497,000
  - *Non-Irish Exchequer Funding*
    - European Union (public) €609,000
    - Foreign Sources €40,000
    - Irish Private Funded €0

Research-active Staff

- HERD (FTEs) – 141
- GOVERD (FTEs) – 670[70]

Students enrolled

- Masters Students (# in system) -73
- PhD students (# in system) – 83

% National activity

- Agricultural Sciences 2006 research-related income was 12.2 % of national total
- Agricultural Sciences 2006 research-active staff made up 12.7% of national total
- Agricultural Sciences 2006 research students represented 2.3% of the Masters and 2% of the PhD national total

10.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Research activity reported over the period 1998-2006 was variable year on year due to changes in reclassification.
- Activity in this area was variable for the period 1998-2006 but was likely due to reclassification from 2000 onwards. Specifically, it was problematic to compare levels of activity across the years due to major changes in the numbers of HEIs reporting activity in this area.
- Keeping the above caveat in mind, growth in research-related income from 1998 to 2006 was 6%. The median for the 19 mFOS was 252%. Research-related income grew by 38% from 2004 to 2006; the median for this time period was 19% for the 19 mFOS.
- Keeping the above caveat in mind, the number of research-active staff increased by 41% from 2004 to 2006 while the median for the 19 mFOS was 17%. However, overall for the period 1998-2006, there was a 34% decrease. The 19 mFOS median for the period was an increase of 163%.
- The numbers of Masters and PhD students have remained fairly constant.

Distribution of Activity

- In earlier years the activity was distributed across a number of HEIs, however from 2000 it was concentrated in Teagasc and UCD.
- In 2006, the majority of national activity was located in Teagasc[71].
- For the period 1998 to 2006 UCD grew their number of research-active staff by circa 200%.

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[69] Research-related income associated with Food has also been captured here as there was overlap in 'Food Science & Technology' between this category and the 'Agricultural Biotechnology & Engineering (including Food)' category. See Annex A8 for a description of the mFOS mapping against the Thomson Reuters journal categories.

[70] Research-active staff associated with Food, have also been captured here as there was overlap in 'Food Science & Technology' between this category and the 'Agricultural Biotechnology & Engineering (including Food)' category. See Annex A8 for a description of the mFOS mapping against the Thomson Reuters journal categories.

[71] When revised OECD Foes are used and GOVERD data is included in analysis, circa 70% of the national research-active staff are located in Teagasc.

10.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 1,427 (2.8% of national total)
- Students (# enrolled in system in 2006): 1834 (1.6% of national total)

Undergraduate graduates (2006): 237 (1.5% of national total)[72]

10.4 Outputs and Outcomes

10.4.1 Results from the Forfás/HEA Bibliometric Study[73] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	203	235	314	+33%
Group Average Papers	1,281	1,463	1,619	+11%
Ireland / Group Average	0.16	0.16	0.19	+20%
Ireland rank within Group	15	17	17	stable
Ireland share of world (%)	0.57	0.59	0.70	+19%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.07 Number of Agricultural Sciences Papers

Ireland shows strong growth in the number of papers published in Agricultural Sciences (33%) which is 11% greater than the average for comparator countries utilised for this study[74]. Ireland ranks 17th in terms of research volume amongst our comparator group, a drop from 15th in 1998. This drop reflects very strong growth by South Korea and Portugal, rather than any particular failing on the part of Irish researchers. Ireland's share of the world total outputs has risen from 0.57% in 1998 to 0.70% by 2007 and now represents the 2nd highest world share for Ireland compared to the other mFOS in this report.

[72] Data not available for this mFOS for the IoTs

[73] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[74] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

10.4.2 Results from the Forfás/HEA Bibliometric Study[75] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.02	1.27	1.92	+51%
Group average citation impact	1.18	1.22	1.51	+24%
Ireland / Group average	0.87	1.04	1.27	+22%
Ireland rank within Group	15	9	6	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.07 Citation Impact of Agricultural Sciences Papers

Irish Agricultural Science papers published in 1998, 1999 and 2002 achieved modest citation rates (just above world average), but in more recent years citation rates have improved significantly and Ireland now ranks 6th out of the comparator nations used for this study. In 2007 Irish research achieved a citation impact of 1.92, well above world average. The overall trend for Irish research in this area is positive.

10.4.3 Masters and PhD output

- Masters Graduates (2006): 25 (6% of national total)
- PhD Graduates (1998/9): 12 (2.3% of national total)
- PhD Graduates (2006): 12 (1.3% of national total)

10.5 Other Relevant Information

Physical and supporting infrastructure

In general capital investment in the Agricultural Sciences has been relatively limited over this time period. However, targeted investment was secured to fund the construction of a purpose built veterinary hospital on the UCD campus which encompasses some research capacity. The Neutraceutical Research Facility has recently been completed in Teagasc Food Research Centre in Ashtown.

[75] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

Strategic developments since 2006

A range of measures are included in 'Building Ireland's Smart Economy, 2008'[76] which aim to build on the strengths in the Agriculture, Fisheries and Food Sectors and exploit the potential of an export-led, natural resources based Agri-food sector. They include income support and capital investment on farms, environment and animal welfare enhancing schemes, further investment in the food processing sector, supporting innovation, marketing and research and development throughout the sectors and continued support for sustainable forestry. These directions reflect the outcomes of the 'Agrivision 2015 Action Plan – Agri-food, fisheries and forestry sectors, *2004*'[77]. The Department of Agriculture, Fisheries and Food (DAFF) 2020 Strategy[78] has taken account of these reports and analyses the prospects for growth of the Irish Agri-food sector and in doing so recognises the need for innovation within the sector. In the period under review and since 2006, significant awards have been made to various research institutions by the DAFF under the Food Institutional Research Measure (FIRM) and Stimulus (for farm level research) to underpin the scientific and knowledge base for further development of the agri-food sector. Teagasc is enhancing its scientific capacity to enable it to foster science based innovation on farms and in firms.

Key Data

- Agricultural Sciences 2006 research-related income was 12.2% of national total
- Agricultural Sciences 2006 research-active staff made up 12.7% of national total
- Agricultural Sciences 2006 research students represented 2.3% of the Masters and 2% of the PhD national totals
- Research activity reported over the period 1998-2006 was variable year on year due to changes in reclassification.
- In earlier years the activity was distributed across a number of HEIs, however from 2000 it has been concentrated in UCD and Teagasc.
- Ireland shows strong growth in the number of papers published in Agricultural Sciences (33%) which is 11% greater than the average for comparator countries utilised for this study. Share of the world total outputs has risen from 0.57% in 1998 to 0.70% by 2007 and this mFoS represents the 2nd highest world share for Ireland compared to the other 19 mFOS in this report.
- In 2007, Ireland achieved a citation impact of 1.92, well above world average in 2007 and now ranks 6th out of our comparator nations by citation impact. The overall trend for Irish research in this area is positive.
- Agricultural Sciences 2006 research graduates represented 5.6% of the Masters and 2.5% of the PhD national total

[76] Building Ireland's Smart Economy – A Framework for Sustainable Economic Growth 2008

[77] Agrivision 2015 Action Plan – Agri-food, fisheries and forestry sectors' 2004

[78] http://www.agriculture.gov.ie/media/migration/agri-foodindustry/agri-foodindustrypublications/2020Foodharvest190710.pdf

11. Earth & Environment Sciences

11.1 Activity Fact File – 2006

Inputs

- Total Income €41,356,749
- Government Sector (GOVERD) €19,201,000
- Higher Education Sector (HERD) €22,155,749
  - Direct Irish Exchequer Funding €11,624,250
  - Non-Irish Exchequer Funding
    - European Union (public) €2,368,650
    - Foreign Sources €473,000
    - Irish Private Funded €1,240,000

Research-active Staff

- HERD (FTEs) – 147
- GOVERD (FTEs) – 128

Students enrolled

- Masters Students (# in system) - 29
- PhD students (# in system) - 89

% National activity

- Earth & Environmental Sciences 2006 research-related income was 5.7% of national total
- Earth & Environmental Sciences 2006 research-active staff made up 4.3% of national total
- Earth & Environmental Sciences 2006 research students represented .9% of the Masters and 2.1% of the PhD national total

11.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- There was a consistent trend of an increase in research activity indicators for the period 1998-2006
- There was slow growth in the reported research-related income (€) up to 2002 and rapid increases thereafter. Growth 1998-2006 was 493%, relative to the 19 mFOS median of 252%. Research-related income 2004 - 2006 grew 34%; the median for this period was 19% for the 19 mFOS.
- A large 317% increase in research-active staff (FTEs) across the period 1998 - 2006. This increase was substantial relative to the 163% median for the 19 mFOS. A rapid increase in research-active FTEs 2004 - 2006 with a large 77% increase. The 19 mFOS median was 17% for this period.
- There was a gradual increase in numbers of Masters students from 2005 onwards[79]. PhD numbers in this field remained fairly constant from 2005 onwards[80].

Distribution of Activity

- A low level of research activity was found across a number of institutions. In the main for those institutions, activity in this mFOS only manifest in recent years; however this may be a FOS categorization artifact.
- The largest increase in research-active staff was reported by UL who, from a very low starting base, represented circa 30% of the national cohort in 2006

[79] No Masters data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08.

[80] No PhD data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08.

11.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): No comparable data for this mFOS
- Students (# enrolled in system in 2006): 817 (0.7% of national total)

Undergraduate graduates (2006): 159 (1.0% of national total)[81]

11.4 Outputs and Outcomes

11.4.1 Results from the Forfás/HEA Bibliometric Study[82] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	179	292	357	+22%
Group Average Papers	2,254	3,000	3,534	+18%
Ireland / Group Average	0.08	0.10	0.10	+4%
Ireland rank within Group	17	18	17	increase
Ireland share of world (%)	0.30	0.37	0.39	+7%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.08 Number of Earth & Environment Sciences Papers

Ireland shows strong growth in the number of papers published in Earth and Environment Science (22% increase, slightly greater than the comparator group[83] average). Ireland has improved its ranking within the comparator group by one place over the last five years, now producing a higher percentage of world output than Singapore. Ireland shows a small but steady rise in its share of overall world output, however in 2007 Ireland's share of total world output was 0.39%, which was low in comparison with other disciplines. In terms of percentage share of world Earth and Environment Science papers, Ireland (0.39%) lags a long way behind its nearest comparators – New Zealand (1.02%), Finland (1.14%), Belgium (1.31%) and Denmark (1.38%).

[81] Data for this mFOS not available for the IoTs

[82] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[83] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

11.4.2 Results from the Forfás/HEA Bibliometric Study[84] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.88	1.07	1.13	+6%
Group average citation impact	1.00	1.11	1.15	+4%
Ireland / Group average	0.88	0.96	0.98	+1%
Ireland rank within Group	14	12	11	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.08 Citation Impact of Earth & Environment Sciences Papers

The impact of Irish Earth & Environment research has improved in recent years but prior to 2005, average citation rates were less than world average. Ireland ranks only 11th within the comparator group utilised for this study behind the USA and most of the European countries, but still ahead of the Asian comparator countries and Brazil. The impact of Irish earth and environment research is gradually improving.

11.4.3 Masters and PhD output[85]

- Masters Graduates (2006): 5 (1% of national total)
- PhD Graduates (1998/9): There is no comparable data available.
- PhD Graduates (2006): 15 (1.6% national total)

11.5 Other Relevant Information

Physical and supporting infrastructure

Specialist facilities and infrastructure in the form of Mace Head Station [NUIG] along with two state-of-the-art specialist/multipurpose marine research vessels, RV Celtic Voyager (1998) and RV Celtic Explorer (2003) have also been supported in recent years, by the HEA and EPA, and the Marine Institute respectively. Investment in such research infrastructure has, and will into the future, facilitate participation in pan-European research infrastructure ESFRI projects.

[84] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[85] This does not include data from the IoTs

Strategic developments since 2006

'Building Ireland's Smart Economy, 2008'[86] had a particular focus on opportunities arising from research in the renewable energy and environmental technologies areas, including the development and commercialisation of ocean energy[87]. The prioritisation of energy research has been clearly signalled by it being added to Science Foundation Ireland's portfolio as a third pillar.

The 'Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, 2009'[88] included recommendations for the creation of world-class research centres where research expertise would be pooled and/or the development of formal (national, all-island and international) research alliances would be advanced to develop scale and critical mass in energy and environmental research. The establishment of Ireland as a test bed for innovative environmental applications is outlined as a priority in particular in areas such as wind and marine renewable energies where Ireland has a clear competitive advantage. A R&D research strategy for the wider environmental goods and services sector which includes a strong focus on waste and water is also highlighted as being required. This aims to build on the work of the Department of Communications, Energy and Natural Resources (DCENR) and Environmental Protection Agency (EPA) research programmes (the EPA STRIVE research programme includes water and waste as priority thematic areas).

Key Data

- Earth & Environmental Sciences 2006 research-related income was 5.7% of national total
- Earth & Environmental Sciences 2006 research-active staff made up 4.3% of national total
- Earth & Environmental Sciences 2006 research students represented .9% of the Masters and 2.1% of the PhD national total
- There was a consistent trend of an increase in research activity indicators for Earth & Environmental Sciences for the period 1998-2006
- A low level of research activity was found across a number of institutions. In the main for those institutions, activity in this mFOS only manifest in recent years; however this may be a FOS categorization artifact.
- Ireland shows strong growth in the number of papers published in Earth & Environment science but still lags a long way behind the nearest comparators in regards % share of world outputs.
- The impact of Irish Earth & Environment research has improved in recent years but prior to 2005 average citation rates were less than world average.
- Earth & Environmental Sciences 2006 research graduates represented 1.1% of the Masters and 1.6% of the PhD national total

[86] Building Ireland's Smart Economy – A Framework for Sustainable Economic Growth, 2008

[87] Much of this research is also going on in fields of Engineering

[88] Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, November 2009

12. Mathematics

12.1 Activity Fact File – 2006

Inputs

- Total Income €18,922,820
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €18,922,820
  - Direct Irish Exchequer Funding €8,755,118
  - Non-Irish Exchequer Funding
    - European Union (public) €349,121
    - Foreign Sources €63,088
    - Irish Private Funded €113,334

Research-active Staff

- HERD (FTEs) – 171
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 38
- PhD students (# in system) - 97

% National activity

- Mathematics 2006 research-related income was 2.6% of national total
- Mathematics 2006 research-active staff made up 2.7% of national total
- Mathematics 2006 research students represented 1.2% of the Masters and 2.3% of the PhD national total

12.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Data on Mathematics was collected under the combined heading of Mathematics, Computer & Information Sciences prior to 2006.
- See Computer & Information Sciences Fact Sheet for combined trend analysis.

12.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): No separate Mathematics data available.
- Students (# enrolled in system in 2006): 752 (0.6% of national total)

Undergraduate graduates (2006): 168 (1.1% of national total)

12.4 Outputs and Outcomes

12.4.1 Results from the Forfás/HEA Bibliometric Study[89] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	146	195	269	+38%
Group Average Papers	1,243	1,613	1,892	+17%
Ireland / Group Average	0.12	0.12	0.14	+18%
Ireland rank within Group	18	18	17	increase
Ireland share of world (%)	0.39	0.41	0.51	+22%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.09 Number of Mathematics Papers

The number of mathematics papers produced in Ireland has increased by 38% in 2007 compared with the average of the previous five years, significantly (18%) better than the increase achieved on average by the comparator group[90] utilised for this study. Ireland's share of world total output has risen to 0.51%, comparable to other Irish research areas. Ireland's share of the total world mathematics output is rapidly growing. A lot of other world countries have seen a decline in world share in 2007 compared with the previous five years. The Czech Republic – in many ways a country with a comparable research base – shows 13% growth in world share, while China has increased its world share by 36%.

12.4.2 Results from the Forfás/HEA Bibliometric Study[91] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.79	0.93	1.32	+42%
Group average citation impact	0.98	1.09	1.13	+3%
Ireland / Group average	0.81	0.85	1.17	+37%
Ireland rank within Group	16	12	6	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.09 Citation Impact of Mathematics Papers

The impact of Irish mathematics research has improved in recent years but prior to 2005 average citation rates were less than the world average citation impact (average = 1.0). Ireland is improving its ranking in terms of citation of mathematics papers published in 2005 and 2007. As a result of citations of papers published particularly in 2007 Ireland has moved up the rankings within the comparator group used for this study to 6th position, ahead of the USA and many European comparator nations and of Australia and New Zealand.

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[89] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[90] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[91] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

12.4.3 Masters and PhD output[92]

- Masters Graduates (2006): 9 (2% of national total)
- PhD Graduates (1998/9): There is no comparable data
- PhD Graduates (2006): 19 (2.1% of national total)

12.5 Other Relevant Information

Physical and underpinning Infrastructure

A number of infrastructural investments have recently been made – notably the Hamilton Institute in NUIM. In addition, the importance of Mathematical Sciences to many research areas has become more evident in recent years (e.g. post 2006) – consequently, infrastructural facilities for mathematics are now beginning to be put in place (e.g. Boole Centre for Research in Informatics), while others are being planned in the context of multi-disciplinary initiatives (e.g. financial services).

Strategic developments since 2006

The 'Innovation Ireland, March 2010'[93] report acknowledged the need for Ireland to raise its level of mathematical achievement, this need having been indicated by the National Competitiveness Council and key enterprise and professional bodies (including ICT Ireland and Engineers Ireland) over recent years. The report states that Mathematics is important because it underpins many other disciplines such as science, technology, business and finance and makes particular recommendations with respect to promoting the uptake of higher level maths. Recommendations to support the business and finance sectors reflect the recommendations of the 'Expert Group on Future Skills Needs Report on the International Financial Services Industry, 2008'[94]. SFI has put in place a number of targeted initiatives on mathematics and there are plans across the system to increase funding of research in the area of financial mathematics over the coming years.

Key Data

- Mathematics 2006 research-related income was 2.6 % of national total
- Mathematics 2006 research-active staff made up 2.7 % of national total
- Mathematics 2006 research students represented 1.2% of the Masters and 2.3% of the PhD national total
- The number of mathematics papers produced in Ireland has increased by 38% in 2007 compared with the average of the previous five years, significantly (18%) better than the increase achieved on average by the comparator group.
- The impact of Irish mathematics research has improved in recent years but prior to 2005 average citation rates were less than the world average citation impact.
- Mathematics 2006 research graduates represented 2% of the Masters and 2.1% of the PhD national total

[92] This does not include data from the IoTs

[93] Innovation Ireland – Report of the Innovation Taskforce, March 2010

[94] Expert Group on Future Skills Needs Report on the International Financial Services Industry, 2008

13. Physics & Materials Sciences

13.1 Activity Fact File – 2006

Inputs

- Total Income €36,646,840
- Government Sector (GOVERD) €2,986,000
- Higher Education Sector (HERD) €33,660,840
  - Direct Irish Exchequer Funding €19,142,000
  - Non-Irish Exchequer Funding
    - European Union (public) €5,381,880
    - Foreign Sources €364,560
    - Irish Private Funded €285,272

Research-active Staff

- HERD (FTEs) – 332
- GOVERD (FTEs) – 64[95]

Students enrolled

- Masters Students (# in system) - 123
- PhD students (# in system) - 176

% National activity

- Physics & Materials Sciences 2006 research-related income was 5.1% of national total
- Physics & Materials Sciences s 2006 research-active staff made up 6.2 % of national total
- Physics & Materials Sciences 2006 research students represented 3.9% of the Masters and 4.2% of the PhD national total

13.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- There was a steady increase in most research activity indicators for this field for the period 1998-2006.
- There was a steady growth in reported research-related income with a 275% increase 1998-2006 relative to the 19mFOS median of 252%. 2004 was a peak year with several HEIs reporting significant funding wins (see below). This gives a -14% drop 2004-2006. The median increase for this latter time period was 19% for the 19mFOS.
- There was a steady increase (163%) in the number of reported research-active staff (FTEs) from 1998 to 2006. The median increase for this period was 163%. For the period 2004-2006 there was a 15% increase, the 19 mFOS median being 17%.
- There appears to be a steady increase in PhD students while the Masters students have remained relatively constant during this time period[96]

Distribution of Activity

- Activity was spread across a number of HEIs however there appears to be substantial growth in this area for several HEIs.
- TCD has consistently reported the highest absolute numbers of research-active staff and appears to have consistently grown year on year over the period. In 2006 TCD research-active staff accounted for approximately 1/3 of the national total in this field.
- WIT reported very large increases in research-active staff (circa 550%) for this area. WIT research-related personnel make up a significant portion of the national total research-active staff (circa 20%) in this field.
- NUIG substantially grew their research-active staff (860%) during this period.

[95] The majority of research-active personnel reported under GOVERD are in the DIAS

[96] No IoT data for 1998/9 and limited data from a number of the other HEIs pre-2005

13.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): There is no comparable data available
- Students (# enrolled in system in 2006): 1526 (1.3% of national total)

Undergraduate graduates (2006): 137 (0.9% of national total)[97]

13.4 Outputs and Outcomes

13.4.1 Results from the Forfás/HEA Bibliometric Study[98] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	486	800	1,000	+25%
Group Average Papers	5,019	6,920	7,930	+15%
Ireland / Group Average	0.10	0.12	0.13	+9%
Ireland rank within Group	17	17	17	stable
Ireland share of world (%)	0.30	0.39	0.45	+16%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.10 Number of Physics & Materials Sciences Papers

Ireland shows strong growth in the number of papers published in physics and material sciences (25%) which is 9% greater than the average for comparator countries utilised in this study[99]. This rate of growth in the six years to 2007 is very strong, exceeded only by China (41%) and India (22%). By contrast three quarters of the countries in the comparator group suffered a net loss in their percentage of world share during the same period. Ireland's share of the world total outputs was only 0.30% in 1998, but Ireland's share of world physics and material sciences papers has increased strongly since 2001 and by 2007 this had increased to 0.45%.

