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HRB
POLICY,
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EXTERNAL
RELATIONS
UNIT

Outputs, outcomes and impacts arising from the HRB's 2000-09 grants portfolio

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List of abbreviations

DCU	Dublin City University
DoH	Department of Health
EI	Enterprise Ireland
EOG	End-of-grant report
ERC	European Research Council
FP	EU Framework Programme
HEA	Higher Education Authority
HIQA	Health Information and Quality Authority
HRB	Health Research Board
HRCS	UK Health Research Classification System
HSE	Health Service Executive
HSR	Health services research
ICORG	All-Ireland Cooperative Oncology Research Group
IP	Intellectual property
IRC	Irish Research Council
IRCHSS	Irish Research Council for Humanities and Social Sciences (now the Irish Research Council)
IRCSET	Irish Research Council for Science, Engineering and Technology (now the Irish Research Council)
MKWFH	*Making Knowledge Work for Health* (2001 national health research strategy)
MRC	UK Medical Research Council
MRCG	Medical Research Charities Group
NIHR	UK National Institute of Health Research
NUI Galway	National University of Ireland, Galway
NUI Maynooth	National University of Ireland, Maynooth
PhD	PhD student
PHS	Population health sciences
PI	Principal Investigator
Post-doc	Post-doctoral researcher
PRTLI	Programme for Research in Third-Level Institutions
RCSI	Royal College of Surgeons in Ireland
SFI	Science Foundation Ireland
SSTI	Strategy for Science, Technology and Innovation
TCD	Trinity College Dublin
UCC	University College Cork
UCD	University College Dublin
WHO	World Health Organization

Executive summary

Introduction

This report presents an analysis of the key outputs, outcomes and impacts that have arisen to date from HRB research grants awarded in the ten-year period from 2000 to 2009. This period was chosen for a number of reasons:

- Sufficient time had elapsed to enable an assessment of the research outputs and outcomes on a portfolio level (a case study approach of a selection of HRB grants awarded in the 1990s was previously published).[1]
- The period was one of significant growth for the HRB, as its budget increased from €15 million in 2001 to a peak of €50 million in 2008, enabling the HRB to award many more grants as well as higher value grants to build critical mass in targeted health areas and fund critically needed infrastructure.
- The period was also one of significant strategic development nationally with the advent of the Department of Health's (DoH) 2001 national health research strategy *Making Knowledge Work for Health* and a resultant significant increase in funding to the HRB; the availability of capital funding that stemmed from the Government's *Strategy for Science, Technology and Innovation* (SSTI) in 2006; and the emergence of other significant funding streams for biomedical research in particular (e.g. Science Foundation Ireland (SFI), Programme for Research in Third-Level Institutions (PRTLI), Irish Research Council for Science, Engineering and Technology (now the Irish Research Council) (IRCSET)), Enterprise Ireland (EI)).
- In response to *Making Knowledge Work for Health*, the HRB initiated a new strategic funding stream ('R&D for Health') which emphasised the need to build high-quality research capability in the health sector and to provide evidence for policy and practice.
- Due to the development of a monitoring and evaluation framework early in the decade, significant output and outcome data relating to this block of grants was already available, and could be updated and built on.
- The period pre-dated the current HRB Strategy 2010–14, enabling a baseline analysis to assess the impact of the strategic shift associated with the 2010 strategy.

Therefore, throughout the 2000–09 period, the HRB broadened its investment beyond biomedical research towards a greater emphasis on clinical research, population health sciences and health services research, such that taking the period as a whole, biomedical research accounted for only 54% of all HRB funding commitments.

The specific objectives of this project were to:

- capture, analyse and report the outputs, outcomes and impacts arising from the HRB's investment in research across the 10-year period 2000–09
- gain strategic insight by analysing the distribution of outcomes across strategic pillar areas and schemes
- provide a baseline analysis for monitoring the impact of the Strategic Business Plan 2010–14
- further enhance internal processes and procedures, including data capture systems, indicators and metrics, for prospective evaluation of the payback from HRB funding
- provide evidence to assist the HRB in maintaining national investment in health research

An International Advisory Group was appointed to provide support and guidance to the HRB in executing this project; details of the group members are included in Appendix A.

Assessment framework

The conceptual assessment framework for the analysis was based on the categories of the Buxton and Hanney Payback Framework, which the HRB has used to assess the impact of its funded research since 2008. Briefly, the framework captures scientific outputs and outcomes (e.g. peer-reviewed publications, PhD graduates), but also health-oriented outcomes (e.g. policy and practice outcomes, new treatments and interventions), and enterprise and economic benefits (e.g. research commercialisation, non-Exchequer funding leveraged). The analysis presented in this report was based on data from an online survey of grant-holders via the HRB Grant Outcomes Tracker system, as well as information collated and verified from other sources such as end-of-grant reports, media stories, international patent databases, the 'Picture of Health' series, and previous HRB evaluation studies.

Summary statistics

The headline output and outcome statistics relating to just over 1,000 grants, with a collective value of €300 million, awarded in the 2000–09 period (equivalent to over 90% of HRB grants awarded in that period) are listed below.[1]

Impact categories	Metric	No.
Knowledge production and capacity-building	No. peer-reviewed publications	3,382
	No. PhDs trained*	651
	No. post-docs funded*	435
	No. health professionals funded*	491
Informing health policy, practice and behaviour	No. policy and practice outputs and impacts	640
	No. health innovations in development	160
	No. patient/public engagement events	1023
Commercial benefits	No. patents	66
	No. licences and spin-out companies	26
	No. academic-industry linkages	197
	Amount of non-Exchequer funding leveraged	€72.9m

* Data relating to funded personnel refer to 867 grants only, due to reasons outlined in Section 4.

[1] It should be noted that some of these grants are still active or have only recently completed and, due to time lags in the research process, additional outputs, outcomes and impacts are expected to emerge in the future.

Key findings by category

Knowledge production

- Some 3,382 peer-reviewed publications associated with HRB funding were identified, predominantly arising from research funded between 2000 and 2009.
- The majority of HRB-supported papers were published in high-impact journals, and over half have been published in the world's top 10% of journals as measured by journal impact factor.
- The normalised citation impact[2] of the collective group of publications was almost 75% higher than the world average (1.74) with an increasing trend (1.84 for the most recent five-year period). This outperforms benchmarks for Irish and UK research in clinical/health/pre-clinical and biological sciences research.
- HRB-supported clinical papers were exceptionally highly cited – over twice the world average (2.20). HRB-supported biomedical papers were very well cited (1.67). HRB-supported population health and health services papers were also well cited relative to the world average (1.40) and citation impact is increasing.
- Around two-fifths (40.8%) of HRB-supported papers were internationally co-authored and this trend continues to rise. There was a significant citation gain associated with internationally co-authored papers (cited on average over twice the world average (2.28).
- The Irish academic sector produced around 90% of HRB-supported papers and the Irish health sector has produced around one-third. These proportions have been more or less constant over time, although there are suggestions that the Irish health sector is producing a greater proportion of HRB-supported papers.

Capacity-building

- A total of 2,095 researchers were supported through 867 HRB grants awarded between 2000 and 2009, including 474 principal investigators (PIs), 266 fellows, and 1,355 staff (including 651 PhD students and 435 post-doctoral researchers).
- 491 health professionals received research funding throughout the period; they included 184 PIs, 185 fellowship holders, and 122 staff employed on projects and programmes.
- 621 follow-on grants were obtained by HRB grant-holders; this provided approximately €206 million of additional research funding to build on their HRB-funded research.

Informing health policy, practice and behaviour

- 28% of the grants portfolio reported a **policy and practice output or impact,** such as production of an evidence-based guideline or policy report, an advisory role or other influences on the policy setting process, or citation of research in clinical guidelines and policy documents. Some examples included:
  - A programme of research, led by Professor Helen Whelton, in UCC developed four evidence-based dental health guidelines in collaboration with the HSE dental care service. The guideline topics were nominated by the Society of Chief and Principal Dental Surgeons in consultation with the research team.

[2] This standardised metric assesses the citation performance of a research paper in relation to the performance of the average paper published in the same research field at the same time.

- Dr Zena Moore, a HRB fellowship holder, developed and validated a novel repositioning technique to reduce the incidence of pressure ulcers in older persons nursed in long-stay settings. The technique was recommended in the *HSE National Best Practice and Evidence Based Guidelines for Wound Management*, and the guidelines were also published by the European Pressure Ulcer Advisory Panel.
- The Healthy Ageing Research Programme, led by Professor Hannah McGee, established the first Irish longitudinal study on community-dwelling older people and resulted in the development of a new quality of care measure of the elderly. The research provided novel information on cardiovascular disease among the elderly in Ireland which informed the DoH's *Changing Cardiovascular Health: National Cardiovascular Health Policy 2010-2019*.
- A HRB clinical research fellow, Dr Paul Gallagher in UCC, validated a new medication review system for older people (STOPP/START). The system has been endorsed by the HSE's clinical care programme for older adults, the EU Geriatric Medicine Society, and it has been included in the Royal College of Physicians (London) Acute Care Toolkit.
- Research by consultant endocrinologist Professor Fidelma Dunne in NUI Galway provided, for the first time, reliable prevalence data for gestational diabetes in the Western region, and showed poorer outcomes for diabetic pregnancy, attributable in part to inadequate pregnancy preparation and fragmented care. To address this, the PI established combined diabetes antenatal clinics and complimentary pre-pregnancy clinics in the Galway region, and is working to get this model of care adopted nationally.

- In terms of HRB strategic pillar areas, Health Services Research produced the largest proportion of policy and practice outputs and impacts (45%), followed by Clinical Research (21%), Population Health Sciences (16%), and Applied Biomedical research (16%).
- In addition, 15% of the grants portfolio reported the development of a **healthcare innovation** such as a new therapeutic drug, vaccine or gene therapy, diagnostic tool, e-health technology, care model, and service innovation. Some examples included:
  - Mary Fitzsimons and her team at Beaumont Hospital developed and validated a web-based electronic patient record system for epilepsy care, which is underpinning the new model of care being rolled out by HSE National Epilepsy Care Programme.
  - Research by HRB Clinician Scientist Professor Peter Kelly led to the development and validation of an improved clinical prediction tool for stroke risk (the ABCDI-3) following a transient ischaemic attack.
  - Translational research led by Professor Jochen Prehn in the Royal College of Surgeons in Ireland (RCSI) resulted in the development of a computational tool designed to aid in assessing patient prognosis and in determining more effective and personalised treatment strategies in colorectal cancer.
  - HRB-funded research physiotherapist Dr Emma Stokes in TCD developed and demonstrated the health benefits of a novel family-medicated exercise intervention for stroke patients that can be delivered in a community setting without any additional healthcare resources.
  - The HRB-funded SPHERE (Secondary Prevention of Heart Disease in General Practice) intervention study led by Professor Andrew Murphy in NUI Galway, the largest non-pharmaceutical clinical trial ever undertaken in Ireland, showed significantly reduced hospital admissions for the intervention group.
  - A HRB project grant awarded to Dr Declan Soden in the Cork Cancer Research Centre led to the development of a medical device (the EndoVE) that can target chemotherapy drugs

to the tumour site, eliminating toxic side effects and leading to potentially shorter stays in hospital for patients.

- The vast majority (75%) of the innovations reported were at the pre-commercial/pre-adoption stage of development. Almost 4% of innovations have been marketed, and a further 21% which were non-commercial in nature have either been adopted or are "adoptable" (i.e. are validated).
- By engaging patients and the wider public in research and **disseminating their findings to lay audiences** through diverse channels, health researchers can directly influence health behaviour and help to promote the benefits of research. One-third of HRB grants reported activity in this area, most commonly coverage of research in local or national press (31% of dissemination events), followed by a talk or presentation to the public or patient groups (25%).

Research commercialisation and non-Exchequer funding leveraged

- Approximately 6% of the HRB grants portfolio was linked to the generation of **intellectual property** (i.e. patents) and activities to commercialise research through licence agreements and the formation of spin-out companies. Some examples of successful HRB-funded research in this category included:
  - Translational research led by Professor Noel Caplice in UCC led to a patent application ('Primitive Vascular Progenitor Cells and uses thereof') for a diagnostic technology based on assessing the movement of a particular cell type in the blood of people with atherosclerosis.
  - With HRB funding, Professor William Gallagher in UCD identified biomarkers for assessing the progression of malignant melanoma as well as potential resistance to chemotherapies. The findings led to a patent application ('Markers for melanoma') which was subsequently granted.
  - Dr Aaron Peace's clinical research fellowship led to the development of a novel high-throughput assay to assess platelet function, which was the subject of a patent application ('A method of generating a platelet reactivity profile for an individual').
  - HRB-funded research in the RCSI, led by Professor Jochen Prehn and Professor Orla Hardiman, demonstrated an association between angiogenin gene mutations and amyotrophic lateral sclerosis (ALS) and showed that angiogenin protein delivery may be beneficial in diagnosing and treating ALS patients. The underlying technology was patented and subsequently licensed to a US-based company that has since marketed diagnostic kits in the US, Canadian and Japanese markets.
  - Professor Pete Humphries' ocular genetics group in TCD, funded by the HRB since the early 1990s, developed and patented gene 'suppression and replacement' technology which led them to establish Genable Technologies Ltd, focused on generating therapies for inherited eye disorders. Genable has developed its first gene therapy for treatment of patients with a particularly debilitating form of retinitis pigmentosa, which it is progressing with the backing of €5 million venture capital.

- **Academic-industry linkages** are considered key to delivering spillover effects and economic impacts. A total of 76 HRB grant-holders reported 151 linkages to companies associated with 103 HRB grants (or 10% of the grants portfolio). In addition, ICORG has collaborated with 46 companies on cancer clinical studies.

- The academic-industry linkages formed by HRB-funded researchers have resulted in concrete outcomes in many cases, including for example:
  - Based on findings from HRB-funded research into bacterial contamination of dental chair units, Professor David Coleman in the Dublin Dental School and Hospital established collaboration with the Finland-based dental chair unit manufacturer Planmeca Oy. This led to the development of Planmeca's *Water Management System*^{TM} which can now be found in dental surgeries around the world.
  - A collaborative academic-industry grant awarded to consultant cardiologist Professor Ken McDonald in UCD contributed to the development of a telehealth system ('HeartPhone') to remotely monitor weight gain in congestive heart failure patients.
  - The HRB-funded cervical screening research programme (CERVIVA) led by Professor John O'Leary in the Coombe Women & Infants University Hospital, in collaboration with their industry partner Leica Microsystems, successfully developed and tested a digital quality assurance system for cervical cytology. The system is now marketed by Leica as part of an iPad/iPhone Application;
  - The HRB-funded ICORG cancer clinical trials network has collaborated with 46 companies since 2001, including some of the world's largest pharmaceutical companies, such as GSK and Pfizer. ICORG-industry collaborative clinical trials have led to the introduction of revolutionary new oncology drugs, such as Herceptin for breast cancer. Other benefits included industry cash contributions of €1.2 million to ICORG in period 2009 to 2011, drugs provided free of charge by industry, scans and other in-kind contributions to ICORG valued at €3-4 million over a period of six years.

- An additional economic benefit was the €72.9 million that HRB-funded researchers **leveraged from non-Exchequer sources** on the back of their HRB funding, including €5 million from industry sources. In addition, a total of 25 technology development grants (collectively worth €4.7 million) were secured from Enterprise Ireland (EI) by researchers, in order to further develop technologies towards the market.

Overall conclusions

- The data presented in this report show that a wide variety of outputs and outcomes have arisen to date from the HRB's 2000–09 grants portfolio. The findings therefore reinforce, for the first time on an entire funding portfolio basis, the HRB 2008 *Making an Impact* report, which demonstrated a variety of outcome types in a selection of case studies.
- The analysis shows a sharp increase in the number of health sector outcomes such as policy and practice outputs and healthcare innovations reported from funding year 2004 onwards – the year that marked the introduction of a variety of strategic funding initiatives (including the Strategic Health Service R&D Awards, Partnership Grants, and the Clinician Scientist Awards).
- Health services research, population health sciences and clinical research produced better 'bang for the buck' in terms of production of non-commercially oriented innovations and policy and practice outputs.
- The basic and applied biomedical research areas were more associated with enterprise sector outputs and outcomes, such as patents, spin-outs, commercially-oriented innovations and academic-industry linkages.

- In several cases – for example, Professor Pete Humphries' group in TCD – it was observed that basic biomedical researchers funded by the HRB and other sources in the 1990s had produced discoveries and potential treatments that were now the subject of translational and clinical research.
- Funding schemes at the applied end of the research spectrum and associated with multidisciplinary collaborations or strategic co-funding arrangements (e.g. with the HSE, industry or charities) tended to produce more outcomes in addition to scientific outputs.
- Compared to outcomes produced by other health and medical research funders, the HRB figures are encouraging. The relative number of products and interventions linked to HRB grants is at a similar level to the UK Medical Research Council (the only other funder that had comparable data available on this type of outcome). In addition, the proportion of HRB grants that reported an influence on policy and practice compares favourably with the UK Medical Research Council (MRC) and the Wellcome Trust.
- This report illustrates some health and economic impacts of HRB-funded research. However, a limitation of the study was that it was unable to comprehensively populate impacts in categories 4 (health benefits) and 5 (broader economic and societal benefits), which require the application of specialised methodologies such as in-depth case study work, policy impact analysis and econometric modelling.
- The baseline data in this report facilitate future tracking of changing trends in the numbers and types of strategic outcomes linked to new funding initiatives under the HRB Strategic Business Plan 2010–14.

1. Introduction

1.1 Project background and objectives

The HRB, through its dedicated evaluation function, has been actively monitoring and evaluating the outputs, outcomes and impacts of its funding portfolio for a number of years. The HRB's evaluation strategy describes the various mechanisms and approaches that are employed in order to monitor and evaluate the HRB's investment at various levels:

- Level 1 – Individual grants (e.g. annual reports, interim reviews, end-of-grant reports)
- Level 2 – Funding schemes and initiatives (e.g. 2013 review of the MRCG-HRB Joint Funding Scheme)
- Level 3 – Research fields (e.g. 2008 review of population health and health services research)
- Level 4 – Overall funding portfolio (by systematic capture of outputs and outcomes arising from HRB grants through annual online surveys, and through the use of case studies to identify the longer term social and economic impacts of HRB-funded research e.g. the 2008 HRB *Making an Impact* report).[3]

This project aimed to complete a comprehensive and updated assessment of the outputs, outcomes and impacts of HRB funding awarded between 2000 and 2009, building on the substantial bank of information that had been collected by the HRB via the various levels of evaluation studies described above. The 2000–09 period was chosen for various reasons, not least because the period was one of significant growth for the HRB. Due to the healthy state of the public finances at the time, and a strong commitment by the Government to invest in scientific research for economic and social development, the HRB budget increased from approximately €15 million in 2001 to over €50 million in 2008 (including revenue and capital), while the value of new funding commitments rose from just €7.6 million in 2000 to over €64 million in 2007. The significant increase in revenue enabled the HRB to award many more grants as well as higher value grants to build critical mass in targeted health areas (e.g. Health Research Centre in Diet and Health) and to fund critically needed infrastructure (e.g. Clinical Research Facilities).

The period was also one of significant strategic development and change for the HRB as the national policy context evolved. Several key documents were published over the period. The most pertinent to the HRB was the publication in 2001 by the then Department of Health and Children (DoHC) of *Making Knowledge Work for Health (MKWFH)*, the first national strategy for health research.[4] This strategy outlined a farsighted approach to building health research capacity as part of the Government's wider commitment to research for future economic and social development, and to underpin a health system of high quality and effectiveness. The strategy committed the Government to enhancing substantially its support for 'science for health' (i.e. investigator-led, bottom-up research), and to commit to fostering a research culture in the health system by supporting health professionals to carry out research, by funding research concerned with the application of findings to improve service delivery, and by developing the research infrastructure in the health system to

[3] Nason *et al.* (2008) *Health Research – Making an Impact: The Economic and Social Benefits of HRB-Funded Research*. Dublin, Ireland: Health Research Board

[4] Department of Health and Children (2001) *Making Knowledge Work for Health: A strategy for health research*. Government Publications. Dublin. http://www.DoHC.ie/publications/making_knowledge_work_for_health.html

enable world-class research. In direct response to *MKWFH*, the HRB initiated a new strategic funding unit ('R&D for Health') and several funding initiatives were introduced (e.g. the Clinician Scientist Awards, Translational Research Programmes, Strategic Health Service R&D Programmes, Partnership for a Healthier Society Awards, and various Fellowship awards targeted at health professionals).

The research landscape also evolved considerably in the 2000–09 period, as other significant funding sources for health research were either newly established (e.g. SFI) or strengthened (e.g. PRTLI). These funding streams complemented and added value to the HRB investment. The HRB also entered into various strategic co-funding ventures with other funders during this period, including SFI in 2010 (Translational Research Awards), the Wellcome Trust in 2007 (Clinical Research Facilities), the Northern Ireland Health and Social Care R&D Division in 2002 (Cochrane Fellowships), and the Medical Research Charities Group (MRCG) in 2006 (joint HRB/MRCG project grants).

In summary, the aims of this project were to:

- build on the significant bank of evaluation data that the HRB had at its disposal relating to outputs, outcomes and impacts from the 2000–09 grants portfolio
- gain strategic insight by analysing the distribution of outcomes across strategic pillar areas and different funding schemes and funding models
- provide a comprehensive 'baseline' analysis for monitoring the impact of the Strategic Business Plan 2010–14
- further enhance internal systems for prospectively capturing the outputs and outcomes of HRB-funded research
- provide evidence to assist the HRB in maintaining investment in health research

1.2 Project framework and approach

Assessment framework

The assessment framework was broadly based on the Buxton and Hanney Payback Framework as previously described in the HRB's 2008 *Making an Impact* report. Briefly, according to the Payback Framework, any assessment of the scientific quality of research is part of the broader assessment of impact. The societal impact of research is the key issue in a multidimensional categorisation of the benefits of health research. The framework incorporates two dimensions – a logic model of the research-impact process, and a categorisation of research outputs, outcomes and impacts into five distinct impact domains (Table 1). The framework covers the broad health research spectrum and takes into consideration the varying strategic objectives and outcomes associated with different fields of health research – e.g. biomedical research versus population health sciences and health services research.

Table 1: The payback categories

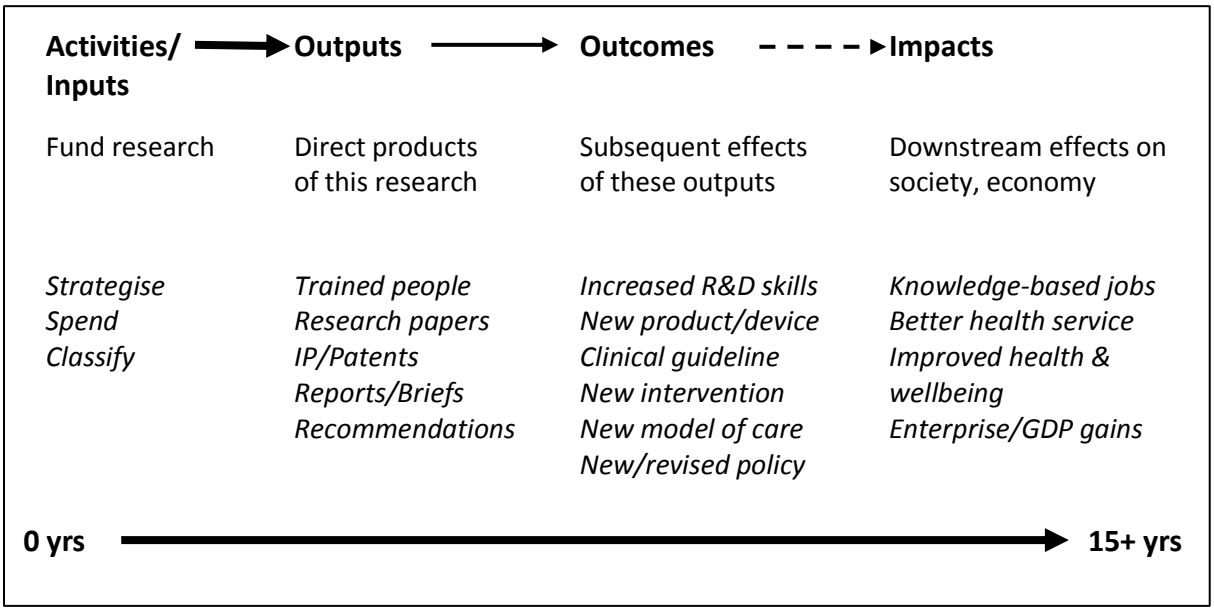
Impact category	Description
Knowledge production	The direct outputs of research, including journal articles, conference presentations, books, book chapters, research reports
Research targeting and capacity-building	Better targeting of future research; development of research skills, personnel and overall research capacity; staff development and educational benefits
Informing policy, practice and product development	Improved information basis for executive decisions, health service configuration, policy-making, and public health behaviour; development of products, interventions and other innovations
Health and health sector benefits	Improved health, cost reduction in delivering existing services, qualitative improvements in the process of delivery, improved equity in service delivery
Broader economic and social benefits	Wider economic benefits from commercial exploitation of innovations arising from R&D; economic benefits from a healthier workforce and reduction in working days lost

Project approach

The project was designed in order to enable a comprehensive identification and assessment of the outputs and outcomes (see Figure 1) linked to new HRB grants awarded between 2000 and 2009, and, where possible, to identify and illustrate some impacts of this research on society and the economy. The aim was to build on the substantial bank of output and outcome data already captured by the HRB evaluation team over the years through various means, so that information gaps could be addressed and a more up-to-date picture obtained of the return on the HRB's 2000–09 investment. Various methodologies were employed to achieve this end, including:

- A Bibliometric analysis of HRB-supported publications was commissioned to assess the scientific impact of research funded in the period.
- An analysis was conducted of personnel supported through HRB grants in the 2000–09 period in order to examine the research capacity that was developed.
- Based on a review of systems used in other countries such as the UK and Canada, a new online survey system was designed and developed (the HRB Grant Outcomes Tracker – see below) in order to seek updated output and outcome data from the 500+ researchers funded during the period.
- Significant desk research was conducted in order to collate and review existing output and outcome data and to comprehensively analyse and classify the 1,000+ grants that were awarded by the HRB in the 2000–09 period. (Much of this analysis is included in the appendices.)
- Data verification and analysis strategies were employed to maximise the utility of survey data, and impact narratives were drafted using information provided in the survey as a starting point.