[97] There is no data available in the mFOS for the IoTs

[98] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[99] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

13.4.2 Results from the Forfás/HEA Bibliometric Study[100] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.21	1.47	1.51	+3%
Group average citation impact	1.08	1.22	1.34	+9%
Ireland / Group average	1.12	1.20	1.13	-6%
Ireland rank within Group	7	6	7	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.10 Citation Impact of Physics & Materials Sciences Papers

Physics and material sciences research from Ireland is fairly well cited and the rate of citation has slightly increased in recent years. Ireland is ranked 7th in the comparator group for this study, ahead of a number of comparable research economies including Sweden, Australia, Belgium, Finland, Portugal, Czech Republic and New Zealand. This healthy citation position is complemented by the 25% increase in research volume.

13.4.3 Masters and PhD output[101]

- Masters Graduates (2006): 18 (4% of national total)
- PhD Graduates (1998/9): There is no comparable data available for this mFOS
- PhD Graduates (2006): 29 (3.2% of national total)

13.5 Other Relevant Information

Physical and supporting infrastructure

The HEA/Forfás Infrastructure Report 2007[102] highlighted that some areas of physics research (e.g. astro-physics, nuclear physics) do not have adequate facilities.

However there has been some significant investment in recent years underpinning research in the areas of Physics and Material Sciences. A significant proportion of this capital investment underpins the role of these disciplines in hardware ICT research. Consequently, there has been significant investment in buildings and equipment to support research into nano-materials and photonics (e.g. Tyndall, CRANN). There has also been investment in buildings and equipment to support a broader materials science research programme (e.g. Materials and Surface Science Institute [UL]). Other infrastructural

[100] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[101] This does not include data from the IoTs

[102] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow, 2007

investments have supported sensor technology (NCSR DCU), plasma science (DCU) and computational physics (DIAS).[103]

Strategic developments since 2006

This field has been viewed as a key underpinning area for technological development. Acknowledging that there are strong areas of performance within this field, and that Ireland has an historical track record in this area, increasingly the policy emphasis is on harnessing the outputs so as to enhance economic and societal impact both directly and indirectly, in addition to enhancing education and research. National policy, and funding programmes across all agencies, are increasingly focusing on knowledge transfer and translation in their widest sense. For example, Enterprise Ireland has established a number of Competence centres related to this mFOS to enable engagement with the private sector. Specific strategic developments relating to aspects of nanotechnology can be found in the Nanotechnology section. The importance of this area to the economy was recognised in 'Building Ireland's Smart Economy, 2008'[104] with proposals to establish a number of industry led competence centres associated with this area, specifically in Advanced Manufacturing Productivity, Energy, BioEnergy, and Composites.

Key Data

- Physics & Materials Sciences 2006 research-related income was 5.1 % of national total
- Physics & Materials Sciences s 2006 research-active staff made up 6.2 % of national total
- Physics & Materials Sciences 2006 research students represented 3.9% of the Masters and 4.2% of the PhD national total
- Steady increase in most research activity indicators for this field for the period 1998-2006.
- Activity was spread across a number of HEIs however there appears to be substantial growth in this area for several HEIs.
- Ireland shows strong growth in the number of papers published in physics and material sciences (25%) which is 9% greater than the average for comparator countries utilised in this study. This rate of growth in the six years to 2007 is very strong, exceeded only by China (41%) and India (22%). By contrast three quarters of the countries in the comparator group suffered a net loss in their percentage of world share during the same period.
- Physics and material sciences research from Ireland is fairly well cited and the rate of citation has slightly increased in recent years. Ireland is ranked 7th in the comparator group for this study, ahead of a number of comparable research economies including Sweden, Australia, Belgium, Finland, Portugal, Czech Republic and New Zealand. This healthy citation position is complemented by the 25% increase in research volume.
- Physics & Materials Sciences 2006 research graduates represented 4% of the Masters and 3.2% of the PhD national total

[103] Sensor technology underpins a number of FOS (e.g. also biology, chemistry, computer science)

[104] Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal, 2008

14. Chemical Sciences

14.1 Activity Fact File – 2006

Inputs

- Total Income €22,315,000
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €22,315,000
  - Direct Irish Exchequer Funding €11,065,000
  - Non-Irish Exchequer Funding
    - European Union (public) €2,091,000
    - Irish Private Funded €146,000

Research-active Staff

- HERD (FTEs) – 217
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 97
- PhD students (# in system) - 205

% National activity

- Chemical Sciences 2006 research-related income was 3.1 % of national total
- Chemical Sciences 2006 research-active staff made up 3.4 % of national total
- Chemical Sciences 2006 research students represented 3.1% of the Masters and 4.9% of the PhD national total

14.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Starting from a relatively strong base in 1998, there was a consistent trend of increase in the level of research activity in Chemical Sciences
- There was steady growth year on year in research-related income (€) from 1998 to 2006. Growth 1998-2006 was 142%. The median for the 19 mFOS was 252% for this time period. Research income grew by 25% from 2004 to 2006. The mFOS median was 19%.
- There was a steady increase year on year in numbers of reported research-active staff (FTEs), with 92% overall growth for the period 1998 to 2006. The median for the 19 mFOS was 163%. There was a 26% increase 2004-2006, which is similar to the median increase of 17% for the 19 mFOS.
- The number of Masters and PhD students has remained fairly stable[105] over this time period

Distribution of Activity

- Activity was fairly concentrated in a number of HEIs
- UCC's research-active staff in 2006 accounted for approximately a third of the national total in this area.
- UCD and TCD reported increases of c. 140% and together accounted for a third of the national research-active cohort.

14.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): There is no comparable data
- Students (# enrolled in system in 2006): 698 (0.6% of national total)

Undergraduate graduates (2006): 167 (1.1% of national total)[106]

[105] No Masters or PhD data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08. See Annex A5, Table 4 & 5.

14.4 Outputs and Outcomes

14.4.1 Results from the Forfás/HEA Bibliometric Study[107] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	347	437	572	+31%
Group Average Papers	2,970	4,173	4,935	+18%
Ireland / Group Average	0.12	0.10	0.12	+11%
Ireland rank within Group	18	17	17	stable
Ireland share of world (%)	0.31	0.32	0.38	+17%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.11 Number of Chemical Sciences Papers

Ireland shows strong growth in the number of papers published in chemical sciences (31%) which is 11% greater than the average for comparator countries utilised in this study[108]. This rate of growth in the six years to 2007 is very strong, exceeded only by China (31%). Ireland's percentage share of all world chemical science papers, although very low (0.38% in 2007) has increased significantly over the ten year period to 2007. Many other countries have suffered a decrease in their world % share. New Zealand's percentage share of world output was greater than Ireland's ten years ago, but its trajectory since then has been downward and New Zealand is now outperformed by Irish researchers.

14.4.2 Results from the Forfás/HEA Bibliometric Study[109] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.26	1.25	1.55	+24%
Group average citation impact	1.07	1.11	1.21	+9%
Ireland / Group average	1.18	1.12	1.29	+14%
Ireland rank within Group	5	6	3	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.11 Citation Impact of Chemical Sciences Papers

Citation of Irish chemical sciences papers has increased by 24% over the last six years to an average citation impact of 1.55 in 2007. Complemented by the 31% increase in research volume this suggests that

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[106] Data was not available for IoTs for this mFOS

[107] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[108] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[109] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

Irish research in this area is in a healthy condition. Irish research published in 2007 ranks 3rd within the comparator group used for this study in terms of citation impact, just behind Scotland and Northern Ireland.

14.4.3 Masters and PhD output[110]

- Masters Graduates (2006): 13 (3% of national total)
- PhD Graduates (1998/9): There was no comparable data available
- PhD Graduates (2006): 73 (7.9% of national total)

14.5 Other Relevant Information

Physical and supporting infrastructure

The level of investment in infrastructure directly supporting the chemical sciences has traditionally been quite low. The exception to this is the Analytical & Biological Chemistry Research Facility [UCC]. In research areas requiring an underpinning knowledge of chemistry (e.g. ICT/Materials Science/Pharmaceutical Sciences/Sensors) there has however been some significant investment in infrastructure. Consequently, the state of the infrastructure for chemical sciences is quite variable, from the very new to adequate. Post 2006, there has been a more concerted effort to improve the state of infrastructure in the chemical sciences through for example the Research Facilities Enhancement Scheme (HEA).

Strategic developments since 2006

Chemical Sciences (a fundamental enabling science) includes aspects of nanotechnology as well as pharmaceutical sciences and has been recognised as an important area of activity in Ireland. Recently recommendations outlined in the 'Maximising the Environment for Company Research and Development, Advisory Science Council, 2010'[111] report include determining the specific process development, formulation and synthetic chemistry needs of the small molecule pharmaceutical industry, both in terms of training requirements and in terms of HEI based R&D activities that need to be initiated. It is also recommended that the need and feasibility of establishing a centre for industrially focused research in process development, formulation and synthetic chemistry for the small molecule pharmaceutical industry be investigated.

[110] Data was not available for the IoTs for this mFOS

[111] Maximising the Environment for Company Research and Development, Advisory Science Council, 2010

Key Data

- Chemical Sciences 2006 research-related income was 3.1 % of national total
- Chemical Sciences 2006 research-active staff made up 3.4 % of national total
- Chemical Sciences 2006 research students represented 3.1% of the Masters and 4.9% of the PhD national total
- Starting from a reasonable base there was steady growth in the level of research activity in Chemical Sciences
- Activity was spread across a number of HEIs
- Ireland shows strong growth in the number of papers published in chemical sciences (31%). By contrast almost half of the countries in the comparator group suffered a net loss in their percentage of world share during the same period.
- Citation of Irish chemical sciences papers has increased by 24% over the last six years to an average citation impact of 1.55 in 2007. Irish research published in 2007 ranks 3rd within the comparator group used for this study in terms of citation impact, just behind Scotland and Northern Ireland. Complemented by the 31% increase in research volume this suggests that Irish research in this area is in a healthy condition.
- Chemical Sciences 2006 research graduates represented 2.9% of the Masters and 7.9% of the PhD national total

15. Nanotechnology

15.1 Activity Fact File – 2006

Inputs

- Total Income €30,726,000
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €30,726,000
  - Direct Irish Exchequer Funding €20,464,000)
  - Non-Irish Exchequer Funding
    - European Union (public) €5,390,000
    - Foreign Sources €2719
    - Irish Private Funded €2,122,000

Research-active Staff

- HERD (FTEs) – 173
- GOVERD (FTEs) – 0

Students enrolled

Student data is not collected for Nano-technology

% National activity

- Nano-technology 2006 research-related income was 4.3 % of national total
- Nano-technology 2006 research-active staff made up 2.7% of national total
- Student data is not collected for Nano-technology

15.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

This Field of Science was not collected prior to 2006, hence it is not possible to do a trend analysis for Nano-technology

15.3 Underpinning Factors

Undergraduate pipeline: Student data is not collected for Nanotechnology

Undergraduate graduates (2006): Student data is not collected for Nanotechnology

See in particular Physical & Material Sciences and Chemical Sciences

15.4 Outputs and Outcomes

15.4.1 Results from the Forfás/HEA Bibliometric Study[112] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	20	32	76	+139%
Group Average Papers	137	255	512	+101%
Ireland / Group Average	0.15	0.12	0.15	+19%
Ireland rank within Group	15	16	13	increase
Ireland share of world (%)	0.52	0.48	0.61	+27%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.12 Number of Nanotechnology Papers

Although the figures presented in the table above suggest an enormous (139%) increase in Irish output, this is largely the result of a very high comparative result in 2007. Overall volume numbers are low, and so not too much should be inferred from this figure. Nonetheless, looking at the overall picture Ireland has shown a consistent increase in volume of research outputs over the last ten years to a current high of 0.61% of total world output (relative to the comparator countries used in the Bibliometric study[113]).

The world nations fall into two groups and Ireland with percentage share of world total of 0.61 is now top of the lower group (which also comprises New Zealand, Finland and Denmark). Low overall numbers of papers mean that this situation is liable to change. It can be seen however that this is a research area where Ireland is performing well in terms of research volume.

15.4.2 Results from the Forfás/HEA Bibliometric Study[114] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	1.17	1.30	1.24	-5%
Group average citation impact	1.11	0.93	1.08	+16%
Ireland / Group average	1.06	1.40	1.15	-18%
Ireland rank within Group	7	3	7	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.12 Citation Impact of Nanotechnology Papers

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[112] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[113] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[114] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

Citation rates for Irish nano-technology papers are significantly better than those achieved on average by other countries within the comparator group utilised for this study[4]. Irish papers published in the five year period 2002 – 2006 received more citations than those from comparator countries with the exception of USA and Denmark.

The small number of papers published in nano-technology worldwide means that there is a lot of variation between years. Irish papers produced in 2002 and 2004 were particularly well cited (citation impact of 1.85 and 1.70 respectively) but in general Irish papers have been in the mid range in terms of citation, although in 2000, 2001, 2005 and 2006 citation rates were less than world average.

15.4.3 Masters and PhD Output

No student data collected for this area. See in particular Physical & Material Sciences and Chemical Sciences

15.5 Other relevant information

Physical and supporting infrastructure

There has been significant and relatively consistent investment since 1998 in infrastructure underpinning research in the area of Nano-science/technology. This has been primarily supported through PRTLI Cycles 1-3 capital programmes but significant additional funding has also come from SFI. All agencies have contributed to the purchase of state-of-the-art equipment. Key infrastructural developments include the National Nanofabrication Facility [Tyndall National Institute] and the Centre for Research in Adaptive Nanostructures and Nano-devices (CRANN; TCD & UCC). A national consortium, INSPIRE, has also been established under PRTLI Cycle 4 to co-ordinate Ireland research and PhD education in this area and it includes all key research performers.

Strategic developments since 2006

As part of the increasing emphasis on knowledge transfer and knowledge translation, Enterprise Ireland has established an industry-led Competence Centre Programme in Applied Nanotechnology. The importance of Nano-science for the future has been recognized by the Forfás report 'Ireland's Nanotechnology Commercialisation Framework, 2010-2014'[115]. This report sets out a range of recommendations and a framework for the development and enhancement of nano-technology in Ireland.

[115] http://www.forfas.ie/media/forfas310810-nanotech_commercialisation_framework_2010-2014.pdf

Key Data

- Nano-technology 2006 research-related income was 4.3 % of national total
- Nano-technology 2006 research-active staff made up 2.7 % of national total
- Student data is not collected for Nano-technology
- This Field of Science was not collected prior to 2006, hence it is not possible to do a trend analysis for Nano-technology
- Although overall numbers of papers produced in Nano-technology are low, Ireland has shown a consistent increase in volume over the last ten years to a current high of 0.61% of total world output indicating that Ireland is performing well in terms of volume.
- Citation rates for Irish nano-technology papers are significantly better than those achieved on average by other countries within the comparator group, however the small number of papers published in nano-technology worldwide means that there is a lot of variation between years. In general Irish papers have been in the mid range in terms of citation impact.

16. Computer & Information Sciences

16.1 Activity Fact File – 2006

Inputs

- Total Income €31,253,000
- Government Sector (GOVERD) €2,091,000
- Higher Education Sector (HERD) €29,162,000
  - Direct Irish Exchequer Funding €14,719,000
  - Non-Irish Exchequer Funding
    - European Union (public) €1,296,000
    - Foreign Sources €156,000
    - Irish Private Funded €114,636

Research-active Staff

- HERD (FTEs) – 298
- GOVERD (FTEs) – 35

Students enrolled

- Masters Students (# in system) - 262
- PhD students (# in system) - 380

% National activity

- Computer & Information Sciences 2006 research-related income was 4.3 % of national total
- Computer & Information Sciences 2006 research-active staff made up 5.2 % of national total
- Computer & Information Sciences 2006 research students represented 8.3% of the Masters and 9% of the PhD national total

16.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

This is a combined trend analysis for Computer & Information Science and Mathematics.[116]

- The research indicators consistently show an increase in activity for this mFOS across the 1998-2006 period.
- There was a steady growth in research-related income 1998 - 2002 and rapid increases thereafter. Overall growth 1998-2006 was 382%; the median for the 19mFOS was 252%. Growth 2004 to 2006 was 15% which is in the region of the mFOS median of approximately 19%.
- Numbers of research-active staff (FTEs) were fairly stable 1998-2000 but a rapid increase occurred thereafter. Overall for the period 1998-2006 there was an increase of 344%, which is large relative to the mFOS median of approximately 163%. The 18% increase 2004-2006 for this area is in line with the 17% median for the 19mFOS.
- Numbers of Masters students increased up until 2005, after which they started decreasing[117]. Numbers of PhD students steadily increased for the period[118].

Distribution of Activity

- Activity was spread across a number of HEIs which have actively been growing their research activity in this area.
- TCD consistently reported the highest absolute numbers of research-active staff in this area and represented circa 24% of the national cohort.
- Very large increases (~500-900%) in research activity from a rel low base over the period by UL, UCD and NUIM.

[116] Prior to 2006 data was collected under the combined heading of 'Mathematics, Computer & Information Sciences.

[117] No data available for the IoTs for 1998/9.

[118] Mathematics data is not captured separately in 1998/9 & 2003/04 and was likely in those years to have been captured under the general 'Science' category which is not included in the 19mFOS.

16.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 2,965 (5.7% of national total) [119]
- Students (# enrolled in system in 2006): 5,486 (4.6% of national total)

Undergraduate graduates (2006): 532 (3.4% of national total)[120]

16.4 Outputs and Outcomes

16.4.1 Results from the Forfás/HEA Bibliometric Study[121] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	104	297	242	-18%
Group Average Papers	942	1,689	1,351	-20%
Ireland / Group Average	0.11	0.18	0.18	+2%
Ireland rank within Group	17	17	16	increase
Ireland share of world (%)	0.40	0.61	0.67	+10%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.13 Number of Computer & Information Sciences Papers

The 2007 figure for the number of Irish publications in Computer & Information Sciences is 18% lower than the average for the period 2002-06. There was however an even larger drop in output across the comparator group[122] (20%) and it is encouraging to note that Ireland still produced 0.67% of world papers in 2007. This is the highest percentage world share for any of the Irish research areas examined in this report, with the exception of agriculture and agricultural biotechnology and engineering.

The number of Irish publications in Computer & Information Sciences rose to a peak in 2005, and then decreased in 2006 and again in 2007. The volume of Irish outputs is the same as Denmark's, and greater than New Zealand. Ireland achieved a 10% increase in its share of total world publications comparing 2007, with the average for the five years 2002-06. Most comparator nations in the study suffered a decrease in share over the same period, with the exception of Belgium which increased its share by 11%.

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[119] Data not available for IoTs

[120] Data not available for IoTs

[121] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[122] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

16.4.2 Results from the Forfás/HEA Bibliometric Study[123] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.67	0.78	0.65	-17%
Group average citation impact	0.91	1.01	1.02	+1%
Ireland / Group average	0.74	0.78	0.64	-18%
Ireland rank within Group	16	15	16	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.13 Citation Impact of Computer & Information Sciences Papers

Citation rates for Irish Computer & Information Sciences papers are well below world average and Ireland is towards the bottom of the comparator group rankings and has been in all years for which data has been collected. Ireland only ranks better than last as a result of years when papers from New Zealand have been cited at an extremely low rate.

16.4.3 Masters and PhD output[124]

- Masters Graduates (2006): 41 (9% of national total)
- PhD Graduates (1998/9): 12 (2.3% of national total)
- PhD Graduates (2006): 64 (7% of national total)

16.5 Other Relevant Information

Physical and supporting Infrastructure

There has been significant investment in infrastructure (both buildings and equipment and systems) in this area across a range of institutions. The Irish Centre for High End Computing (ICHEC) is specific specialised infrastructure and is engaging in the PRACE (Partnership for Advanced Computing Europe) ESFRI pan-European project. Grid Ireland is also a member of the European Grid Initiative- an organisation being developed to coordinate the European Grid Infrastructure, based on the federation of individual National Grid Infrastructures. Post 2006, investment in this area has continued – e.g. E-INIS (PRTLI Cycle 4), a federation of core electronic infrastructure providers dedicated to the provision of a sustainable national infrastructure for the support of advanced research activities in Ireland has been established.

Strategic developments since 2006

ICT was highlighted as a national strategic priority with the establishment of Science Foundation Ireland in 2001/2. Since that time it has continued to be of strategic importance for enterprise and economic development.

[123] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[124] Data not available for IoTs

Computer and Information Science is one of the key areas where convergence opportunities exist with a number of other Fields of Science, as indicated in the 'Innovation Ireland, 2010'[125] report. As such, recommendations for the enhancement of ICT research and enabling infrastructure are ubiquitous in policy reports across many areas. In particular the creation of critical mass, multi-disciplinary and industry-oriented research grouping in the field of sensors and intelligent systems are highlighted. In order to promote key sectors that can drive exports and job creation, the development of renewable energy capabilities was included in the key recommendations from the 'Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, Nov 2009'[126] report. Specifically, for wind and wave energy for which Ireland has one of the most favourable locations in the world, the ICT capabilities of the grid to leverage Ireland's existing ICT skills base and support the development of new competencies and activities, would be enabled.

Related themes are found in 'The Knowledge Society Strategy – Technology Actions to support the Smart Economy, July 2009'[127] report which aims to attract foreign direct investment by promoting Ireland as a test location for new Information Communications Technologies (ICT). It identified six actions in 5 areas for action including:

- Exemplar Smart Communications Networks,
- Establishing Ireland as a centre for energy efficient Data Centres and Cloud Computing,
- The establishment of an International Content Services Centre (ICSC) modelled on the IFSC attempts to harness Ireland's reputation in three areas: Digital creative Arts (film, games, music and animation); Modern communications technology; Legal and other professional services.
- A Smart Electricity Network to facilitate bi-directional flows of energy and information...
- The Internet of Things, extending the Internet to include information coming from sensors attached to equipment and physical objects. ....
- Work Flow, a new concept using web-enabled mobile traffic sensors, communication and collaboration tools and flexible work practices to increase productivity reduce congestion and lower carbon emissions.
- SmartBay aims to establish a Marine Research, Test and Demonstration Platform in Galway Bay. It will link surface and underwater sensors and networks to enable environmental research

[125] Innovation Ireland – Report of the Innovation Taskforce, 2010

[126] Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, November 2009

[127] Knowledge Society Strategy – Technology Actions to Support the Smart Economy, July 2009

Key Data

- Computer & Information Sciences 2006 research-related income was 4.3 % of national total
- Computer & Information Sciences 2006 research-active staff made up 5.2 % of national total
- Computer & Information Sciences 2006 research students represented 8.3% of the Masters and 9% of the PhD national total
- Increases in activity across the research indicators are consistent for the 1998-2006 period.
- Activity in Computer & Information Science and Mathematics was spread across a number of HEIs which have actively been growing their research activity in this area.
- The Irish percentage share of world papers in Computer & Information Sciences increased even though the overall volume produced dropped, this was because a larger drop occurred in the majority of the comparator nations. Ireland produced 0.67% of world papers in 2007. This is the highest percentage world share for any of the Irish research areas examined in this report, with the exception of Agriculture and Agricultural Biotechnology and Engineering.
- Citation rates for Irish Computer & Information Sciences papers have been consistently well below world average and Ireland is towards the bottom of the comparator group rankings. In 2007, Computer & Information Sciences held the lowest citation ranking of all the 19 mFOS.
- Computer & Information Sciences 2006 research graduates represented 9.1% of the Masters and 7% of the PhD national total

17. Civil Engineering

17.1 Activity Fact File – 2006

Inputs

- Total Income €7,178,000
- Government Sector (GOVERD) €54,000
- Higher Education Sector (HERD) €7,124,000
  - Direct Irish Exchequer Funding €2,160,000
  - Non-Irish Exchequer Funding
    - European Union (public) €477,087
    - Foreign Sources €34,000
    - Irish Private Funded €22,000

Research-active Staff

- HERD (FTEs) – 98
- GOVERD (FTEs) – 1

Students enrolled

- Masters Students (# in system) - 117
- PhD students (# in system) - 90

% National activity

- Civil Engineering 2006 research-related income was 1% of national total
- Civil Engineering 2006 research-active staff made up 1.6% of national total
- Civil Engineering 2006 research students represented 3.7% of the Masters and 2.1% of the PhD national total

17.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Research activity in this field has generally increased for the period 1998-2006.
- Growth in research-related income from 1998 to 2006 was just 71%, compared to the circa 252% median for the 19 mFOS. Research-related income remained fairly constant for the period 2004 to 2006 with just a 2% increase relative to the 19% median for the 19 mFOS.
- The number of research-active staff (FTE) increased from 1998 to 2006 by 164%. The median increase for this period was 163%. From 2004 to 2006 the number of research-active staff grew by 37%. The median increase for this period was 17% for the 19 mFOS.
- There has been an increase in the number of PhD enrolments in this field while the number of Masters students has increased more gradually.

Distribution of Activity

- Activity is spread across a number of HEIs. The profile of activity was variable from year to year for each HEI which may reflect a reporting artifact.
- UCD research-active staff accounted for circa 20% of the national total in 2006.
- In 2006 AIT reported a large number of research-active staff in this category for the first time. This represented the second highest reported location for research-active staff in this area nationally.

17.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 250 (0.5% of national total)
- Students (# enrolled in system in 2006): 8,088 (6.8% of national total)

Undergraduate graduates (2006): 299 (1.9% of national total)[128]

17.4 Outputs and Outcomes

17.4.1 Results from the Forfás/HEA Bibliometric Study[129] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	10	24	59	+144%
Group Average Papers	231	411	476	+16%
Ireland / Group Average	0.04	0.06	0.12	+110%
Ireland rank within Group	18	17	17	stable
Ireland share of world (%)	0.17	0.24	0.48	+104%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.14 Number of Civil Engineering Papers

This analysis is presented for information but should be treated with caution as it is based on very small volumes. Engineering research outputs are disseminated in a number of different ways, and as a result a lot of good research will not necessarily be found in articles and reviews. That said, in terms of these indicators Ireland has shown huge increases in output (144%) and percentage share of world output relative to the comparator countries used in the bibliometric study[130], had increased to 0.48% by 2007 (from only 0.17% in 1998).

Importantly the change in volume of Irish publications in civil engineering is the result of progressive improvement rather than just one or a few key papers. By 2007 Ireland was on a par with Finland, and starting to close the gap with New Zealand. This is positive, but the small volume makes this a vulnerable area nationally.

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[128] Data not available for the IOTs

[129] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[130] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

17.4.2 Results from the Forfás/HEA Bibliometric Study[131] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.88	0.75	1.53	+104%
Group average citation impact	0.96	1.20	1.16	-3%
Ireland / Group average	0.92	0.62	1.32	+112%
Ireland rank within Group	11	19	5	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.14 Citation Impact of Civil Engineering Papers

This analysis is presented for information but should be treated with caution as it is based on very small number of publications. Civil engineering research outputs are disseminated in a number of different ways, and as a result a lot of good research will not necessarily be found in articles and reviews. Citation levels for Irish civil engineering papers have generally been very low. Publications in 2001, 2005 and 2007 achieved on average citation rates above world average. The large variations in citation can be attributed to the small number of papers produced, and diverse patterns of research dissemination, within civil engineering.

17.4.3 Masters and PhD output[132]

- Masters Graduates (2006): 33 (7% of national total)
- PhD Graduates (1998/9): No data available for this area
- PhD Graduates (2006): 10 (1.1% of national total)

17.5 Other Relevant Information

Physical and supporting infrastructure

The standard of buildings was noted by the 2007 HEA/Forfás Research Infrastructures report to be generally adequate, but with some cases not fit for purpose. One area that has received some infrastructural support is the area of building design for sustainability and operating efficiency is the ERI building (UCC- PRTLI Cycle 2) and it is an example of infrastructural investment supporting civil engineering research in this context. EU framework funding has also played an important role in providing targeted up-to-date research equipment.

[131] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[132] This does not include data from the IoTs

Since 2006, there has also been a more concerted effort to put in place more general modern engineering facilities (both for undergraduate educational and research purposes). Some of these have already been constructed (e.g. the new Engineering building in AIT) while others are under construction (NUIG's Engineering Building) or are in planning.

Strategic developments since 2006

Post 2006, there has been increased focus within the broad engineering disciplines (including civil) on the area of sustainable energy and energy conservation. Consequently, this area is beginning to receive more attention. By their nature, world class centres and the development of infrastructure to enable the recommendations from the 'Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, Nov 2009'[133], particularly in the area of ocean and wind energy, will require civil engineering expertise and research. Specifically, efficient energy use and management (including Eco-Construction) and the development of effective tools to improve the cost competitiveness of all enterprises and support green enterprises, is highlighted as a priority.

Key Data

- Civil Engineering 2006 research-related income was 1% of national total
- Civil Engineering 2006 research-active staff made up 1.6% of national total
- Civil Engineering 2006 research students represented 3.7% of the Masters and 2.1% of the PhD national total
- Research activity in this field has generally increased for the period 1998-2006.
- Activity was spread across a number of HEIs. The profile of activity was variable from year to year for each HEI which may reflect a reporting artifact.
- Engineering research outputs are disseminated in a number of different ways, and as a result a lot of good research will not necessarily be found in articles and reviews. That said, in terms of these indicators Ireland has shown huge increases in output (144%) and percentage share of world output had increased to 0.48% by 2007 (from only 0.17% in 1998). Importantly the change in volume of Irish publications in civil engineering appears to be the result of progressive improvement rather than just one or a few key papers. This is positive, but the small volume makes this a vulnerable area nationally.
- Citation levels for Irish civil engineering papers have generally been very low. Publications in 2001, 2005 and 2007 achieved on average citation rates above world average.
- Civil Engineering 2006 research graduates represented 7.3% of the Masters and 1.1% of the PhD national total

[133] Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, November 2009

18. Electrical Engineering, Electronic Engineering, Information Engineering

18.1 Activity Fact File – 2006

Inputs

- Total Income €31,961,184
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €31,961,184
  - Direct Irish Exchequer Funding €18,619,590
  - Non-Irish Exchequer Funding
    - European Union (public) €2,553,713
    - Foreign Sources €171,148
    - Irish Private Funded €140,000

Research-active Staff

- HERD (FTEs) – 281
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 138
- PhD students (# in system) - 152

% National activity

- Electrical, Electronic and Information Engineering 2006 research-related income was 4.4 % of national total
- Electrical, Electronic and Information Engineering 2006 research-active staff made up 4.4 % of national total
- Electrical, Electronic and Information Engineering 2006 research students represented 4.3% of the Masters and 3.6% of the PhD national total

18.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Overall there was a general trend of an increase in research activity for this area for the period 1998-2006.
- There was steady year on year growth for the period 1998-2006[134] with an overall increase of 247%. The mFOS median for this period was circa 252%. Research-related income increased by 25% over the period 2004 to 2006. The mFOS median was 19%.
- There was a 216% increase in research-active staff (FTEs) 1998 – 2006. The mFOS median increase for this period was circa 163%. There was a 66% increase for 2004 - 2006 which is larger than the mFOS median increase of 17% for this period.
- There has been a gradual decrease in the numbers of Masters students[135]. PhD numbers in this field have remained fairly constant[136].

Distribution of Activity

- Activity was distributed across a number of HEIs, however it has become increasingly concentrated after a small number increased their activity in this field.
- NUIG reported a circa 2,000% increase in research-active staff for the period 1998-2006. From a very low base, they have grown to account for approximately 20% of the national total of research-active staff in this area in 2006.
- After significant growth (circa 200%), UCD and UL accounted for a further third of the research-active staff in this area in 2006

[134] There is no HERD data for 2000 for this mFOS

[135] No Masters data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08.

[136] No PhD data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08.

18.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): There is no comparable data available
- Students (# enrolled in system in 2006): 747 (0.6% of national total)

Undergraduate graduates (2006): 245 (1.6% of national total)[137]

18.4 Outputs and Outcomes

18.4.1 Results from the Forfás/HEA Bibliometric Study[138] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	161	246	408	+66%
Group Average Papers	1,721	2,123	2,584	+22%
Ireland / Group Average	0.09	0.12	0.16	+36%
Ireland rank within Group	17	17	15	increase
Ireland share of world (%)	0.31	0.40	0.57	+40%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.15 Number of Electrical Engineering, Electronic Engineering, Information Engineering Papers

Ireland shows very strong growth in the number of papers published in electrical engineering, electronic engineering and information engineering (66% in the six years to 2007). This is the highest growth rate across our comparator group utilised for this study[139], matched only by China (also 66% growth). Ireland's share of world outputs has risen dramatically from 0.31% in 1998 to 0.57% in 2007. Ireland has moved up in the rankings to 15th position in terms of research volume, and is now ahead of Denmark and the Czech Republic, as well as New Zealand and Northern Ireland.

Ireland's percentage share of world electrical engineering, electronic engineering and information engineering papers has increased strongly and since 2001 – an increase of 40%. In the same time frame Australia has achieved an increase in percentage share of world output of 7%, albeit starting from a much higher baseline (2.1% as opposed to 0.3%). Many other nations have seen their percentage share stay the

[137] No data available for the IoTs

[138] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[139] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

same or fall. These branches of engineering are now amongst the top hitters in terms of research volume for the Irish mFOS.

18.4.2 Results from the Forfás/HEA Bibliometric Study[140] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.92	1.19	0.97	-19%
Group average citation impact	1.05	1.13	1.17	+3%
Ireland / Group average	0.88	1.05	0.83	-21%
Ireland rank within Group	12	8	12	decrease

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.15 Citation Impact of Electrical Engineering, Electronic Engineering, Information Engineering Papers

Citation rates for Irish Electrical, Electronic & Information Engineering papers are generally poor – below world average and towards the bottom of the rankings in terms of the comparator group utilised for this study. In 2007 Irish citation rates were worse than all comparators with the exception of Australia, New Zealand and the Asian nations. Ireland compares poorly with other nations over the ten year period 1998 – 2007 – the only exception to this being New Zealand where research in electrical, electronic and information engineering received even lower levels of citation.

18.4.3 Masters and PhD output[141]

- Masters Graduates (2006): 35 (8% of national total)
- PhD Graduates (1998/9): There is no comparable data available
- PhD Graduates (2006): 58 (6.3% of national total)

18.5 Other Relevant Information

Physical and supporting Infrastructure

There has been some considerable capital investment (both in terms of buildings and equipment) in this area, most notably in micro-electronics and related disciplines (e.g. in the Tyndall National Institute and in its precursor the NMRC). However, the investment has been uneven across the sub-disciplines (2007 HEA/Forfás Research Infrastructure in Ireland report). Post 2006, there has been a more concerted effort to put in place more general modern engineering facilities (both for undergraduate educational and research purposes). Some of these have already been constructed (e.g. the new Engineering building in AIT) while others are under construction (NUIG's Engineering Building) or are in planning.

Strategic developments since 2006

This mFOS is one of the key areas where convergence opportunities exist with a number of other Fields of Science. As such, recommendations for the enhancement of research and enabling infrastructure for this area are ubiquitous in policy reports across many areas. Support for this underpinning area is highlighted

[140] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[141] This does not include data from the IoTs

in conjunction with recommendations for the enhancement of ICT systems and the development of the Green Economy, including renewable energy and environmental technologies areas. For example, in order to promote key sectors that can drive exports and job creation, the development of renewable energy capabilities was included in the key recommendations from the 'Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, Nov 2009'[142] report. The importance of this area to the economy was recognised in the 'Building Ireland's Smart Economy, 2008'[143] report, which proposed the establishment of an industry led competence centre specifically in Advance CMOS Circuits. This report also signalled the importance of this area in energy technology research. An Ocean Energy Development Programme 2008-2012 has been established by Government.

The underpinning nature of this area is further exemplified in 'The Knowledge Society Strategy – Technology Actions to support the Smart Economy, July 2009'[144] report which included a number of recommendations including the establishment of 'a Smart Electricity Network to facilitate bi-directional flows of energy and information...' The report noted that Irish companies such as Glen-Dimplex are already developing a range of intelligent home heaters using smart meters and motion detectors, and that Ireland also has the potential to play a lead role in the widespread deployment of electric vehicles. Other recommendations in the report were the establishment of the 'The Internet of Things, which would extend the Internet to include information coming from sensors attached to equipment and physical objects, and 'Work Flow' a new concept using web-enabled mobile traffic sensors, communication and collaboration tools and flexible work practices to increase productivity, reduce congestion and lower carbon emissions.

Key Data

- Electrical, Electronic and Information Engineering 2006 research-related income was 4.4 % of national total
- Electrical, Electronic and Information Engineering 2006 research-active staff made up 4.4 % of national total
- Electrical, Electronic and Information Engineering 2006 research students represented 4.3% of the Masters and 3.6% of the PhD national total
- Overall there is a general trend of an increase in research activity for this area for the period 1998-2006.
- Activity was distributed across a number of HEIs, however a number have been increasing their activity in this field
- Ireland shows very strong growth in the number of papers published in electrical engineering, electronic engineering and information engineering (66% in the six years to 2007). This is the highest growth rate across our comparator group, matched only by China (also 66% growth). Citation rates for Irish electrical, electronic and information engineering papers are generally poor – below world average and towards the bottom of the rankings in terms of the comparators utilised for this study.
- Electrical, Electronic and Information Engineering 2006 research graduates represented 7.8% of the Masters and 6.3% of the PhD national total

[142] Developing the Green Economy in Ireland – Report of the High-Level Group on Green Enterprise, November 2009

[143] Building Ireland's Smart Economy – A Framework for Sustainable Economical Renewal, 2008

[144] Knowledge Society Strategy – Technology Actions to Support the Smart Economy, July 2009

19. Mechanical Engineering

19.1 Activity Fact File – 2006

Inputs

- Total Income €14,847,400
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €14,847,400
  - Direct Irish Exchequer Funding €7,136,000
  - Non-Irish Exchequer Funding
    - European Union (public) €558,000
    - Foreign Sources €131,000
    - Irish Private Funded €100,000

Research-active Staff

- HERD (FTEs) – 116
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 25
- PhD students (# in system) - 21

% National activity

- Mechanical Engineering 2006 research-related income was 2.1% of national total
- Mechanical Engineering 2006 research-active staff made up 1.8 % of national total
- Mechanical Engineering 2006 research students represented 0.8% of the Masters and 0.5% of the PhD national total

19.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- There was no data collected prior to 2006 for Mechanical Engineering, hence it was not possible to do a trend analysis

19.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): There is no comparable data available
- Students (# enrolled in system in 2006): 377 (0.3% of national total)

Undergraduate graduates (2006): 93 (0.6% of national total)[145]

[145] There is no data available for the IoTs

19.4 Outputs and Outcomes

19.4.1 Results from the Forfás/HEA Bibliometric Study[146] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	90	113	104	-8%
Group Average Papers	1,088	1,302	1,440	+11%
Ireland / Group Average	0.08	0.09	0.07	-17%
Ireland rank within Group	18	18	18	stable
Ireland share of world (%)	0.27	0.29	0.24	-17%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.16 Number of Mechanical Engineering Papers

Mechanical engineering is a research area where Irish share of published research has remained very low over the last ten years – 0.27% in 1998, 0.24% in 2007. Other comparator counties utilised for this study[147] have increased the number of publications, while Irish numbers have declined by 8%. In terms of ranking by volume, Ireland is at the bottom, with the exception of Northern Ireland. Irish mechanical engineering can derive some small comfort from the way that the comparator countries are all flat-lining in terms of their percentage share of world papers.

19.4.2 Results from the Forfás/HEA Bibliometric Study[148] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value	Current relative to Recent
Ireland citation impact	0.80	1.35	1.64	+22%
Group average citation impact	1.06	1.15	1.19	+4%
Ireland / Group average	0.76	1.17	1.38	+17%
Ireland rank within Group	16	3	3	stable

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.16 Citation Impact of Mechanical Engineering Papers

From a low citation rate in 1998, mechanical engineering research in Ireland has now reached the position where it is cited more frequently than research from any of the comparator countries with the exception of Finland and Denmark. This is a subject where volume of research has decreased (by 17%) while impact has increased. Irish mechanical engineering papers have been cited more frequently than world average for most years between 1998 and 2007, with higher rates of citation in 2002, 2004 and 2007. In recent years Irish research has been ranked third within the comparator countries for this study.

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[146] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[147] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[148] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

19.4.3 Masters and PhD output[149]

- Masters Graduates (2006):7 (2% of national total)
- PhD Graduates (1998/9): There is no comparable data available
- PhD Graduates (2006): 6 (% of national total)

19.5 Other Relevant Information

Physical Infrastructure

The standard of buildings was noted by the 2007 HEA/Forfás Research Infrastructures Report[150] to be generally adequate, but with some cases not fit for purpose. Equipment was not considered to be sufficient to ensure researcher competitiveness going forward. Exceptions tend to relate to highly specific research areas such as the biomechanical aspects of biomedical engineering and some work in the mechanical aspects of new materials.

Post 2006, there has been a more concerted effort to put in place more general modern engineering facilities (both for undergraduate educational and research purposes). Some of these have already been constructed (e.g. the new Engineering building in AIT) while others are under construction (NUIG's Engineering Building) or are in planning. A more targeted infrastructure is the Hydraulics and Maritime Research Centre (HMRC) based at UCC, for example, hosts the only facilities for wave simulation in Ireland with a Wave Flume and an Ocean Wave Basin. This infrastructure will be key to underpinning energy research.

Strategic developments since 2006

The importance of this area to the economy was recognised in 'Building Ireland's Smart Economy, 2008'[151] with a proposal to establish a number of industry led competence centres associated with this area, specifically in Advanced Manufacturing Productivity, Energy, BioEnergy, and Composites. More recently in 'Innovation Ireland, 2010[152]' it was highlighted that in enabling inter-firm collaborations to take advantage of convergence opportunities, engineering should be one of the sectors engaged in the process.

[149] Data was not available for the IoTs

[150] HEA/Forfas Research Infrastructure in Ireland = Building for Tomorrow, 2007

[151] Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal, 2008

[152] Innovation Ireland – Report of the Innovation Taskforce, 2010

Key Data

- Mechanical Engineering 2006 research-related income was 2.1% of national total
- Mechanical Engineering 2006 research-active staff made up 1.8 % of national total
- Mechanical Engineering 2006 research students represented 0.8% of the Masters and 0.5% of the PhD national total
- There was was no data collected prior to 2006 for Mechanical Engineering, hence it is not possible to do a trend analysis
- Mechanical engineering is a research area where Irish share of published research has remained very low over the last ten years. Other comparator counties have increased the number of publications, while Irish numbers have declined by 8%.
- From a low citation rate in 1998, mechanical engineering research in Ireland has now reached the position where it is cited more frequently than research from any of the comparator countries with the exception of Finland and Denmark. This is a subject where volume of research has decreased (by 17%) while impact has increased.
- Mechanical Engineering 2006 research graduates represented 1.6% of the Masters and 0.7% of the PhD national total

20. Social Sciences

20.1 Activity Fact File – 2006

Inputs

- Total Income €58,883,565
- Government Sector (GOVERD) €3,996,000
- Higher Education Sector (HERD) €54,887,565
  - Direct Irish Exchequer Funding €13,774,000
  - Non-Irish Exchequer Funding
    - European Union (public) €4,034,000
    - Foreign Sources €180,000
    - Irish Private Funded €3,778,000

Research-active Staff

- HERD (FTEs) – 493
- GOVERD (FTEs) – 83

Students enrolled

- Masters Students (# in system) - 295
- PhD students (# in system) - 359

% National activity

- Social Sciences 2006 research-related income was 8.2 % of national total
- Social Sciences 2006 research-active staff made up 9.0 % of national total
- Social Sciences 2006 research students represented 9.3% of the Masters and 8.5% of the PhD national total

20.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- There was a consistent trend of high research activity across the indicators for Social Sciences 1998-2006.
- A steady growth in research-related income 1998 - 2004 followed by a slowing 2004-2006. Overall, 197% growth for the period 1998-2006 which was less than the median growth of 252% for the 19mFOS. There was just 2% growth reported for the period 2004-2006 relative to the median increase of 19% for the 19 mFOS.
- Fairly constant number of research-active staff (FTEs) for the period 1998 – 2006 with an overall increase of just 35%. The median increase was 163% for the 19 mFOS. From 2004-2006 there was a 16% drop whereas the mFOS median for this period was a 17% increase.
- A steady increase in both Masters and PhD student numbers for this period.