Figure 1: Defining inputs, outputs, outcomes and impacts[5]



For planning purposes, the project was divided into two distinct phases:

Phase 1 – Collation, analysis and review of existing data

- identification and collation of relevant output and outcome data submitted to the HRB over the last ten years via end-of-grant reports, previous evaluation surveys, 'Picture of Health' and so on
- re-formatting of the data collated from various sources into a uniform format and migration of this data into an bespoke online system
- classification and analysis of the HRB portfolio 2000–09 according to health research strategic pillar areas and the UK Health Research Classification System, which showed that much of the research funded by the HRB in this period was aetiological in nature (see Appendix G).

Phase 2 – Capture, validation and analysis of new data

- tender, design, testing and implementation of an online grant-holder Outcomes Tracker survey to capture new and updated outputs and outcomes arising from the HRB funding portfolio 2000–09
- cleaning, validation and analysis of output and outcome data collated into a uniform spreadsheet
- commissioning of a Bibliometric analysis of HRB-supported publications to gauge the scientific impact of HRB-funded research measured against international benchmarks
- preparation and drafting of impact narratives to illustrate examples of outcomes and impacts arising from HRB grants awarded between 2000 and 2009
- drafting of a comprehensive report describing outputs, outcomes and impacts arising from HRB grants 2000–09.

[5] Diagram reproduced and adapted with permission from Dr Ian Viney, Director of Strategic Evaluation, MRC based on his presentation to the 5th ESF Evaluation Forum, Dublin, November 2009

The HRB Grant Outcomes Tracker

A new bespoke online survey was designed and executed for the purpose of this project; the survey was named the HRB Grant Outcomes Tracker. The system was designed so that grant-holders could attribute a single outcome across multiple grants held in the 2000–09 period (care was taken not to double count outputs and outcomes at an aggregated level), in order to minimise the burden placed on researchers who were awarded multiple HRB grants in the period. In addition, data collated from end-of-grant reports and other sources in Phase 1 was migrated into the Outcomes Tracker system to facilitate ease-of-completion and to make best use of existing information. The Outcomes Tracker comprised the following sections:

Section 1	Grant-holder details
Section 2	Main output types
Section 3	Publications
Section 4	Intellectual property (IP) and commercial activities
Section 5	Leveraged funding
Section 6	Health innovations
Section 7	Engagement of patients and public
Section 8	Influences on health policy and practice

Response rate

The Outcomes Tracker survey was opened to the research community in September 2012, with a deadline for completion of end October 2012. In total, 428 grant-holders who held 746 grants completed the Outcomes Tracker, representing an excellent grant response rate of 77% (information was obtained from end-of-grant reports and other sources for a further 271 grants, whose grant-holder who did not complete the survey). Further analysis of the Outcomes Tracker respondent and non-respondent pool is included in Appendix I.

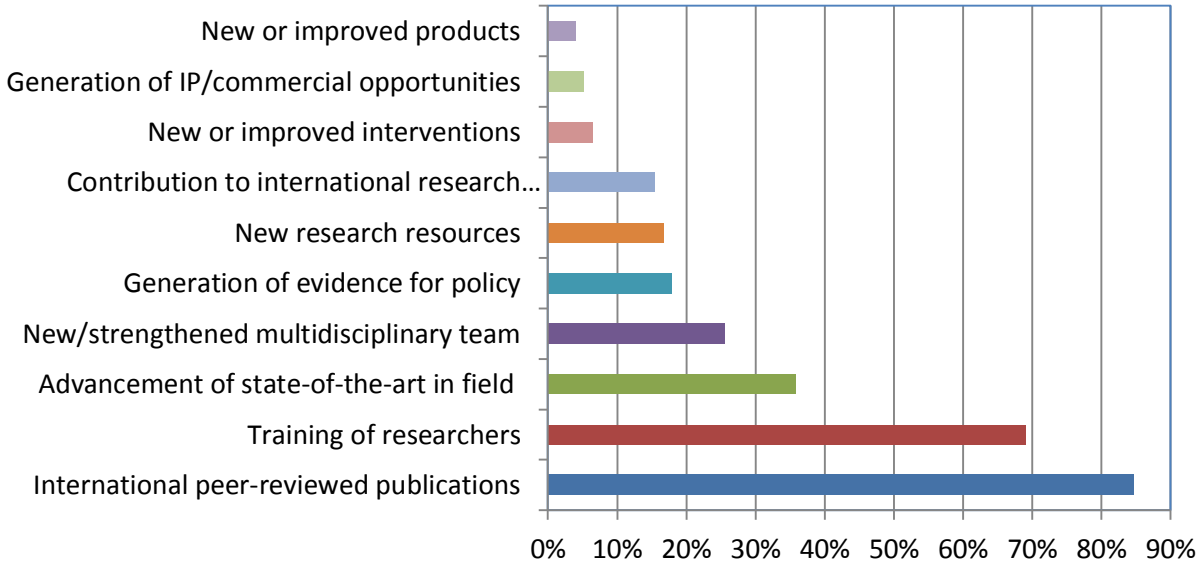
Limitations of the approach vis-à-vis the Payback Framework

The main objective of this project was to provide an updated and comprehensive picture of the outputs and outcomes from the entire portfolio of grants awarded by the HRB between 2000 and 2009, targeted primarily at categories 1-3 of the Payback Framework, which could then be used as a basis for future in-depth impact assessments to populate category 4 (health sector impacts) and category 5 (broad economic and societal benefits) of the framework. Such impact assessments require specialised methodologies and expertise, including in-depth case study analysis, policy impact analysis, and econometric modelling to estimate monetary gains of health benefits linked to research findings. This was outside the scope of the current study. Nevertheless, where good examples of policy, health and economic impact were identified via information provided by HRB grant-holders in the Outcomes Tracker survey, these examples were further developed and included in the report as 'mini' case studies, in order to illustrate the facts and figures.

2. Main types of outputs reported by HRB grant-holders

In the HRB Outcomes Tracker, grant-holders were asked to select the three main outputs arising from their award from a dropdown list, and to rank the selected options according to how important they perceived them to be. Figure 2 shows the proportion of the 746 respondent grants that selected each output type, while Figure 3 shows the three most important output types as ranked by respondents.

Figure 2: Proportion of grants that selected each output type



A number of observations can be deduced from examining the data in Figure 2:

- The production of international peer-reviewed publications was by far the most common type of output reported by grant-holders; it was followed by training of researchers.
- The four most common types of output reported by grant-holders were academic-level outcomes, rather than outcomes in other spheres, such the health sector or economy.
- For almost one-fifth of grants, generation of policy-relevant research evidence was reported as a main output.
- Given that 16% of grants contributed to the development of a health innovation, it was perhaps surprising that grant-holders selected a new or improved product or intervention as a main output for approximately 10% of grants only. This may indicate that some researchers regard academic-level outcomes as more important than other types of outcomes.

Figure 3: Top three output types by ranked importance (by respondents)

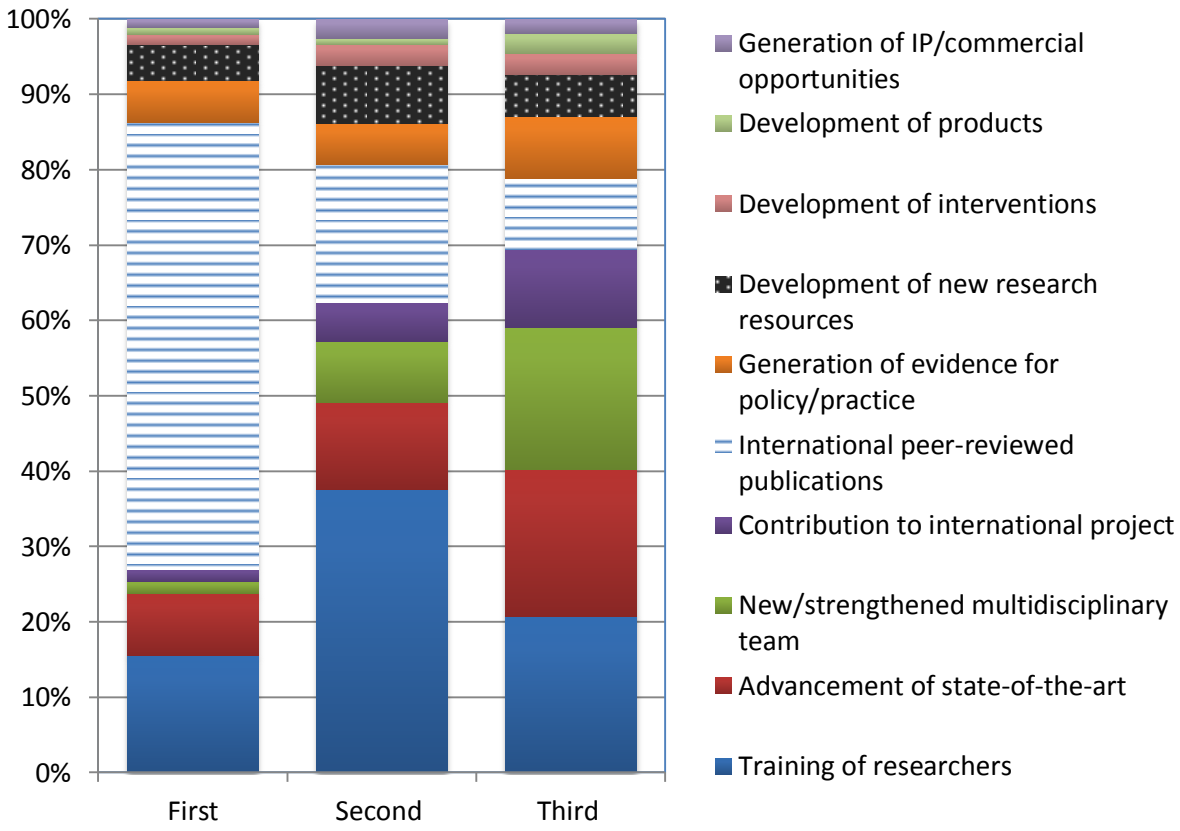


Figure 3 confirms that researchers generally perceive academic outputs as most important to them, and also that that these types of outputs tend to be by far the most common types of outputs generated. Specifically:

- Generation of international peer-reviewed publications was by far the most common first-ranked output type (selected for 60% of grants) – the next most common first-ranked output was training of researchers (selected for 15.5% of grants).
- The most common second-ranked output type reported was training of researchers, selected for 37.5% of grants, followed by generation of peer-reviewed publications.
- The most common third-ranked output type was predominantly an academic output (selected for 84.3% of grants) with non-academic outputs such as generation of policy-relevant evidence, development of a new product or intervention, or generation of IP or commercial opportunities selected for 15.7% of grants.

3. Knowledge production

3.1 Peer-reviewed publications and citation impact

The HRB commissioned Thomson Reuters (*Evidence*) to conduct a Bibliometric analysis of HRB-supported publications from 2000 to 2012. The analysis was based on a HRB internal catalogue of publications linked to grants awarded between 2000 and 2009, which were subsequently matched to the Thomson Reuters *Web of Knowledge℠* and supplemented with publication data based on a search of the funding acknowledgement section of papers. The key findings of the Bibliometric analysis are summarised below.[6]

Key findings:

- Some 3,382 HRB-supported publications in the 2000–12 period were matched to the *Web of Knowledge.* Of these 3,382 publications, a total of 3,226 papers that were used in the citation analysis.
- HRB-supported papers have grown rapidly in volume, and these papers have made an increasing contribution to Irish clinical/health/pre-clinical and biological sciences research, as well to as the wider Irish research base.
- The majority of HRB-supported papers have been published in high-impact journals, and more than half have been published in the world's top 10% of journals, as measured by journal impact factor.
- The citation impact of HRB-supported papers is very high (1.74, 2000–12) and increasing, approaching twice the world average (1.84, 2008-12). This outperforms benchmarks for similar Irish and UK research in clinical/health/pre-clinical and biological sciences research.
- One-fifth (18.9%) of HRB-supported papers are in the world's top 10% as measured by citation impact. There has been a high uptake and use of HRB-supported papers, with very few papers prior to 2010 uncited.
- The Impact Profile® of HRB-supported papers outperforms benchmarks for Irish clinical/health/pre-clinical and biological sciences research.
- In terms of HRB strategic pillar areas, over two-thirds of HRB-supported papers were in the Biomedical category; around one-fifth were Clinical and over one-tenth were focused on population health and health services research. The latter two HRB strategic pillar areas have increased as a share of HRB-supported papers, concordant with the HRB broadening its funding portfolio in response to *MKWFH.*
- HRB-supported clinical papers are exceptionally highly cited – over twice the world average (2.20). HRB-supported biomedical papers are very well cited (1.67). Citation impact in these fields is driven by internationally co-authored papers. HRB-supported population health and health services research papers are well cited (1.40), and citation impact is increasing.
- With the exception of two fields (cell biology and endocrinology and metabolism), HRB-supported papers by its top 20 *Web of Science℠* journal categories by volume are very well cited, relative to the world, and relative to benchmarks for similar Irish clinical/health/pre-

[6] The full Bibliometric analysis report is published on the HRB website as a companion report.

clinical and biological sciences research. HRB-supported papers are particularly highly cited in oncology, immunology, genetics and heredity, and psychiatry.

- Around two-fifths of HRB-supported papers have been internationally (40.8%) and domestically (40.0%) co-authored. This has risen from around one-third of HRB-supported papers (33.8% and 34.7% respectively) to over two-fifths (43.8% and 42.1%). Internationally co-authored HRB-supported papers are very highly cited – over twice the world average (2.28) and rising.
- The citation impact of internationally co-authored papers in the HRB Clinical strategic pillar area is over three times the world average (3.29) compared to all papers in this pillar area (2.20). In the HRB Biomedical strategic pillar area, internationally co-authored papers have a citation impact over twice the world average (2.11) compared to all papers in this pillar area (1.67). The citation impact gain of internationally co-authored papers compared to all papers in the HRB Population Health and Health Services Research strategic pillar area is more negligible (1.51 compared to 1.40 respectively). There is little difference in citation impact between the three HRB strategic pillar areas that were authored purely at the national level.
- Researchers from the USA and the UK have been the most frequent international co-authors of HRB-supported papers (43.6% and 43.1% of internationally co-authored papers respectively), suggesting a strong Anglophone dimension to international co-authorship along with partners from countries such as Australia and Canada (10.3% and 8.1% respectively). European partners also feature, particularly countries such as Germany (12.6% of internationally co-authored papers), Italy (8.7%) and France (8.7%).
- The Irish academic sector has produced around 90% of HRB-supported papers and the Irish health sector has produced around one-third. These proportions have been more or less constant over time, although there are suggestions that the Irish health sector is producing a greater proportion of HRB-supported papers.

HRB-supported papers and citation impact by HRB funding scheme

Table 2 shows that there are some very highly cited papers associated with HRB funding schemes, particularly for schemes under the broad headings of Infrastructure and Special Initiatives, but also for Cancer Consortium-related papers (notably the ICORG Cancer Clinical Trials Network). Funding schemes related to career development (such as Clinician Scientist Awards, fellowships and PhD training programmes) are also very highly cited. For information, **citation impact** or more specifically 'field normalised' citation impact, is the number of citations accrued by a publication corrected for the research field and year of publication, both of which influence the number of citations linked to a publication. Individual citation impact values are then averaged over a group of papers to give a mean normalised citation impact. The world average is 1.0, so any citation impact value higher than this indicates a set of papers cited more than average for similar research worldwide.

Table 2: Citation impact of HRB-supported publications by funding scheme

HRB funding scheme and grant type	Papers	Citation impact
Cancer Consortium awards	**101**	**3.96**
Jointly funded projects and fellowships	54	1.47
ICORG Cancer Clinical Trials Network	47	6.82
Clinician Scientist Awards	**117**	**3.36**
Health Research Awards	**103**	**1.40**
Health Research Centres	**53**	**1.07**
Infrastructure Awards	**104**	**4.07**
Clinical Research Facilities	45	4.72
Equipment grant	27	2.89
Health Information System award	13	8.03
Imaging Award	19	1.52
Medical Research Charities Group co-funded project	**118**	**1.25**
Medical-AHP Fellowships	**327**	**1.94**
Cochrane Training Fellowship	31	1.01
Health Professionals Fellowship	165	2.36
Medical Fellowship	124	1.69
Summer studentship	8	0.76
PhD Scholars Programme	**163**	**2.16**
Post-Doctoral Fellowships	**302**	**2.35**
Programmatic Grants (five-years)	**455**	**1.56**
Programme Grant	284	1.73
Strategic Health Services R&D Award	46	1.04
Translational Research Programme	127	1.34
Project Grants (three-years)	**1,661**	**1.46**
Global Health Research Award	22	1.58
Interdisciplinary Project	26	1.16
North-South Cooperation Project grant	65	1.38
Partnership Award	32	0.79
Research Project Grant	1,528	1.48
Special Initiatives	**37**	**4.07**
Autism Genome Project	17	3.96
ELDERMET	16	5.17
Other	4	0.23

4. Research capacity-building

In total, approximately 2,095 research-related positions were either directly created or supported through 867 HRB grants[7] (including Clinical Research Facilities and ICORG) that were awarded between 2000 and 2009. This figure includes salaried fellowship awardees and non-salaried PIs as well as personnel funded through all grants, such as PhD students and post-doctoral researchers.

A breakdown of the total research personnel supported on HRB grants is provided in Table 3. A total of 474 unique PIs were funded by the HRB between 2000 and 2009. A proportion of PIs were in receipt of multiple grants over the period, hence the disparity between the total number of grants and the total number of PIs. A total of 651 PhD students were trained, or continue to be trained, through HRB funding awarded in the 2000–09 period. This figure includes the 169 students who were funded through the six HRB PhD Scholars Programmes (in cancer biology, neuroscience, molecular medicine, therapeutics and disease, immunology, and health services and population health research). A total of 435 post-doctoral researchers (post-docs) were funded either through a targeted post-doctoral fellowship award or via employment on a project or programme grant.

Table 3: Breakdown of personnel supported by HRB grants awarded in the 2000–09 period

	Total No. funded	No. PhDs	No. post-docs	No. health professionals
PIs	474	n/a	n/a	184
Fellows	266	127	77	185
Grant personnel	1355	524	358	122
Total	2095	651	435	491

Health professionals trained

Of interest to the HRB, which aims to foster a research culture in the health service, is that 491 HRB-funded personnel came from a health professional background, equal to 23% of the total number of personnel. Of these 491 personnel, 260 (or 53%) either came from a medical background or were currently practising medicine. The remaining 231 personnel were from a broad mix of other health professional backgrounds such as dentistry, nursing and midwifery, physiotherapy, speech and language therapy, occupational therapy, clinical psychology, and radiography. The health professionals in many cases had completed a PhD or were established PIs.

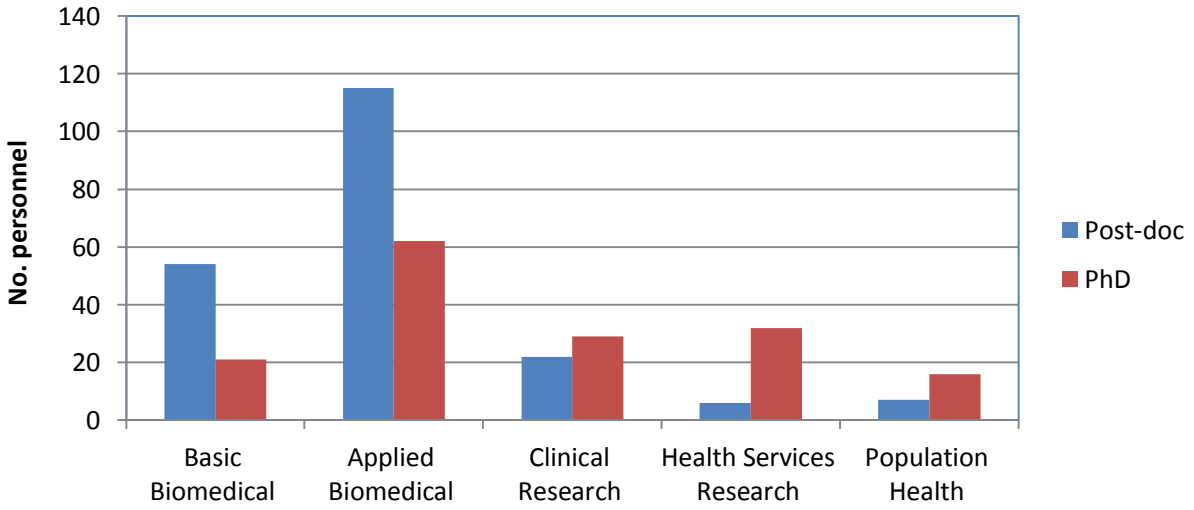
PhDs and post-docs

Figure 4 provides information on the distribution of a subset of 364 PhDs and post-docs across the HRB strategic pillar areas that had been previously compiled for the 2010/2011 HRB Outputs report

[7] The 867 number is less than the total number of 1,100+ HRB grants awarded between 2000 and 2009 because some grants were awarded for the purchase of equipment only, other grants were small and were insufficient to cover the cost of employing staff, and personnel data were not readily available for other grants (e.g. MRCG grants).

(based on end-of-grant report data). While only representing a sample of the total cohort of PhD and post-doctoral personnel employed over the 2000–09 period, there is a fairly solid basis on which to extrapolate the data as the pillar areas of the sample grants are similar in distribution to the overall 2000–09 portfolio (i.e. predominantly biomedical in nature). The bar chart shows that basic or applied biomedical research grants employed 83% of all post-docs and 52% of all PhD students, and that the number of post-doctoral researchers employed in population health sciences and health services research was disproportionately low. The HRB Strategic Business Plan 2010–14 has addressed this deficit through targeted capacity-building initiatives in population health sciences and health services research, most notably through funding for a dedicated PhD Scholars Programme and the Interdisciplinary Collaborative Enhancement (ICE) awards targeted at post-doctoral level (and the Research Leaders awards at PI level).

Figure 4: Breakdown of 364 PhD and post-doc positions by pillar area



Figures 5 and 6 show the breakdown of PhD graduates and post-doctoral researchers by funding scheme. Not surprisingly given the number funded, three-year research project grants were the predominant mechanism through which both PhD students and post-doctoral researchers were funded. However, the six PhD Scholars Programmes collectively trained 150 PhD students (the six subject areas were cancer biology, immunology, molecular medicine, neuroscience, therapeutics and disease, and health services research).

Figure 5: No. PhD graduates by scheme

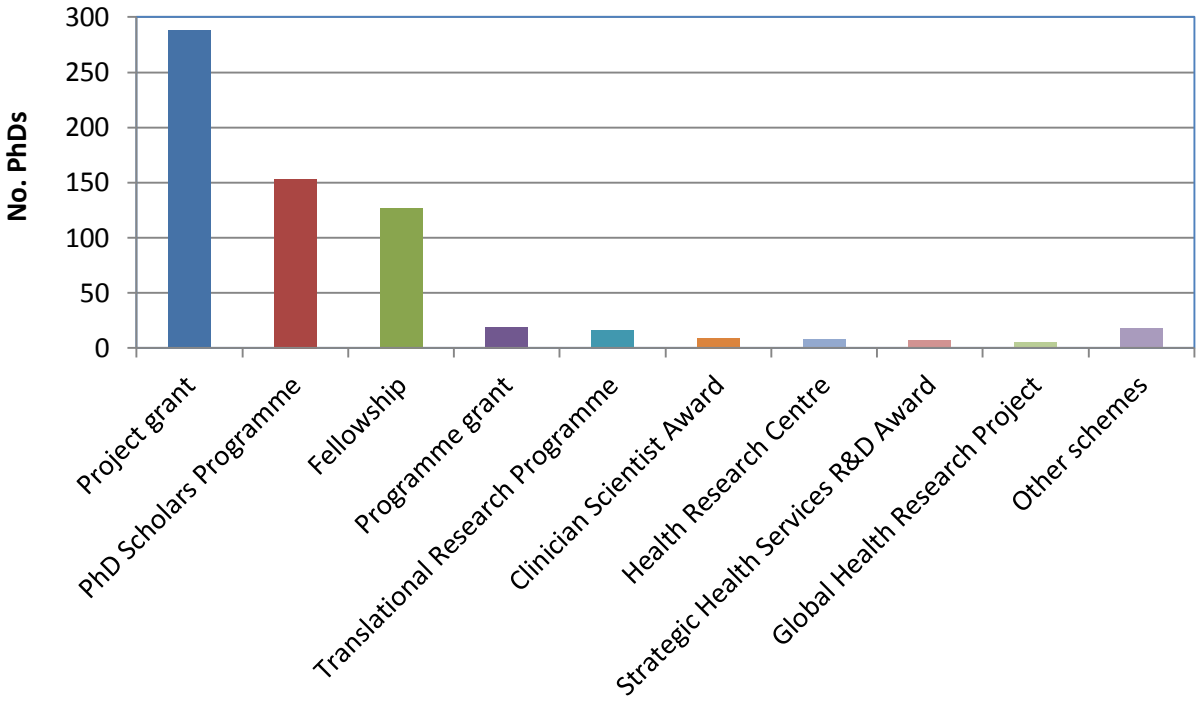
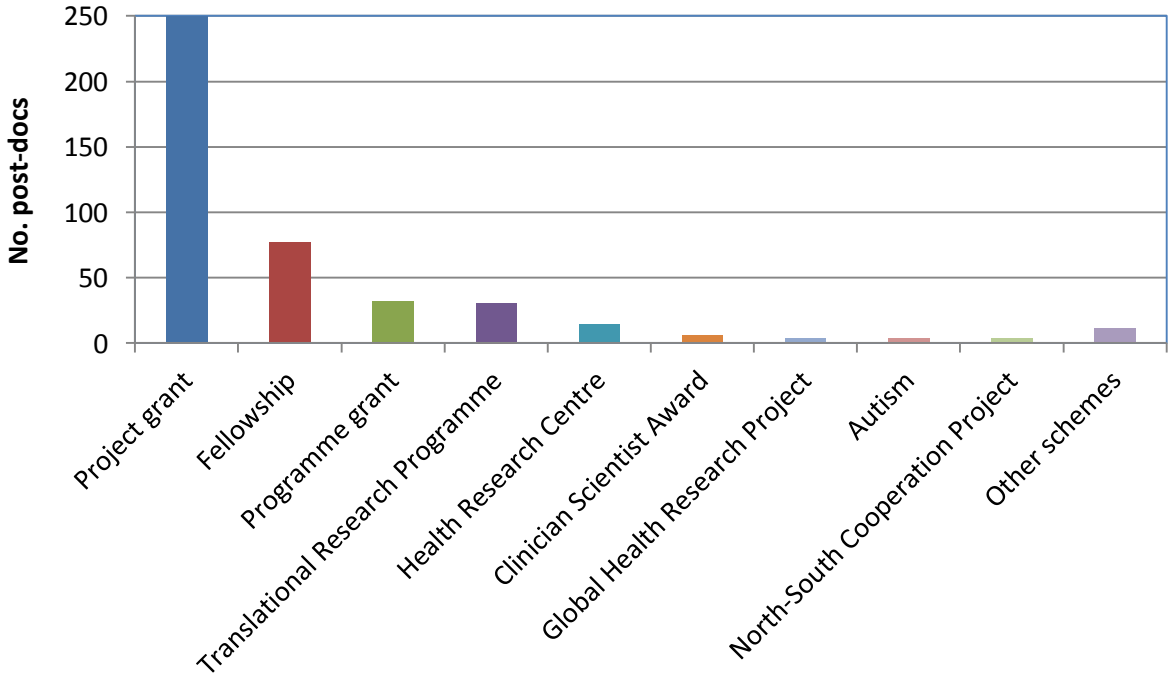


Figure 6: No. post-doctoral researchers funded by scheme



5. Informing health policy, practice and behaviour

5.1 Policy and practice outputs and impacts

A key area in terms of assessing the impact of HRB-funded research relates to the health sector and, specifically, to outputs and activities of researchers that may influence, or have already influenced, health policy, clinical practice and patient care. Such 'influences' on policy and practice may be directly informed by HRB-funded research findings (e.g. citation of HRB research in policy or guideline documents), or the influence may be more indirect and may arise from the personal network of an individual PI or his/her pre-eminence and recognition as a leading expert in their field. In other cases, it may be a combination of both a PI occupying a position of influence and a highly relevant piece of research that results in an impact on policy or practice.

In an effort to ascertain the number and value of outputs and activities aimed at influencing policy and practice, HRB grant-holders were asked to describe any activities undertaken that may lead to an impact in these areas, including:

- practice guidelines, policy reports, policy briefs, handbooks and so on that were targeted at health policy-makers or practitioners
- any interactions (such as meetings, seminars hosted) that they had with potential research beneficiaries/users in health policy or clinical practice sectors
- any advisory roles or expert group memberships (e.g. guidelines committee, policy development group) linked to their HRB-funded research
- any instances of their HRB-funded research being cited or referred to in key clinical or health policy documents, in material read by health professionals or policy-makers, or research findings being used to inform the education or training of health professionals or policy-makers.

The main findings from this part of the analysis were:

- A total of 641 influences on health policy and practice were reported by grant-holders linked to 282 grants (or 28% of total grants).
- The three most common types of influence were (ranked in order) advisory role/member of expert group, meeting with research users, and production of a guideline or policy report/brief.
- The vast majority of influences resulted from research funded by the HRB between 2004 and 2008, with the highest number arising from research funded in 2005.
- In relative terms, grants funded in 2004, 2005 and 2008 produced the most influences per million euro spent.
- Health Services Research produced the largest proportion of influences (45%), followed by Clinical Research (22%), Population Health Sciences (16%), and Applied Biomedical (15%).

- The grant types that produced the most influences on policy and practice, on average per grant, were Health Research Centres (11.5 influences per grant), Strategic Health Service R&D Programmes (6.9 per grant), and the Global Health Research Awards scheme (2.8 per grant).

Details of policy and practice influences

In the Outcomes Tracker survey, grant-holders were asked if any of their HRB grants awarded between 2000 and 2009 produced outputs or were associated with activities that influenced, or had the potential to influence, health policy, clinical practice and health service provision. Respondents could select one of 11 types of outputs or activities and could insert up to 20 instances of such outputs. In addition, respondents could attribute a single output/activity to more than one grant (as described in the previous section on Innovations). Table 4 tabulates the overall number of unique policy/practice outputs and activities by sub-type (actual examples of these influences are set out on pages 29-33).

Table 4: No. of policy and practice influences by sub-category

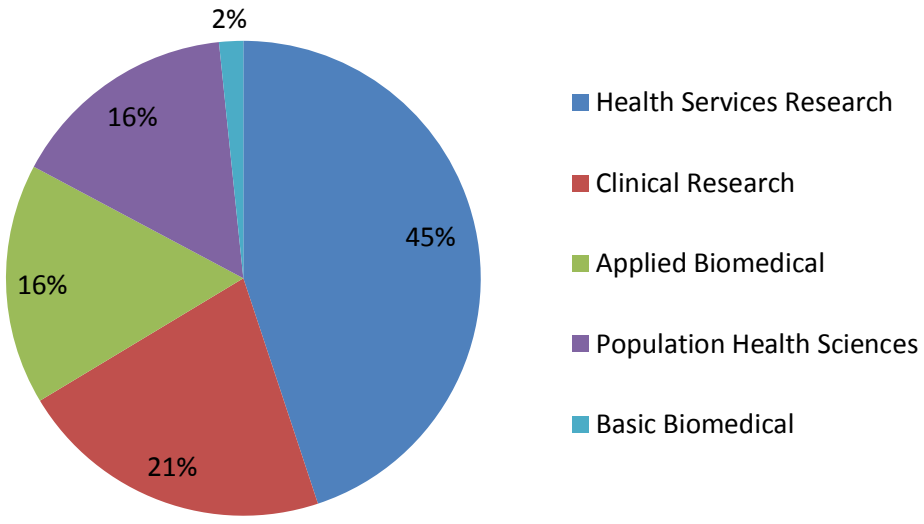
Type of output or influence	Number
Advisory role, or member of policy/guidelines expert panel or working group	151
Meetings with policy-makers, health managers or other key users to present/discuss findings	104
Produced practice or treatment guidelines or a policy report/brief or booklet	68
Research featured in specialised medical or health press (e.g. *Irish Medical Times, Health Manager*)	64
Research informed or led to training or education programmes for health or other professionals and/or policy-makers	54
Hosted or presented research findings at a stakeholder seminar or workshop	47
Citation/inclusion of research in policy documents or key government reports	35
Research featured in newsletter, or on website of professional body	34
Produced or updated a Cochrane systematic review as part of HRB-funded research	30
Citation/inclusion of research in clinical guidelines, clinical reviews, or systematic reviews	28
Submission of research evidence to a national consultation process (e.g. service review, health policy or legislative consultation)	26
Total	**641**

Influences by strategic pillar

Figure 7 shows the number of influences broken down by strategic pillar area. The standout messages from the analysis of influences by strategic pillar are:

- Health services research accounted for the largest proportion (45%) of influences – perhaps expectedly given the aims and objectives of grants funded under this stream. The two most common types of influence reported by HSR grant-holders were advisory roles and meetings with research users.
- Clinical research accounted for just over one-fifth of influences – a common type of influence reported under this stream was member of guidelines committee or other expert committee. Also, due to the widespread use of Cochrane reviews in the development of treatment and best practice guidelines, production of Cochrane reviews under the Cochrane Fellowship scheme (many by health professionals) were included as an influence type.
- Population health sciences research produced as many influences as Applied Biomedical research (while receiving far less funding). Similar to the HSR profile, the most common types of influence produced by Population Health researchers were via the PI (i.e. advisory roles, meetings with research users).
- The most common type of influence reported by biomedical researchers was their research findings featured in a specialised medical or health publication, such as the *Irish Medical Times, Health Manager*, HSE newsletter etc.

Figure 7: Proportion of influences by strategic pillar area



Number of influences by grant type/scheme

To derive further strategic insights and to identify the types of grants that are more associated with these types of strategic outcomes, the number of influences was analysed according to the scheme linked to the underpinning grants (Table 5 and Figures 8 and 9). The main observations from an analysis of this data include:

- While the average number of influences produced by a Project grant was very low at 0.3 (due to the high number of biomedical research grants in this grant category), the average number of influences produced by a Project grant in Health Services Research was 1.33, which is well above the average number.
- The Health Research Centres (11.5 per grant) and the Strategic Health Service R&D Awards (6.9 per grant) stand out as having produced the most influences on average per grant.
- The Global Health Awards (2.8 per grant), Clinician Scientist Awards (2.1 per grant) and the co-funded Partnership Awards (2.1 per grant) also produced significantly higher than average influences per grant.
- Many of the grants funded under the above schemes that produced multiple influences were funded between 2004 and 2007, which explains the high level of influences produced in those years.
- The relatively high level of influences produced through these schemes is not surprising when one looks at their strategic funding objectives, which were about fostering a research culture in the health sector and producing outputs oriented towards informing policy and practice (e.g. Health Research Centres).
- Also, several of the schemes listed above were either primarily targeted at health professionals (e.g. Clinician Scientists) or it was expected that health professionals and/or policy stakeholders would form an integral part of the collaborative research team (e.g. Strategic Health Service R&D Awards, Partnership Awards).

Table 5: No. of influences per grant type

Grant type (No. grants)	**Total no. influences**
Project (543)	174
Fellowship (235)	156
Strategic R&D (11)	77
Partnership (29)	64
Global health (10)	29
Health Research Centre (2)	24
Programme (18)	22
MRCG (46)	19
Clinician scientist (7)	16
Co-funded in health services research (19)	12
Health information system (13)	11
Translational (9)	10
North-South (19)	8
Interdisciplinary (7)	4
Blood (4)	4
Imaging (2)	4
Autism (3)	3
Nursing priorities (2)	1
Cancer Consortium (10)	1
PhD scholars (6)	1
Junior clinician scientist (2)	1
Total (1,017 grants)	**641**

Figure 8: Average number of influences per grant type

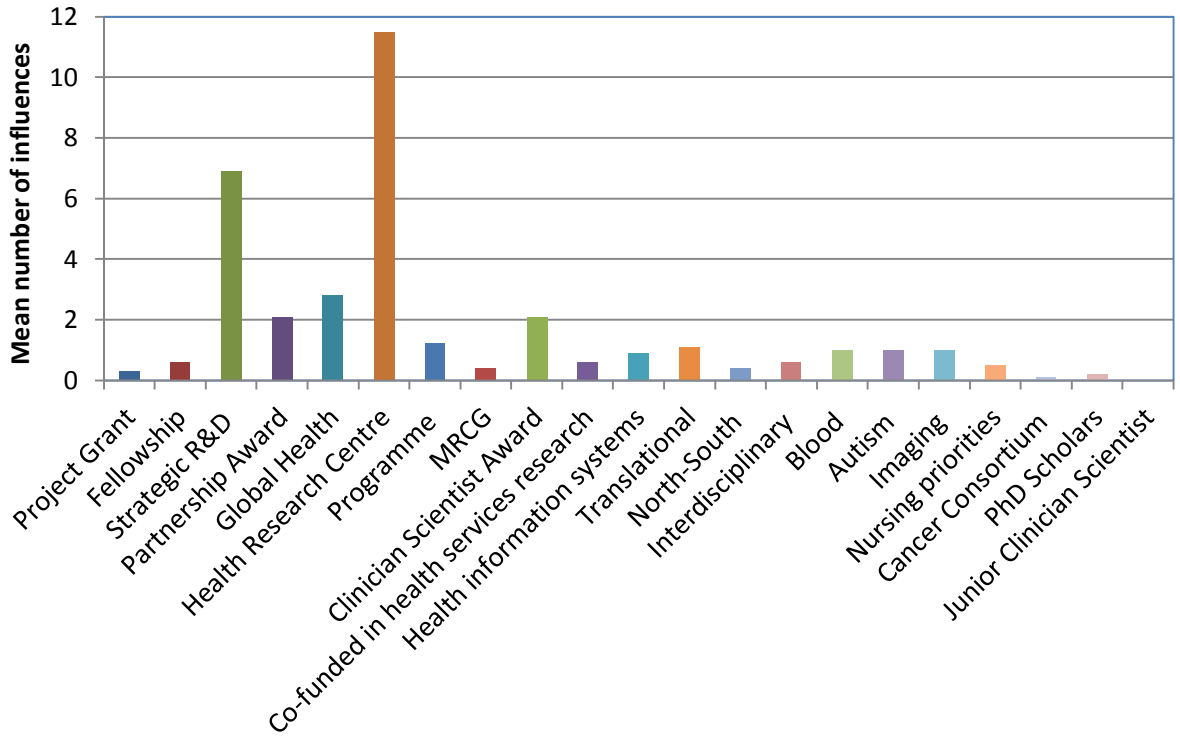
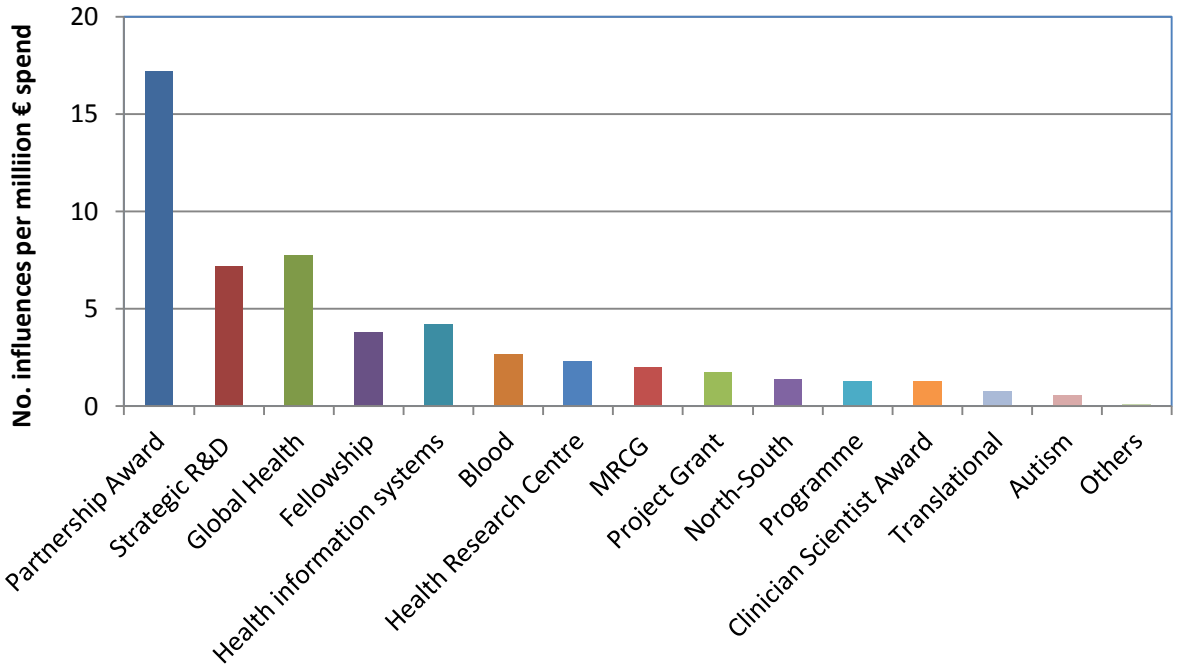


Figure 9: Number influences on policy and practice per million euros spent by scheme



Examples of influences and impacts on health policy and clinical practice

Grant title: Healthy ageing research programme – maximising quality at the interface between individuals and the healthcare system
Grant type: Programme grant (five-year grant)
PI: Professor Hannah McGee, RCSI
Year awarded: 2001

This five-year Programme grant, funded in 2001, established the first Irish longitudinal study on community-dwelling older people in Ireland, and examined ageing in Ireland from many perspectives (e.g. perception of ageing, quality of life, quality of care). The research led to the development of a new measure of quality of care of the elderly, based on the Institute of Medicine framework. The research also provided novel and important policy-relevant information on key cardiovascular groups (stroke and heart failure) in Ireland, which led to three key policy impacts:

- Owing largely to the appointment of Professor McGee as the Chairperson of the expert group that drafted the new National Cardiovascular Health Policy (Changing Cardiovascular Health – National Policy 2010-2019), data produced through this programme, and general expertise attained during the programme, directly informed the development of this policy.
- On the basis of the heart failure project which formed part of the programme, the PI and another team member were asked to inform the HSE planning for the 'National Action Plan for Heart Failure 2008–2011'
- The programme provided valuable experience and one-year stroke follow-up data to complement Ireland's first National Stroke Audit, in which the PI and one of the co-PIs were closely involved. The audit was widely published and presented in Ireland, and drove a wide range of developments and service planning for stroke as one of the most neglected areas of healthcare.

Grant title: Repositioning for the prevention of pressure ulcers
Grant type: Nursing and Midwifery research training fellowship (three-year grant)
Fellow: Dr Zena Moore, RCSI
Year awarded: 2006

Pressure ulcers impact negatively on quality of life and contribute to increased morbidity and mortality. This fellowship grant sought to determine the effectiveness of a novel preventative technique on the number of pressure ulcers developed by older persons nursed in 12 long-stay settings. The aim was to investigate if repositioning at three-hourly intervals using a '30 degree tilt' technique – achieved by rolling the patient 30 degrees to a slightly tilted position with pillow support at the back – could prevent or significantly decrease the number of pressure ulcers that they developed. The results showed significantly reduced incidence of pressure ulcers in the 30-degree tilt group compared to the usual care group.

Health economic analysis showed that using the 30-degree tilt intervention in the hospitals where the study was conducted would yield an annual saving of €250,676 when compared with usual care costs. Furthermore, this method of repositioning is less time consuming, requires less manpower and is more cost-effective when compared to usual care. The recommendations from this study have been included in the HSE *National Best Practice and Evidence Based Guidelines for Wound Management* and subsequently adopted by the European Pressure Ulcer Advisory Panel (Dr Moore was a member of both guideline committees).

Grant title: Appropriate prescribing in late life
Grant type: Clinical research training fellowship (three-year grant)
Fellow: Dr Paul Gallagher, Cork University Hospital
Year awarded: 2006

Dr Gallagher's clinical research fellowship validated and tested a new medication review system, developed by the PIs group, called STOPP (Screening Tool of Older Persons' potentially inappropriate Prescriptions) and START (Screening Tool to Alert to Right Treatment). The study showed that implementation of STOPP/START recommendations led to significant and sustained reductions in the prescription of unnecessary and potentially harmful drugs, as well as a reduction in the under-use of clinically beneficial drugs. The criteria have been formally endorsed by the EU Geriatric Medicine Society Special Interest Group in Old Age Pharmacology (of which Dr Gallagher is a member), and have been published in several European languages. STOPP/START was also cited as a reference tool in the medications management section of the HSE's clinical care programme for older adults, and in the Royal College of Physicians of London Acute Care Toolkit 3 (Acute Medical Care for Older People).

STOPP/START recommendations and criteria have now been implemented as an audit tool in several countries, resulting in significant improvements in prescribing quality. Furthermore, a recent Spanish study examined the cost implications of applying STOPP/START criteria in a cohort of patients with advanced dementia, and found that annual savings of €5,000 per year (based on 25 persons in a long-stay psychogeriatric unit) could be achieved by implementing the criteria. The lead investigator of the Spanish group concluded that apart from the enhancement in care indicators (reducing polymedicine) and in healthcare management (pharmaceutical savings), the benefit of including STOPP/START criteria was also in "reducing complications linked to the administration of many pharmaceutical drugs, both from the healthcare perspective (less side-effects and interactions) and from the management point of view (reducing the associated indirect cost)". Finally, a software prototype of the system has been developed as a commercial product by Clinical Support Information Systems Ltd.

Grant title: Atlantic diabetes in pregnancy network. Prospective studies to examine the outcome of pregnancy in diabetic women
Grant type: Strategic Health Service R&D award (five-year grant)
PI: Professor Fidelma Dunne, NUI Galway and Galway University Hospital
Year awarded: 2005

Professor Dunne's research provided, for the first time, reliable prevalence data for gestational diabetes (GDM) as well as pre-gestational diabetes in the west of Ireland using a universal screening policy. Using both World Health Organisation (WHO) criteria and more recent criteria adopted by the International Association of the Diabetes and Pregnancy Study Groups, the group identified the prevalence of GDM at > 9% and > 12% respectively, which was broadly consistent with international rates identified in previous studies. The group also showed that pre-diabetes/diabetes continued postnatally in 18% of women with GDM compared with 3% of women who had a normal pregnancy, while metabolic syndrome was twice as common in women with GDM. Moreover, the study showed that maternal and infant outcomes in diabetic pregnancy were significantly poorer than outcomes of pregnancy for non-diabetic women, mainly due to poor pregnancy preparation and poor glycaemic control, but also because of fragmented care throughout pregnancy. The research findings clearly had major implications for the clinical care of women with GDM, as well as highlighting the need for policies and interventions to prevent GDM.

In her position of consultant endocrinologist at Galway University Hospital, coupled with her close links with HSE West, the PI was empowered to facilitate change in order to address the fragmented care issues identified in the research. She changed the process of care in the three antenatal centres in the Galway region with the establishment of combined diabetes antenatal clinics and

complimentary pre-pregnancy clinics. More recently, the group have been promoting behavioural change in women with GDM to prevent future Type 2 diabetes, as psychological intervention in pregnant women with GDM has been shown to be an important aspect of the care of these women. The potential for national policy and practice impact from this research was also facilitated by the appointment of Professor Dunne as Chairperson of the 'Obesity in Pregnancy' sub-group of the Department of Health National Obesity Taskforce, and her appointment as Chairperson of the 'Diabetes in Pregnancy' sub-group of the HSE National Diabetes Working Group. In terms of prevention, Professor Dunne is a partner in the FP7 collaborate project 'Vitamin D and lifestyle intervention to prevent GDM' and will utilise the findings from that research to further influence policy and practice.

Grant title: Economic modelling of services utilisation data and epidemiological data for oral health services
Grant type: Research project grant (three-year grant)
PI: Dr Noel Woods/Professor Helen Whelton, Oral Health Services Research Centre, CUH
Year awarded: 2002

This research project, funded in 2002, analysed the treatment provided to adult medical card holders eligible under the Dental Treatment Services Scheme (DTSS) and compared it with their need for care as assessed by the National Survey of Adult Oral Health. In summary, large variations in patterns of service provision were found across health boards – above average treatment content per visit was encountered in health boards with the greatest number of dentists per capita. The researchers did not find evidence that this 'over treatment' was in response to any additional need for care, and the patterns of service provision suggested that supplier inducement may have been a factor (the structure of the DTSS was conducive to dentists acting in response to economic incentives).

Based on the project findings, the group recommended that a system of probity be introduced to prevent, detect and deter the provision of services other than those based on need. The findings were published in the *Journal of Dental Research* and Dr Woods made key presentations summarising the research at a Department of Health seminar in Farmleigh House, Phoenix Park, Dublin, 12–13 April 2005). The Department of Health subsequently introduced new probity checks to the Irish dental system in the Spring of 2006. In an agreement with the Irish Dental Association, the probity checks involve regular random checks on dentists in each former health board (now HSE) region.

Grant title: Recruitment, adaptation and retention of foreign nurses in Ireland
Grant type: Research project grant (three-year grant)
PI: Professor Ruairi Brugha, RCSI
Year awarded: 2006

This project, termed the 'Nurse Migration Project', demonstrated the extent to which Ireland has come to rely on nurses from outside the EU to staff its health system. Between 2000 and 2009, 38% of nurses newly registered in Ireland came from outside the EU, a dependence on migrant nurses that indicated an inability to supply enough nurses locally to meet demand. The project also developed a profile of migrant nurses working in Ireland, providing policy-makers with demographic information, insights into their prior nursing experience and qualifications, information on their career progression and their overall experience in Ireland. A key finding was that only one in five migrant nurses intended to remain in Ireland in the long term, and the researchers highlighted the impact their onward migration would have on health service provision in Ireland.

Given the policy relevance of their findings, the group produced a series of policy briefs detailing the origins, experiences and issues faced by migrant nurses in Ireland. In addition, Professor Brugha regularly disseminated findings from the Nurse Migration Project to the WHO Global Health

Workforce Policy Advisory Council during the course of the six international meetings of the Global Council, 2007–10. This Council drafted the Global Code of Practice on the International Recruitment of Health Personnel, and elements of the Global Code were informed by the findings from the HRB-funded research. Professor Brugha was invited to sit on a new national interagency working group comprising the HSE, Irish Aid and the Department of Children, with the aim of promoting joined-up policy-making in areas of common interest. One of the first issues discussed was the WHO Global Code of Practice on the International Recruitment of Health Personnel. The PI's membership of the group ensures that knowledge and data gleaned from the Nurse Migration Project will inform a more coherent health workforce planning strategy for the Irish health service.

Grant title: The continuous evaluation of patient perception of acute hospital in-patient care in Ireland using the dashboard and map integration techniques
Grant type: Strategic Health Service R&D Award (five-year grant)
PI: Dr Hilary Dunne, Irish Society for Quality and Safety in Healthcare
Year awarded: 2006

This health service R&D programme tested and validated a survey to assess patients' perception of acute hospital in-patient care in Ireland, and developed an assessment measure (the "Patient Perception of Care Scale"), a valid and reliable scale which can be embedded within patient experience surveys in a variety of healthcare fields. The group also validated a series of key performance indicators (KPIs) for those dimensions that have the greatest impact on patient satisfaction, and they developed a software-based geographical 'dashboard' of these KPIs, which can be presented at the level of individual hospitals. In order to maximise the use of the system, the team engaged stakeholders throughout the research process and engaged in multiple activities to disseminate their outputs to decision-makers.

To date, the group have delivered presentations and held meetings with (i) DoH Deputy Chief Medical Officer (ii) senior Health Information and Quality Authority (HIQA) personnel (iii) HSE Corporate including the Director of Advocacy, the National Lead for Service User Involvement, and Head of Clinical Audit (iv) HSE Dublin North East and West Regions (v) participating hospitals – oral presentations to six hospitals to date and 25 individual hospital reports disseminated to 25 participating hospitals. Key impacts to date include the use of the survey adapted for Mental Health Services (commissioned by the Mental Health Commission), a successful pilot of the survey by the Rotunda maternity hospital which has led to the recruitment of five hospitals/units interested in participating in a national maternity survey, and mapping of the survey to the new HIQA National Standards for Safer Better Healthcare, which can assist hospitals in demonstrating their compliance with these standards.