Distribution of Activity

- Activity was distributed across a number of HEIs.
- Historically UCD and UCC accounted for the highest absolute numbers of research-active staff.
- DIT reported a substantial increase in research-active staff for this period (circa 250%) while TCD and NUIG reported an increase in the region of 100-150%. In comparison, the remainder of HEIs either remained constant or decreased research-active staff for this period.

20.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 6,122 (11.8% of national total)
- Students (# enrolled in system in 2006): 19,214 (16.3% of national total)

Undergraduate graduates (2006): 2976 (18.9% of national total)[153]

20.4 Outputs and Outcomes

20.4.1 Results from the Forfás/HEA Bibliometric Study[154] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	112	157	246	+57%
Group Average Papers	1,493	1,676	1,916	+14%
Ireland / Group Average	0.08	0.09	0.13	+37%
Ireland rank within Group	16	16	15	increase
Ireland share of world (%)	0.34	0.42	0.58	+37%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.17 Number of Social Sciences Papers

Growth in the number of social science papers produced by Irish authors has been phenomenal over the last ten years. From a very low base in 1998 (only 112 papers, or 0.34% of total world output) Ireland in 2007 produced 246 papers, or 0.58% of world output. Within Ireland, in volume terms, social science is now one of the stronger project research areas considered in this report. Share of the total world output has increased by 37% - the greatest improvement amongst any of the comparator group utilized for this study[155]. If current trajectories continue Ireland's world share could exceed that of Finland within the next few years. These dramatic percentages must be interpreted in the light of publishing patterns within social sciences, where a lot of research is published in reports rather than as papers, and where patterns of research dissemination are rapidly evolving.

[153] There is no data available for the IoTs

[154] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[155] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

20.4.2 Results from the Forfás/HEA Bibliometric Study[156] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.77	0.82	1.23	+51%
Group average citation impact	0.86	0.94	0.93	-1%
Ireland / Group average	0.90	0.87	1.33	+53%
Ireland rank within Group	14	14	4	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.17 Citation Impact of Social Sciences Papers

Indexed journal articles in social science research are dominated by the USA and UK, where large and active communities extensively co-cite and hence elevate the world average. Comparative citation rates for Irish social science research are well below that world average for publications produced each year since 1998, with the exception of 2005 and 2007. Average citation rates for other members of the comparator group utilized for this study are also however low, but even so Ireland only achieves a ranking of 14th out of the 19 nations for the five year period 2002-2006. However Irish papers published in 2007 were cited more frequently (citation impact = 1.23) and Ireland was ranked 4th out of the 20 comparator nations in 2007.

20.4.3 Masters and PhD output[157]

- Masters Graduates (2006): 27 (6% of national total)
- PhD Graduates (1998/9): 8 (1.6% of national total)
- PhD Graduates (2006): 79 (8.6% of national total)

20.5 Other Relevant Information

Physical and supporting infrastructure

Some significant infrastructural investment has taken place in the area of social sciences – notably the development of PRTLI-funded initiatives such as the Geary Institute [UCD] which hosts the Irish Social Science Data Archive; the National Institute for Regional & Spatial Analysis [NUIM]; the Urban Institute of Ireland [UCD]; the Institute for International Integration Studies [TCD]; the Centre for Innovation and

[156] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[157] Data was not available for the IoTs

Structural Change [NUIG]; the Centre for Transport Research & Innovation in People [TCD]. In addition, the IRCHSS has funded Irish participation in the European Social Survey (ESS) ESFRI project.

Strategic developments since 2006

The Social Sciences is a vast field which spans numerous subcategories and supports a range of strategic areas. Social science research is a prerequisite for making informed policy choices in areas that impinge crucially on quality of life as highlighted in the RIA report 'Advancing Humanities and Social Sciences Research in Ireland, 2007'[158].

The area of Social Sciences was highlighted in 'Innovation Ireland, March 2010'[159] as a particular area with a key role in driving and enabling technological convergence across platforms and providing valuable contribution to the innovation ecosystem. The report 'Playing to our strengths: the role of the Arts, Humanities and Social Sciences and implications for public policy', highlights the importance of the Arts, Humanities and Social Sciences in producing a more skilled workforce and indicates that they have a key role to play in the enhancement of economic opportunity.

Key Data

- Social Sciences 2006 research-related income was 8.2 % of national total
- Social Sciences 2006 research-active staff made up 9% of national total
- Social Sciences 2006 research students represented 9.3% of the Masters and 8.5% of the PhD national total
- There was a consistent trend of high research activity across the indicators for Social Sciences 1998-2006
- Activity was distributed across a number of HEIs.
- Starting from a low base, growth in the number of social science papers produced by Irish authors has been phenomenal over the last ten years. Within Ireland, in volume terms, social science is now one of the stronger project research areas considered in this report. Share of the total world output has increased by 37% - the greatest improvement amongst any of the comparator group utilized for this study. These dramatic percentages must be interpreted in the light of publishing patterns within social sciences, where a lot of research is published in reports rather than as papers, and where patterns of research dissemination are rapidly evolving.
- Comparative citation rates for Irish social science research were well below the world average for publications produced each year since 1998, with the exception of 2005 and 2007 (Ireland was ranked 4th out of the 20 comparator nations in 2007).
- Social Sciences 2006 research graduates represented 6% of the Masters and 8.6% of the PhD national total

[158] Royal Irish Academy Report - Advancing Humanities and Social Sciences Research in Ireland, 2007

[159] Innovation Ireland – Report of the Innovation Taskforce, March 2010

21. Economics & Business

21.1 Activity Fact File – 2006

Inputs

- Total Income €36,986,000
- Government Sector (GOVERD) €9,035,000
- Higher Education Sector (HERD) €27,951,000
  - Direct Irish Exchequer Funding €4,991,000
  - Non-Irish Exchequer Funding
    - European Union (public) €2,341,000
    - Irish Private Funded €1,058,000

Research-active Staff

- HERD (FTEs) – 231
- GOVERD (FTEs) – 138

Students enrolled

- Masters Students (# in system) - 489
- PhD students (# in system) - 217

% National activity

- Economics & Business 2006 research-related income was 5.1% of national total
- Economics & Business 2006 research-active staff made up 5.8% of national total
- Economics & Business 2006 research students represented 15.4% of the Masters and 5.1% of the PhD national total

21.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Generally the trend of an increase in activity was consistent across the majority of research activity indicators.
- Research -related income (€) from 1998 to 2004 was fairly constant, followed by a large 266% increase 2004-2006. The median for the period 2004-2006 was just 19%. Overall growth for the period 1998-2006 was 293% driven largely by the rapid growth reported in 2006. The median increase 1998-2006 for the mFOS was 252%.
- There was a steady increase in reported research-active staff (FTEs) from 1998 to 2002 with a dip in 2004 followed by a substantial 118% increase thereafter in 2006. This was much larger than the mFOS median of 17% for 2004-2006. Overall there was a 108% increase 1998-2006 for this area and the mFOS median was 163% for this period.
- The number of Economics and Business Masters students appeared to be decreasing while the numbers of PhD students increased.

Distribution of Activity

- Historically activity was distributed across HEIs, however in 2006 a concentrated number of HEIs reported rapid and large increases.
- For the period 2004-2006, a number of HEIs reported a substantial increase in research-active staff including UCD and TCD (circa 220%).
- UCD research-active staff accounted for approximately a third of national total in 2006.

21.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 7,040 (13.6% of national total)[160]
- Students (# enrolled in system in 2006): 22,176 (18.8% of national total)

Undergraduate graduates (2006): 2,269 (14.4% of national total)[161]

21.4 Outputs and Outcomes

21.4.1 Results from the Forfás/HEA Bibliometric Study[162] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	81	85	143	+68%
Group Average Papers	799	941	1,142	+21%
Ireland / Group Average	0.10	0.09	0.13	+39%
Ireland rank within Group	15	18	17	increase
Ireland share of world (%)	0.46	0.41	0.56	+38%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.18 Number of Economics & Business Papers

Ireland shows strong growth (68% increase in 2007 compared with the average 2002-06) in terms of economics and business publications. This headline figure needs to be interpreted carefully however, in the context of firstly a very low baseline (only 81 papers in 1998; 85 average 2002-06), and secondly a possibly aberrant figure for 2007. Irish inputs as a share of the world total, also appears to have increased dramatically (by 38%). Were it not for the high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period. In terms of ranking by volume within the comparator group utilised for this study[163], Ireland has moved up to 17th position, ahead of the Czech Republic and Northern Ireland.

[160] Data not available for the IoTs

[161] Data not available for the IoTs

[162] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[163] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

21.4.2 Results from the Forfás/HEA Bibliometric Study[164] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.65	0.73	0.91	+25%
Group average citation impact	0.76	0.87	0.89	+3%
Ireland / Group average	0.85	0.85	1.03	+22%
Ireland rank within Group	13	14	8	increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.18 Citation Impact of Economics & Business Papers

Business research is dominated by exceptional activity and a distinctive publishing and citation culture in the USA. Irish economics and business research improved in terms of rates of citation in the period 2005 – 2007. Overall however performance is weak relative to the USA-centric world average. Publications for all years over the period 1998 – 2007 (with the exception of 2006) achieved average citation rates which were lower than the world average. Ireland's ranking within the comparator group utilised for this study has moved up to 8th, but this position reflects other poor performances relative to world average by a number of nations rather than increased strength in the Irish research.

21.4.3 Masters and PhD output[165]

- Masters Graduates (2006): 15 (3% of national total)
- PhD Graduates (1998/9): 17 (3.3% of national total)
- PhD Graduates (2006): 38 (4.1% of national total)

21.5 Other Relevant Information

Physical and supporting infrastructure

The 2007 HEA/Forfás Infrastructure Report[166] indicated that infrastructure in these disciplines is generally adequate with some notable recent investments e.g. the Kemmy Business School (UL), Geary Institute (UCD). This area also benefitted from capital investments being made to support data management facilities, and from the link between mathematics and economics/business initiatives.

[164] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[165] Data not available from the IoTs

[166] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow, 2007

Strategic developments since 2006

The challenges being faced nationally related to this mFOS, whilst also being related to the Mathematics mFOS, include shortages of suitably qualified individuals with certain high skills (particularly in areas requiring quantitative and mathematical skills, specialist taxation and legal skills, experienced accountants etc), were identified in the 'Expert Group on Future Skills Needs Report on the International Financial Services Industry, 2008'[167].

Related to this mFOS, Services innovation is also highlighted in 'Catching the Wave: A service strategy for Ireland, Services Strategy Group: Background Report Forfás , Sept 2008'[168] and in the 'Maximising the Environment for Company Research and Development, March 2010[169]' reports as an area of significant potential for driving growth in the Irish economy.

Furthermore the international financial services industry specifically has been highlighted in a number of national reports including 'Building Ireland's Smart Economy, 2008'[170], 'Innovation Ireland, March 2010'[171], and 'Knowledge Society Strategy – Technology Actions to support the Smart Economy, July 2009'[172], as a particular target area for future investment.

Key Data

- Economics & Business 2006 research-related income was 5.1 % of national total
- Economics & Business 2006 research-active staff made up 5.8% of national total
- Economics & Business 2006 research students represented 15.4% of the Masters and 5.1% of the PhD national total
- The general trend of an increase in activity was consistent across the majority of research activity indicators.
- Historically activity has been distributed across HEIs, however in 2006 a number of HEIs reported rapid and large increases.
- Ireland shows strong growth in terms of economics and business publications but this was from a very low baseline. Irish inputs as a share of the world total also appear to have increased dramatically (by 38%). Were it not for the high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period.
- Publications for all years over the period 1998 – 2007 (with the exception of 2006) achieved average citation rates which were lower than world average. Ireland's ranking within the comparator group utilised for this study has moved up to 8th, but this position reflects other poor performances relative to world average by a number of nations rather than increased strength in the Irish research.
- Economics & Business 2006 research graduates represented 3.3% of the Masters and 4.1% of the PhD national total

[167] Expert Group on Future Skills Needs Report on the International Financial Services Industry, 2008

[168] Forfas Report: Catching the Wave: A Service Strategy for Ireland, Services Strategy Group: Background Report, Sept 2008

[169] Forfas Report: Maximising the Environment for Company Research and Development, March 2010

[170] Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal, 2008

[171] Innovation Ireland – Report of the Innovation Taskforce, March 2010

[172] Knowledge Society Strategy – Technology Actions to support the Smart Economy, July 2009

22. Psychology

22.1 Activity Fact File – 2006

Inputs

- Total Income €8,999,921
- Government Sector (GOVERD) €0
- Higher Education Sector (HERD) €8,999,921
  - Direct Irish Exchequer Funding €1,685,000
  - Non-Irish Exchequer Funding
    - European Union (public) €1,211,000
    - Foreign Sources €0
    - Irish Private Funded €425,000

Research-active Staff

- HERD (FTEs) – 77
- GOVERD (FTEs) – 0

Students enrolled

- Masters Students (# in system) - 45
- PhD students (# in system) - 163

% National activity

- Psychology 2006 research-related income was 1.2 % of national total
- Psychology 2006 research-active staff made up 1.2 % of national total
- Psychology 2006 research students represented 1.4% of the Masters and 3.9% of the PhD national total

22.2 Activity – Emerging Trends (1998-2006)

Growth/decline in Activity

- Overall there has been a general increase in research activity in this field for the period 1998-2006, from what was a very low base.
- There was a steady growth in reported research-related income up to 2002 and a rapid increase thereafter. Overall growth 1998 - 2006 was 234%. The mFOS median for this period was 252%. Research-related income 2004 to 2006 dropped 13%. The mFOS median growth for this period was 19%.
- There was a steady increase (117%) in reported research-active staff (FTEs) for the period 1998 - 2006. The mFOS median for this period was 163%. Research-active FTEs were fairly constant 2004 to 2006 with a 6% increase. This was small relative to the mFOS median increase of 17% for this period.
- Masters students have remained fairly constant while PhD students have gradually been increasing for this period[173].

Distribution of Activity

- Historically activity was spread across a number of HEIs, but from 2000 TCD have consistently reported the highest absolute number of research-active staff.
- In 2006 TCD represented circa 40% of the national cohort of research-active staff in Psychology.

[173] No Masters or PhD data for this mFOS prior to 2005 but this is the trend for the period 05/06 - 07/08.

22.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): No comparable data available
- Students (# enrolled in system in 2006): 565 (0.5% of national total)

Undergraduate graduates (2006): 141 (0.9% of national total)[174]

22.4 Outputs and Outcomes

22.4.1 Results from the Forfás/HEA Bibliometric Study[175] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	84	80	133	+66%
Group Average Papers	976	1,129	1,312	+16%
Ireland / Group Average	0.09	0.07	0.10	+43%
Ireland rank within Group	12	14	14	stable
Ireland share of world (%)	0.38	0.32	0.46	+43%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.19 Number of Psychology Papers

Whilst the data above suggests a significant increase in the volume of psychology publication to 2007, this needs to be treated with care firstly because overall numbers of papers are low, and secondly because the figure for 2007 is unexpectedly high, with no increase in previous years leading up to this. Ireland's ranking within the group remains unaltered at 14th. Ireland's percentage share of world publications has risen to 0.46% which is slightly higher than the 0.4% share achieved in 2000.

Ireland's share of world psychology papers is small set against the comparator nations utilised for this study. Were it not for the relatively high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period. The Netherlands and Belgium are the only comparator countries which show a general increase in their percentage share of world publications.

[174] Data not available for the IoTs

[175] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

22.4.2 Results from the Forfás/HEA Bibliometric Study[176] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.40	0.81	1.86	+130%
Group average citation impact	0.88	0.86	1.02	+18%
Ireland / Group average	0.46	0.94	1.83	+94%
Ireland rank within Group	19	12	2	Increase

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.19 Citation Impact of Psychology Papers

The increase in citation impact, taken together with the increase in research volume this suggests that 2007 was an extremely good year for psychology research in Ireland. These data need to be interpreted with some scepticism firstly as the total volume of psychology research is quite low, secondly in case this is just a one-year peak in performance and thirdly as this good year needs to be seen in the context of generally very weak citation performance both by Ireland and its comparator nations[177]. The overall trend shows an improvement in the rate of citation of Irish psychology papers. Note however that for every year except 2007 citation rates was less than the world average.

22.4.3 Masters and PhD output178

- Masters Graduates (2006): 8 (2% of national total)
- PhD Graduates (1998/9): There is no comparable data available
- PhD Graduates (2006): 27 (2.9% of national total)

22.5 Other Relevant Information

Physical and supporting Infrastructure

The 2007 HEA/Forfás Research Infrastructures Report[179] highlights that the standard of infrastructure supporting psychology research was seriously inadequate in most instances. It also noted an absence of library provision to support this discipline. However, it may be noted that two new library investments (PRTLI Cycles 1 & 3) have significantly increased the library support provision in the HE sector.

[176] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[177] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

[178] Data not available for IoTs for this mFOS

[179] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow, 2007

Psychology is important in many aspects of modern life including in child development, education, health, work, sport and communication. It underpins the examination of societal development. In particular in the health service, for policy formation psychology is a key area of research.

Key Data

- Psychology 2006 research-related income was 1.2 % of national total
- Psychology 2006 research-active staff made up 1.2 % of national total
- Psychology 2006 research students represented 1.4% of the Masters and 3.9% of the PhD national total
- Overall there has been a general increase in research activity in this field for the period 1998-2006.
- Historically activity was spread across a number of HEIs, but from 2000 TCD have consistently reported the highest absolute number of research-active staff.
- Ireland's share of world psychology papers is small set against the comparator nations utilised for this study. Were it not for the relatively high number of papers published in 2007 Ireland's share of world outputs overall would be fairly constant over the ten year period.
- The overall trend in Psychology was for an improvement in both the volume of papers and the rate of citation, with 2007 being an extremely good year for Ireland Psychology. Given that preceding performance was generally weak, the high citation ranking of 2nd in the comparator group in 2007 needs to be interpreted with care, especially as total volume of psychology papers is quite low and for every year except 2007, citation rates was less than the world average.
- Psychology 2006 research graduates represented 1.8% of the Masters and 2.9% of the PhD national total

23. Humanities

23.1 Activity Fact File - 2006

Inputs

- Total Income €39,685,216
- Government Sector (GOVERD) €275,000
- Higher Education Sector (HERD) €39,410,216
  - Direct Irish Exchequer Funding €5,403,540
  - Non-Irish Exchequer Funding
    - European Union (public) €548,143
    - Foreign Sources €9,000
    - Irish Private Funded €4,082,000

Research-active Staff

- HERD (FTEs) – 486
- GOVERD (FTEs) – 1

Students enrolled

- Masters Students (# in system) - 570
- PhD students (# in system) - 773

% National activity

- Humanities 2006 research-related income was 5.5 % of national total
- Humanities 2006 research-active staff made up 7.6 % of national total
- Humanities 2006 research students represented 18% of the Masters and 18.3% of the PhD national total

23.2 Activity - Emerging Trends (1998-2006)

Growth/decline in Activity

- Overall there was a consistent high level of research activity in this field for the period 1998-2006.
- There was growth year on year in research-related income. Overall from 1998 to 2006 there was a 238% increase. The mFOS median for this period was 252%. Research-related income grew by 14% over the period 2004 to 2006. This was in the range of the 19% mFOS median for this period
- There was a 53% increase in research-active staff (FTEs) from 1998 to 2006. The mFOS median was 163%. From 2004 to 2006 research-active staff in this area grew 12%, in line with the mFOS median of 17% for this period.
- There was a consistently high number of Masters students during this period. Starting from a high baseline, there was a gradual increase in PhD numbers over this period.

Distribution of Activity

- Activity was spread across HEIs
- NIUG reported a circa 220% increase in research-active staff over this period and accounted for 22% of the national cohort in 2006.
- UCD also accounted for circa 20% of the national cohort research-active staff in this area in 2006.

23.3 Underpinning Factors

Undergraduate pipeline:

- Students (# enrolled in system in 1998/9): 14,189 (27.5% of national total)
- Students (# enrolled in system in 2006): 22,088 (18.7% of national total)

Undergraduate graduates (2006): 4327 (27.5% of national total)[180]

[180] Data was not available for the IoTs for this mFOS

23.4 Outputs and Outcomes

23.4.1 Results from the Forfás/HEA Bibliometric Study[181] (Volume)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland Papers	132	127	128	+1%
Group Average Papers	937	995	1,022	+3%
Ireland / Group Average	0.14	0.13	0.13	-2%
Ireland rank within Group	10	12	11	Increase
Ireland share of world (%)	0.54	0.49	0.49	-1%

Source Data & analysis: Evidence, Thomson Reuters, Table 1.03.20 Number of Humanities Papers

The number of humanities papers published by Irish authors has remained pretty much constant over the last ten years. Ireland was ranked 11th, by output volume, in the comparator group in 2007 which represents the highest output volume ranking for all of the 19mFOS. Ireland's high volume ranking within the comparator group[182] utilised for this study must be seen in the light of countries with relatively large research capacity (e.g. India, Brazil) which publish virtually no humanities research. These data should also be interpreted with care as in the humanities (and also for example in the performing arts) a high proportion of research outputs are in the form of books, chapters in books or non-publication formats. Ireland's share of the world's humanities papers has remained at about 0.5% over the last ten years. Ireland's performance is very much on a par with a number of comparator countries – New Zealand, Denmark, Sweden and Finland.