Grant title: Efficacy of a four-level community-based intervention programme for depression and suicidal behaviour: A pilot study
Grant type: Partnership for a healthier society (two-year grant)
PI: Dr Ella Arensman, National Suicide Research Foundation (NSRF)
Year awarded: 2006

This grant funded a pilot study to implement a complex intervention in Ireland – the intervention was originally developed in Germany – to address depression and suicidal behaviour at four levels: general practitioners, community facilitators, depressed patients and their relatives, and the general public. The pilot study was successfully completed and the implementation project subsequently received funding under FP7 (OPSI-Europe) with the NSRF as the Irish partner among a consortium of 14 European organisations in 11 countries. The goal of OPSI-Europe is to further optimise the four-level intervention previously applied and to provide health politicians, stakeholders and the European Commission with an evidence-based and efficient concept for suicide prevention, with corresponding materials and instruments for community-based interventions.

An important spin-off from the Irish pilot study came from the 'Gatekeeper' training programmes offered to, and undertaken by, 243 community facilitators to increase their awareness of depression and suicidal behaviour. The training was effective in increasing awareness and improving people's confidence in dealing with people who are depressed and/or suicidal. During the course of the study, the Gatekeeper training programme became a structural module for trainee GPs, trainee psychiatrists, counsellors, guidance counsellors and juvenile liaison officers in the intervention region. The research group recommended that this approach be implemented in healthcare and community services with some success – for example, the Youth Federation in Cork (Ógra Chorcaí) has implemented this training approach among all employees and volunteers in their organisation. Finally, the four-level approach and positive mental health perspective were also incorporated in submissions to the *Reach Out, National Strategy for Action on Suicide Prevention, 2005-2014* and *Vision for Change, Report of the Expert Group on Mental Health Policy*.

Grant title: Developing evidence-based clinical practice guidelines for the dental services in Ireland
Grant type: Strategic Health Service R&D award (five-year grant)
PI: Professor Helen Whelton, Oral Health Services Research Centre, Cork University Hospital
Year awarded: 2004

This programme of research succeeded in producing and publishing four evidence-based dental health guidelines. The topics for guidelines development were nominated by the Society of Chief and Principal Dental Surgeons in consultation with the guidelines project team. The project built on and strengthened the existing partnership between the HSE dental service and the Oral Health Services Research Centre (ORSRC). The guidelines were developed as a collaborative exercise between frontline HSE dental staff of all grades, dental service managers and two researchers based at the OHSRC, both of whom had worked in the HSE dental services. In this way, a true partnership existed in that the guidelines were developed for the service, by the service, with full academic support. This ensured that the guidelines produced were both evidence-based and specific to the Irish context.

The guidelines research team applied internationally recognised methodologies in developing its three 'de novo' guidelines and adapting another guideline. The success of the guidelines resource centre is evidenced by the inclusion of its guidelines in the international guideline repositories of the National Guidelines Clearinghouse in the US and the library of the Guidelines International Network which is the global organisation representing guidelines developers. In addition, the guidelines project team was contacted by the American Dental Association Council on Scientific Affairs for the evidence tables for one of the guidelines, as part of its preparations for developing one of its own guidelines. Members of the project team were also invited to review and comment on two draft guidelines produced by the American Dental Association Council.

5.2 Development of treatments, diagnostics and care models

Research is the basis for many product innovations in the commercial life sciences/biotech sector, as well as treatment and service innovations in the health sector. In the Outcomes Tracker, HRB grant-holders were asked whether their HRB-funded research contributed to the development of health-related 'innovations'. Such innovations were defined broadly to include products (e.g. diagnostics, drugs, devices), non-drug interventions, health IT systems, clinical decision support tools, disease management strategies, clinical care models, new health services and so on.

The main findings from this analysis were:

- A total of 160 unique health innovations were reported by 129 grant-holders linked to HRB funded-research.
- The innovations were attributed to 149 unique grants, or just under 15% of the total number of grants.
- The three most common types of innovation reported were (ranked in order) a therapeutic drug, an ICT-based technology, and a non-imaging based diagnostic tool.
- The vast majority of innovations (80%) are at a pre-commercial or pre-adoption stage of development.
- While Applied Biomedical research produced the most innovations in absolute terms (as expected given the number of grants in this area), Clinical Research and Health Services Research produced the most innovations for every million euro spent.
- Most innovations were produced by grants awarded between 2004 and 2007. In relative terms, (number of innovations per million euros spent), 2002 and 2006 were the most productive years.
- HRB funding was the major contributor to the research that underpinned 70% of the innovations, while 39% of the innovations were produced solely by HRB funding.
- As would be expected given their volume, project grants produced the highest number of innovations. In relative terms, however, co-funded Partnership awards and the interdisciplinary projects produced the most innovations by far for every million euros spent.
- An analysis of the benefits or likely benefits of the innovations was carried out and showed that a small number of innovations have been adopted and have impacted favourably on the health and commercial sectors (see narrative examples). Several other innovations have the potential for wide societal and economic impact if and when fully developed and adopted.

Details of innovations

Grant-holders were asked whether their HRB-funded research led to, wholly or in part, the development of any health-related innovations. The number and type of innovations reported by respondents is tabulated in Table 6. As might be expected given the predominant focus on biomedical research in the 2000–09 period, new therapeutic molecules with the potential to lead to marketable products were the most common type of innovation reported. Other commercially-oriented devices, such as diagnostic and prognostic tools and medical devices, were also reported by grant-holders in the biomedical space. However, a large proportion of the reported innovations were also non-biomedical and non-commercial in nature e.g. non-drug interventions, service innovations, care models, and decision support tools.

Table 6: Health innovations by type

Health innovations	No.
Therapeutic intervention – New drug or indication	22
New ICT-based technology (system or software)	18
Diagnostic tool – non-imaging	19
Therapeutic intervention – psychological/behavioural	14
Therapeutic intervention – cell or gene therapy	14
Prognostic tool (imaging, algorithm or other)	12
Care model or service	10
Strategy to manage disease or condition	7
Diagnostic tool – imaging	7
Preventative intervention – physical/biological risk modification	5
Therapeutic intervention – vaccine or immunotherapy	5
Clinical decision support tool	4
Preventative intervention – behavioural risk modification	3
Therapeutic intervention – surgery	3
Other*	17
Total	**160**

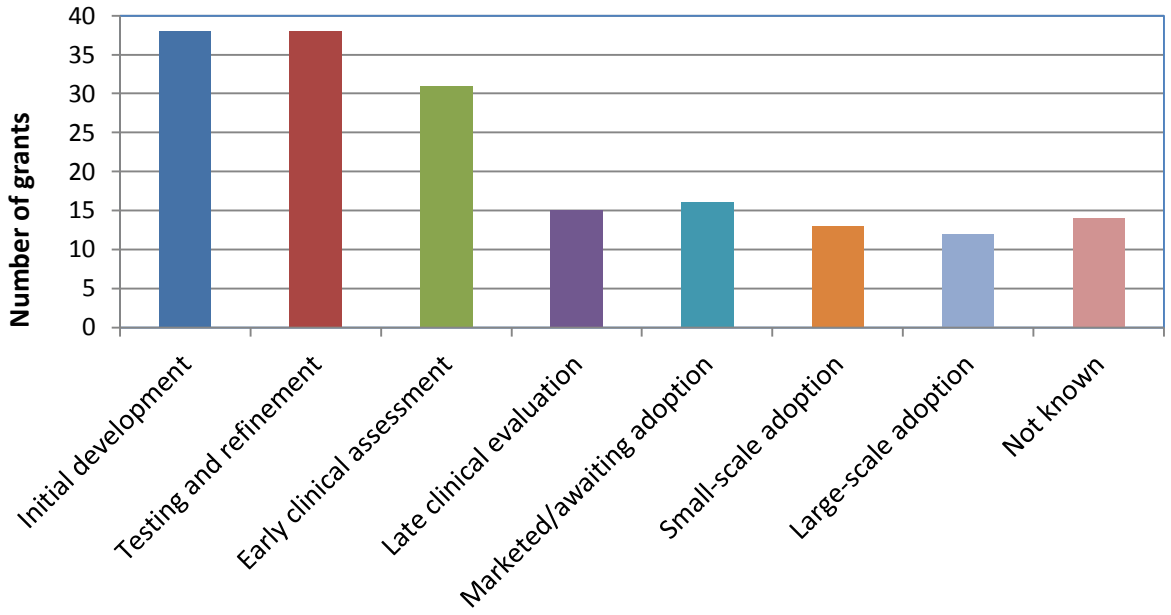
*** Composition of the 'Other' category**

	Name of innovation
1.	Biofilm control systems for dental hospitals
2.	Clinical assays to test for systemic inflammation in cystic fibrosis
3.	Colorectal cancer screening programme
4.	Dental Caries Risk Assessment Checklist
5.	Dental Chair Water Management System
6.	Detection platforms for monitoring oxygen respiration in early stage embryos to assess their viability
7.	Diabetic 'Foot Wound Alert Cards'
8.	Drug delivery mechanism based on conducting polymers
9.	GP prescribing feedback programme
10.	Increased testing for Alpha-1 antitrypsin deficiency among at risk populations
11.	Irish Nursing Minimum Dataset Tools
12.	Manuka honey for wound healing
13.	New models for the eruption of, and the progression of, caries in permanent molars in children
14.	Patient Perception of Care Scale
15.	Statistical model to facilitate more efficient ordering of blood in hospitals
16.	Stroke Activity Scale
17.	Thermo-sensitive hydrogels for drug-eluting stents

Current stage of development of reported innovations

Grant-holders were also asked about the current stage of development of their innovation along the discovery-development-adoption continuum (Figure 10). For products such as pharmaceuticals, biological and gene therapies with commercial potential, the developmental process follows a well-known and tightly regulated path from pre-clinical testing and human clinical trial phases through to formal regulatory approval and market entry. The developmental pathway for other types of innovations, such as non-drug interventions, care models and ICT-based innovations, while not as structured, follows a broadly similar phased process from initial development to testing and validation, hopefully culminating in wide-scale adoption by the health services (perhaps even on an international scale). Therefore, regardless of the type of innovation reported, grant-holders were asked to indicate the stage of development from a list of options provided in the survey.

Figure 10: Stage of development of innovations



The main observations that could be made from an analysis of the developmental stage of innovations are:

- The majority of innovations (80%), and all of the biologically-based innovation types (i.e. new drug, vaccine, stem cell or gene therapy), are at an early pre-commercial or pre-adoption stage of development.
- Excluding the 14 innovations with an unknown or unstated stage of development, 20% of the innovations have progressed to a commercial stage (i.e. marketed) or have been validated and are either awaiting health service adoption or have already been adopted/implemented.
- Six of the 10 new care models or services, which were developed in part by HRB-funded research, have been validated and adopted on a small scale at least.

Innovations linked to HRB-funded research that have been adopted on a large scale

The following innovations linked to HRB funding have been adopted on a national scale

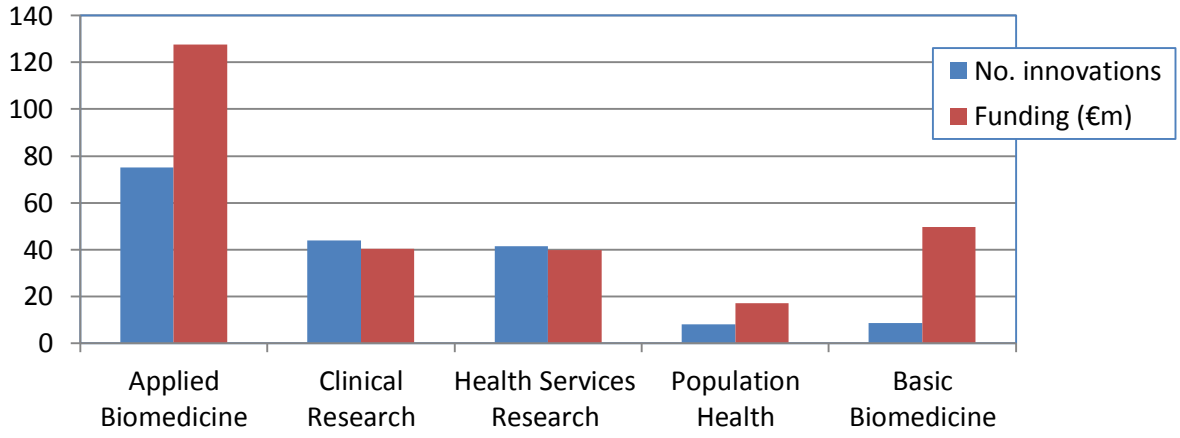
Innovation type	Name of innovation
Therapeutic intervention – psychological/behavioural	'Working Things Out' adolescent mental health treatment programme
Care model or service	Colorectal cancer screening programme
New ICT-based technology	Epilepsy Electronic Patient Record
Care model or service	Testing for Alpha-1 antitrypsin deficiency among at-risk populations
Preventative intervention – behavioural risk modification	Mental Health Promotion Programme (aimed at school students)
Care model or service	New model of epilepsy care in Ireland
Other	Patient 'Perception of Care' Scale
Diagnostic tool – non-imaging	Rapid real-time diagnostic screen for *P. aeruginosa* in cystic fibrosis

Innovations by strategic pillar

The overall number of innovations was analysed by the strategic pillar area of the associated grants linked to development of each innovation, and the number of innovations per pillar area was compared to the overall amount of funding per million euro that was awarded under each area (Figure 11). The following observations were made from this analysis:

- In absolute terms, grants in applied biomedical research accounted for the largest proportion of innovations (42% of the total). This is expected, given that this field accounted for the largest proportion of overall funding (46% of total).
- In relative terms, clinical research grants and health services research grants provided the best value for money in terms of producing innovations (1.09 and 1.04 innovations per million euro spent, respectively).
- Basic biomedical grants accounted for 18% of total funding, but only 5% of innovations – this is not unexpected given the broadly exploratory nature of this type of research.
- Population health sciences accounted for 6% of total funding and 5% of innovations – again this is not unexpected given that the population health sciences community in Ireland has traditionally focused on aetiological and descriptive health and less so on the design and evaluation of population health interventions.
- Perhaps unsurprisingly, Applied Biomedical research mainly produced diagnostics, new drug, cell or gene therapy treatments and prognostics.
- The types of innovations mainly produced by Clinical research grants were psychological interventions, treatment guidelines, and ICT-based interventions or healthcare technologies.
- Again as expected, Health Services Research mainly produced new care models and services, and also accounted for a relatively high proportion of the total number of ICT-based technologies, disease management strategies and practice guidelines.

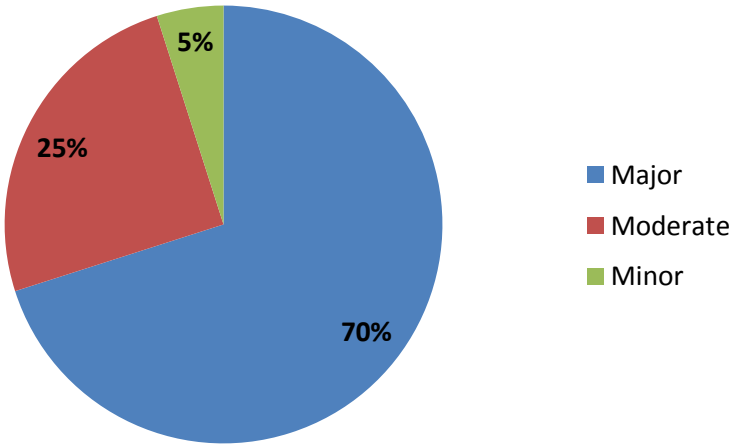
Figure 11: Comparison of number of innovations against value of funding commitments by strategic pillar



Contribution of HRB funding to development of innovations

In order to address the issue of attribution and to better understand the link between the innovation and HRB funding vis-à-vis other funding sources, grant-holders were asked to indicate the level of importance of their HRB funding to the development of the reported innovation (options were Minor, Moderate or Major). Figure 12 shows that, excluding the 20% of innovations where no significance rating was stated, HRB funding was the 'major' contributor to the research that underpinned 70% of the innovations. Furthermore, HRB funding made a 'moderate' contribution to an additional 25% of innovations, and a 'minor' contribution to an additional 5% of innovations.

Figure 12: Respondents' rating of importance of HRB funding to development of health innovation



Grant-holders were then asked to indicate the predominant alternative source of funding for the research underpinning the innovation, if indeed any other funding made a contribution. Excluding the innovations where it was not stated if another funding source was involved, 39% of the

innovations were due exclusively to HRB funding. After HRB funding, the single most common source of funding that contributed to development of the innovations was industry (10% of innovations) followed closely by SFI, EI and charities.

Number of innovations by grant type

To gain further strategic insight, the innovations were analysed according to the funding scheme under which the contributing grants were awarded. It was possible for respondents to attribute the development of a single innovation across multiple grants if these grants were awarded to that respondent in the 2000–09 period (for example Professor Anthony Staines attributed the development of an algorithm to assist hospitals with managing blood stocks to both a North-South Cooperation Project grant and a Blood Contamination Research Award, both of which were awarded in the period of interest). Therefore, while there were 184 reports of innovations linked to HRB grants, this actually equated to 160 unique innovations when double counting of innovations was corrected for.

Table 7 provides the overall number of innovations linked to each scheme and the relative number of innovations expressed as a percentage of the overall number of grants awarded under each scheme, while Figure 13 plots the number of innovations per million euro spent, by scheme. Some observations from this analysis include:

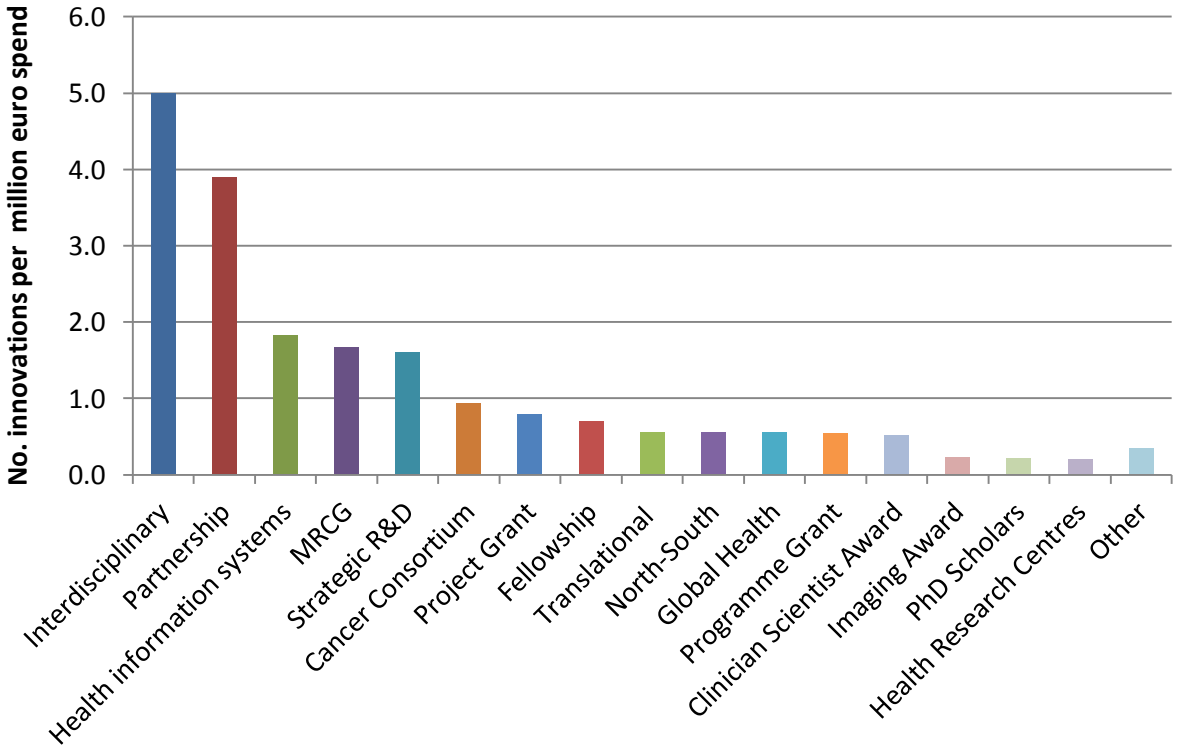
- Co-funded Partnership awards and the Interdisciplinary projects stand out as being linked to the most innovations for every million euro spent.
- Other schemes that produced a high number of innovations in relative terms include the Strategic Health Service R&D Awards, the MRCG/HRB joint funding scheme, and Health Information Systems.
- Many novel funding schemes (such as Partnership, MRCG, Strategic R&D, Clinician Scientist Awards, and Translational Research Programmes) that produced high numbers of innovations were funded between 2004 and 2007 and were rooted in *Making Knowledge Work for Health*.
- As stated previously, some major grants, such as the two Health Research Centres, are still active and would be expected to produce more outcomes, including innovations, in the future.

Table 7: No. of innovations linked to grant type/scheme (schemes in green font were expected to produce this type of outcome)

Grant type (No. grants)	No. innovations reported	No. innovations as % of total no. grants
Project (543)	72	13%
Fellowship (235)	22	9%
Strategic R&D programme (11)	16	145%
MRCG co-fund awards (46)	15	33%
Partnership awards (29)	12	41%
Programme grants (18)	9	50%
Translational research (9)	7	78%
PhD Scholars (6)	6	100%

Grant type (No. grants)	No. innovations reported	No. innovations as % of total no. grants
Clinician Scientist Awards (7)	5	71%
Health Information Systems (13)	5	38%
Interdisciplinary project (7)	4	57%
North-South Cooperation Project (19)	3	16%
Health Research Centre (2)	2	100%
Cancer Consortium (10)	2	20%
Global Health Awards (10)	1	10%
Co-funded in HSR (19)	1	5%
Nursing priorities study (2)	1	50%
Blood contamination (4)	1	25%
Total	**184**	

Figure 13: Number of innovations per million euros spent, by scheme



Examples of health innovations linked to HRB-funded research

Grant title: Revolutionising chronic disease management with information and communication technology – A socio-technical project applied to epilepsy care in Ireland
Grant type: Strategic Health Service R&D award (five-year grant)
PI: Dr Mary Fitzsimons, Beaumont Hospital
Year awarded: 2005

The research under this Strategic Health Service R&D award developed and validated a web-based Electronic Patient Record (EPR) for epilepsy care. With the EPR, clinical information is available in a more timely fashion and more clinicians have access to the same information, thus promoting the model of integrated epilepsy care being rolled out by the National Epilepsy Care Programme. To date more than 1,900 individual epilepsy patients have a validated electronic record, and the EPR is on course to be rolled out as the repository for healthcare records for all epilepsy patients. Furthermore, as the model of care evolves more towards self-management, a requirement for up to 11,000 patients to have access to limited modules of the EPR is expected to emerge.

The EPR developed by the team has been in daily use for the last three years and a study just published by the group in the *European Journal of Epilepsy* shows that the EPR supports clinical care and is a good tool for objectively and efficiently monitoring service quality. The EPR has been shown to meet the American Academy of Neurology quality indicators for epilepsy care, which will enable efficient and objective performance monitoring of epilepsy care in Ireland. The EPR is improving quality and safety and is promoting a service that is more responsive to the needs of patients. The epilepsy EPR also provides a good learning model that is generalisable to other similarly complex chronic diseases. In recognition of their work in developing the EPR, the research group received a Taoiseach's award for Public Service Excellence in June 2012.

Grant title: Prediction of recurrent stroke following transient ischaemic attack and first stroke. A population-based prospective cohort study
Grant type: Clinician Scientist Award (five-year grant)
PI: Professor Peter Kelly, Mater Hospital and UCD
Year awarded: 2006

Professor Kelly's research under his Clinician Scientist Award, in collaboration with international groups, has led to the development of an improved clinical prediction tool for stroke risk following a transient ischaemic attack (TIA). Professor Kelly's programme of research provided a significant part of the evidence that addition of brain and carotid MRI imaging to the standard ABCD2 score (i.e. ABCD3-I score) might help to further standardise and refine risk stratification after TIA. The ABCD3-I score provides robust evidence to target early imaging after TIA, thus identifying high-risk patients who should be referred to specialist services, and potentially avoiding need for hospital admission for low-risk patients, with resulting clinical efficiency and cost savings.

The original derivation and validation study (in approximately 2,000 patients) for ABCD3-I was published by Professor Kelly and his collaborators in *Lancet Neurology* in 2010, and the score has been independently validated again in a large multi-centre Spanish study. The findings could directly impact clinical practice in Ireland, as the PI is the co-lead of the HSE Stroke National Clinical Care Programme, and ABCD3-I is being considered as a template for the TIA care pathway as part of the National Stroke Programme. Professor Kelly also participated in the Ministerial consultation and advisory group in drafting the 2010–19 Cardiovascular and Stroke Strategy.

Grant title: Qualitative and quantitative analysis of factors contributing to apoptosis resistance in colorectal cancer: Evaluation of new prognostic and therapeutic avenues
Grant type: Translational Research Award (five-year grant)
PI: Professor Jochen Prehn, RCSI
Year awarded: 2007

This research involved a comprehensive characterisation of the expression levels of proteins involved in apoptosis in cancer biopsy samples. The aim was to determine their value as prognostic markers in colorectal cancer via correlation with long-term clinical outcome in a prospective patient cohort.

The work was successfully completed and led to the development of 'APOPTO-CELL' – a computational tool designed to aid in assessing patient prognosis and in determining more effective and personalised treatment strategies in colorectal cancer.

The studies completed to date indicate clinical potential of the tool in predicting patient outcome and responsiveness to novel targeted treatment paradigms. The group have filed an invention disclosure form with the RCSI Technology Transfer Office and are in discussions in relation to filing for patents. Following IP protection, further clinical validation studies, and publication of this work, the group aims to engage with clinicians and industry to further develop the tool to improve diagnosis and treatments for patients with colorectal cancer and other malignancies.