23.4.2 Results from the Forfás/HEA Bibliometric Study[183] (Citation Impact)

	Original value (1998)	Recent Average (2002-2006)	Current Value (2007)	Current relative to Recent
Ireland citation impact	0.22	0.77	0.41	-47%
Group average citation impact	1.02	1.03	0.84	-19%
Ireland / Group average	0.22	0.75	0.49	-35%
Ireland rank within Group	19	15	15	Stable

Source Data & analysis: Evidence, Thomson Reuters, Table 1.07.20 Citation Impact of Humanities Papers

[181] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

[182] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea

[183] Research strengths in Ireland: a bibliometric study of the public research base (Forfás/HEA 2007).

Irish humanities research is generally cited at a low level relative to world average. Ireland is 15th in the rankings for citation impact, better only than Brazil, India and Singapore (countries with poor performance in these disciplines). These results need to be interpreted with care, however, as the volume of humanities research is fairly low relative to other fields in Ireland, and research dissemination in the humanities often focuses on books and monographs rather than research papers

23.4.3 Masters and PhD output[184]

- Masters Graduates (2006): 49 (11% of national total)
- PhD Graduates (1998/9): 106 (20.6% of national total)
- PhD Graduates (2006): 122 (13.3% of national total)

23.5 Other Relevant Information

Physical and supporting infrastructure

The quality of the infrastructure across the humanities sector is somewhat varied with some significant investments delivering fit-for-purposes modern infrastructure. However, some not fit for purposes facilities still exist. In particular, major investment focused on improving the library facilities providing essential research resource for the humanities community. In addition, there was also significant investment in the provision of dedicated fit-for-purpose accommodation (e.g. the Humanities Institute of Ireland (UCD); Moore Institute (NUIG)).

There was some investment in digitization facilities during 1998-2006. However, the 2007 HEA/Forfás Research Infrastructures Report[185] notes that these investments often related to independent and unconnected activities. Since 2006, investment in this area has focused on coordinating and consolidating the various digitisation initiatives in humanities (notably with the establishment of the Digital Humanities Observatory under PRTLI Cycle 4, which will enable engagement in pan-European research infrastructures).

Strategic developments since 2006

The Humanities is an expansive field of Science spanning numerous subcategories and supporting a range of strategic areas. HSS research is a prerequisite for making informed policy choices in areas that impinge crucially on quality of life as highlighted in 'Advancing Humanities and Social Sciences Research in Ireland, RIA 2007'. With the development of new technologies, the HSS also have an ever-growing role in the preservation of Ireland's unique resources (libraries, museums and archives), thus ensuring that Ireland's cultural heritage is recorded and maintained for posterity. This point is highlighted in the Arts Council report of 2008 'Point of Alignment'[186].

[184] This does not include data from the IoTs

[185] HEA/Forfas Research Infrastructure in Ireland – Building for Tomorrow, 2007

[186] Arts Council - 'Point of Alignment' Report, 2008

The arts culture, creative industry and film/media have been highlighted in a number of national reports including 'Building Ireland's Smart Economy, 2008'[187], 'Knowledge Society Strategy – Technology Actions to support the Smart Economy, July 2009'[188], 'Skills in Creativity Design and Innovation, Forfás 2009'[189], and 'Innovation Ireland, March 2010'[190], as particular areas which have a key role in driving and enabling technological convergence across platforms and providing valuable contribution to the innovation ecosystem.

The report 'Playing to our strengths: the role of the Arts, Humanities and Social Sciences and implications for public policy', highlights the importance of the Arts, Humanities and Social Sciences in producing a more skilled workforce and indicates that they have a key role to play in the enhancement of economic opportunity.

Key Data

- Humanities 2006 research-related income was 5.5 % of national total
- Humanities 2006 research-active staff made up 7.6 % of national total
- Humanities 2006 research students represented 18% of the Masters and 18.3% of the PhD national total
- Overall there was a consistent high level of research activity in this field for the period 1998-2006.
- Activity was spread across HEIs
- The number of humanities papers published by Irish authors has remained pretty much constant over the last ten years. in 2007, Ireland was ranked 11^{th,} by output volume, in the comparator group which represents the highest output volume ranking for all of the 19mFOS. Ireland's high volume ranking within the comparator group[191] utilised for this study must be seen in the light of countries with relatively large research capacity (e.g. India, Brazil) which publish virtually no humanities research. Ireland's share of world papers is very much on a par with a number of comparator countries – New Zealand, Denmark, Sweden and Finland.
- Irish humanities research is generally cited at a low level relative to world average. These results need to be interpreted with care, however, as the total volume of humanities research is fairly low relative to other fields in Ireland, and research dissemination in the humanities often focuses on books and monographs rather than research papers.
- Humanities 2006 research graduates represented 10.9% of the Masters and 13.3% of the PhD national total

[187] Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal, 2008

[188] Knowledge Society Strategy – Technology Actions to Support the Smart Economy, July 2009

[189] Forfas Report - Skills in Creativity Design and Innovation, 2009

[190] 'Innovation Ireland – Report of the Innovation Taskforce, March 2010'

[191] An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea

Annex 1. Methodology

The data used was not originally intended for this purpose and there have been a number of changes in the data collection process during this time period. In 2006, Higher Education Research & Development (HERD) data was collected in both the old and new OECD format and this was the last year that all data sets were available. This provided a natural point at which to conclude this first fundamental analysis and as such this statement consists of a profile of the public research activity up to 2006. For some activity measures more recent data was available (Bibliometric and Student data), and this was presented where relevant.

Source Data

Activity Fact File - 2006[192]

1. Financial input and staff information on the Government Sector was taken from the Forfás Government Research and Development (GOVERD) 2006 survey[193] and aggregated into the 19 mFOS.
2. Financial input and staff information on the Higher Education Sector was taken from the Forfás Higher Education Research and Development (HERD) 2006 survey[194] and aggregated into the 19 mFOS. Full-time equivalent (FTE) research-active staff was calculated as HERD research personnel FTE minus administration staff FTE.
3. Full-time student enrolment information was taken from HEA student records[195] and the Department of Education and Skills (DES)[196] and mapped onto the 19 mFOS (see note on Student data below).
4. National Activity for research-related income and research-active staff was calculated as the sum of the 2006 GOVERD and HERD data for each mFOS. % national activity is where mFOS data for an indicator is expressed as a % of the national activity indicator total. For research students, the % represents the approximate proportion of the total national student population for the academic year 2005/06.
5. The 19 mFOS profiles do not add up to the overall 2006 total for GOVERD, HERD or the total student population as (i) there are 'other' categories in the OECD revised FOS which it was not possible to aggregate into the 19mFOS. (ii) a small number of categories where errors were returned in the original survey meant that data could not be included in a revised FOS and therefore was not aggregated into the 19mFOS. As a result, the % national activity indicators from the 19 mFOS profiles do not add up to 100%.

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[192] For 'Activity Fact File – 2006', all data was categorised according to the OECD revised minor FOS. See Annex A2 for a table listing the OECD revised FOS categories that were aggregated into the 19 mFOS. See Annex A6 for source data for the Activity Fact File – 2006.

[193] Forfás Government Research and Development (GOVERD) 2006 survey. See Annex A7 for a table of sources.

[194] Forfás Higher Education Research and Development (HERD) 2006 survey. See Annex A7 for a table of sources.

[195] http://www.hea.ie/en/statistics

[196] IoT data pre 2007

Activity- Emerging Trends (1998-2006)[197]

1. Financial input and staff information on the Higher Education Sector was based on Forfás Higher Education Research and Development (HERD) survey's 1998 – 2006 and input from the Higher Education Institutions (HEIs). The OECD original FOS classification was used in earlier survey's to collect data and the 2006 data was available by both the original and revised FOS classification. To facilitate comparison across years, the OECD original FOS classification was used for all years, including 2006, and mapped onto the 19 mFOS in the trend analysis. This means that for some of the 19 mFOS there was no trend analysis because data for these fields was not available under the OECD original FOS classification (i.e. Biotechnology, Nanotechnology and Mechanical Engineering). There were two categories where data was collected together in a combined category in the OECD original FOS classification (i.e. Computer & Information Science and Mathematics).
2. Full-time equivalent (FTE) research-active staff was calculated as FTE research personnel minus FTE administration staff.
3. To give an indication of the general trend in research-related income and research-active staff activity across the years, the percentage difference between 1998 and 2006 was calculated and presented for each mFOS.
4. Full-time student enrolment data was taken from HEA student records[198] and the Department of Education and Skills (DES)[199] and mapped onto the 19 mFOS (see note on Student data below).
5. Comments on the distribution of activity were based on the above data. The aim was to broadly indicate mFOS where activity was distributed, compared to mFOS where activity was concentrated. Research-active staff was used as the key indicator of research activity in preference to research-related income[200]. Where relevant, exceptions to the normal pattern were indicated. For 2006, where the % of national cohort FTE exceeded circa 20% for a given mFOS, this was reported.

Underpinning Factors[201]

1. Full-time undergraduate student enrolment data was taken from HEA student records[202] and the Department of Education and Skills (DES)[203] and mapped onto the 19 mFOS (see note on Student data below).
2. Undergraduate student data was taken from HEA student records and mapped onto the 19 mFOS. There was no graduate data available for the IoTs (see note on Student data below).

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[197] For 'Activity-Emerging Trends (1998-2006)', all data was categorised according to the OECD original minor FOS. See Annex A2 for a table showing how the OECD original minor FOS categories were mapped onto the 19 mFOS. See Annex A8 and Annex A9 for source data for the 'Activity-Emerging Trends (1998-2006)'.

[198] http://www.hea.ie/en/statistics

[199] IoT data pre 2007

[200] The amount of research-related income reported was not a reliable indicator of research activity in a given year as it included income associated with capital infrastructure.

[201] See Annex A10 for source data for 'Underpinning Factors'

[202] http://www.hea.ie/en/statistics

[203] IoT data pre 2007

Outputs and Outcomes - Results from the Forfás/HEA Bibliometric Study

The Bibliometric commentary is taken from the Forfás/HEA Research strengths in Ireland: a bibliometric study of the public research base, 2009 report[204]. The data sources used were the Thomson Reuters databases[205] and a ten year period of time was used for the analysis (1998-2007).

The Bibliometric analysis reported the volume of Irish publications and the rates of citation. The rate of citation can be used as a proxy indicator for research quality as a high rate of citation is generally agreed to be associated with other measures of research excellence. However bibliometric impact is a weak indicator of performance in some fields of science (i.e. engineering research, social sciences and humanities) where communication of research outcomes to users may be through other avenues (e.g. professional media, monographs). As such, the bibliometric analysis is to be interpreted in conjunction with other measures of activity such as research-active staff, the number of research students and research-related income.

An international comparator group of 20 geographical entities was used including: Ireland, USA, UK, Belgium, Denmark, Finland, Netherlands, Portugal, Sweden, Czech Republic, EU27 group, Northern Ireland, Scotland, Australia, Brazil, China, India, New Zealand, Singapore and South Korea.

Outputs and Outcomes – Masters and PhD graduates[206]

Graduate student data was taken from HEA student records[207] and mapped onto the 19 mFOS (see note on Student data below). There was no graduate data available for the IoTs (see note on Student data below).

Other relevant information

1. This includes a brief summary of where physical and supporting Infrastructure has been put in place which enables research activity in a particular mFOS.
2. Strategic developments since 2006 – this represents a summary of the recent relevant policy reports that have indicated potential directions and impacts for the mFOS in the future.
3. Key data – this is a summary of the key data from the mFOS Activity and Output profiles.

Student Data

1. Historically, the HEA collected student data from the universities and some colleges[208] and up until 2006 the Department of Education and Science (DES) collected student data from the Institutes of Technology (IoTs). From 2007 onwards, the HEA has collected student data from all Higher Education Providers.

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[204] Research strengths in Ireland: a bibliometric study of the public research base.

[205] See Annex A11 for a table listing the Thomson Reuters journal categories mapped against the mFOS

[206] See Annex A12 for source data for 'Outputs and Outcomes – Masters and PhD Graduates'

[207] http://www.hea.ie/en/statistics

[208] DCU, Mater Dei, MIC, NCAD, NUIG, NUIM, RCSI, SPD, TCD, UCC, UCD, UL

2. Student data was collected by the International Standard Classification of Education (ISCED) codes[209]. Level 3 ISCED codes were mapped onto the 19 mFOS using the OECD revised FOS classification[210].
3. In earlier years, student data was collected under level 1 or level 2 ISCED codes which contained a smaller number of broader categories, therefore it was not possible to extract out student data for some of the 19 mFOS in the earlier years (i.e. Psychology, Biotechnology, Mechanical Engineering, Electrical Engineering, Chemical Sciences, Earth & Environmental Sciences, Mathematics, Material and Physical Sciences, Biological Sciences, Clinical Medicine).
4. In the 'Activity – Emerging Trends (1998-2006)' section, the Computer and Information Science student data was presented in combination with the Mathematics student data, in keeping with the trend data available.
5. There was no nanotechnology student data available for any time period
6. For the academic year 1998/9 and 2006/07 there was no IoT student data available. Dublin Institute of Technology was the exception, as 2006/07 data was available but no 1998/9 data.
7. The Masters data represented full-time Research Masters students for all institutions, except the IoTs for which the Masters data represented the combined Taught and Research Masters students[211].
8. The student enrolment data represented full-time student enrolments.
9. The graduate student data represented all students graduating in a given calendar year, regardless of how they obtained their degree (i.e. full-time study or part-time study).
10. There was no graduate student data available for the IoTs over the period.
11. The 19 mFOS do not add up to the overall total student population as there were a number of ISCED combined categories that encompass several of the 19mFOS and these couldn't be separated out. Such combined categories were left separate and were not included in the 19mFOS. Where appropriate, they are referenced in the relevant mFOS profiles. As a result, the % national activity indicators from the 19mFOS do not add up to 100%.

[209] http://www.hea.ie/en/node/1162

[210] See Annex A5 for mapping of Level 3 ISCED codes onto the 19 mFOS.

[211] Separate Research and Taught Masters data was available for the IoTs for the academic year 2007/08 but not for earlier years.

Annex 2. OECD FOS Categories

OECD Original FOS (FOS in FM 2002) Versus OECD Revised FOS Categories

COMPARISON OF THE REVISED FOS CLASSIFICATION WITH THAT IN FM 2002

	FOS in FM 2002	Revised FOS
1. Natural Sciences	1.1 Mathematics and computer sciences 1.2 Physical sciences 1.3 Chemical sciences 1.4 Earth and related environmental sciences 1.5 Biological sciences	1.1 Mathematics 1.2 Computer and information sciences 1.3 Physical sciences 1.4 Chemical sciences 1.5 Earth and related environmental sciences 1.6 Biological sciences 1.7 Other natural sciences
2. Engineering and Technology	2.1 Civil engineering 2.2 Electrical engineering, electronics 2.3 Other engineering sciences	2.1 Civil engineering 2.2 Electrical engineering, electronic engineering, information engineering 2.3 Mechanical engineering 2.4 Chemical engineering 2.5 Materials engineering 2.6 Medical engineering 2.7 Environmental engineering 2.8 Environmental biotechnology 2.9 Industrial Biotechnology 2.10 Nano-technology 2.11 Other engineering and technologies
3. Medical and Health Sciences	3.1 Basic medicine 3.2 Clinical medicine 3.3 Health sciences	3.1 Basic medicine 3.2 Clinical medicine 3.3 Health sciences 3.4 Health biotechnology 3.5 Other medical sciences
4. Agricultural Sciences	4.1 Agriculture, forestry, fisheries and allied sciences 4.2 Veterinary medicine	4.1 Agriculture, forestry, and fisheries 4.2 Animal and dairy science 4.3 Veterinary science 4.4 Agricultural biotechnology 4.5 Other agricultural sciences
5. Social Sciences	5.1 Psychology 5.2 Economics 5.3 Educational sciences 5.4 Other social sciences	5.1 Psychology 5.2 Economics and business 5.3 Educational sciences 5.3 Sociology 5.5 Law 5.6 Political Science 5.7 Social and economic geography 5.8 Media and communications 5.7 Other social sciences
6. Humanities	6.1 History 6.2 Languages and literature 6.3 Other humanities	6.1 History and archaeology 6.2 Languages and literature 6.3 Philosophy, ethics and religion 6.4 Art (arts, history of arts, performing arts, music) 6.5 Other humanities

The first column indicates the six major fields. The original Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS) classification was updated in 2007 to reflect the emergence of new technology fields in particular ICT, biotechnology and nanotechnology. The second column indicates the original minor field classification. The third column indicates the revised classification of the minor fields. Further details of the OECD FOS classification in the Frascati Manual can be found at http://www.oecd.org/dataoecd/36/44/38235147.pdf

Table listing the OECD revised FOS Categories that were aggregated into the 19 mFOS (OECD revised FOS code in brackets)

Mathematics (1.1)	
Computer & Information Sciences (1.2)	
Chemical sciences (1.4)	
Biological sciences (1.6)	
Earth & Environment Science	Earth and related environmental sciences (1.5)
	Environmental engineering (2.7)
Material Science	Physical sciences (1.3)
	Materials engineering (2.5)
Civil engineering (2.1)	
Electrical engineering, electronic engineering, information engineering (2.2)	
Mechanical engineering (2.3)	
Biotechnology	Chemical engineering (2.4)
	Medical engineering (2.6)
	Environmental biotechnology (2.8)
	Industrial Biotechnology (2.9)
	Health biotechnology (3.4)
Ag. Biotechnology and engineering (including Food) (4.4 & 2.11)	
Nano-technology (2.10)	
Pre Clinical & Health	Basic medicine (3.1)
	Health Sciences (3.3)
Clinical Medicine (3.2)	
Agricultural Sciences (4) (excluding 4.4)	
Social Sciences (5) (excluding 5.1 & 5.2)	
Psychology (5.1)	
Economics and business (5.2)	
Humanities (6)	

Table showing how the OECD original FOS categories were mapped onto the 19 mFOS (OECD original FOS in FM 2002 code in brackets)

Clinical Medicine (3.2)	
Pre Clinical & Health	Basic medicine (3.1)
	Health Sciences (3.3)
Biological sciences (1.5)	
Ag. Biotechnology & engineering (including Food)	Other engineering sciences (2.3)
Agricultural Sciences	Agriculture, forestry, fisheries, and allied sciences (4.1)
	Veterinary medicine (4.2)
Earth & Environment Science	Earth and related environmental sciences (1.4)
Mathematics	Mathematics and Computer sciences (1.1)
Computer & Information Sciences	
Physics & Materials Sciences	Physical sciences (1.2)
Chemical sciences (1.3)	
Civil engineering (2.1)	
Electrical engineering, electronic engineering, information engineering	Electrical engineering, electronics (2.2)
Social Sciences	Educational sciences (5.3)
	Other social sciences (5.4)
Economics and business	Economics (5.2)
Psychology (5.1)	
Humanities	History (6.1)
	Languages and literature (6.2)
	Other humanities (6.3)

Annex 3. Glossary of Terms

Public Research Base

For the purpose of this study, the public research base was understood to comprise higher-education institutions (HEIs)and other public research organisations (PROs) such as Teagasc.

Original FOS

The original Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS) prior to updating in 2007.

Revised FOS

The revised Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS) after updating in 2007.

Modified FOS

The resulting Fields of Science and Technology (FOS) after aggregation of the revised Organisation for Economic Co-operation and Development (OECD) system of Fields of Science (FOS) into 19 modified FOS categories for the purposes of this mapping study.

Government Sector (GOVERD)

This represented income for R&D performed in the State sector as reported in the Forfás Government Research and Development (GOVERD) survey.

Higher Education Sector (HERD)

This represented income for R&D performed in the higher education sector as reported in the Forfás Higher Education Research and Development (HERD) survey.

Direct Irish Exchequer Funding

This represented direct funding for higher education R&D programmes from the Irish exchequer as reported in the Forfás Higher Education Research and Development (HERD) survey. Direct government funding of individual research projects in the higher education sector comes through various government departments and their agencies. Indirect R&D government funding is that reported to be sourced from the Higher Education Authority (HEA) block grant.

Research-Related Income

This represented reported 'research-related' income in a given year and was not used as a direct measure of research activity for that year as it included income associated with capital infrastructure. Research-related income is not directly linked to the number of research-active staff.

Full-time Equivalent (FTE)

From Frascati Manual OECD 2002:

"One FTE may be thought of as one person-year. Thus, a person who normally spends 30% of his/her time on R&D and the rest on other activities (such as teaching, university administration and student counselling) should be considered as 0.3 FTE. Similarly, if a full-time R&D worker is employed at an R&D unit for only six months, this results in an FTE of 0.5. Since the normal working day (period) may differ from sector to sector and even from institution to institution, it is not meaningful to express FTE in person-hours."

Research-Active Staff

This represented the number of reported full-time equivalent (FTE) 'research-active' staff and did not reflect the total number of staff employed in a specific year. For the purposes of this study, full-time equivalent (FTE) research-active staff was calculated as the Forfás Higher Education Research and Development (HERD) survey research personnel FTE minus administration staff FTE.