Grant title: Assistive image analysis based virtual colonoscopy
Grant type: Interdisciplinary project grant (three-year grant)
PI: Professor Paul Whelan, DCU
Year awarded: 2001

This research, led by Professor Whelan and consultant radiologist Dr Helen Fenlon, described promising results when their virtual colonoscopy (VC) system was tested against conventional colonoscopy at the Mater Hospital. In VC, X-ray scans are taken and used to build a 'virtual model' of the colon through the generation of 2-D and 3-D images. Professor Whelan's system used computer vision software that allowed computer-aided diagnosis (CAD) for automated reading of the images of the patient's colon created by VC. The team subsequently received funding from SFI to develop a prototype of their VC-CAD system.

More recently, EI helped them to commercialise it, and they are now in the process of licensing it to a UK company, where it will soon be included in its suite of medical imaging products. The system has been tested on hundreds of patient datasets from key hospitals in the United States and Europe, with good feedback from gastroenterologists and radiologists. Impact on clinical practice is also likely, as Dr Fenlon is a member of the Working Group on Virtual Colonoscopy, which comprises a group of North American and European radiologists with an interest in CT colonography research, development and implementation. This group has published a number of papers providing guidelines for performance of CT colonography studies.

Grant title: FAME - a randomised controlled trial of a family mediated exercise intervention following stroke
Grant type: HRB/MRCG co-funded project grant (three-year grant)
PI: Dr Emma Stokes, TCD
Year awarded: 2006

The first Irish National Audit of Stroke Care (2008) commissioned by the Irish Heart Foundation stated that "stroke is the third most common cause of death and the most common cause of acquired major physical disability in Ireland. A failure to recognise effective therapies has led to a fatalistic approach to treatment and an often nihilistic approach to coping with the survivors." The FAME (Family-Mediated Exercise) intervention developed by Dr Stokes through this grant responds to the clear need for the provision of an evidence-based intervention that can be delivered in the hospital or the community setting, and that is acceptable to people with stroke and their family members.

The focus of the FAME project was to examine the impact of additional exercise therapy on outcome following early stroke. Family members of acute stroke patients were trained to complete a series of daily exercise activites, in addition to routine physiotherapy, with the patient for a period of eight weeks. Following the intervention, stroke patients had improved significantly more, in terms of walking ability, balance, confidence and social participation, than individuals who had received routine physiotherapy only. These improvements were maintained at a three-month follow-up assessment. The additional FAME programme did not appear to add pressure to the daily lives of patients or their family members, and the FAME programme was reported as a positive experience both physically and psychologically. According to the PI, the intervention is a concrete, evidence-based model that could now be delivered in a hospital or a home setting.

Grant title: A prospective study of the incidence, outcomes, immune response and antimicrobial susceptibility of toxin-variant *C. difficile*
Grant type: Research project grant (three-year grant)
PI: Dr Lorraine Kyne, UCD and Mater Hospital
Year awarded: 2005

This research investigated the hospital superbug *Clostridium difficile,* a common healthcare-associated bacterium that can cause severe diarrhoea in patients who are receiving or have recently received antibiotics. The group found that certain strains of *C. difficile* were common in Ireland and were extremely resistant to a group of antibiotics called the fluoroquinolones, which are used frequently in clinical practice. The research shed light on how *C. difficile* acquires resistance to commonly used antibiotics, allowing the bug to spread more easily and contribute to outbreaks of *C. difficile* infection (CDI) in healthcare facilities. The findings highlight the importance of infection prevention and control programmes which include antibiotic stewardship policies.

In addition, using clinical data and antibody levels, Dr Kyne and her collaborators developed and validated a clinical prediction rule for recurrent CDI. This simple, reliable and accurate prediction rule will help clinicians in identifying high-risk patients most likely to benefit from measures to prevent recurrent CDI. The tool will also be of value in selecting high-risk patients for clinical trials of novel agents to prevent recurrent CDI.

Grant title: Secondary prevention of heart disease in general practice: A randomised controlled trial with qualitative, economic and policy analyses of an intervention to produce improved and sustained outcomes
Grant type: Programme grant (five-year grant)
PI: Professor Andrew Murphy, NUI Galway
Year awarded: 2001

The SPHERE (Secondary Prevention of Heart Disease in General Practice) intervention, co-funded by the HRB and Irish Heart Foundation, was the largest non-pharmaceutical clinical trial ever undertaken on the island of Ireland. Over 900 patients in 48 different general practices took part in the study, with one group following the SPHERE intervention programme and the other receiving usual care. The aim of the SPHERE study was to design, implement and test an intervention to improve the process of care and objective clinical outcomes for patients with established coronary heart disease in primary care in Ireland. The ultimate objective was to reduce rates of illness and premature death for patients with heart disease and to improve the care they receive in general practice.

In summary, the study found that admissions to hospital were significantly reduced in the SPHERE intervention group (following the intensive 18-month intervention programme) compared to the usual care group. No significant differences in relation to other clinical outcome measures were found, possibly due to a ceiling effect related to improved management of the disease. Final results from the original study were published in the *British Medical Journal* in October 2009. A follow-up study of the SPHERE intervention, funded by the HRB, commenced in January 2012. The aim of the follow-up study is to trace the 903 original SPHERE participants and to ascertain whether the positive changes observed following the original intervention are still happening, six years later.

Grant title: Application of electroporation to internal tumours
Grant type: Research project grant (three-year grant)
PI: Dr Declan Soden, Cork Cancer Research Centre, UCC
Year awarded: 2006

The outcome of this project grant was the development of an endoscopic electroporation device (EndoVE). When using the device, chemotherapy drugs are absorbed only in the area treated by the electrical field. This means lower drug concentrations, less toxic side effects and potentially shorter stays in hospital, thus reducing costs significantly for the healthcare provider. The technology was validated in pre-clinical studies, and recently approved by the Irish Medicines Board for a phase I trial in the treatment of inoperable rectal cancers. There is considerable interest from other clinical sites in Europe and the US to develop multi-centre studies to validate the technology and to expand its application to other internal cancers. The longer-term outcomes include the potential to greatly benefit patients who have inoperable cancers through a minimally invasive endoscopic approach without the normally associated toxic side effects from radio/chemo therapy.

The HRB-funded research also contributed to the development of the ThoraVe – a novel probe to enable thoracoscopic delivery of electroporation to lung tumours. Similar in approach to the EndoVe probe, the ThoraVe was awarded innovation of the year by UCC in 2011. In 2010, Dr Soden co-founded a spin-out company (MITAMED) in order to further develop and commercialise the EndoVE and ThoraVe medical devices for cancer treatment.

Grant title: Targeted siRNA delivery to the lungs for the treatment of inflammatory lung disease
Grant type: Research project grant (three-year grant)
PI: Dr Sally-Ann Cryan, RCSI
Year awarded: 2005

Chronic inflammatory lung diseases including emphysema and chronic obstructive pulmonary disease (COPD) are major public health problems and some of the leading causes of chronic morbidity and mortality worldwide. Therefore, there is a great need for new medicines to treat these diseases. With the increased understanding of disease at a genetic level, medicines that target the cause of these diseases, and not just the symptoms, are being designed. Indeed, new ribonucleic acid (RNA)-based medicines are being developed that could potentially treat a number of these inflammatory lung diseases, but the usefulness of these medicines has been limited by the inability to deliver them efficiently to patients.

In this project, Dr Cryan and her team developed novel drug delivery technologies that will allow patients to inhale their RNA medicines using nebulisers and dry powder inhalers. The technologies will target the RNA medicines to the disease site i.e. the lungs, thereby improving the medicines' effectiveness and decreasing side effects for the patient. Once in the lungs, the targeted carriers have been designed to be quickly and efficiently internalised by the airway cells that cause inflammation where the RNA can act to stop inflammation. The work is now being tested in a pre-clinical model of inflammatory lung disease, with the aim of commencing human clinical trials. The PI has established a commercial collaboration with Aerogen, an indigenous medical device company based in Galway that specialises in advanced inhaler development. Aerogen has a device nebuliser suitable for delivery of siRNA in the clinic, so the collaboration is focusing on harnessing Aerogen's device for delivery of novel RNA-based therapies to the lungs.

Grant title: The Role of microRNA in modulating vascular smooth muscle cell phenotype – novel regulators of vascular physiology and disease
Grant type: Health Research Award (three-year grant)
PI: Dr Ronan Murphy, DCU
Year awarded: 2009

Vascular smooth muscle cells (VSMC) play an important role in cardiovascular disease, vascular remodelling and repair. These cells have the ability to change their phenotype, and hence fate, in response to their environment. However, how these changes and fate 'decisions' are ultimately orchestrated and coordinated in adult VSMC was poorly understood. With this HRB grant, Dr Murphy and his team elucidated the mechanisms underpinning VSMC changes, specifically as to how the function of a class of molecules called 'microRNAs' (a recently discovered class of non-coding RNA molecules that play key roles in the regulation of gene expression) regulate VSMC function.

In addition, Dr Murphy and his team have developed a pre-clinical diagnostic test for monitoring cardiovascular health and detecting disease based on circulating endothelial cells having a unique microRNA signature. The hope is that the test will be able to predict a person's vascular competence or cardiovascular health before they go on to develop disease. By doing this, it should be possible to use interventional measures to improve their health and monitor their progress. While the work is at an early stage, a Proof of Concept grant from EI has just been awarded to Dr Murphy to progress the research and advance the technology towards commercialisation.

Examples of impacts on people's health linked to HRB-funded research

Governments and organisations such as the HRB fund health research in the hope that it will ultimately lead to improvements in people's health, as well as improving the effectiveness of health services, and lead to competitiveness gains for the economy. However, demonstrating impacts on people's health from research funded by a particular source is very challenging given the attributional issues described in Section 1 (e.g. the number and variety of factors that influence people's health and the length of time it can take for research to lead to eventual societal impacts). These issues notwithstanding, there is some evidence that at least 19 HRB grants have led to the development of innovations or policies that have impacted favourably on people's health by virtue of national or international adoption. Three such examples are described below.

Grant title: The All-Ireland Cooperative Oncology Research Group (ICORG)
Grant type: Cancer clinical trials network, involving 11 hospitals and a coordinating central office
Year awarded: 2001 (renewed every three years since then)

ICORG has played a leading role in some major international studies which have resulted in very successful new treatments being introduced into routine patient care, and very rapidly in the case of ICORG-participating Irish hospitals. For example, ICORG was one of the leading international centres for the Phase 3 study of the breast cancer treatment Herceptin (Trastuzumab), one of the first targeted treatments tailored to patients with Her2 positive genetic expression. In total, 129 Irish patients were enrolled in this study by ICORG, which found that Herceptin reduced breast cancer relapse by approximately 50%. Indeed, there is strong consensus among Irish oncologists that ICORG's comprehensive breast cancer research portfolio has helped Ireland to rapidly absorb new treatments and diagnostics that have contributed to a 10% improvement in the five-year survival rate in breast cancer (from 70% in 1997 to 80.6% in 2007).

ICORG has also contributed to the development of new diagnostics and prognostics that have been shown to improve health and which have been adopted by health systems. For example, ICORG was the leading international centre for the TAILORx (Trial Assigning Individualized Options for Treatment) breast cancer study. This study examined whether genes that are frequently associated with risk of recurrence for women with early-stage breast cancer can be used to assign patients to the most appropriate and effective treatment. Led by the National Cancer Institute in the US, almost 11,000 patients participated in this study. In Ireland, ICORG's TAILORx trial included 690 patients that benefitted from this new approach. The corresponding diagnostic test was subsequently approved for clinical use in Ireland by the National Cancer Control Programme.

Grant title: Solar disinfection of drinking water for use in developing countries or in emergency situations – health impact assessment in Cambodia
Grant type: Global Health Research Award (three-year grant)
PI: Dr Kevin McGuigan, RCSI
Year awarded: 2006

It is estimated that over one billion people in the world have no access to safe drinking water on a daily basis, and this results in the deaths of around 1.5 million children under five each year from diarrhoeal disease. Dr McGuigan, who leads the Solar Disinfection Group at RCSI, is trying to address this problem in an affordable and easy-to-use way, using the SOlar DISinfection (SODIS) method. The method, which harnesses the ability of sunlight to disinfect water, was developed by the Swiss Federal Institute of Aquatic Sciences and studies at the RCSI (led by Dr McGuigan and Professor Ronan Conroy) confirmed its effectiveness and its positive effect on people's health. The PI received

a HRB/Irish Aid Global Health Research award in 2006 to work with CARE Cambodia on a SODIS study involving almost 1,000 young children in Cambodia.

The study found that if a participating family used SODIS to clean their drinking water, there was a 50% reduction in dysentery and a 63% reduction in non-dysentery diarrhoea among the children under five, compared to families who did not use SODIS. In each case they found that the bacterial count in the solar disinfection bottles was over 10 times less than the count in the test bottles. Visiting a year after the Cambodian trial had finished, the group found that SODIS was a major success – not only had almost all the trial's participants continued using SODIS, but people who were in the comparison group had also switched to SODIS. People who had not taken part in the trial were using it up too. SODIS was found to represent a very culturally acceptable method of household water treatment in Cambodia and neighbouring countries. Of note is the fact that the World Health Organization (WHO) now recommends the use of SODIS as a viable method for household water treatment and safe storage.

Grant title: Adolescent depression and suicidal behaviour – making knowledge work for health
Grant type: Strategic Health Service R&D award (five-year grant)
PI: Professor Carol Fitzpatrick, Mater Hospital and UCD
Year awarded: 2005

This research programme developed and validated two mental health programmes that have been adopted on a national scale. The first, titled 'Working Things Out Adolescent Mental Health Programme', is an eight-session group-based cognitive behavioural therapy programme for adolescents with mental health difficulties. A randomised control trial showed that the programme was successful in helping adolescents develop positive coping strategies, and that young adolescent boys who completed the programme reported significant improvements in their positive social behaviours. The programme was manualised, successfully launched, and training courses in its delivery were provided to mental health professionals, counsellors and youth workers from all over Ireland. Dissemination of this programme and training in its delivery was taken over by Parents Plus Charity and the Mater Child and Adolescent Mental Health Service.

The second programme, titled 'Working Things Out through SPHE', is a mental health promotion programme which enhances the Social, Personal and Health Education Programme (SPHE), part of the curriculum in Irish post-primary schools. It involves lesson plans for teachers of SPHE to use in order to enhance their delivery of the mental health promotion aspects of SPHE. The lessons use animated stories made by young people about their experiences of getting through tough times, which encourage others to seek help, and which explain what helped these young people to cope. The randomised control trial (RCT) showed that young male students who had the greatest level of difficulties before they started the programme got most benefit from it, and the programme was very popular with teachers and young people alike. Throughout the programme, the research team worked closely with the SPHE support service in the Department of Education (DoE). The group published a manual jointly with the DoE for teachers delivering 'Working Things Out through SPHE' and training in the delivery of this programme is now provided by the DoE SPHE support service, thus ensuring its national implementation.

5.3 Engagement of patients and the public

Engagement of patients and the 'public' in research and lay dissemination of new health research findings can influence health behaviour (hopefully leading to health gains), improve the public understanding and appreciation of the value of scientific research, and can help to engage patients and the public in important research studies (e.g. clinical trials). Also, by communicating the outcomes and benefits of health research it addresses the issue of public accountability for taxpayers' money and can increase the public demand for research.

In this context, HRB grant-holders were asked whether they had engaged in any public or patient dissemination events linked to their HRB-funded research. A total of 1,023 dissemination events were reported by 256 grant-holders linked to 340 grants (or 33.4% of the total). A breakdown of the types of dissemination events reported by grant-holders is shown in Figure 14.

- The most common type of dissemination event was coverage of the research in local or national press (31%), followed by a talk or presentation to the public or patient groups (25%).
- Coverage in international media (press or broadcast media) comprised 5% of reported events, but this may well be an underestimate, due to the difficulty in tracing this type of activity.
- References to HRB-funded research findings in emerging online media such as blogs, social media (e.g. Twitter, Facebook) accounted for 3% of activities, but again this is bound to be an underestimate, as it relies on researchers' awareness and interest in such fora.
- Related to the above point, the advent of web analytics software and 'alt-metrics' (i.e. the creation and study of new metrics based on the Social Web for analysing, and informing scholarship) will greatly enhance the ability of funders and researchers to track coverage of and references to their research by both the 'public' and academic audiences on the Internet in years to come.

Audiences for the dissemination events

An analysis of the different types of audience that HRB-funded researchers were targeting with their non-academic dissemination efforts was also conducted. A breakdown of the total number of dissemination events by target audience is displayed in Figure 15, and shows that:

- Most dissemination events that occurred through the mass media and online social media, which were not targeted at any particular lay audiences, were classified as 'general public'.
- 140 dissemination events (14% of total) were targeted at patients or patient groups; such events included presentations at charity annual conferences or features in charity newsletters.
- 5% of activities were targeted at school children or teachers; such activities included school talks, university open day talks and other events (e.g. 'ScienceWorks for Schools' workshops which aim to attract secondary schoolchildren to careers in science).
- A small subset of activities (3%) were focused on researcher engagement with the charity itself rather than patients – for example, researchers who were asked to advise the charity on their research strategy or activities via an advisory group or individual advisory role.
- The target audiences for 1% of activities included specific groups such as the Council of Europe, refugee support groups, Public Service Evaluation Network etc.

Figure 14: Breakdown of dissemination events by event type

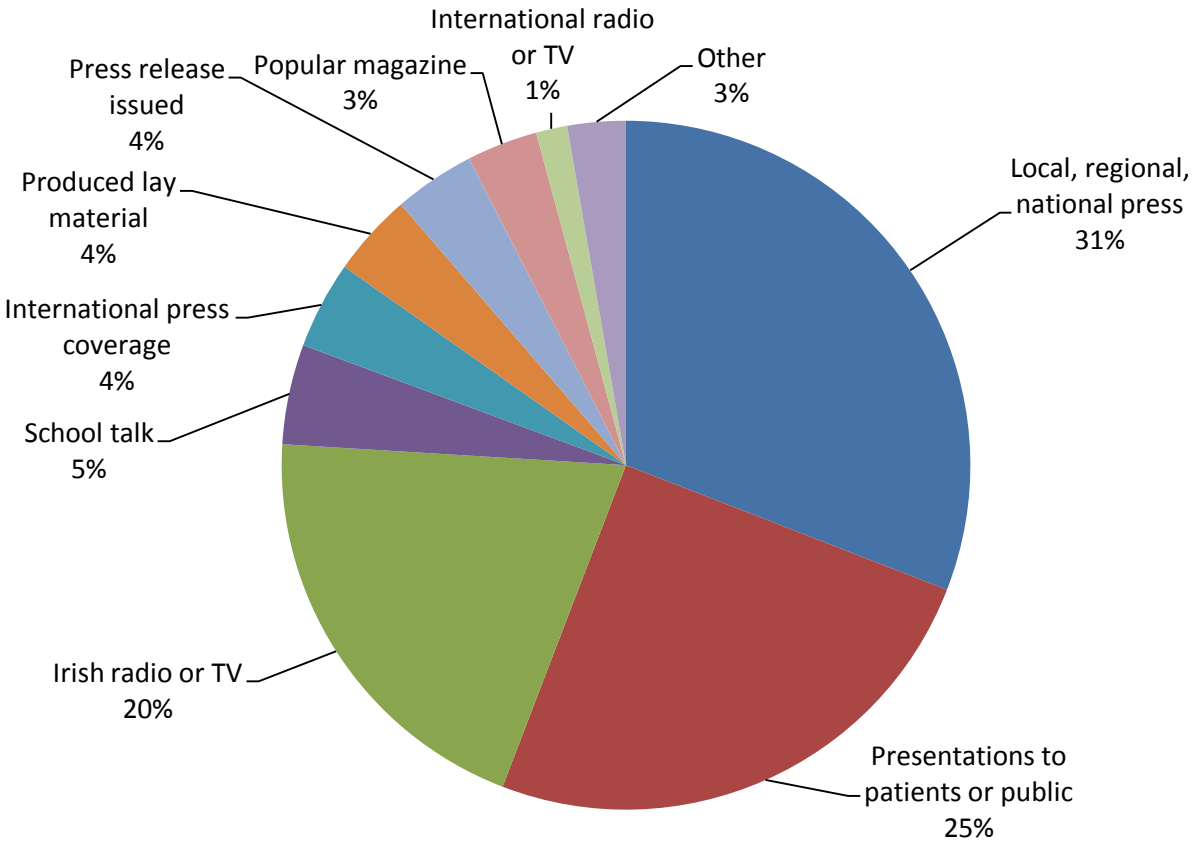
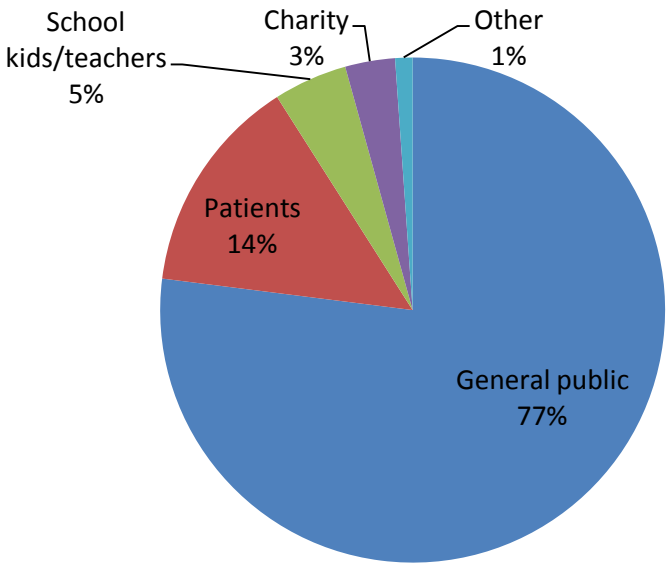


Figure 15: Target audiences of dissemination events

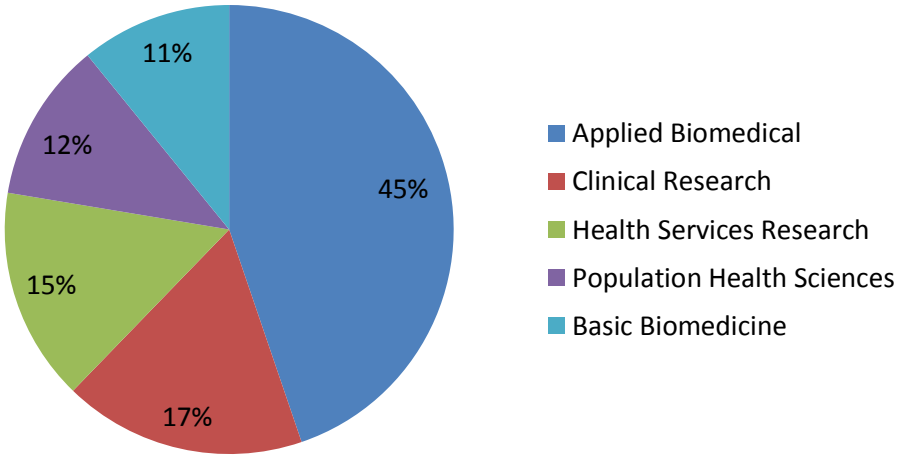


Dissemination by strategic pillar

Figure 16 shows a breakdown of the dissemination events by strategic pillar area:

- Applied Biomedical accounted for 45% of dissemination activities, which would not be unexpected given that this pillar accounted for 46% of overall funding and 41% of the total number of awards.
- Population Health Sciences accounted for 12% of activities compared to 6% of funding and 6% of total number of awards. This may also be expected given that the findings from population health studies tend to be directly relevant to patients and the public.
- Basic Biomedical research accounted for 11% of dissemination activities compared to 18% of total funding and 25% of the total number of awards – this is likely to be explained by the fact that research in this field tends to be the furthest removed from patients and the general public, and only 'breakthroughs' or discoveries with treatment potential tend to be reported in the media.

Figure 16: Proportion of dissemination events by strategic pillar area



Dissemination by grant type/scheme

An analysis of the dissemination events by grant type is tabulated in Table 8 and the following observations can be made:

- The Health Research Centres (€5 million per award) reported the highest average number of dissemination events. This was mainly due to the Health Research Centre in Diet and Health which reported 43 events
- The Autism Genome Project (€5 million) funded by the HRB in 2006 reported 42 dissemination events, many in the international media. The project was an international €12 million study funded by several public and charitable bodies across 11 countries. It generated coverage in high-impact scientific publications (e.g. *Nature*), which in turn led to significant coverage in the national and international media.

- The seven Clinician Scientist Awards (34 events in total), the 11 Strategic Health Service R&D Awards (42 events in total), and the 29 Partnership Awards (95 events in total) were also associated with significantly higher-than-average numbers of dissemination events.
- Almost 80% of the Medical Research Charity Group/HRB jointly funded grants reported at least one dissemination event. There could be some under-reporting under this scheme, as each MRCG grant-holder must submit a progress report of their research to their co-funding charity (which counts as a dissemination event).
- While caution must be taken in terms of basing any assessment on numbers alone, the overall proportion of HRB grants that reported a dissemination event (33%) seems relatively low. For instance, a recent report published by the Wellcome Trust that analysed the outputs of grants concluding in 2012 shows that 47% of Trust grants were associated with wider dissemination events.[8]

Table 8: No. of dissemination events per grant type

Grant type (No. grants for which data were captured)	No. events	Mean no. events per grant
Project (543)	430	0.8
Fellowship (235)	139	0.6
Partnership (29)	95	3.3
MRCG (46)	50	1.1
Health Research Centres (2)	49	24.5
Autism (3)	47	15.7
Strategic R&D Awards (11)	42	3.8
Programme (18)	38	2.1
Clinician Scientist Awards (7)	34	5
Translational Research (9)	24	2.7
Global Health Awards (10)	13	1.3
PhD Scholars (6)	12	2
North-South Cooperation Project (19)	9	0.5
Blood (4)	7	1.8
Health Information Systems (13)	7	0.5
Co-funded awards in Health Services Research (19)	6	0.3
Cancer Consortium (10)	14	1.4
Interdisciplinary (7)	4	0.6
Imaging Awards (2)	3	1.5
Nursing Priorities Studies (2)	1	0.5
Equipment Grants (20)	0	0
Total (1,017 grants)	**1,023**	**1.0**

[8] *Assessment Framework Report* (Volume 1, 2011/2012). Wellcome Trust

Examples of dissemination and engagement events

Grant title: Autism Genome Project
PI: Professor Michael Gill (TCD) and Professor Andrew Green (UCD)
Grant type: Special Initiative
Year awarded: 2006

The Autism Genome Project was a collaboration of international researchers aimed at understanding susceptibility to autism spectrum disorders (ASD), in order to pave the way towards the development of better diagnostics and treatments. The results of this research revealed many new genetic and functional targets in ASD that have increased the understanding of the causes of this condition, which, in turn, will inform future therapeutic approaches. The key research findings were published in the prestigious international science journal *Nature* in June 2010. A joint press release was issued by UCD and TCD to coincide with the publication ('Irish researchers discover new autism gene as part of a global Autism Genome Project'). The press release was subsequently picked up by multiple national media outlets, including the *Irish Independent*, *The Irish Times, Irish Medical Times*, and *Business and Finance*, and the PIs were featured on the RTÉ *Six One News*. In addition, a large number of international newspaper articles (c. 30) were published on the findings of the research, based on the press release.

Grant title: Psychosocial/psychoeducational intervention for people with recurrent suicide attempts (PISA): A pilot randomised control trial of effectiveness and individual response
PI: Dr Evelyn Gordon (DCU)
Grant type: Health Research Award (three-year grant)
Year awarded: 2009

This DCU research study is evaluating, through a pilot RCT across four clinical sites in the first instance, a Psychological Intervention for people with recurrent Suicide Attempts (PISA) which aims to decrease suicidal behaviour, increase resilience and enable the person to begin their journey to recovery. The intervention is education, support and skills based; for example, it teaches people how to stay safe, how to manage their emotions and relationships, and how to improve their problem-solving skills. The PISA research team created a project website (www.pisa.dcu.ie) which contains valuable resources and important information for the study participants and the wider public on the topic of suicide (e.g. leaflets for carers and publications), in addition to information about the PISA project. This website is updated on a regular basis and is actively promoted and publicised by the project team.

Grant title: A pharmacogenomic study of chronic refractory epilepsy
PI: Gianpiero Cavalleri (RCSI)
Grant type: MRCG/HRB co-funded project (three-year grant)
Year awarded: 2008

This research made a significant contribution to an international study, the findings of which were published in the prestigious *New England Journal of Medicine* in 2011. The study identified a gene that could indicate if epilepsy patients starting a common drug treatment (carbamazepine) are likely to experience side effects ranging from a mild skin irritation to severe blistering of the whole body, fever, hepatitis and kidney inflammation. As a result of this discovery, a simple genetic test could now be able to predict which patients are likely to experience side effects, thus allowing clinicians to prescribe the drug with greater confidence, and saving many patients the significant trauma of adverse reaction. A press release (entitled 'Scientists identify gene responsible for skin reaction in epilepsy treatment') was issued by the RCSI to coincide with the publication, and this was subsequently picked up by multiple national and international media outlets.

Grant title: A longitudinal study of women's experiences of carrying a baby with fetal abnormality up to and beyond the birth: A grounded theory approach
PI: Dr Joan Lalor (TCD)
Grant type: Nursing and Midwifery research training fellowship (three-year grant)
Year awarded: 2003

The research carried out under this fellowship led to the development of a framework ('Recasting Hope') intended for use as a tool to assist health professionals to care for women carrying a baby with a fetal abnormality up to and beyond birth. This framework was significant as it was the first comprehensive evidence-based model designed to underpin the practice of caring for women following an adverse diagnosis in pregnancy. Consideration of the impact of an advanced midwife practitioner role on the process of recovery was also recommended in order to ensure that all women have continued access to specialist support. A press release arranged through the *Journal of Advanced Nursing* was issued to coincide with the publication of a paper in that journal in 2006 (entitled 'Fetal anomaly screening: what do women want to know?'). This led to extensive national and international coverage of the issues in print and electronic media, including an interview with Dr Lalor on national radio.

Grant title: Directed analysis of genomic risk regions in coeliac disease
PI: Dr Ross McManus (TCD)
Grant type: Research project grant (three-year grant)
Year awarded: 2004

This research was carried out as part of an international consortium, which proved to be very successful, with the discovery of over 12 new risk genes for coeliac disease, explaining almost 50% of the genetic risk factors for the disease. The group also confirmed the existence of shared susceptibility genes between coeliac disease and type 1 diabetes, conditions long known to co-present with increased frequency. This work contributed to major advances in the field of coeliac disease genetics, with several high-impact publications resulting, including two papers in *Nature Genetics.* The research received considerable media attention – the PI was interviewed on the RTÉ *Six-one News* on 4 March 2008 (story titled 'Trinity researchers discover coeliac genes') and the findings were featured in articles in *The Irish Times* ('Researchers find diabetes link for coeliac disease') and the ('Breakthrough in coeliac disease') in March 2008.

Grant title: Access for all – A formal methodology for quantifying and planning access to health services in Ireland
PI: Professor Alan Kelly (TCD)
Grant type: Research project grant (three-year grant)
Year awarded: 2002

This research led to the development of an algorithm-based software tool to facilitate optimal location-allocation modelling for any health service centre in Ireland (including Northern Ireland). The tool was shown to be highly efficient and capable of finding the optimal locations, taking into account different factors aimed at minimising possible geographic and social inequalities in health service provision. Application of the tool led the group to recommend abolishing the 'healthcare border' and allowing people living in Border counties to have quicker hospital access to centres located on either side of the Border. The publication of a paper in June 2004 ('The potential impact on travel times of closure and redistribution of A&E units in Ireland' (*Irish Medical Journal*) was followed by coverage in the national press (*The Irish Times*), TV (RTÉ 1 *Six O'Clock News*) and radio (RTÉ Radio 1 *News At One* and *Five Seven Live*) and elicited significant political interest, including a response from the Minister for Health.

6 Research commercialisation and non-Exchequer funding leveraged

6.1 Intellectual property and commercialisation of research

It is well recognised that health research can yield economic returns as well as health benefits. Such economic impacts can be produced both indirectly, for instance as a result of health gains (e.g. decreased absenteeism) from research-based treatments, or directly via commercial gains from the sale of new or improved products and services. An increasingly important indicator of the impact of publicly funded research in Ireland is the number of intellectual property (IP) outputs, such as patents, and progress with commercialising this IP through licence agreements or the formation of spin-out companies. Similarly, academic-industry linkages and collaborations are considered key to enabling knowledge spillover effects and conferring economic impacts. Therefore, in the Outcomes Tracker survey, HRB grant-holders were asked about:

- intellectual property rights they had secured linked to their HRB-funded research
- any licence agreements entered into or spin-out companies established linked to their HRB-funded research
- any linkages to industry such as academic-industry collaborations or advisory/consultancy roles to industry

A summary of economic outputs and commercial activities arising from HRB grants funded in the 2000–09 period is presented in Table 9, and further analysed in subsequent sections of this chapter.

Table 9: Summary of economic outputs and commercial activities

Activity type	No.
Patent applications (filed or granted)	66
Innovations with commercial potential	67
Licensed technologies	15
Spin-out companies	11
Academic-industry linkages	197
EI commercialisation awards	26

Patents

A total of 66 unique patent applications were reported by 51 grant-holders across 60 grants (or 6% of total number of grants). The key summary points of the analysis carried out on these patents are:

- 62 of these patents were matched to the European Patent Office's worldwide patent database (i.e. no details could be found for four of the reported patents, which may be due to insufficient details provided by grant-holders).
- 60% of patent applications were filed in 2008 or later, corresponding to the significant increase in HRB funding from 2004 onwards.
- Grants awarded in 2006 and 2007 produced the highest number of patents. For unknown reasons, only two patents were filed in 2011 – a very low number compared with preceding and subsequent years.
- 60% of patent applications have a pending or filed status, 27% have been granted, and 13% have lapsed (i.e. annual renewal fees were not paid by the applicant institution).
- RCSI-based researchers out-performed researchers in the other institutions, with the exception of Trinity College, in terms of overall number of patents produced. In relative terms, NUI Maynooth, followed by the RCSI, produced the most patents per number of HRB grants received.
- Applied Biomedical grants accounted for 66% of patent applications, Basic Biomedical grants accounted for 28%, while Clinical Research accounted for 6% (Health Services Research and Population Health Sciences, as expected, did not produce any patents).

Figure 17: Number of patent applications by year of first filing with a patent office

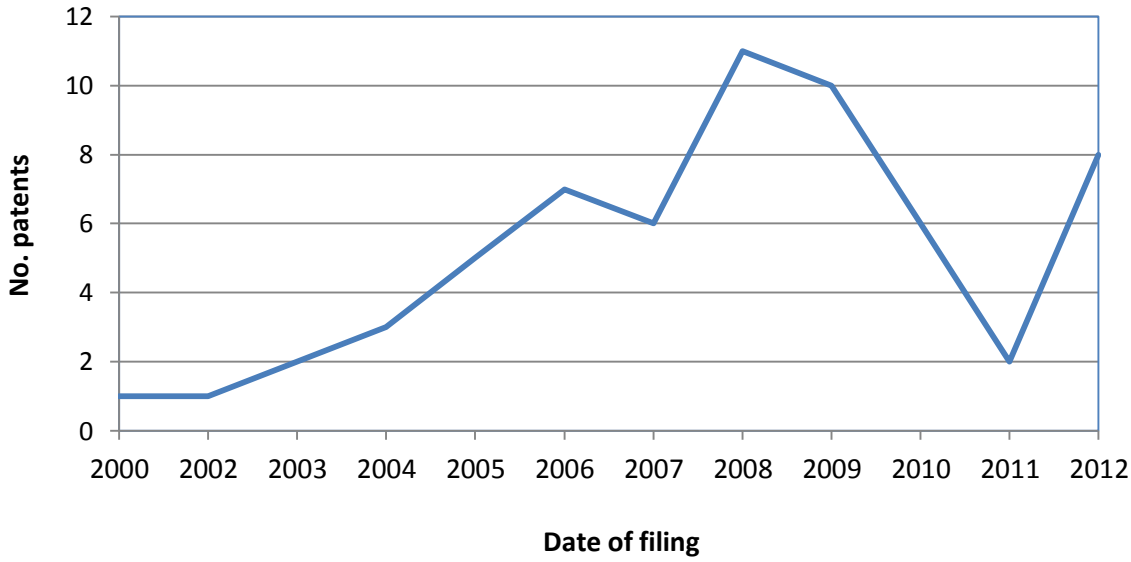
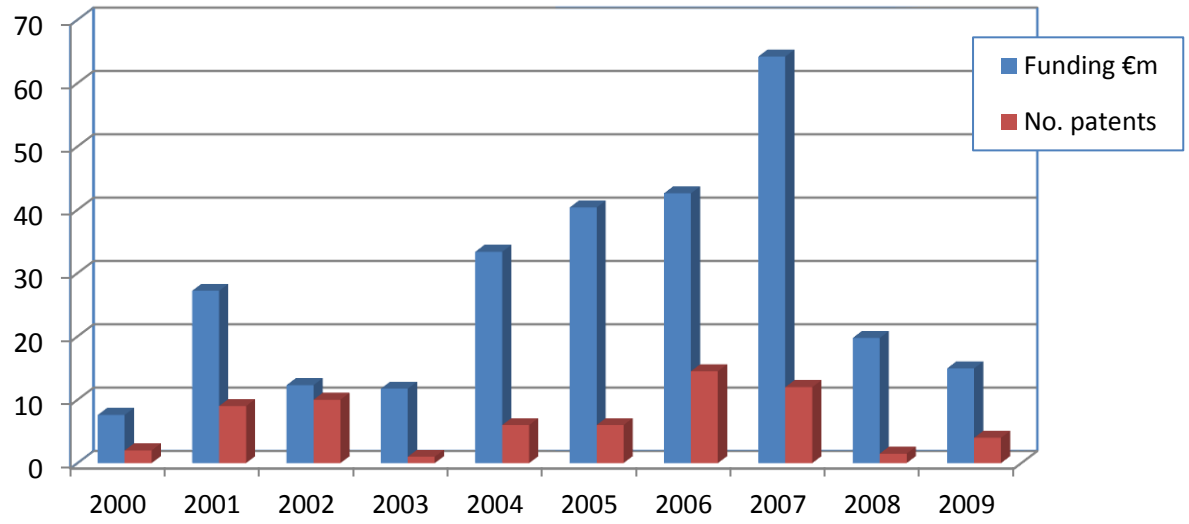


Figure 17 shows that one-third of all patents were filed in the two-year period 2008 to 2009, while Figure 18 shows that the funding years 2006 and 2007 produced the highest numbers of patent applications. However, the funding year 2002 produced the most patent applications for every million euro spent (these were mainly the outcomes of Project Grants awarded in 2002).

Figure 18: Number of patent applications for every million euro spent, by year



Status of patent applications

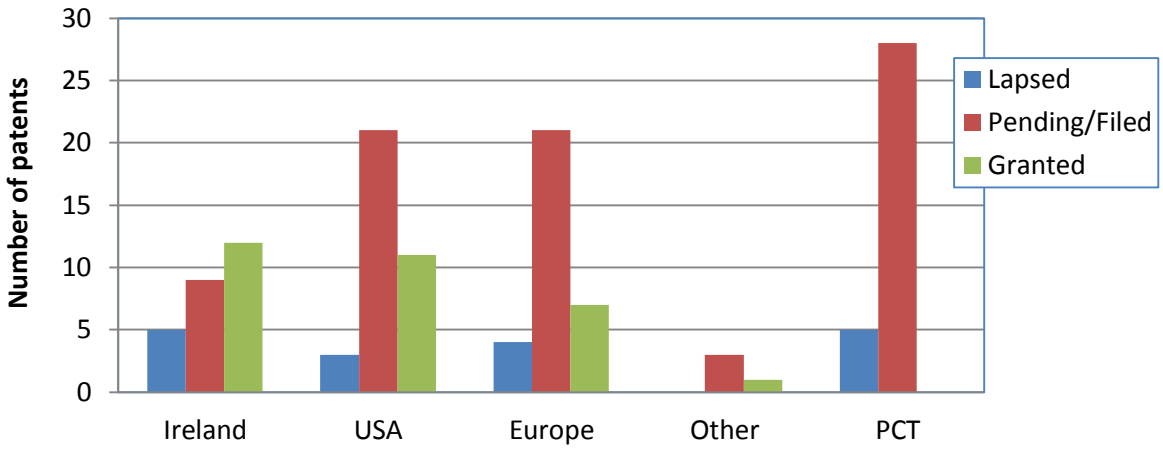
In the Outcomes Tracker survey, grant-holders were asked to state the current status of their patent application across five main countries/regions: Ireland, the US, Europe, PCT[9], other countries/ regions. Analysis of the responses is shown in Figure 19. The key findings were:

- Many Irish-based researchers seeking patent protection for their invention file a European patent application or PCT application (both of which cover Ireland), rather than file with the Irish Patent Office.
- Typically, it can take between 2 and 4.5 years for a patent to be granted, once the application is filed – hence the high number of patent applications with a pending status;
- A PCT (see below) application does not itself result in the grant of a patent, since there is no such thing as an "international patent". The granting of patents remains under the control of the national or regional patent offices. Thus, PCT patent applications never have a "granted" status, but only "filed" status.
- To maintain a patent in force, annual renewal fees must be paid each year from the third year (at least for Ireland, although this can vary from country to country). If the annual renewal fees are not paid by the applicant institution, the patent application lapses.
- A European patent application submitted to the European Patent Office allows the applicant to obtain protection in European countries that are members of the European Patent Convention.

[9] The Patent Cooperation Treaty (PCT) was established in 1970. It is administered by the International Bureau of the World Intellectual Property Organization (WIPO) in Geneva. Ireland ratified the Treaty in 1992. The main objective of the Treaty is the streamlining of patent application filing and novelty search procedures for applicants wishing to obtain patent protection in a wide number of countries around the world (147 countries are currently signed up to the PCT). The PCT provides a system whereby a single international application allows for the designation of some or all of the contracting countries. The relevant national patent authority is normally the granter of a patent pursuant to an application filed under the Treaty.

- There is, inevitably, an under-reporting of patent applications, either pending or granted, to 'other' regions and countries such as Australia, China, and Japan (for example, these may have been designated countries in some of the PCT applications). This under-reporting was due to the technical limitations of the survey.

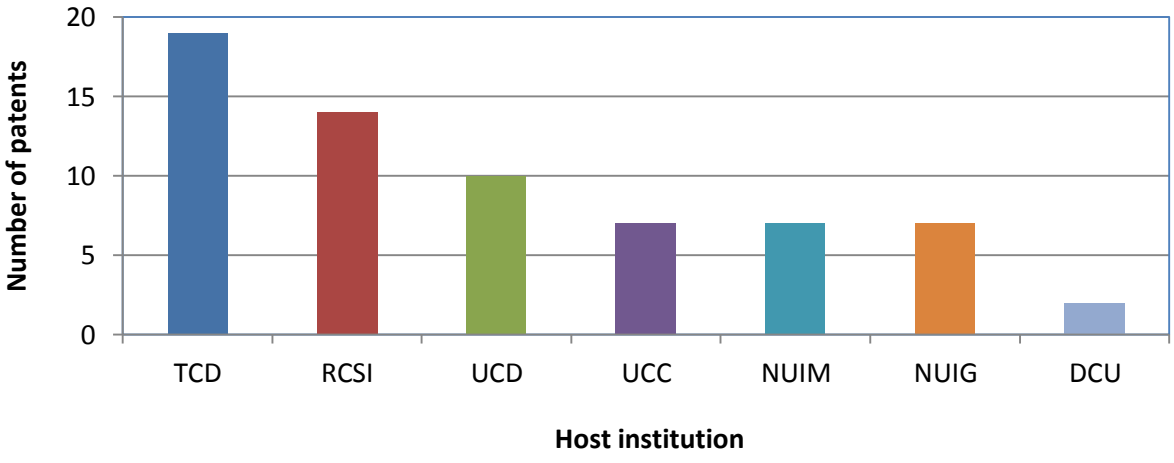
Figure 19: Status of patent applications per region



Patents by host institution

An analysis of the 66 patent applications by host institution of the grant (see Figure 20 for details) showed that Trinity College Dublin produced the most patent applications. However, in relative terms, NUI Maynooth produced the most patent applications per HRB grant received (on average 19% of grants produced a patent application), followed by the RCSI (on average 11% of grants produced a patent application).

Figure 20: No. of patents by applicant institution

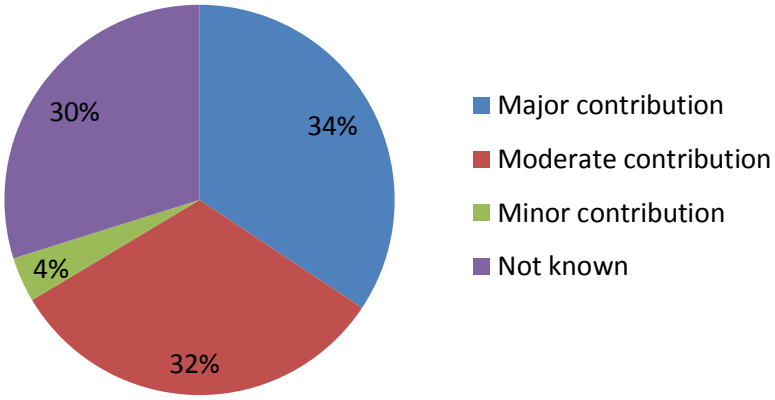


Importance of HRB funding to the research that underpinned the patents

Similar to the question asked of grant-holders in relation to the Innovations section of the survey, researchers who reported a patent application linked to their HRB funding were asked to indicate the level of importance of the contribution of their HRB funding to the research that underpinned the patent (there were three options – Minor, Moderate, Major). Analysis of the responses is shown in Figure 21:

- Where a response to this question was recorded, HRB funding was indicated to have made a moderate or major contribution to two-thirds of patent applications. HRB funding made a minor contribution in only 4% of cases.
- While the question was not asked in this part of the survey, it can be reasonably inferred that SFI and EI (which both fund in the biomedical space), and perhaps the EU Framework Programmes in a minority of cases, were the other main contributing sources of funding to the research underpinning the patents.

Figure 21: Respondents' rating of importance of HRB-funded research to patent



Examples of patented technologies

Grant title: Bifidobacteria mediated cancer gene therapy **PI: Dr Mark Tangney, UCC** **Grant type: Research project grant (three-year grant)** **Year awarded: 2007**
Dr Tangney's research focuses on the development of novel tumour therapeutic strategies, primarily employing bacteria as a vehicle to target therapeutics to tumours. Bacteria present an attractive class of gene vectors, possessing a natural ability to grow specifically within tumors following intravenous (IV) injection. The group demonstrated that IV injection or ingestion of a species of probiotic bacterium, *Bifidobacterium breve*, in high numbers, results in trafficking of the bacteria throughout the body and accumulation specifically within cancerous tissue. The research led to a patent application: "Orally administered bacteria as vehicles for systemic delivery of agents". The bacterial vector technology is under pre-clinical development, aimed at commencing clinical trials within two to three years. Currently, the PI has active funding from the HRB as well as EU FP7 funding to progress development of the technology.

Grant title: Screening for pregnancy endpoints (SCOPE) Ireland
PI: Professor Louise Kenny, Cork University Hospital
Grant type: Clinician Scientist Award (five-year grant)
Year awarded: 2007

Professor Kenny's HRB Clinician Scientist Award resulted in a contribution of 3,000 Irish women to a global study of 10,000 women, with well-characterised diagnostic data and associated clinical outcomes. This represents a unique biobank of samples allied to extensive high-quality data that will act as a platform for research for years to come. The research led to the discovery of a unique set of metabolites that can accurately predict pre-eclampsia, based on a blood sample taken at 15 weeks. This is the world's first predictive diagnostic blood test for pre-eclampsia. Two patent applications were filed as a result of the research (entitled 1. "Detection of risk of pre-eclampsia"; 2. "Metabolomic profiling"). The PI subsequently co-founded a campus spin-put company named Metabolomic Diagnostics Ltd to provide predictive diagnosis of Pre-eclampsia in early pregnancy (the company plans to employ 40 people). Further research is ongoing to develop and validate a clinically useful early pregnancy screening test for pre-eclampsia, based on a combination of metabolomic biomarkers and certain clinical risk factors.

Grant title: APOCOLON: Qualitative and quantitative analysis of factors contributing to apoptosis resistance in colorectal cancer - Evaluation of new prognostic and therapeutic avenues
PI: Professor Jochen Prehn, RCSI
Grant type: Translational Research award (five-year grant)
Year awarded: 2007

Professor Prehn's HRB Translational Research Programme in colorectal cancer has to date facilitated three patent applications in relation to computationally-based prognostic technologies:

1. 'A computer-implemented system and method for the prediction of cancer response to genotoxic chemotherapy and personalised neoadjuvant treatments'
2. 'Treatment and prognosis of solid tumour cancers'
3. 'DR_MOMP: Dose-response medicinal outcome model predictor and method'

The latter is a prognostic tool based on a systems analysis of Bcl-2 family protein interactions that explores the ability of cancer cells to activate apoptosis, indicative of response to classical, genotoxic therapy. The tool is also designed to predict therapy responses to Bcl-2 antagonists, a novel class of apoptosis sensitisers currently in clinical development.

Grant title: Primitive vascular progenitor cells in atherosclerosis
PI: Professor Noel Caplice, Cork University Hospital
Grant type: Translational Research award (five-year grant)
Year awarded: 2007

Professor Caplice's 2007 HRB Translational Research Programme investigated the role of a blood-borne cell type called primitive vascular progenitor cells (PVPC). These cells have multiple stem cell-like characteristics, a predisposition to differentiate into vascular smooth muscle cells *in vitro*, and the capacity to integrate in vasculature *in vivo*. Based on the rationale that PVPCs are an attractive candidate from a diagnostic and therapeutic perspective in atherosclerosis, Professor Caplice set out to develop a diagnostic assay to evaluate PVPC mobilisation in the blood of human subjects with atherosclerosis, and to optimise this assay into a commercial test for atherosclerosis monitoring. The research led to a patent application ("Primitive Vascular Progenitor Cells and uses thereof"). The PVPC has been developed as a stem cell line for generation of smooth muscle cells that can be used to make vascular grafts, and it has been preliminarily tested in animal models with success. The technology is now being further developed with a view to large-scale clinical testing and clinical translation.

Grant title: Malignant melanoma: functional studies using DNA methyltransferase inhibitors and genetic suppressor element technology
PI: Professor William Gallagher, UCD
Grant type: Research project grant (three-year grant)
Year awarded: 2003

Through this 2003 HRB grant and a subsequent 2006 HRB project grant, Professor Gallagher's team identified a shortlist of biomarkers for assessing the progression of malignant melanoma as well as potential resistance to chemotherapies. The findings led to a patent application in 2006 (Gallagher WM *et al.* 'Markers for melanoma'), subsequently granted. The PI founded a spin-out company OncoMark Ltd, centred on the development and application of biomarker panels, particularly to support oncology drug development. This particular line of research in relation to melanoma is being progressed via an EU Marie Curie Industry-Academia Partnerships and Pathways grant (entitled 'Target-Melanoma') from 2009 to 2013 with a value of just over €1.75 million. There are seven research partners, including two SMEs (Oncomark and Cellix Ltd) and five European academic centres (including UCD).

Grant title: The forgotten female! Does sex have a role in thrombotic risk?
Fellow: Dr Aaron Peace, RCSI (PI: Professor Dermot Kenny)
Grant type: Clinical research training fellowship (three-year grant)
Year awarded: 2006

Cardiovascular disease, the largest cause of global mortality, is frequently due to thrombosis mediated by platelets. Current assays to initiate therapy in either primary or secondary prevention of thrombosis have significant limitations. Dr Peace's clinical research training fellowship in 2006 aimed to address the many limitations of the available tests of platelet function and to investigate gender differences in thrombotic risk. The grant led to the development of a novel high-throughput microtitre platelet aggregation assay, which was the subject of a patent application ('A method of generating a platelet reactivity profile for an individual.') The patent is currently proceeding through the national phase, following a PCT filing, in the US, Japan, Australia, Canada, Israel and New Zealand. This technology and related technologies are being developed by Professor Kenny as part of the Biomedical Diagnostics Institute, an SFI-funded Centre for Science, Engineering and Technology.