Students enrolled

This was the total number of students enrolled in an academic year (i.e. 2005/06 = students enrolled as at 1st March 2006) and included all students (e.g. those in their 1st, 2nd, 3rd … years of study)

Graduates

This was the number of undergraduate students graduating in the calendar year 2006 (i.e. number of students that graduated as at December 2006)

Annex 4. List of Acronyms

AIT	Athlone Institute of Technology
CIT	Cork Institute of Technology
CMOS	Complementary metal-oxide-semiconductor
CRANN	Centre for Research on Adaptive Nanostructures and Nanodevices
DAFF	Department of Agriculture, Fisheries and Food
DCENR	Department of Communications, Energy and Natural Resources
DCU	Dublin City University
DES	Department of Education and Skills
DIAS	Dublin Institute for Advanced Studies
DIT	Dublin Institute of Technology
DKIT	Dundalk Institute of Technology
EI	Enteprise Ireland
E-INIS	e-Irish National Infra-Structure
EPA	Environmental Protection Agency
ERI	Environmental Research Institute
ESFRI	European Strategy Forum on Research Infrastructures
ESS	European Social Survey
FDI	Foreign Direct Investment
Forfás	Ireland's National Policy Advisory Board for Enterprise and Science
FOS	Field of Science
FTE	Full-time equivalent
GMIT	Galway Mayo Institute of Technology
GMP	Good Manufacturing Process
GOVERD	Research and Development in the Government Sector
HE	Higher Education
HEA	Higher Education Authority
HEI	Higher Education Institution

HERD	Research and Development in the Higher Education Sector
HMRC	Hydraulics and Maritime Research Centre
HRB	Health Research Board
HSE	Health Service Executive
HSS	Humanities and Social Sciences
ICHEC	Irish Centre for High End Computing
ICSC	International Content Services Centre
ICT	Information and Communication Technologies
IDA	Ireland's inward investment promotion agency
IFSC	International Financial Services Centre
INSPIRE	Integrated NanoScience Platform for Ireland
IoT	Institute of Technology
IRCHSS	Irish Research Council for the Humanities and Social Sciences
ISCED	International Standard Classification of Education
ITB	Institute of Technology Blanchardstown
ITC	Institute of Technology Carlow
ITS	Institute of Technology Sligo
ITT	Institute of Technology Tallaght
ITTralee	Institute of Technology Tralee
LIT	Limerick Institute of Technology
LYIT	Letterkenny Institute of Technology
MIC	Mary Immaculate College
mFOS	Modified field of science
NACE	Statistical Classification of Economic Activities in the European Community
NCAD	National College of Art and Design
NCSR	National Centre for Sensor Research
NIBRT	National Institute for Bioprocessing Research and Training
NMRC	National Microelectronics Research Centre
NSAFP	National SpR/SR Academic Fellowship Programme
NUIG	National University of Ireland, Galway
NUIM	National University of Ireland, Maynooth
MMI	Molecular Medicine Ireland

OECD	Organisation for Economic Co-operation and Development
REMEDI	Regenerative Medicine Institute
PRACE	Partnership for Advanced computing Europe
PRO	Public research organisation
PRTLI	Programme for Research in Third Level Institutions
RCSI	Royal College of Surgeons in Ireland
RIA	Royal Irish Academy
SPD	St. Patricks College Drumcondra
SFI	Science Foundation Ireland
TCD	Trinity College Dublin
Teagasc	The Irish Agriculture and Food Development Authority
TYNDALL	The Tyndall national institute
UCC	University College Cork
UCD	University College Dublin
UL	University of Limerick
WIT	Waterford Institute of Technology

Annex 5. ISCED level 3 codes mapped onto the mFOS

Level 3 ISCED codes mapped onto the OECD revised FOS categories and aggregated into the 19 mFOS (OECD revised FOS code in brackets)

Field of Study (ISCED) Level 3	Field of Science - mFOS for Mapping Study
General Programmes	
Basic / broad general programmes*(010)	Basic / broad general programmes*(010)
Literacy and numeracy(080)	Literacy and numeracy(080)
Personal skills(090)	Personal skills(090)
Education Science	**Social Sciences**
Education science(142)	Social Sciences (5) (excluding 5.1 & 5.2)
Training for pre-school teachers(143)	Social Sciences (5) (excluding 5.1 & 5.2)
Training for teachers at basic levels(144)	Social Sciences (5) (excluding 5.1 & 5.2)
Training for teachers with subject specialisation(145)	Social Sciences (5) (excluding 5.1 & 5.2)
Training for teachers of vocational subjects(146)	Social Sciences (5) (excluding 5.1 & 5.2)
Humanities and Arts	**Humanities**
Combined Arts & Humanities(200)	Humanities (6)
Combined Arts(210)	Humanities (6)
Fine arts(211)	Humanities (6)
Music and performing arts(212)	Humanities (6)
Audio-visual techniques and media production(213)	Humanities (6)
Design(214)	Humanities (6)
Craft skills(215)	Humanities (6)
Combined Humanities(220)	Humanities (6)
Religion(221)	Humanities (6)
Foreign languages(222)	Humanities (6)
Mother tongue(223)	Humanities (6)
History and archaeology(225)	Humanities (6)
Philosophy and ethics(226)	Humanities (6)

Field of Study (ISCED) Level 3	Field of Science - mFOS for Mapping Study
Social Science, Business and Law	**Social Sciences**
Combined Social Science, Business and Law(300)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined Social and behavioural science(310)	Social Sciences (5) (excluding 5.1 & 5.2)
Psychology(311)	Psychology (5.1)
Sociology and cultural studies(312)	Social Sciences (5) (excluding 5.1 & 5.2)
Political Science and civics(313)	Social Sciences (5) (excluding 5.1 & 5.2)
Economics(314)	Economics and Business (5.2)
Combined Journalism and Information(320)	Social Sciences (5) (excluding 5.1 & 5.2)
Journalism and reporting(321)	Social Sciences (5) (excluding 5.1 & 5.2)
Library, information, archive(322)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined Business and Administration(340)	Economics and Business (5.2)
Wholesale and retail sales(341)	Economics and Business (5.2)
Marketing and advertising(342)	Economics and Business (5.2)
Finance, banking, insurance(343)	Economics and Business (5.2)
Accounting and taxation(344)	Economics and Business (5.2)
Management and administration(345)	Economics and Business (5.2)
Secretarial and office work(346)	Economics and Business (5.2)
Working life(347)	Social Sciences (5) (excluding 5.1 & 5.2)
Law(380)	Social Sciences (5) (excluding 5.1 & 5.2)
Science	**Natural Sciences**
Combined Science, Mathematics and Computing(400)	Combined Science, Mathematics and Computing(400)
Combined Life Science(420)	Biological Sciences (1.6)
Biology and biochemistry(421)	Biological Sciences (1.6)
Environmental Science(422)	Earth and related Environmental Sciences (1.5), (2.7)
Combined Physical Science(440)	Material Science (1.3), (2.5)
Physics(441)	Material Science (1.3), (2.5)
Chemistry(442)	Chemical Sciences(1.4)
Earth Science(443)	Earth and related Environmental Sciences (1.5), (2.7)
Combined Maths and Statistics(460)	Mathematics(1.1)

Field of Study (ISCED) Level 3	Field of Science - mFOS for Mapping Study
Mathematics(461)	Mathematics(1.1)
Statistics(462)	Mathematics(1.1)
Computer Science(481)	Computer & Information Sciences(1.2)
Computer Use(482)	Computer & Information Sciences(1.2)
Engineering, Manufacturing, Construction	**Engineering and Technology**
Combined Engineering, Manufacturing and Construction(500)	Combined Engineering, Manufacturing and Construction(500)
Combined Engineering & Engineering Trades(520)	Combined Engineering & Engineering Trades(520)
Mechanics and metal work(521)	Mechanical Engineering (2.3)
Electricity and energy(522)	Electrical engineering, electronic engineering, information engineering (2.2)
Electronics and automation(523)	Electrical engineering, electronic engineering, information engineering (2.2)
Chemical and process(524)	Biotechnology(2.4),(2.6),(2.8),(2.9),(3.4)
Motor vehicles, ships and aircraft(525)	Civil Engineering (2.1)
Combined Manufacturing and Processing(540)	Agricultural Biotech/Engineering (incl Food and Beverage Science) (4.4 & 2.11)
Food processing(541)	Agricultural Biotech/Engineering (incl Food and Beverage Science) (4.4 & 2.11)
Textiles, clothes, footwear, leather(542)	Material Science (1.3), (2.5)
Materials (wood, paper, plastic, glass)(543)	Material Science (1.3), (2.5)
Mining and extraction(544)	Earth and related Environmental Sciences (1.5), (2.7)
Combined Architecture and building(580)	Civil Engineering (2.1)
Architecture and town planning(581)	Civil Engineering (2.1)
Building and civil engineering(582)	Civil Engineering (2.1)
Agriculture and Veterinary	**Agricultural Sciences**
Combined Agriculture & Veterinary(600)	Agricultural Science (4) (excluding 4.4)
Combined Agriculture, forestry and fishery(620)	Agricultural Science (4) (excluding 4.4)
Crop and livestock production(621)	Agricultural Science (4) (excluding 4.4)
Horticulture(622)	Agricultural Science (4) (excluding 4.4)
Forestry(623)	Agricultural Science (4) (excluding 4.4)
Fisheries(624)	Agricultural Science (4) (excluding 4.4)

Field of Study (ISCED) Level 3	Field of Science - mFOS for Mapping Study
Veterinary(641)	Agricultural Science (4) (excluding 4.4)
Health and Welfare	**Medical and Health Sciences**
Combined Health and Welfare(700)	Pre and Health Clinical (3.1), (3.3)
Combined Health(720)	Pre and Health Clinical (3.1), (3.3)
Medicine(721)	Clinical Medicine (3.2)
Nursing and caring(723)	Pre and Health Clinical (3.1), (3.3)
Dental Studies(724)	Clinical Medicine (3.2)
Medical diagnostic and treatment technology(725)	Biotechnology(2.4),(2.6),(2.8),(2.9),(3.4)
Therapy and Rehabilitation(726)	Pre and Health Clinical (3.1), (3.3)
Pharmacy(727)	Pre and Health Clinical (3.1), (3.3)
Combined Social Services(760)	Pre and Health Clinical (3.1), (3.3)
Child Care and youth services(761)	Pre and Health Clinical (3.1), (3.3)
Social work and counselling(762)	Pre and Health Clinical (3.1), (3.3)
Services	**Social Sciences**
Combined Services(800)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined Personal Services(810)	Social Sciences (5) (excluding 5.1 & 5.2)
Hotel, restaurant and catering(811)	Social Sciences (5) (excluding 5.1 & 5.2)
Travel, tourism and leisure(812)	Social Sciences (5) (excluding 5.1 & 5.2)
Sports(813)	Social Sciences (5) (excluding 5.1 & 5.2)
Domestic services(814)	Social Sciences (5) (excluding 5.1 & 5.2)
Hair and beauty services(815)	Social Sciences (5) (excluding 5.1 & 5.2)
Transport services(840)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined Environmental Protection(850)	Social Sciences (5) (excluding 5.1 & 5.2)
Environmental protection technology(851)	Social Sciences (5) (excluding 5.1 & 5.2)
Natural environments and wildlife(852)	Social Sciences (5) (excluding 5.1 & 5.2)
Community sanitation services(853)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined Security Services(860)	Social Sciences (5) (excluding 5.1 & 5.2)
Protection of persons and property(861)	Social Sciences (5) (excluding 5.1 & 5.2)
Occupational health and safety(862)	Social Sciences (5) (excluding 5.1 & 5.2)

Field of Study (ISCED) Level 3	Field of Science - mFOS for Mapping Study
Military and defence(863)	Social Sciences (5) (excluding 5.1 & 5.2)
Combined	
Balanced Combination across difference Fields of Education(900)	Balanced Combination across difference Fields of Education(900)
Balanced Combination of 'Humanities/Arts' and 'Social Sciences Business/Law'(910)	Balanced Combination of 'Humanities/Arts' and 'Social Sciences Business/Law'(910)

	Field of science level 1 (FOS L1)
Field of study	Field of science level 2 (FOS L2)- aggregated
	Combined courses that can't be categorised

Annex 6. Activity Fact File data - revised FOS into mFOS

Table 1: Number of research-active staff, students and research-related income in 2006 per mFOS

mFOS	Research-Active Staff (HERD FTEs)	Research-Active Staff (GOVERD FTEs)	Masters enrolled Students	PhD enrolled Students	Research-Related Income (HERD €)	Research-Related Income (GOVERD €)
Clinical Medicine	292	0	77	214	29,729,720	0
Pre-Clinical & Health	638	32	160	74	78,923,670	3,516,000
Biological Sciences	352	78	278	498	40,900,130	6,575,000
Biotechnology	502	19	14	47	34,750,982	0
Agricultural Biotechnology & Engineering	46	0	19	19	8,310,000	0
Agricultural Sciences	141	670	73	83	15,851,533	72,219,000
Earth & Environment Sciences	147	128	29	89	22,155,749	19,201,000
Mathematics	171	0	38	97	18,922,820	0
Physics & Materials Sciences	332	64	123	176	33,660,840	2,986,000
Chemical Sciences	217	0	97	205	22,315,000	0
Nano-technology	173	0	NA	NA	30,726,000	0
Computer & Information Sciences	298	35	262	380	29,162,000	2,091,000
Civil Engineering	98	1	117	90	7,124,000	54,000
Electrical, Electronic, Information Eng.	281	0	138	152	31,961,184	0
Mechanical Engineering	116	0	25	21	14,847,400	0
Social Sciences	493	83	295	359	54,887,565	3,996,000
Economics and Business	231	138	489	217	27,951,000	9,035,000
Psychology	77	0	45	163	8,999,921	0
Humanities	486	1	570	773	39,410,216	275,000
Sum of Other Categories	23	0	296	567	50,317,670	0

Source: Forfás Higher Education Research and Development (HERD) 2006 survey; Forfás Government Research and Development (GOVERD) 2006 survey; Higher Education Authority (HEA) student statistics, http://www.hea.ie/en/statistics, Department of Education and Skills (DES) student data for the Institutes of Technology (IoTs)

Annex 7. Research and Development Performers

Government Research and Development (GOVERD) Performers

Central Bank
Central & Regional Fisheries Boards
Department of Agriculture, Fisheries and Food
Department of Arts, Sport and Tourism
Department of Communications, Marine and Natural Resources
Department of Education and Skills
Department of Enterprise, Trade and Employment
Department of the Environment, Heritage and Local Government
Department of Social & Family Affairs
Dublin Institute for Advanced Studies
Economic and Social Research Institute
Environmental Protection Agency
FAS (Irish National Training and Employment Authority)
Food Safety Authority of Ireland
Forfás (Ireland's National Policy Advisory Board for Enterprise and Science)
Health Research Board
Higher Education Authority
Intertrade Ireland
Irish Sea Fisheries Board
Irish Research Council for Science, Engineering & Technology
Irish Research Council for the Humanities & Social Sciences
Marine Institute
Met Éireann (The Irish National Meteorological Service)
National Economic and Social Council
National Roads Authority
Radiological Protection Institute of Ireland
Shannon Development
Teagasc (The Irish Agriculture and Food Development Authority)

Higher Education Research and Development (HERD) Performers

Athlone Institute of Technology
Cork Institute of Technology
Dublin City University
Dublin Institute of Technology
Dundalk Institute of Technology
Galway-Mayo Institute of Technology
Institute of Technology Blanchardstown
Institute of Technology Carlow
Institute of Technology Sligo
Institute of Technology Tallaght
Institute of Technology Tralee
Letterkenny Institute of Technology
Limerick Institute of Technology
Mary Immaculate College
National University of Ireland, Galway
National University of Ireland Maynooth
Royal College of Surgeons in Ireland
St. Patricks College Drumcondra
Trinity College Dublin
University College Cork
University College Dublin
University of Limerick
Waterford Institute of Technology

Annex 8. Activity – Emerging Trends (1998-2006) data - original FOS into mFOS

Research-Active Staff (FTEs)

Table 2: Number of research-active staff (FTEs) per mFOS for the period 1998-2006

mFOS	1998	2004	2006
Clinical Medicine	22	222	254
Pre-Clinical & Health	57	618	678
Biological Sciences	409	655	582
Agricultural Biotechnology & Engineering (including Food)	168	517	472
Agricultural Sciences	213	100	141
Earth & Environment Sciences	41	96	170
Computer and Information Sciences/Mathematics	104	391	462
Physics & Materials Sciences	122	278	321
Chemical Sciences	141	214	271
Civil Engineering	43	83	114
Electrical, Electronic, Information Engineering	88	168	279
Social Sciences	406	658	549
Economics and Business	80	77	168
Psychology	35	73	77
Humanities	331	454	508
Sum of Other Categories	-	-	64

Source: Based on Forfás Higher Education Research and Development (HERD) survey data and input from Higher Education Institutions (HEIs) for the period 1998-2006.

Research-related Income (€)

Table 3: Total research-related income (€000) per mFOS for the period 1998-2006

mFOS	1998	2004	2006
Clinical Medicine	1,163	22,292	29,200
Pre-Clinical & Health	6,531	64,406	79,445
Biological Sciences	27,403	77,215	61,425
Agricultural Biotechnology & Engineering (including Food)	13,076	49,694	66,046
Agricultural Sciences	14,937	11,454	15,852
Earth & Environment Sciences	3,817	16,923	22,639
Computer and Information Sciences/Mathematics	10,082	42,226	48,637
Physics & Materials Sciences	8,264	34,295	29,464
Chemical Sciences	10,539	20,364	25,554
Civil Engineering	5,233	8,828	8,973
Electrical, Electronic, Information Engineering	8,436	23,494	29,274
Social Sciences	31,066	60,053	63,163
Economics and Business	4,907	5,273	19,276
Psychology	2,694	10,291	8,999
Humanities	18,268	38,178	42,049
Sum of Other Categories	-	-	49,372

Source: Based on Forfás Higher Education Research and Development (HERD) survey data and input from Higher Education Institutions (HEIs) for the period 1998-2006

Masters Student Enrolment Data

Table 4: Number of Masters students enrolled each academic year per mFOS

mFOS	1998/9	2003/04	2004/05	2005/06	2006/07	2007/08
Clinical Medicine	N/A	N/A	93	77	81	147
Pre-Clinical & Health	83	263	58	160	194	80
Biological Sciences	110	147	290	278	240	269
Biotechnology	N/A	N/A	16	14	20	22
Agricultural Biotechnology & Engineering (incl Food)	89	65	24	19	49	67
Agricultural Sciences	74	74	70	73	74	55
Earth & Environment Sciences	N/A	N/A	25	29	45	71
Mathematics	23	38	41	38	43	91
Physics & Materials Sciences	133	158	146	123	85	101
Chemical Sciences	N/A	N/A	98	97	98	130
Nano-technology	N/A	N/A	N/A	N/A	N/A	N/A
Computer & Information Sciences	130	300	340	262	181	148
Civil Engineering	61	78	75	117	75	46
Electrical, Electronic, Information Engineering	N/A	N/A	161	138	76	95
Mechanical Engineering	N/A	N/A	71	25	46	46
Social Sciences	145	397	279	295	394	220
Economics and Business	67	520	458	489	357	119
Psychology	N/A	N/A	42	45	39	49
Humanities	525	590	560	570	482	573
Sum of Other Categories	468	840	249	296	55	191

Source: HEA & DES

PhD Student Enrolment Data

Table 5: Number of PhD students enrolled each academic year per mFOS

mFOS	1998/9	2003/04	2004/05	2005/06	2006/07	2007/08
Clinical Medicine	N/A	N/A	207	214	234	429
Pre-Clinical & Health	93	273	131	74	106	96
Biological Sciences	N/A	14	523	498	609	571
Biotechnology	N/A	N/A	52	47	46	64
Agricultural Biotechnology & Engineering (incl Food)	25	44	18	19	20	44
Agricultural Sciences	57	84	90	83	91	149
Earth & Environment Sciences	N/A	N/A	85	89	81	108
Mathematics	N/A	N/A	81	97	84	106
Physics & Materials Sciences	N/A	17	129	176	173	211
Chemical Sciences	N/A	N/A	244	205	233	291
Nano-technology	N/A	N/A	N/A	N/A	N/A	N/A
Computer & Information Sciences	63	163	337	380	355	404
Civil Engineering	5	0	63	90	52	77
Electrical, Electronic, Information Engineering	N/A	N/A	197	152	145	225
Mechanical Engineering	N/A	N/A	40	21	37	47
Social Sciences	116	266	323	359	376	437
Economics and Business	47	132	193	217	213	243
Psychology	N/A	N/A	132	163	193	205
Humanities	476	723	727	773	890	991
Sum of Other Categories	1,224	1,959	490	567	604	518

Source: HEA & DES

Annex 9. Distribution of Activity – Original FOS into mFOS

Research-active Staff (FTEs) Trend for the Period (1998-2006)[212]

Figure 1: Research-active Staff (FTEs) in Clinical Medicine for the Period (1998-2006)

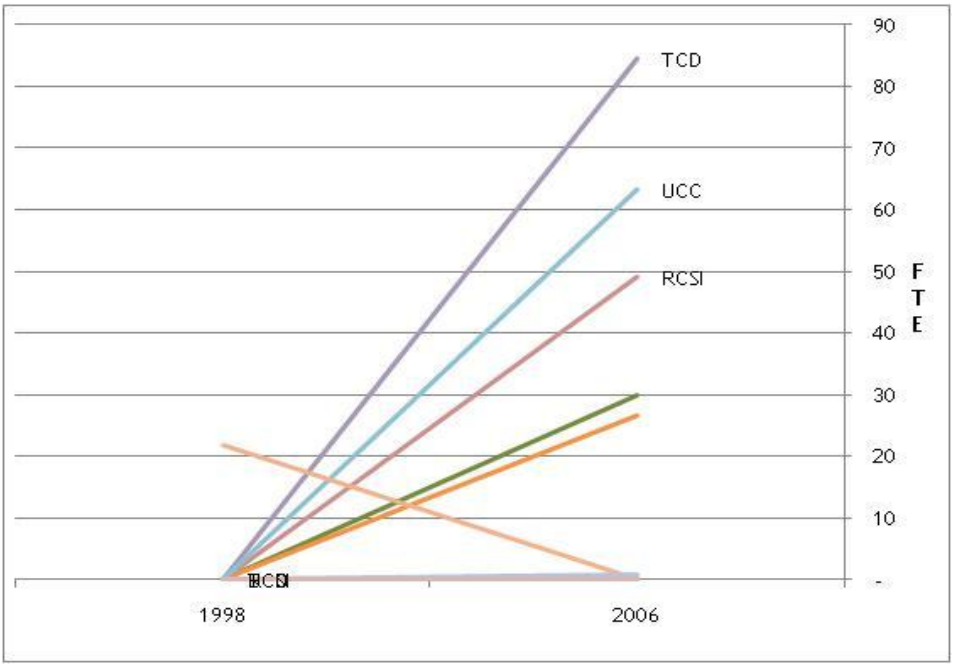
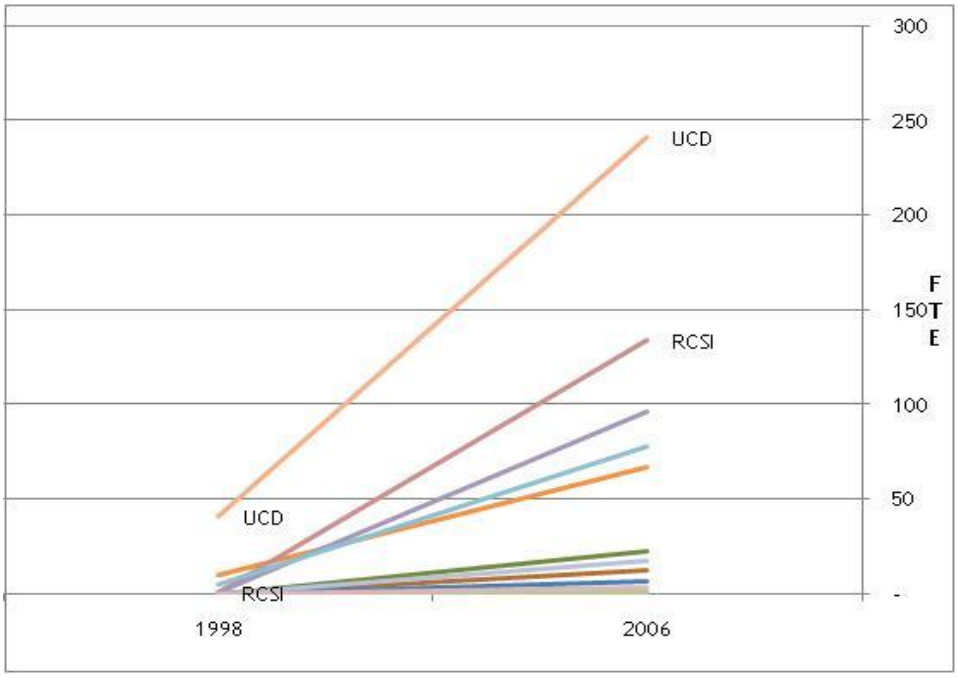


Figure 2: Research-active Staff (FTEs) in Pre-clinical & Health for the Period (1998-2006)



[212] Based on Forfás Higher Education Research and Development (HERD) survey data and input from Higher Education Institutions (HEIs) for the period 1998-2006

Figure 3: Research-active Staff (FTEs) in Biological Sciences for the Period (1998-2006)

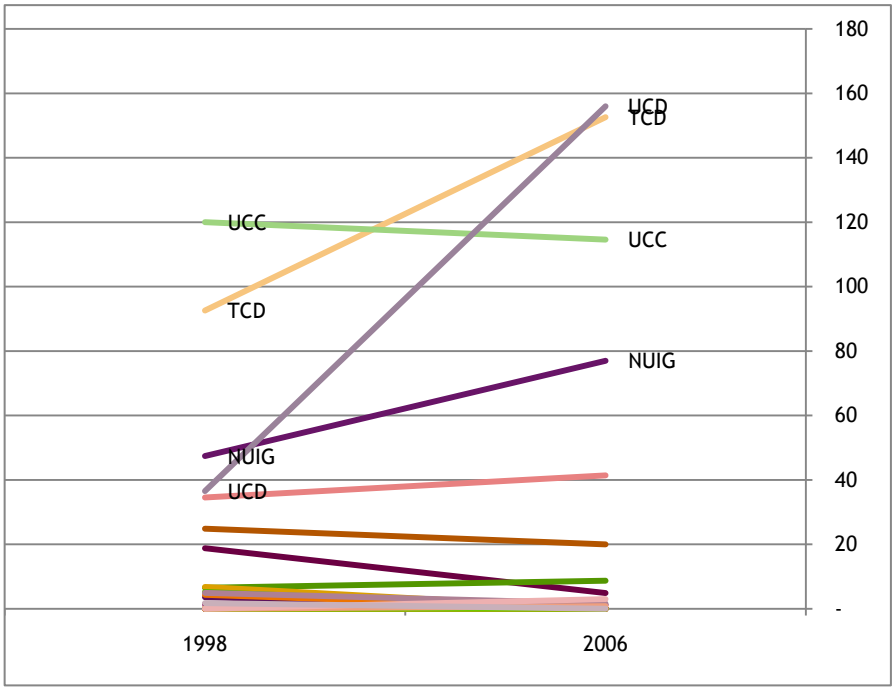


Figure 4: Research-active Staff (FTEs) in Agricultural Biotechnology & Engineering (including Food) for the Period (1998-2006)

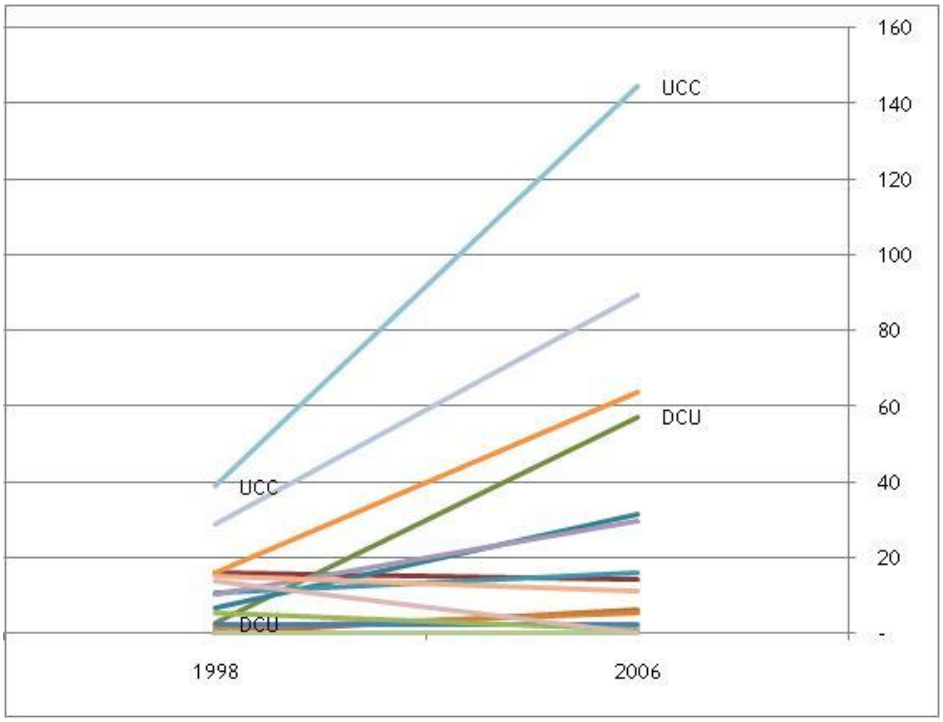


Figure 5: Research-active Staff (FTEs) in Agricultural Sciences for the Period (1998-2006)

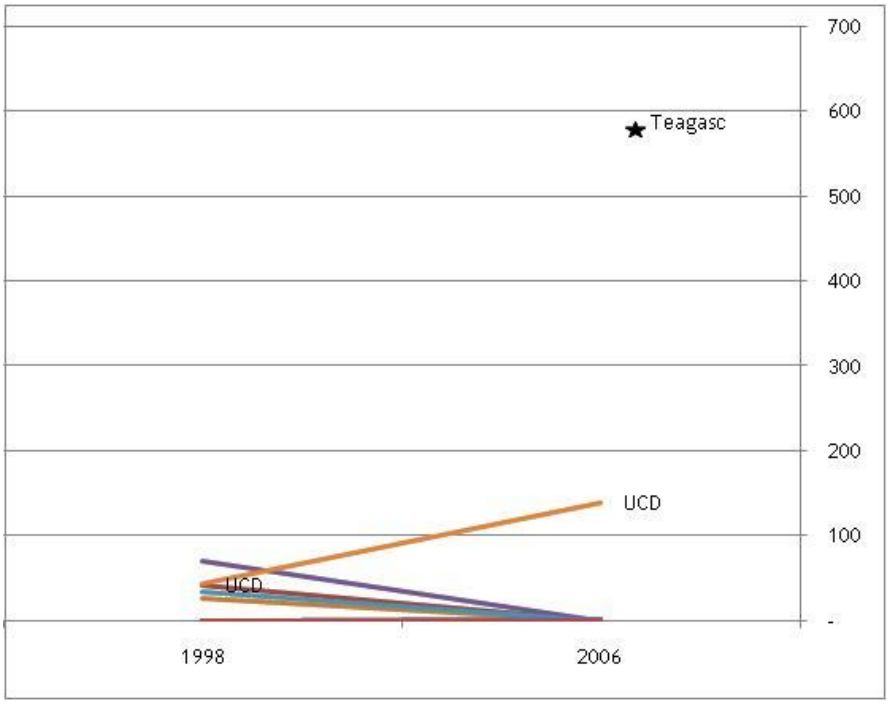


Figure 6: Research-active Staff (FTEs) in Earth & Environmental Sciences for the Period (1998-2006)

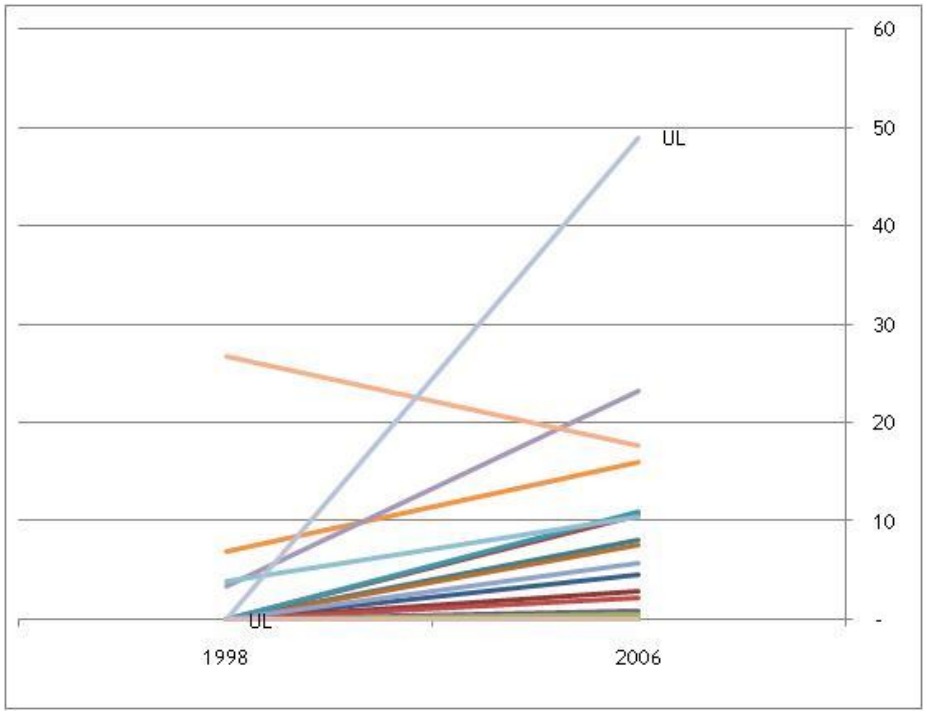


Figure 7: Research-active staff (FTEs) in Computer & Information Sciences/Mathematics for the Period (1998-2006)

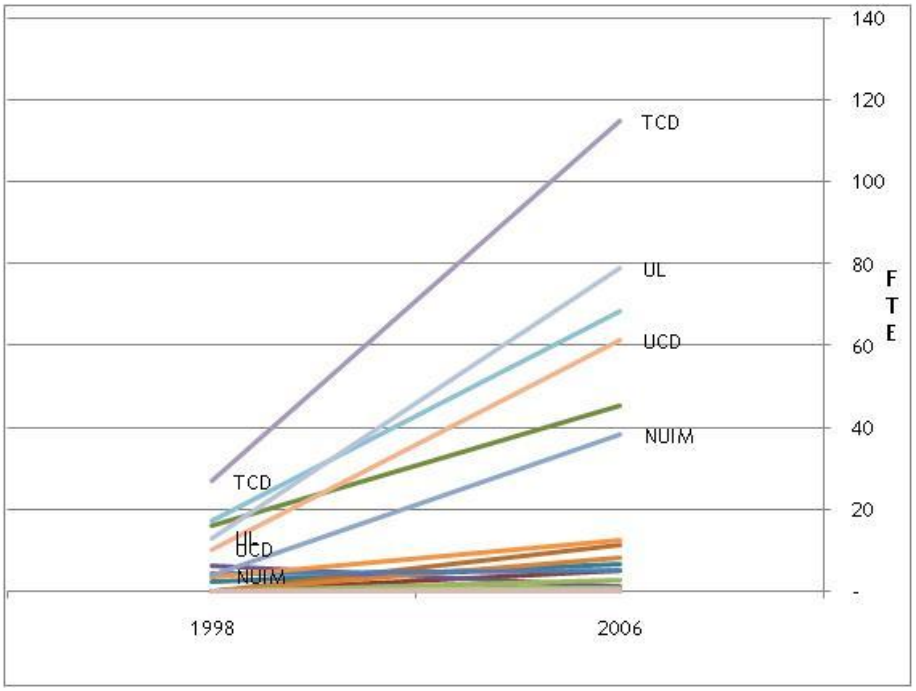


Figure 8: Research-active Staff (FTEs) in Physics & Materials Sciences for the Period (1998-2006)

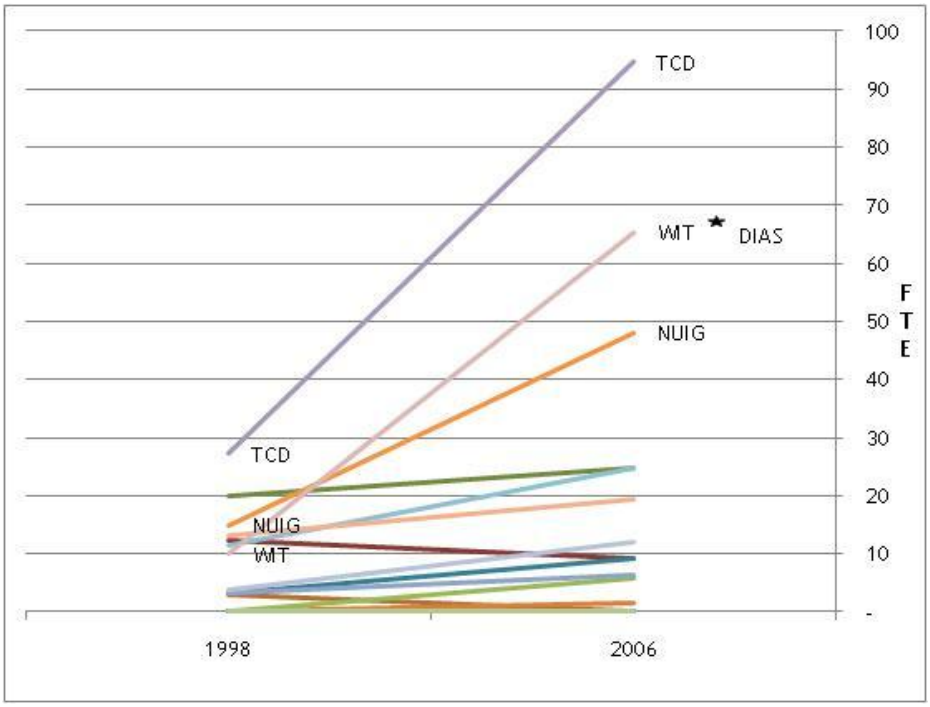


Figure 9: Research-active staff (FTEs) in Chemical Sciences for the Period (1998-2006)

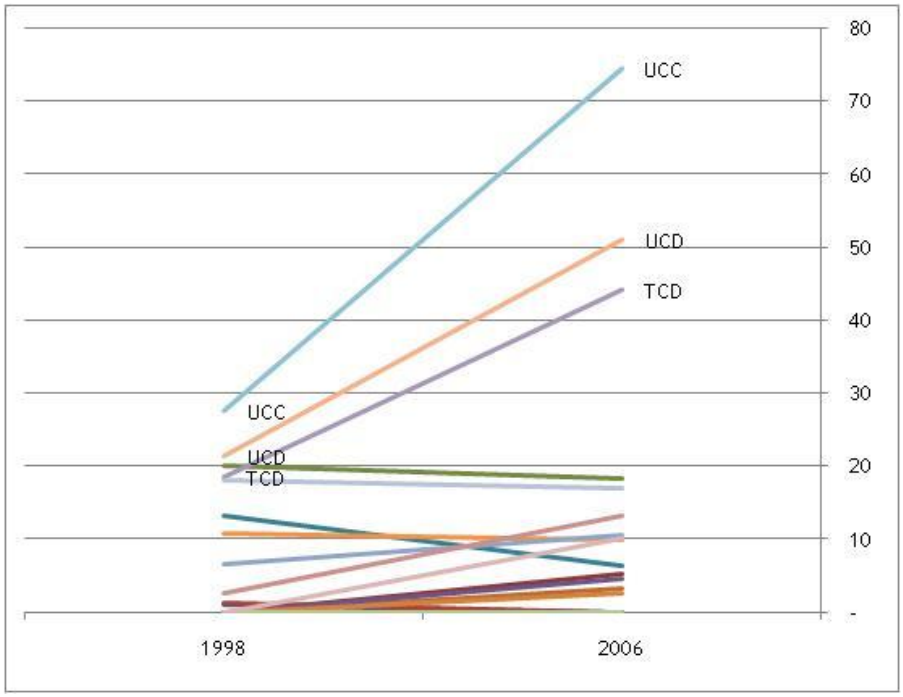


Figure 10: Research-active staff (FTEs) in Civil Engineering for the period (1998-2006)

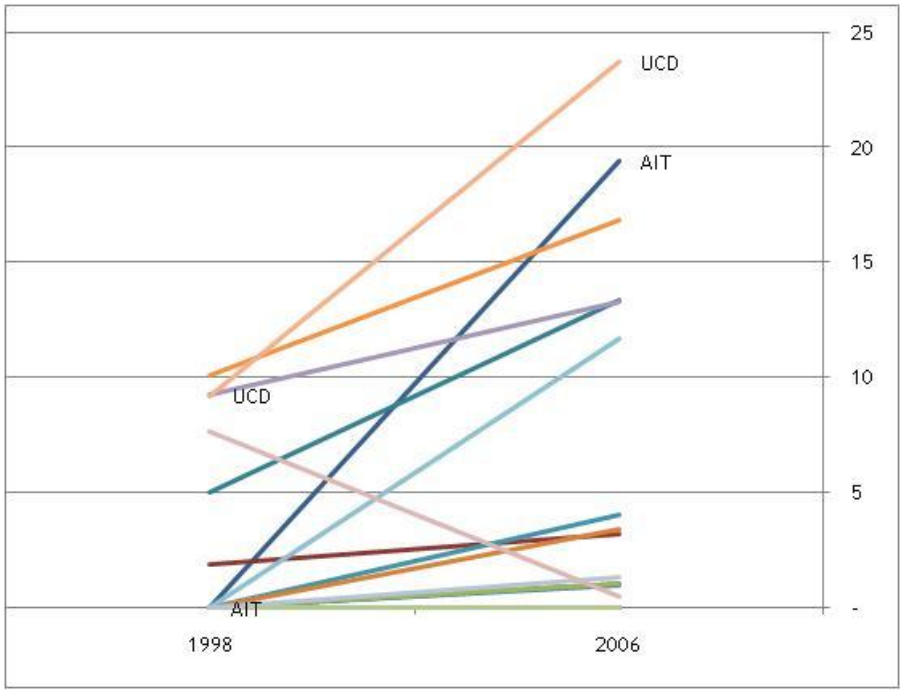


Figure 11: Research-active staff (FTEs) in Electrical Engineering, Electronic Engineering, Information Engineering for the period (1998-2006)

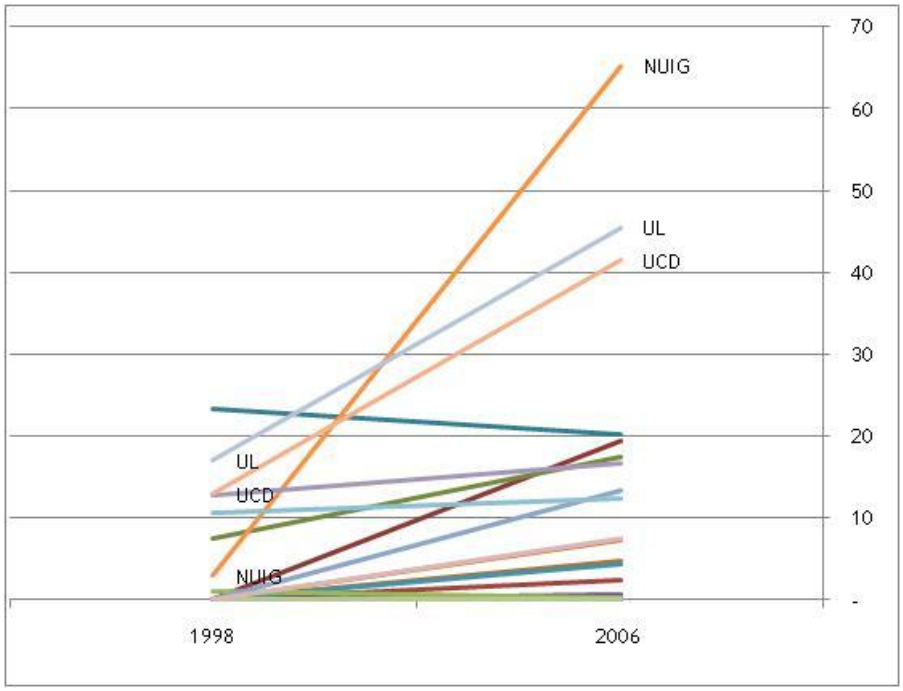


Figure 12: Research-active staff (FTEs) in Social Sciences for the period (1998-2006)