Licensed technologies

The traditional route to commercialise technologies developed in academic institutions is to license the patented technology to a company which may then further develop and validate the technology before pursuing market approval. An analysis of the responses in this section of the Outcomes Tracker survey found that:

- A total of 15 licensed technologies were reported by 12 HRB grant-holders linked to 15 grants (1.5% of total).
- Nine of the 15 technologies were licensed to companies based overseas, while six were licensed to companies based in Ireland. (In fact, these six were 'in-licences' to campus spin-out companies where the inventing PI was typically a co-founder) (Table 10).
- One-third of the licences were "exclusive" (i.e. the licensee had exclusive rights to commercialise the technology).

Table 10: No. licences by type and location of licensing company

Location of licensee	Exclusive licence	Non-exclusive licence	Total
Overseas company	2	7	9
Irish company	3	3	6
Total	**5**	**10**	**15**

Examples of licensed technologies

Grant titles: The role of stress responses and BH3-only proteins in disease progression in ALS mice; Hypoxia-induced neurotrophic factors in the Irish ALS population (fellowship)
PIs: Professor Jochen Prehn; Dr Matt Greenway (fellow) and Professor Orla Hardiman
Grant type: Research project grant; Clinical research fellowship (both three-year grants)
Year awarded: 2007 (Prehn project grant) and 2006 (Greenway fellowship)

This stream of work relates to research carried out by Professor Prehn's group in collaboration with Dr Greenway and Professor Hardiman, dating back to 2006, when they demonstrated an association between angiogenin mutations and amyotrophic lateral sclerosis (published in the journal *Nature Genetics*). The group subsequently demonstrated that angiogenin protein delivery may be beneficial in diagnosing and treating patients with newly diagnosed ALS. The underlying technology was protected through a series of IP filings, recently granted. Shortly before grant of the patent, the RCSI Technology Transfer Office (TTO) had identified a number of commercial partners before finally settling on Athena Diagnostics, based in Massachusetts, as the partner of choice. Following negotiations, a formal licence agreement was executed; this agreement permitted the market launch of diagnostic kits in the US, Canadian and Japanese markets.

Grant title: Real-time simultaneous monitoring *in vivo* of glutamate and H2O2 in brain tissue, using a novel implantable polymer-enzyme composite device
PI: Professor John Lowry, NUI Maynooth
Grant type: Research project grant (three-year grant)
Year awarded: 2002, and related project and equipment grants awarded since 2004

The research carried out by Professor Lowry's group has been focused on the development of sensors and biosensors to selectively monitor important neurochemicals in the living brain on a timescale from milliseconds to days, and to use these studies to contribute to the understanding of the complex functioning of the brain in terms of behaviour and disease. As a result of the broad programme of research, partly funded by the HRB, various brain monitoring technologies have been developed and patented. The PI and NUI Maynooth subsequently entered into four licence agreements (valued at over €150,000) with Dutch company Solvay Pharmaceuticals, involving two different types of sensors. At the time, Professor Lowry anticipated that future licence agreements would involve a range of new sensors, including the glutamate biosensor. However, Professor Lowry subsequently decided to establish a spin-out company named BlueBox Sensors Ltd in 2009, to commercially exploit the sensor technologies.

Grant title: *In vivo* response of collagen scaffolds for orthopaedic regenerative medicine **Fellow: Dr Frank Lyons, RCSI** **Grant type: Health professionals fellowship (three-year grant)** **Year awarded: 2009**
Under this fellowship award, Dr Lyons carried out pre-clinical evaluation of the 'HydroxyColl' bone repair technology, a novel bone graft substitute which combines bone's two main constituents, collagen and hydroxyapatite, in a bioactive scaffold for the repair of bone tissue defects. As a result of the pre-clinical validation, the HydroxyColl technology was in-licensed to SurgaColl Technologies, an RCSI spin-out campus company established to commercialise patented technologies developed in the laboratory of Professor Fergal O'Brien (Dr Lyon's fellowship supervisor). Surgacoll recently closed a €2 million venture capital funding round to bring these products to the market, and new applications for the technologies are currently being investigated under a HRB-SFI Translational Research Award. SurgaColl has been engaging with the Irish Medicines Board about potential clinical trials, and following the very successful results from the pre-clinical animal studies, it is proposed to have Hydroxycoll in human clinical trials in 2013.

Spin-out companies

In general, licensing a patented technology to an existing company with the necessary infrastructure already in place to commercialise the technology (such as marketing expertise, manufacturing facilities, commercial management etc.) is likely to be a more resource-effective option and lower risk strategy for academic institutions seeking a commercial return from their research. However, where the new technology is very novel (i.e. disruptive) and/or where it is still far from the market, then creating a new company may be the only realistic alternative. There is also increasing pressure on academic institutions from government, funders and regional development bodies to establish a company with employment potential, rather than out-license the technology to, say, a company based overseas.

Grant-holders were asked if their HRB-funded research had contributed to the establishment or development of a spin-out company (Table 11). The findings were as follows:

- 12 grant-holders reported that their HRB-funded research contributed to the formation or further development of 11 spin-out companies (attributed to 12 grants or 1% of the total number of grants)
- Of these 11 companies that HRB-funded research contributed to, nine are still in existence. (One company, SlidePath, was sold to a UK company for €3.5 million, while no information can be found on a second company, and so it is presumed that this company was wound up soon after incorporation.)
- Of the nine companies currently in existence, three have launched at least one product on the market, while six companies are exclusively in the pre-commercial stage of development at present. In addition, Slidepath's e-pathology technologies have been commercialised and marketed by Leica Microsystems (a subsidiary of the UK Genetix Group that purchased Slidepath).
- It is estimated that HRB-funded research contributed at a 'major' level to the formation of three companies, at a 'moderate' level to the formation of an additional five companies, and at a 'minor' level to the formation of an additional three companies.

Table 11: List of spin-outs linked to HRB-funded research

Company name	Founding PI	Nature of business	Product on market?
OncoMark	Professor William Gallagher (UCD)	Biomarkers to support oncology drug development	Yes
Slidepath (sold to UK Genetix Group)	Dr Donal O'Shea	Digital pathology	Yes
BlueBox Sensors	Professor John Lowry (NUI Maynooth)	Brain sensors for pre-clinical application	Yes
Clinical Support Information Systems	Dr Denis O'Mahoney (UCC)	Computational rules for prescribing in the elderly	Yes
Surgacoll Technologies	Professor Fergal O'Brien (RCSI)	Bone and cartilage repair	No
Genable Technologies	Professor Peter Humphries, Professor Jane Farrar, Dr Paul Kenna (TCD)	Gene therapies for inherited eye disorder	No
MITAMED	Dr Declan Soden (UCC)	Medical devices for cancer treatment	No
Orbsen Therapeutics	Professor Frank Barry and Professor Tim O'Brien (NUI Galway)	Stem cell therapy for selected target conditions	No
Metabolomic diagnostics	Professor Louise Kenny (UCC)	Biomarker algorithms to predict pregnancy outcome	No
Peat Distill (Closed)	Dr Gianluca Pollastri (UCD)	Bioinformatic 'in silico' drug testing models	No
AvenaTherapeutics	Professor Peter Humphries (TCD)	Blood-brain barrier modulation technology	No

Examples of spin-out companies

Grant title: Exploration of therapeutic interventions at the genetic level in degenerative diseases of the retina (Humphries); Exploration of exogenous microRNAs as a suppression tool and endogenous microRNAs in the context of retinal degenerations (Kenna)
PI: Professor Peter Humphries and Dr Paul Kenna, Ocular genetics unit, TCD
Grant type: Programme grant (five-year grant) and Research fellowship in rare diseases (three-year grant)
Year awarded: 2001 (Humphries programme) and 2005 (Kenna fellowship)

The research team led by Professor Humphries in the Department of Genetics, Trinity College Dublin has been funded by the HRB since the early 1990s. The team's 'suppression and replacement' technology led them to establish a spin-out company called Genable Technologies Ltd, focused on generating therapies for inherited eye disorders. The technology is protected by a broad suite of granted patents and patent applications in the USA, EU and worldwide. Genable's first gene therapy, GT038, is for treatment of patients with rhodopsin (RHO)-linked autosomal dominant retinitis pigmentosa (adRP) – a debilitating form of inherited blindness. The therapy has just recently been awarded Orphan Drug status by the FDA. In 2011 the company successfully completed a new venture capital financing round for €5 million. This funding will support the ongoing development of Genable's gene therapy technology and will progress their lead product GT038.

Grant title: Application of electroporation to internal tumours **PI: Dr Declan Soden, Cork Cancer Research Centre, UCC** **Grant type: Research project grant (three-year grant)** **Year awarded: 2006**
Dr Soden co-founded MITAMED Ltd in 2010, in order to further develop and commercialise the EndoVE and ThoraVe medical devices for cancer treatment, previously described in Section 5.2. The company is currently conducting a clinical trial of the EndoVE® in the Mercy University Hospital, Trinity College Dublin, Tallaght Hospital (AMNCH) and St James's Hospital, Dublin. The establishment of new sites in the UK, Germany and Sweden are currently under discussion, and should be facilitated by the expected European conformity (CE) approval for the EndoVe in 2013. MitaMed's key objectives for the next 18 months include the completion of the current clinical trial, expansion of trials into other forms of cancer and into a multi-centre European study, design optimisation, CE marking and commencement of volume manufacturing. MitaMed won the ITLG University Challenge award for the 2013 best Irish university start-up company.

Grant title: Automated grading of ductal carcinoma *in situ* **PI: Dr Donal O'Shea (DCU, now based in Leica Microsystems Ltd)** **Grant type: Research project grant (three-year grant)** **Year awarded: 2001**
An outcome of this grant was the development of the 'ReplaySuite' system to exploit the power of digital microscopy, which can capture the detail of microscopic samples at suitable resolution for diagnosis. The system tracks where a pathologist visits as they view a digital slide, and can then replay this to others, whether trainee pathologists or for quality assurance assessment. Dr O'Shea was a co-founder of Slidepath Ltd, a DCU spin-out, focused on the provision and analysis of high-resolution digital pathology images over the Internet. Slidepath developed rapidly to employ 25 people and deliver a turnover of €1.5 million. It was subsequently sold to UK-based company Genetix Group plc for up to €3.7 million in cash and shares. Products developed by Slidepath are now marketed by Leica Microsystems, a subsidiary of the Genetix Group.

6.2 Academic-industry linkages and resulting outcomes

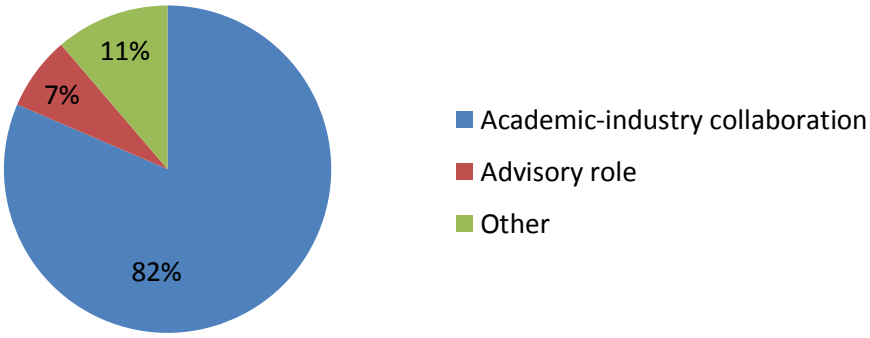
Academic-industry linkages are considered of growing importance by science funders and policy-makers as an important medium to levering spillover effects and economic gains from publicly-funded research. The extent to which publicly-funded researchers are engaged with the private sector is often considered an indicator of the quality of their research as well as the degree of commercial relevance and potential of their work. In this context, HRB grant-holders were asked if they had engaged with any companies in either a formal (e.g. joint research, advisory role) or informal manner (e.g. networking event).

Following an analysis of the data, the main findings in this section were:

- 76 grant-holders reported 151 linkages to companies, linked to 103 HRB grants (or 10% of all grants). In addition, ICORG has collaborated with 46 companies on cancer clinical studies.
- As shown in Figure 22, the main type of linkage reported was academic-industry collaboration (82% of linkages), while acting in an advisory role to industry accounted for 7% of linkages.

- As shown in Figure 23, the most common purpose of the industry linkages reported by respondents was joint research (50% of linkages). Sharing knowledge and networking was the main purpose reported for 36% of linkages, while a material transfer agreement was the basis for 14% of linkages.
- Grants awarded in 2005 and 2007 collectively were linked to almost 50% of the total number of industry linkages. The proportion of grants that were linked to an industry engagement rose from an average of 5% of grants in the 2000–03 period to an average of 16% of grants in the 2007–09 period.
- A small number of grant-holders who had liaised with multiple companies were responsible for a relatively high proportion of linkages. The most active PIs were Professor John O'Leary (Coombe Hospital – 11 companies), Dr David Finn (NUI Galway – 10 companies), Professor Gerry McElvaney (RCSI – 7 companies), Professor John Crown (SVUH – 6 companies), Professor Jochen Prehn (RCSI – 6 companies), Dr Orina Belton (UCD – 5 companies), Professor Bernard Mahon (NUI Maynooth – 5 companies).
- Companies based in Ireland were involved in 38% of the academic-industry linkages. Companies based in other European countries, including the UK, accounted for 40.5% of linkages, while US-based companies accounted for 21.5% of linkages (Table 12).

Figure 22: Linkages activities by type



The 'Other' category mainly comprised presentations to pharmaceutical companies and receipt of educational grants from industry, with one instance of a PI being appointed as a 'research convenor' by the PI's academic school, which had responsibility for liaising with industry representative groups.

Figure 23: Purpose of the commercial activity

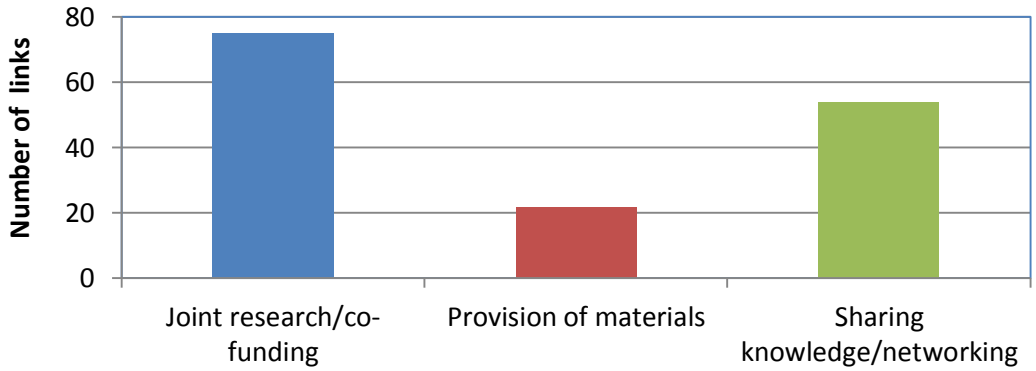


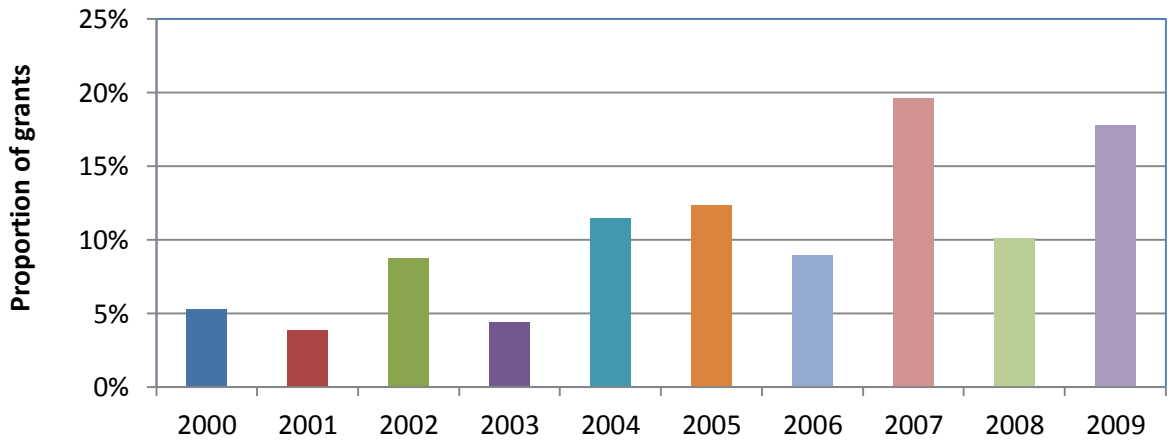
Table 12: Number of industry linkages broken down by location of primary contact

Country	No.
Ireland	44
USA	24
UK	12
Germany	8
Belgium	5
Austria	4
Netherlands	3
Switzerland	3
Denmark	2
Finland	2
Israel	2
Italy	2
Norway	2
Spain	2
Japan	1
Not stated	81
Total	**197**

Proportion of HRB grants with a link to industry

An analysis was carried out of the proportion of grants awarded in each year that were associated with a linkage to industry, whether it an academic-industry collaboration, an advisory role to industry, or another type of linkage. As shown in Figure 24, the proportion of grants linked to industry generally increased over the 10-year period, reaching a peak of 20% of grants in 2007, before dropping to 10% of grants in 2008 and increasing again to 18% in 2009. This is explained by the significant increase in funding for Applied Biomedical research over the years, particularly from 2007.

Figure 24: Proportion of grants linked to industry engagement by year



Examples of outcomes produced from academic-industry collaborations

Grant title: An investigation of bacterial contamination of dental chair units, dental unit water and water lines with Pseudomonas species and *Burkholderia cepacia*
PI: Professor David Coleman, Dublin Dental School & Hospital
Grant type: Research project grant (three-year grant)
Year awarded: 2000

Based on the findings from this HRB grant, the PI established valuable collaborative links with the Finland-based dental chair unit manufacturer Planmeca Oy. This collaboration led to the development of practical solutions to biofilm contamination of dental units. Dental School researchers worked with Planmeca's engineers to develop the automated Planmeca Water Management System, a system to reduce bacterial counts in the water cooling and suction systems that are part of dental chair units (DCUs). DCUs fitted with the system can now be found in hundreds of single dental surgeries around the world as well as in large dental hospitals in North America and Canada and throughout Europe.

Professor Coleman has also worked with the Irish water technology company Trustwater to develop fully automated, self-cleaning, biofilm control systems for dental hospitals. The installation of one such unit at the Dublin Dental Hospital paid for itself within a year. The Copenhagen Dental School is now also equipped with the system and installations at several other large dental schools in Europe are currently in progress. According to the PI, the system is also being applied to reduce the infection risk from other medical devices.

Grant title: Novel screening modalities for colorectal cancer
PI: Professor Colm O'Morain, TCD and Tallaght Hospital
Grant type: Co-funded award in Health Services Research (two-year grant)
Year awarded: 2003

Professor O'Morain and his team investigated a new screening test that combines the higher accuracy of colonoscopy with the non-invasive nature of Faecal Occult Blood Testing (FOBT). The test involved measuring levels of a marker enzyme called Tumour M2-PK in stool samples. Funding for the work came jointly from the HRB and the manufacturer of the test (Schebo Biotech, Germany) which was a key collaborator in the project. The study found a significant relationship between elevated levels of Tumour M2-PK, pre-cancer and cancer. The test was sensitive enough to detect 97% of all colorectal cancers and 76% of adenomas detected by colonoscopy. It also had a specificity of 98% i.e. it could reliably distinguish colorectal pre-cancer and cancer from other conditions of the colon.

The test has since been marketed by Schebo (as the Tumor M2-PK™ Stool Test) as a non-invasive colorectal cancer screening tool with high sensitivity and specificity. Furthermore, Tumor M2-PK gives additional information that is generally not provided by classical tumour markers which reflect tumour burden. Urological centres have shown the suitability of Tumor M2-PK as a marker for renal cell carcinoma, and since Tumor M2-PK is a highly tumour-specific protein and has not shown any organ specificity, the test is also suitable for the diagnosis of non-urogenital tumours including gastric, oesophageal and pancreatic cancer.

Grant title: The Irish Cervical Screening Research Consortium (CERVIVA)
PI: Professor John O'Leary, TCD and Coombe Women's Hospital
Grant type: Strategic Health Services R&D Award (five-year grant)
Year awarded: 2005

CERVIVA was established in 2005 and was initially funded by the HRB to perform high-quality research in the area of cervical screening in Ireland, with an overarching aim of supporting CervicalCheck (the National Cervical Screening Programme). CERVIVA evolved into a multi-investigator collaboration encompassing researchers at seven Irish academic institutions, eight hospitals and 10 commercial diagnostic or biotechnology companies. It received new funding from the HRB in 2012 and has leveraged several million euro in funding under FP7 and from a variety of other sources. One of the CERVIVA project areas funded by the HRB (Digital EQA for cervical cytology) has been successfully developed, tested and marketed by Leica Microsystems, one of CERVIVA's main industry project partners, as part of an iPad/iPhone Application ('SlidePath Gateway').

SlidePath Gateway is a digital pathology viewing application with built-in educational content from leading institutes and pathologists. The application provides access to high-quality whole slide images captured on the Leica SCN400 slide scanner, with expert review findings and content provided by contributing bodies including:

- ASCP CheckPath Anatomical Pathology EQA Program (2006)
- Cerviva Cervical Cytology EQA Pilot (2009)
- NHS Breast Screening Pathology EQA Program (2010)
- UK National Urologic Pathology EQA Program (2009)
- UKNEQAS HER2 Breast Interpretive EQA Pilot (2011)

Grant title: Targeted siRNA delivery to the lungs for the treatment of inflammatory lung disease
PI: Dr Sally-Ann Cryan, RCSI
Grant type: Research project grant (three-year grant)
Year awarded: 2005

The work funded by this award, previously described in Section 5.2, is now entering pre-clinical testing in a rodent model of inflammatory lung disease. Should these studies be successful, then the RNA medicines would be brought into clinical trials. The successful development of RNA-based medicines could have a significant effect on clinical practice in the future. To this end, the PI has established a commercial collaboration with Aerogen, an indigenous medical device company based in Galway that specialises in advanced inhaler development.

Aerogen has a device nebuliser suitable for delivery of siRNA in a clinical setting, so the collaboration is focusing on harnessing the Aerogen device for delivery of novel RNA-based therapies to the lungs. The RNA therapies developed by the PI and her team in RCSI as part of this HRB award are now being tested with this nebuliser. This collaboration is mutually beneficial to both partners, as it facilitates bringing the PI's novel RNA therapies from bench to bedside, and it provides critical proof-of-concept data for Aerogen's devices, thereby providing a unique RNA delivery platform for respiratory disease developed entirely in Ireland. Dr Cryan is also working closely with a number of other small spin-out companies developing inhaled therapies, to which she offers consultancy and drug development expertise.

Grant title: Home telemonitoring in a high-risk heart failure population
PI: Professor Ken MacDonald, UCD and St Vincent's University Hospital
Grant type: Partnership for a healthier society award (two-year grant)
Year awarded: 2008

This grant was co-funded by the HRB, BiancaMed (a collaborating UCD spin-out company subsequently purchased by ResMed Ltd) and the National Digital Research Centre. The research contributed to the development of the 'HeartPhone'. For congestive heart failure patients, abrupt weight gain is a clear indicator of deterioration of heart condition. HeartPhone is a mobile phone-enabled healthcare system capable of accurately tracking "at risk" changes in a patient's weight remotely. It will allow medical professionals to get real-time information on patients, presenting the prospect of more timely intervention. The technology has the potential to improve the overall management of the patient through connected care; it reduces healthcare costs and reduces the number of visits by patients to hospital.

Underpinning the HeartPhone is a novel algorithm for detecting weight changes as predictors of deterioration of heart failure. According to the PI, the algorithm significantly improves the sensitivity of weight gain or deterioration compared to the current European Guideline approach. This algorithm is the subject of a European Patent Office (EPO) PCT Filing. There are three potential licensees for this algorithm, and exclusive and non-exclusive options are being negotiated.

Grant title: The All-Ireland Cooperative Oncology Research Group (ICORG)
Grant type: Cancer clinical trials network, involving 11 hospitals and a coordinating central office
Year awarded: 2001 (renewed every three years since)

A recent impact assessment of ICORG carried out by Technopolis Ltd found that, since 2002, ICORG has collaborated with 46 companies, including almost all the large pharmaceutical companies based in Europe and some of the largest pharmaceutical companies in the world, such as GSK and Pfizer. Some examples of benefits accruing from these collaborations include the approximately €1.2 million that was invested by industry in ICORG in the three years up to 2011, the drugs provided free-of-charge by industry partners (e.g. ICORG participation in the Herceptin studies allowed patients free access to drugs that cost €50,000 a year), and other in-kind contributions to ICORG, with a stable annual estimated value of between €3 million and €4 million over the last six years.

Furthermore, industry values the collaboration with ICORG – in an industry survey conducted as part of the ICORG impact assessment, industry collaborators described the relationship with ICORG as very positive and beneficial. One company had changed its protocol design on a number of studies in order to align with ICORG's protocol, stating that this had led to better outcomes. Overall, ICORG was cited by key industry collaborators as a major factor in the business decision to perform clinical trials in Ireland, with one company stating:

> *"(The company) cut its R&D footprint in one-third of all countries across Europe. In Ireland we were also impacted by this decision and we are now not allowed to work in any therapeutic area apart from haematology and oncology. The reason we were allowed to continue in oncology and haematology is because of the ICORG network."*

PI: Professor Gerry McElvaney (RCSI/Beaumont Hospital)
Grant type: Multiple grants awarded to Professor McElvaney and his team over the 2000–09 period related to cystic fibrosis and alpha one antitrypsin deficiency disorder (including three Research project grants, three MRCG/HRB co-funded project grants, and the RCSI PhD Scholars Programme in Therapeutics and Diagnostics for disease for which Professor McElvaney is the Director)

Through their work into cystic fibrosis (CF) and alpha 1 antitrypsin deficiency (AATD) funded by the HRB through multiple grants over the 2000–09 period, Professor McElvaney's team have become one of the largest and most respected centres in the world for the study of these conditions. The team

are collaborating with multiple companies throughout the world to develop several new treatments for CF and AATD:

- In collaboration with the Israeli company Kamada Ltd, the group have pioneered aerosol therapy with alpha one antitrypsin in CF and have instituted one of the earliest studies of this mode of therapy in AATD. Their work has led to a major clinical trial in CF, which is almost complete, and the only trial of aerosolised alpha one antitrypsin for individuals with AATD.
- In collaboration with Talecris Biotherapeutics (now owned by Spanish company Grifols Ltd) the group led a major study on evaluating intravenous plasma purified alpha one antitrypsin for AATD. This study over seven years has just ended and showed that the therapy is effective in slowing the progression of lung tissue loss and emphysema in patients with AATD.
- The RCSI team is one of only three centres worldwide involved in this novel therapy for AATD utilizing an adeno-associated viral vector delivery system to deliver the alpha one gene into the muscle of AATD patients. The early data are encouraging and justify further clinical studies. The therapy was developed by the US-based company Applied Genetic Technologies Corporation, a key collaborator on the study.
- The group have derived a number of assays to test for systemic inflammation in CF, which in collaboration with US-based company Vertex Pharmaceuticals and other companies, they envisage will support the development of ground-breaking CF therapies, including ion channel potentiators and correctors.