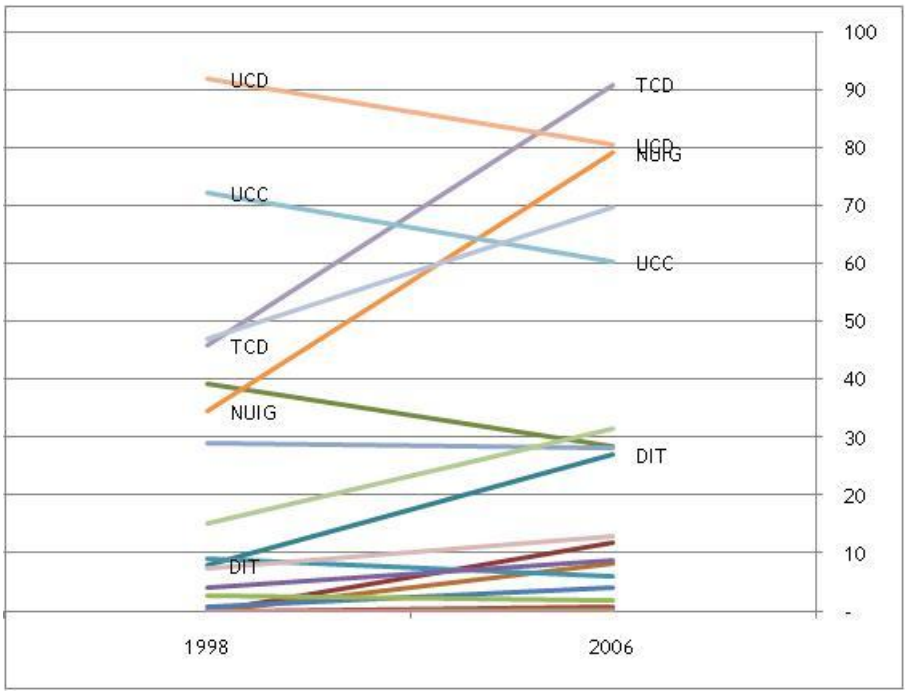


Figure 13: Research-active staff (FTEs) in Economics & Business for the period (1998-2006)

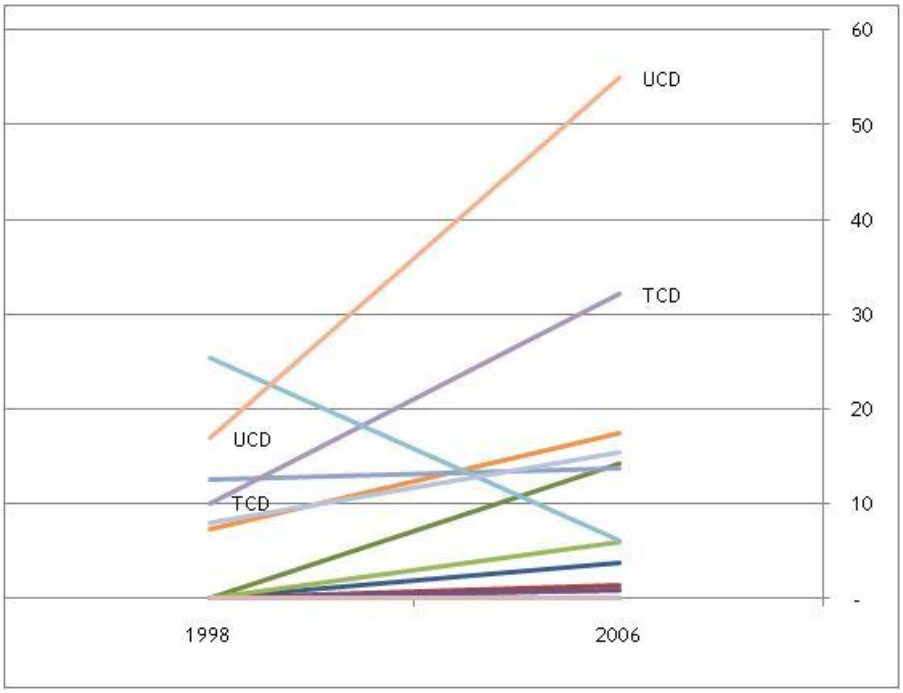


Figure 14: Research-active staff (FTEs) in Psychology for the period (1998-2006)

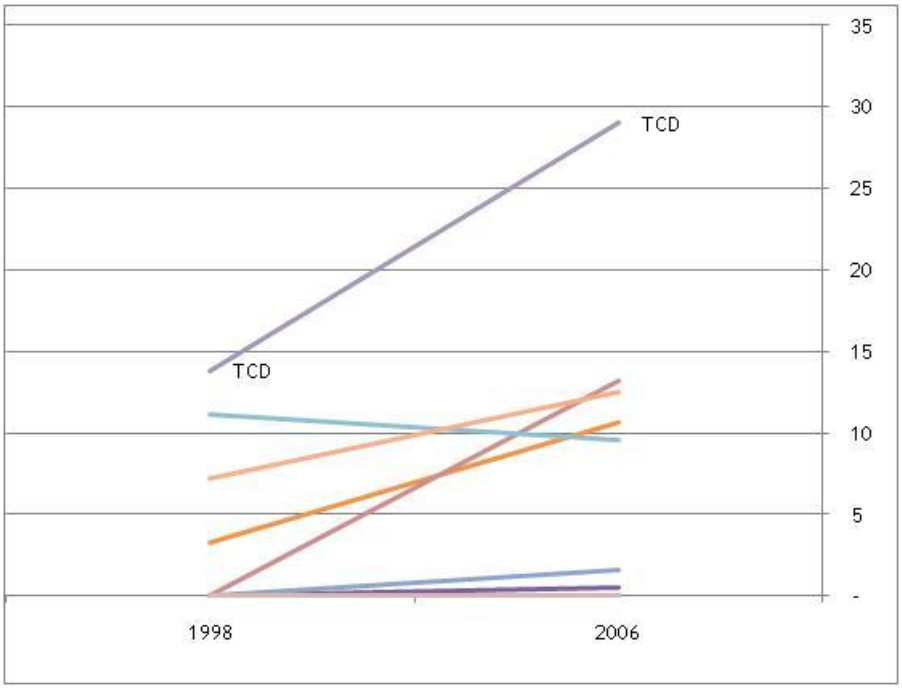
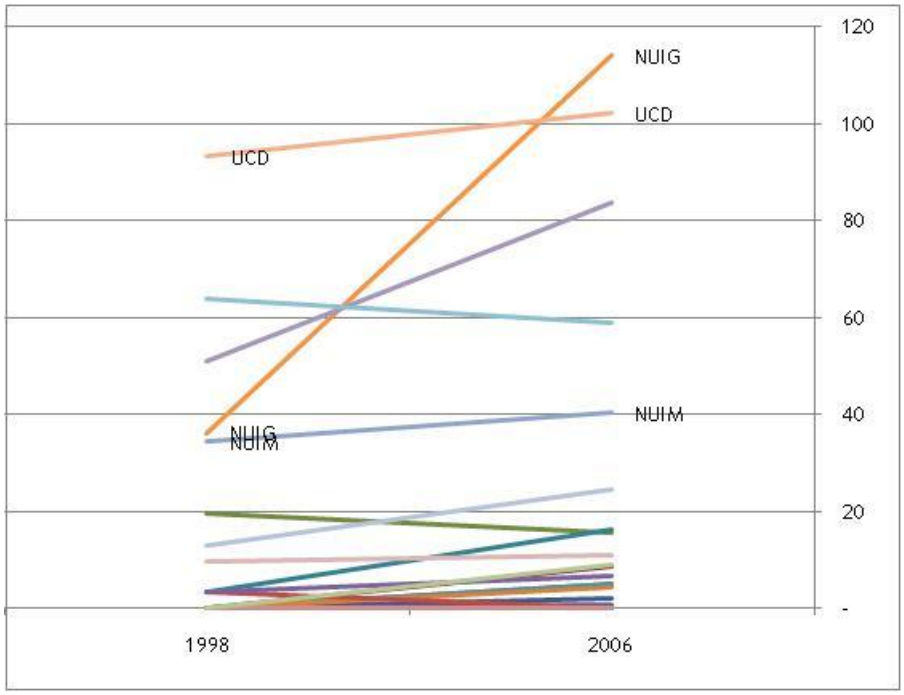


Figure 15: Research-active staff (FTEs) in Humanities for the period (1998-2006)



Distribution of National HEI Research-Active Cohort in 2006

Table 1: Percentage of national research-active staff (FTEs) cohort in HEIs by original FOS in 2006

HEI / mFOS	AIT	CIT	DCU	DIT	DKIT	GMIT	ITB	ITC	ITS	ITT	IT Tralee	LIT	LYIT	MIC	NUIG	NUIM	RCSI	SPD	TCD	UCC	UCD	UL	WIT
Clinical Medicine	0%	0%	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	0%	19%	0%	33%	25%	0%	0%	0%
Pre-Clinical & Health	0%	0%	3%	0%	2%	0%	0%	0%	0%	0%	1%	0%	0%	0%	10%	0%	20%	0%	14%	11%	36%	3%	0%
Biological Sciences	0%	1%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	13%	7%	0%	0%	26%	20%	27%	1%	0%
Agricultural Biotechnology & Engineering (including Food)	0%	3%	12%	7%	1%	0%	0%	0%	3%	1%	0%	0%	0%	0%	13%	0%	0%	0%	6%	31%	2%	19%	0%
Agricultural Sciences[213]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	99%	1%	0%
Earth & Environment Sciences	3%	2%	0%	5%	4%	6%	0%	1%	6%	0%	0%	1%	0%	0%	9%	3%	0%	0%	14%	6%	10%	29%	0%
Computer & Information Sciences/Mathematics	0%	1%	10%	1%	2%	0%	0%	0%	0%	2%	1%	0%	1%	0%	3%	8%	0%	0%	25%	14%	13%	17%	0%

[213] Teagasc represent the largest proportion of national research-active staff in Agricultural Sciences when GOVERD and HERD OECD revised FOS 2006 data is used.

Physics & Materials Sciences	0%	3%	8%	3%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	15%	2%	0%	0%	30%	8%	6%	4%	20%
Chemical Sciences	0%	2%	7%	2%	1%	0%	0%	2%	0%	1%	0%	0%	0%	0%	4%	4%	5%	0%	16%	27%	19%	6%	4%
Civil Engineering	17%	3%	0%	12%	0%	1%	0%	0%	4%	3%	1%	0%	1%	0%	15%	0%	0%	0%	12%	10%	21%	1%	0%
Electrical, Electronic and Information Engineering	0%	7%	6%	7%	2%	1%	0%	1%	2%	3%	0%	0%	0%	0%	23%	5%	0%	0%	6%	4%	15%	16%	3%
Social Sciences	0%	2%	5%	5%	2%	0%	0%	0%	1%	0%	1%	0%	0%	2%	14%	5%	0%	6%	17%	11%	15%	13%	2%
Economics and Business	2%	0%	8%	0%	1%	1%	0%	2%	0%	0%	0%	0%	4%	0%	10%	8%	0%	0%	19%	4%	32%	9%	0%
Psychology	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	14%	2%	17%	0%	38%	12%	16%	0%	0%
Humanities	0%	2%	3%	3%	1%	0%	0%	0%	1%	1%	0%	0%	0%	1%	22%	8%	0%	2%	16%	12%	20%	5%	2%
Sum of Other Categories	0%	0%	2%	3%	0%	0%	14%	0%	0%	0%	2%	2%	0%	0%	65%[214]	0%	0%	0%	0%	0%	9%	2%	2%

Source: Based on Forfás HERD survey data and input from Higher Education Institutions (HEIs) using original FOS for the period 1998-2006.

[214] Data belongs to engineering but it was unable to be placed in a specific engineering field due to an error on the returned HERD survey.

Annex 10. Underpinning Factors

Table 1: Number of undergraduate students enrolled in academic years 1998/9 and 2005/6 and the number of undergraduate students graduating in the calendar year 2006.

	UG Enrolled		UG Graduates
mFOS	**1998/9**	**2005/06**	**2006**
Clinical Medicine	1,028	4,742	714
Pre-Clinical & Health	5,496	12,952	1,403
Biological Sciences	N/A	3,539	378
Biotechnology	N/A	643	154
Agricultural Biotechnology & Engineering (incl Food)	603	1,257	118
Agricultural Sciences	1,427	1,834	237
Earth & Environment Sciences	N/A	817	159
Mathematics	N/A	752	168
Physics & Materials Sciences	N/A	1,526	137
Chemical Sciences	N/A	698	167
Nano-technology	N/A	N/A	N/A
Computer & Information Sciences	2,965	5,486	532
Civil Engineering	250	8,088	299
Electrical, Electronic, Information Engineering	N/A	747	245
Mechanical Engineering	N/A	377	93
Social Sciences	6,122	19,214	2,976
Economics and Business	7,040	22,176	2,269
Psychology	N/A	565	141
Humanities	14,189	22,088	4,327
Sum of Other Categories	12,548	10,729	1,189

Source: HEA & DES

Annex 11. Mapping between mFOS and Thomson Reuters journal categories

Project research area	Thomson Reuters description
Other	Multidisciplinary Sciences
Clinical medicine	Allergy, Anaesthesiology, Andrology, Cardiac & Cardiovascular Systems, Clinical Neurology, Critical Care Medicine, Dentistry, Oral Surgery & Medicine, Dermatology, Emergency Medicine, Endocrinology & Metabolism, Gastroenterology & Hepatology, Geriatrics & Gerontology, Gerontology, Haematology, Integrative & Complementary Medicine, Medicine, General & Internal, Neuroimaging, Obstetrics & Gynaecology, Oncology, Ophthalmology, Orthopaedics, Otorhinolaryngology, Paediatrics, Peripheral Vascular Disease, Psychiatry, Radiology, Nuclear Medicine & Medical Imaging, Respiratory System, Rheumatology, Surgery, Transplantation, Urology & Nephrology
Pre-clinical & health	Anatomy & Morphology, Medicinal Chemistry,, Health Care Sciences & Services, Health Policy & Services, Immunology, Infectious Diseases, Medical Ethics, Medical Informatics, Medicine, Legal, Medicine, Research & Experimental, Neurosciences, Nursing, Nutrition & Dietetics, Parasitology, Pathology, Pharmacology & Pharmacy, Physiology, Psychology, Clinical, Psychology, Psychoanalysis, Public, Environmental & Occupational Health, Rehabilitation, Biomedical Social Sciences, Sport Sciences, Substance Abuse, Toxicology, Tropical Medicine
Biological sciences: Molecular & Cellular Biology	Biochemical Research Methods, Biochemistry & Molecular Biology, Biophysics, Cell Biology, Genetics & Heredity, Microbiology, Virology
Biological sciences: Organismal Biology	Biodiversity Conservation, Biology, Biology, Miscellaneous, Developmental Biology, Ecology, Entomology, Evolutionary Biology, Limnology, Marine & Freshwater Biology, Mathematical & Computational Biology, Mycology, Ornithology, Plant Sciences, Reproductive Biology, Zoology
Biotechnology	Biotechnology & Applied Microbiology, Biomedical Engineering, Chemical Engineering, Materials Science, Biomaterials, Medical Laboratory Technology, Microscopy
Agricultural biotechnology *	Agricultural Engineering (part), Biotechnology & Applied Microbiology (part), Food Science & Technology (part),
Agricultural sciences	Agricultural Engineering, Food Science & Technology, Agricultural Economics & Policy, Dairy & Animal Science, Multidisciplinary Agriculture, Agronomy, Fisheries, Forestry, Horticulture, Soil Science, Veterinary Sciences
Earth & Environment Science	Energy & Fuels, Environmental Engineering, Geological Engineering, Marine Engineering, Ocean Engineering, Petroleum Engineering, Environmental Sciences, Geochemistry & Geophysics, Physical Geography, Geology, Multidisciplinary Geosciences, Meteorology & Atmospheric Science, Mineralogy, Mining & Mineral Processing, Oceanography, Palaeontology, Remote Sensing, Water Resources
Mathematics	Pure Mathematics, Applied Mathematics, Interdisciplinary Applications in Mathematics, Mathematical Physics, Statistics & Probability
Physical & materials sciences	Acoustics, Astronomy/Astrophysics, Ceramics, Materials Characterisation & Testing, Coatings & Films, Composites, Multidisciplinary Materials Science, Paper & Wood, Textiles, Metallurgy & Metallurgical Engineering, Optics, Applied Physics, Atomic, Molecular & Chemical Physics, Condensed Matter Physics, Fluids & Plasmas, Multidisciplinary Physics, Nuclear Physics, Particles & Fields
Chemical sciences	Analytical Chemistry, Applied Chemistry, Inorganic & Nuclear Chemistry, Multidisciplinary Chemistry, Organic Chemistry, Physical Chemistry, Crystallography, Electrochemistry, Polymer Science
Nanotechnology	Nanoscience & Nanotechnology

Project research area	Thomson Reuters description
Computer and information sciences	Artificial Intelligence, Cybernetics, Information Systems, Interdisciplinary Applications in Computer Science, Software Engineering, Computer Science Theory & Methods
Civil engineering	Construction & Building Technology, Civil Engineering, Transportation Science & Technology
Electrical engineering, electronic engineering, information engineering	Automation & Control Systems, Communication, Computer Science, Hardware & Architecture, Electrical & Electronic Engineering, Imaging Science & Photographic Technology, Instruments & Instrumentation, Robotics, Spectroscopy, Telecommunications
Mechanical engineering	Aerospace Engineering, Mechanical Engineering, Multidisciplinary Engineering, Mechanics, Nuclear Science & Technology, Thermodynamics
Economics and Business	Business, Economics, Finance, Industrial Relations & Labour, Management, Operations Research & Management Science
Social sciences	Anthropology, Area Studies, Asian Studies, Criminology & Penology, Demography, Education & Educational Research, Education – Scientific Disciplines, Special Education, Environmental Studies, Ethnic Studies, Family Studies, Geography, Information Science & Library Science, International Relations, Law, Planning & Development, Political Science, Public Administration, Social Issues, Interdisciplinary Social Sciences, Mathematical Methods in Social Sciences, Social Work, Sociology, Transportation, Urban Studies, Women's Studies
Psychology	Behavioural Sciences, Ergonomics, Psychology, Applied Psychology, Biological Psychology, Developmental Psychology, Educational Psychology, Experimental Psychology, Mathematical Psychology, Multidisciplinary Psychology, Social Psychology
Humanities	Archaeology, Architecture, Art, Classics, Dance, Ethics, Film, Radio & Television, Folklore, History, History & Philosophy of Science, History of Social Sciences, Multidisciplinary Humanities, Language & Linguistics, Literary Reviews, Literary Theory & Criticism, Literature, Literature of specific areas (African, Australian & Canadian; American; British Isles; German, Dutch & Scandinavian; Romance; Slavic), Medieval & Renaissance Studies, Music, Philosophy, Poetry, Religion, Theatre

* *Agricultural biotechnology* As the text elsewhere explains, while individual projects may be recognised as 'agricultural biotechnology' and there may be a distinctive investment and economic description, the research base does not recognise a significant volume of biotechnology research which is addressed solely at the agricultural sector. The distinctions between biotechnology for agriculture, environment, health and/or industry which are made by OECD for economic purposes do not sit easily with a discipline based structure for universities and research institutes. A compromise structure has been created here for this report so that some preliminary and indicative outcomes are available, but this is likely to be a satisfactory analysis only within the broad overview of this project. A more detailed and comprehensive analysis at journal level would be desirable if resources were available. If supported by advice from relevant sectoral specialists, this might then lead to a more detailed and targeted deconstruction of the links between the academic, applied and industrial elements of the 'agricultural biotechnology' theme..

Annex 12. Outputs and Outcomes – Masters and PhD Graduate Data

Table 1: Number of Masters and PhD Students Graduating in the Calendar Years 1998 and 2006.

	Masters Graduates	PhD Graduates	
mFOS	**2006**	**1998**	**2006**
Clinical Medicine	54	62	95
Pre-Clinical & Health	15	N/A	11
Biological Sciences	24	N/A	138
Biotechnology	13	N/A	10
Agricultural Biotechnology & Engineering	11	12	12
Agricultural Sciences	25	12	12
Earth & Environment Sciences	5	N/A	15
Mathematics	9	N/A	19
Physics & Materials Sciences	18	N/A	29
Chemical Sciences	13	N/A	73
Nano-technology	N/A	N/A	N/A
Computer & Information Sciences	41	12	64
Civil Engineering	33	N/A	10
Electrical, Electronic, Information Engineering	35	N/A	58
Mechanical Engineering	7	N/A	6
Social Sciences	27	8	79
Economics and Business	15	17	38
Psychology	8	N/A	27
Humanities	49	106	122
Sum of Other Categories	48	318	90

Source: HEA & DES

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