6.3 Funding leveraged from non-Exchequer sources

There is a range of national and international funding sources for biomedical researchers based in Ireland, including EU funding, Science Foundation Ireland, Enterprise Ireland, the Higher Education Authority PRTLI, and industry and charitable organisations. There are fewer options for researchers in other areas of health research, such as clinical research, health services research and population health sciences. Researchers in the latter two fields in particular are more dependent on HRB funding as a national source of funding, compared to researchers in the biomedical sciences. Notwithstanding this context, as an indicator of the success of the original HRB-funded research and a likely contributor to the development of potential outcomes, the HRB is interested in obtaining information on any subsequent funding that researchers have secured from various sources.

In the Outcomes Tracker survey, HRB grant-holders were therefore asked to list any additional research grants from non-HRB sources obtained at least in part as a result of HRB funding received in the 2000–09 period. Of particular interest was the proportion of leveraged funding obtained from outside Ireland and from the private sector, since this represents a real financial gain to the Irish economy.

The main findings from the analysis of responses in this section were:

- 234 researchers secured 621 grants based at least in part on their HRB-funded research.
- The combined value of the grant amounts allocated to HRB-grant-holders was €206.6 million (referred to as "allocated grant amounts" in this section).
- The overall value of the 621 grants that HRB-funded researchers helped to secure was €844 million. (Some grants, such as EU Framework Programme (FP), grants were multi-million multi-institutional awards, and the respondents were asked to indicate the amount of their allocation for the purpose of attribution and data quality.)

- As shown in Table 13 and Figure 25, the most common single funding source was SFI, which accounted for 23% of the total number of leveraged grants and just over 50% of total funding (i.e. allocated grant amounts). Charitable sources accounted for 22% of the total number of leveraged grants but only 11% of total funding.
- Non-Irish Exchequer sources collectively accounted for 43% of the total number of leveraged grants and 35% of the total allocated grant amount (equal to €72.9 million).
- A total of 37 grants, collectively worth €5 million, were secured from industry sources, either based in Ireland or overseas.
- The number of grants leveraged rose sharply from 2006 onwards (the number for 2012 is lower, which is most likely explained by the survey cut-off point in October 2012).
- As shown in Figure 26, the vast proportion (85%) of leveraged funding came from governmental/public sources either nationally or internationally.
- 20 researchers reported a total of 25 EI commercialisation development grants (an indicator of the development of innovative technologies with commercial potential), which seems a low figure, particularly when compared with the number of innovations described in Section 3.2. This might signal an under-reporting by some researchers in this section, or that the technology was at too early a stage of development even for an EI grant.

Table 13: Number of leveraged grants per funding source

Funding source	No. grants
SFI	145
Charity	138
Other national	76
EU Framework Programme	53
IRCSET/IRCHSS	52
Other international	38
EI	36
Industry (overseas)	22
HEA	20
EU other	16
Industry (Irish-based)	15
HSE	8
European Research Council	2
Grand total	**621**

Figure 25: Total value of allocated grant amounts by funding source

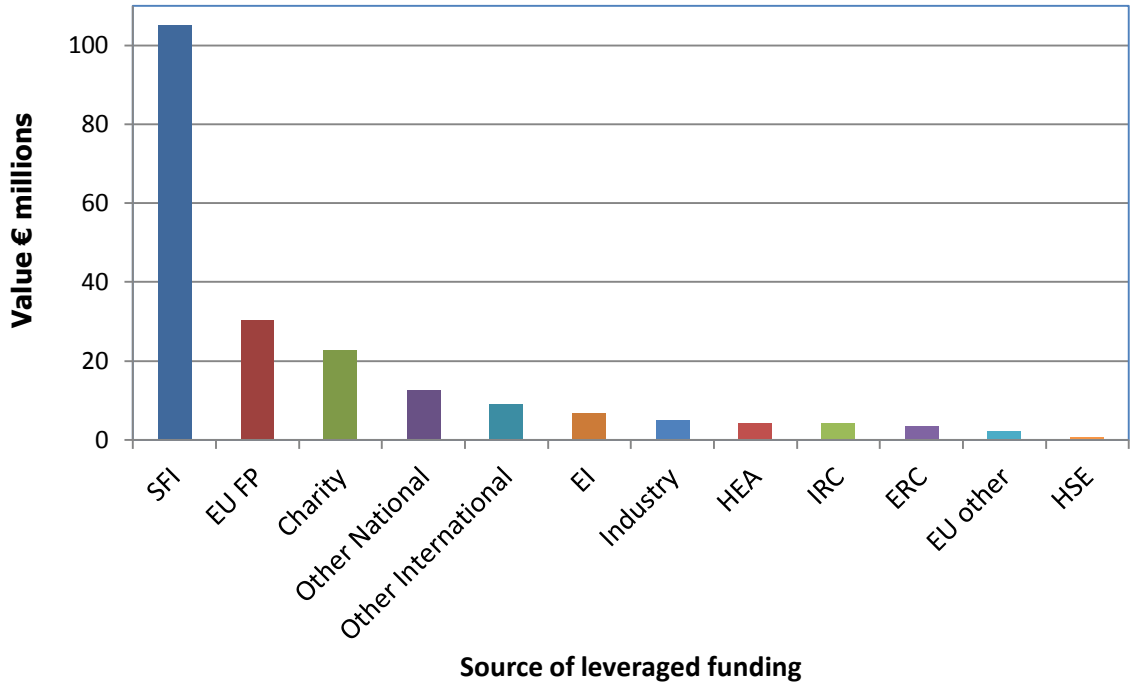
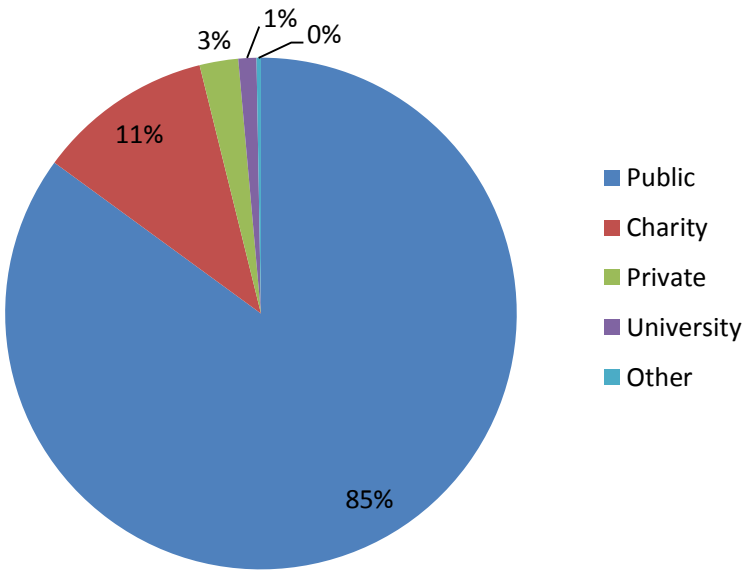


Figure 26: Proportion of leveraged grants by sector of awarding body



7 Conclusion

This report describes a wide variety of outputs and outcomes (and illustrates some impacts) produced by research grants awarded by the HRB in the 2000–09 period. The findings reinforce – for the first time on an entire funding portfolio level and on a longitudinal basis – the message of the 2008 *Making an Impact* case study report, which showed that significant outputs, outcomes and impacts arise from health research carried out in Ireland. The report is timely for the HRB as it provides a useful evidential input to the process, due to begin in 2014, of developing a new corporate strategy for the 2015–19 period. From an external perspective, the findings will assist the HRB in making the case for health research to key stakeholders, and it will facilitate the HRB's efforts to report against the Research Prioritisation Exercise metrics framework.

The findings show that the number and level of healthcare innovations, and the proportion of grants that led to influences on policy and practice (over a quarter of all grants), is significant given that the broad thrust of the HRB's portfolio over the 2000–09 period was based predominantly on exploratory biomedical research. Specifically, there was a sharp increase in the number of policy and practice-oriented outputs, influences and innovations reported to have occurred from funding year 2004 onwards – the year when a number of strategic funding initiatives in response to *Making Knowledge Work for Health* began to come on stream (including the Strategic Health Service R&D Awards, co-funded Partnership grants, Clinician Scientist Awards), while initiatives such as the Translational Research Awards, Health Research Centres, Imaging Awards, and Global Health Research Awards came on stream between 2004 and 2007.

This analysis also confirms that different outcomes are associated with different areas of health research. For instance, biomedical research was more associated with commercially-oriented outputs and outcomes such as patents, therapeutic and diagnostic products, as well as academic-industry collaborations (although clinical research initiatives such as ICORG also produce many of these types of outcomes). On the other hand, health services research, population health sciences and clinical research were more strongly associated with the development of therapeutic and preventive interventions, care models, guidelines, and interactions with policy-makers. As might be expected, grants at the applied end of the research spectrum, grants associated with multi-disciplinary collaborations and involvement of health professionals (e.g. Health Research Centres, Strategic R&D Awards, Clinician Scientist Awards), and grants associated with strategic co-funding arrangements with HSE or industry (e.g. Partnership Awards) tended to produce more outputs and outcomes in addition to traditional scientific outputs.

The implication of the report findings, in the context of the HRB's Strategic Business Plan 2010–14 and the shift away from basic biomedical research towards patient-oriented research/population health sciences/health services research, is that over the coming years we should see an increase in health sector outcomes such as development of innovations (e.g. interventions, therapies) and influences on policy and practice (e.g. clinical guidelines, policy briefs, advisory roles).

While the study marked a significant step forward for the HRB in terms of the richness of evaluative data relating to its historic grants portfolio and the enhancement of systems to prospectively capture grant outputs and outcomes, it did have some limitations. Firstly, the study was not able to populate each of the five payback categories in a comprehensive fashion, in particular categories 4 (health sector impacts) and 5 (broad economic and societal benefits) which require more specialised methodologies such as in-depth case study work, policy analysis, and econometric modelling to convert health gains into monetised gains. Secondly, the survey relied heavily on grant-holders' engagement and their ability to recall activities and outputs linked to grants that may have concluded

several years ago. While data was validated as much as possible in an attempt to verify the accuracy of reported outputs, it is possible that there was incomplete reporting of outputs by grant-holders, particularly for older grants.

Another consideration is that a minority of grants (nevertheless representing a significant HRB investment) are still active or have only recently concluded. Due to normal time lags in the research process, additional outputs, outcomes and impacts linked to these grants may be expected to emerge in the future. Therefore, while this project represented an unprecedented capture and analysis of outputs and outcomes arising from HRB grants on an entire funding portfolio level, it should not be considered a conclusive assessment of the impact of the HRB's grants portfolio in the 2000–09 period. To order to deliver a conclusive assessment, the HRB may consider commissioning a follow-on study at some future point to assess if some of the interesting outputs and outcomes identified have contributed to ultimate impacts in the health, societal and economic spheres (as represented by categories 4-5 of the Buxton and Hanney Payback Framework) through the application of the specialised methodologies outlined above.

Finally, an attempt was made by the HRB evaluation team to obtain comparable output and outcome data from other health research funders, in order to place the HRB data in context. This proved difficult to obtain in the first instance, as very few funders capture output data that is directly comparable to the HRB data. However, where data were broadly comparable to other funders (with some caveats), the HRB figures were encouraging – for instance, the relative number of products and interventions linked to HRB grants was at a similar level to the UK Medical Research Council, while the proportion of HRB grants that reported an influence on policy and practice compared favourably with both MRC and Wellcome Trust grants. In terms of future benchmarking exercises, it is noteworthy that the various health and medical research funders in the UK have agreed to use a common system for capturing outputs and outcomes. There is an opportunity for Irish funders, including the HRB, to consider the developments in the UK in the interests of streamlining and benchmarking output and outcome collection.

Appendix A: Membership of the International Advisory Group

Following a request from the Board to explore approaches that would ensure the credibility of the findings (given that the project was being carried out internally), a number of international experts in the field of research evaluation and impact assessment were appointed to an independent external group – the International Advisory Group.

The Group's terms of reference were to:

1. Advise the HRB on the project approach and implementation
2. Assist with monitoring the project, and provide expert input as requested
3. Review and endorse the project findings
4. Advise the HRB on implementing internal process improvements for prospective capture of outputs, outcomes and impacts.

The Group met twice during the project – the first meeting took place in April 2012, the second in November 2012. The members of the Group were:

- Dr Claire Donovan (Chair), Reader, Health Economics Research Group, Brunel University London
- Dr Ian Viney, Head of Strategic Evaluation, Medical Research Council UK
- Ms Laura Hillier, Director, Evaluation and Outcome Assessment, Canada Foundation for Innovation
- Dr Per Janson, Senior Analyst, Swedish Research Council (now based at the City of Stockholm)
- Dr David Kryl, Business Intelligence Unit, National Institute for Health Research
- Dr Jack Spaapen, Policy Advisor and Executive Secretary of the Humanities Council at Royal Netherlands Academy of Arts and Sciences

Appendix B: Definitions of HRB strategic pillar areas

Basic Biomedical Research

Research conducted to increase the knowledge base and understanding of the physical, chemical and functional mechanisms of life processes and diseases. It is often called fundamental or 'pure' research, and is not directed at solving any particular biomedical problem in humans or animals but provides the building blocks on which other types of biomedical research are based.

Applied Biomedical Research

Research that seeks to understand specific diseases in terms of the characteristics, manifestations, management, treatment, and their relationship with predisposing factors. It includes research that is directed at specific goals and discoveries, such as the development of new drugs, therapies, devices or surgical procedures. It involves using existing knowledge, and methodically expanding this knowledge to address specific clinical issues. Applied biomedical research includes research conducted with animal and non-animal modal systems, computer models, and it may even include studies on human subjects or samples that do not have a diagnostic or therapeutic orientation.

Clinical Research

Research with the goal of improving the diagnosis and treatment (including rehabilitation and palliation) of disease and injury; improving the health and quality of life of individuals as they pass through normal life stages. It involves research on, or for, the treatment of patients. Types of studies include clinical trials and non-drug intervention randomised control trials (RCTs).

Health Services Research

Research with the goal of improving the efficiency and effectiveness of health professionals and the healthcare system through changes to practice and policy. Health services research is a multidisciplinary field of scientific investigation that studies how social factors, financing systems, organisational structures and processes, health technologies, patient needs, and personal behaviours affect the quality and cost of – and access to – healthcare and, ultimately, to health and well-being.

Population Health Sciences Research

Research with the goal of improving the health of the population, or of defined sub-populations, through a better understanding of the ways in which social, cultural, environmental, occupational and economic factors determine health status, or through the identification of effective interventions for improving health status and reducing health inequalities.

Appendix C: Overview of HRB funding between 2000 and 2009

In total, the HRB awarded 1,109 grants, with a combined total value of €330.3 million, between 2000 and 2009. There was significant variability in the number of annual awards over this period – from a low of 88 new awards in the year 2000 to a high of 162 new awards in 2006, while the value of new funding commitments rose from €7.6 million in 2000 to a high of over €64 million in 2007 (the year the HRB received SSTI capital to fund high-value awards such as the PhD Scholars Programmes and Health Research Centres) – see Figure C1. This variability was due to the HRB budget increasing sharply from approximately €15 million in 2001 to over €50 million in 2008, as shown in Figure C2. Of note, while 2008 was the year when the HRB annual budget peaked, the number and value of new awards made in that year was relatively low. This was because the 2008 budget was largely pre-committed due to the large number and high value of grants that had been awarded in the preceding years. Similarly, as the HRB budget began to decrease in 2009 due to the decline in the public finances, the number of new awards fell to a six-year low, as most of the budget was serving existing grant commitments.

Figure C1: New awards by year

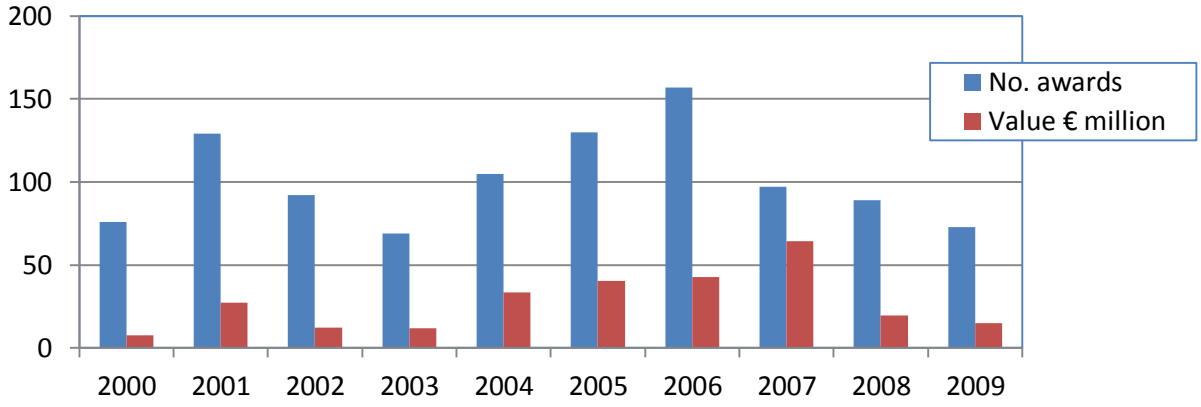
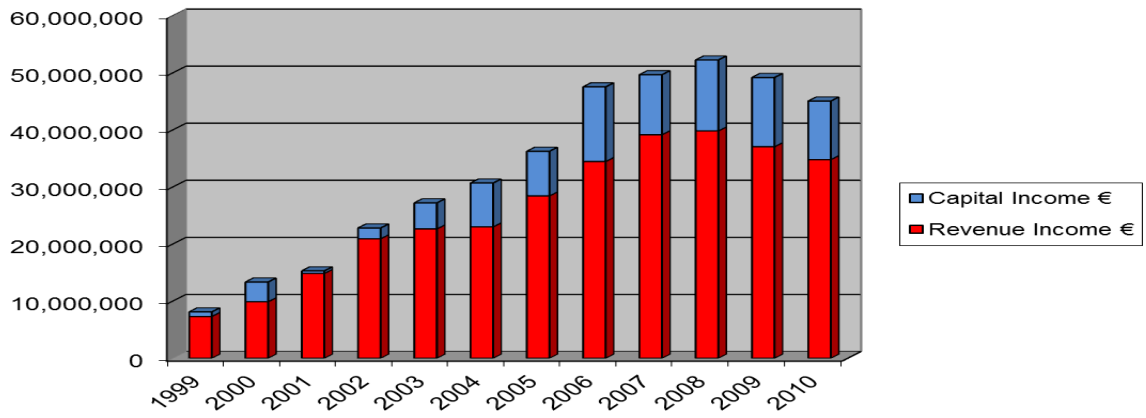


Figure C2: Annual HRB Budget 1999-2010



Breakdown of total funding by HRB strategic pillar area

Figure C3 shows that over the period 2000–09, Basic and Applied Biomedical research together accounted for over half (54%) of HRB investment, while clinical research accounted for almost 30% of HRB investment. In that same period, Population Health Sciences and Health Services Research accounted for only 17% of the funding portfolio. It should be noted that for the purpose of this analysis, each grant was designated a single categorisation in terms of pillar area, according to the predominant focus of the grant. However, the objectives and methodologies of many grants can cut across two or more pillar areas – for instance, grants involving randomised controlled trials can sometimes entail a significant element of health services research (e.g. health economic analysis to examine the cost-effectiveness of a new intervention vis-à-vis usual treatment). Such grants are classified as purely 'Clinical Research' for the purpose of this analysis.

Figure C3: Proportion of funding by strategic pillar area

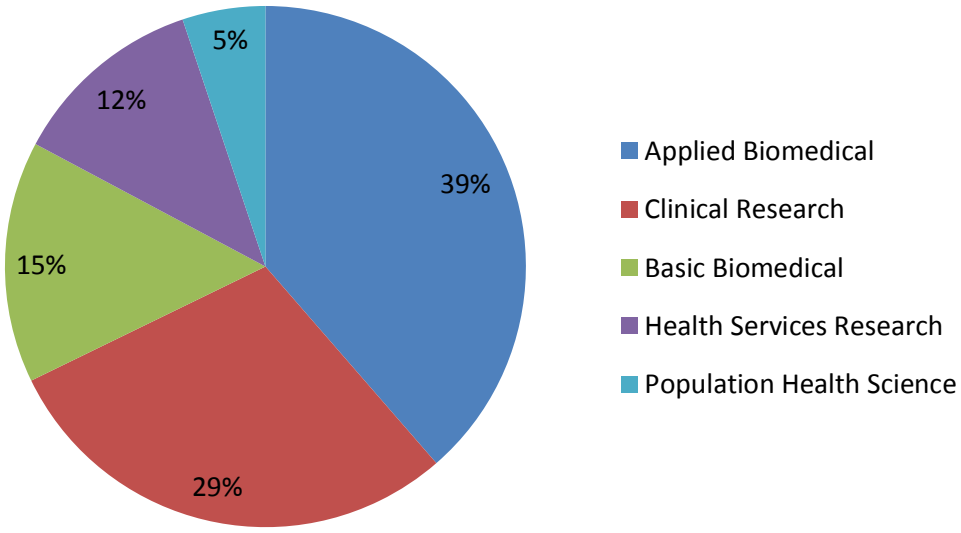
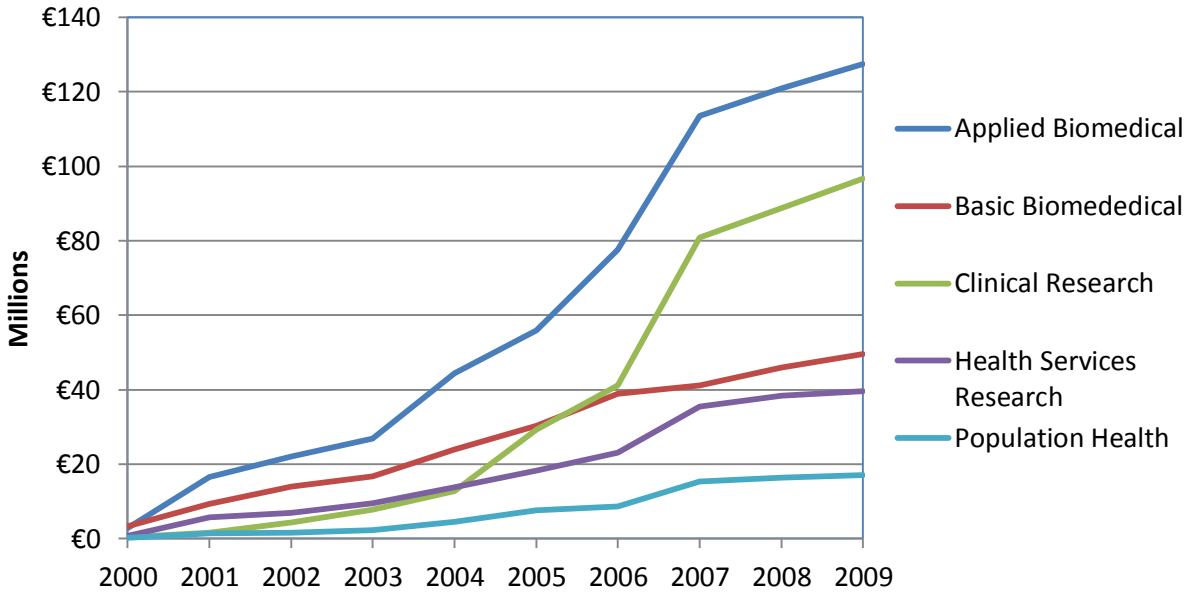


Figure C4 plots the value of cumulative commitments by HRB strategic pillar area. It shows that the combined value of new funding commitments rose sharply between 2003 and 2007, mainly due to significant increases in the HRB's annual budget during this period. The total value of new funding commitments for Applied Biomedical research more than doubled between 2005 and 2007. A number of high-value funding initiatives mainly accounted for this increase; these initiatives included three PhD Scholars Programmes (total value €14.2 million), the Autism Genome Project (€5 million), and the Translational Research Programmes (total value €7.3 million). Funding for Clinical Research almost trebled in the same three-year period (2005-2007). A small number of very high-value strategic awards mainly account for this increase, most notably the three Clinical Research Facilities (total value of €28.6 million), the two Imaging Centre awards (total value of €8.5 million), three Clinician Scientist Awards (total of €5 million), and significantly increased funding for ICORG cancer clinical trials (>€4 million). In addition, investment in Population Health Sciences and Health Services Research increased significantly in 2007; this was mainly due to the funding for two Health Research Centres (combined value of €10 million) which was awarded in that year.

Figure C4: Cumulative value of new funding commitments by strategic pillar area



Appendix D: Overview of grants included/excluded from the analysis

For the purpose of this project, a small number of grants were excluded from the analysis. These were the three Clinical Research Facility (CRF) grants, the Centre for Support and Training in Analysis and Research (CSTAR) grant, and the Irish Clinical Research Infrastructure Network (ICRIN) award. The CRF grants were excluded because the establishment of each of these facilities has met with significant delays, and all three facilities are at a very early stage of development. The CSTAR and ICRIN grants were excluded, as they were strategic research support initiatives that have been reviewed recently as unique entities.

Table D1: Total number and value of grants awarded in 2000–09 period

	No. grants	Value (€ million)
Included in analysis	1,104	€300.6
Excluded from analysis: - CRF grants - CSTAR award - ICRIN award	5 - 3 - 1 - 1	€29.7 - €28.6 - €0.6 - €0.5
Total	**1,109**	**€330.3**

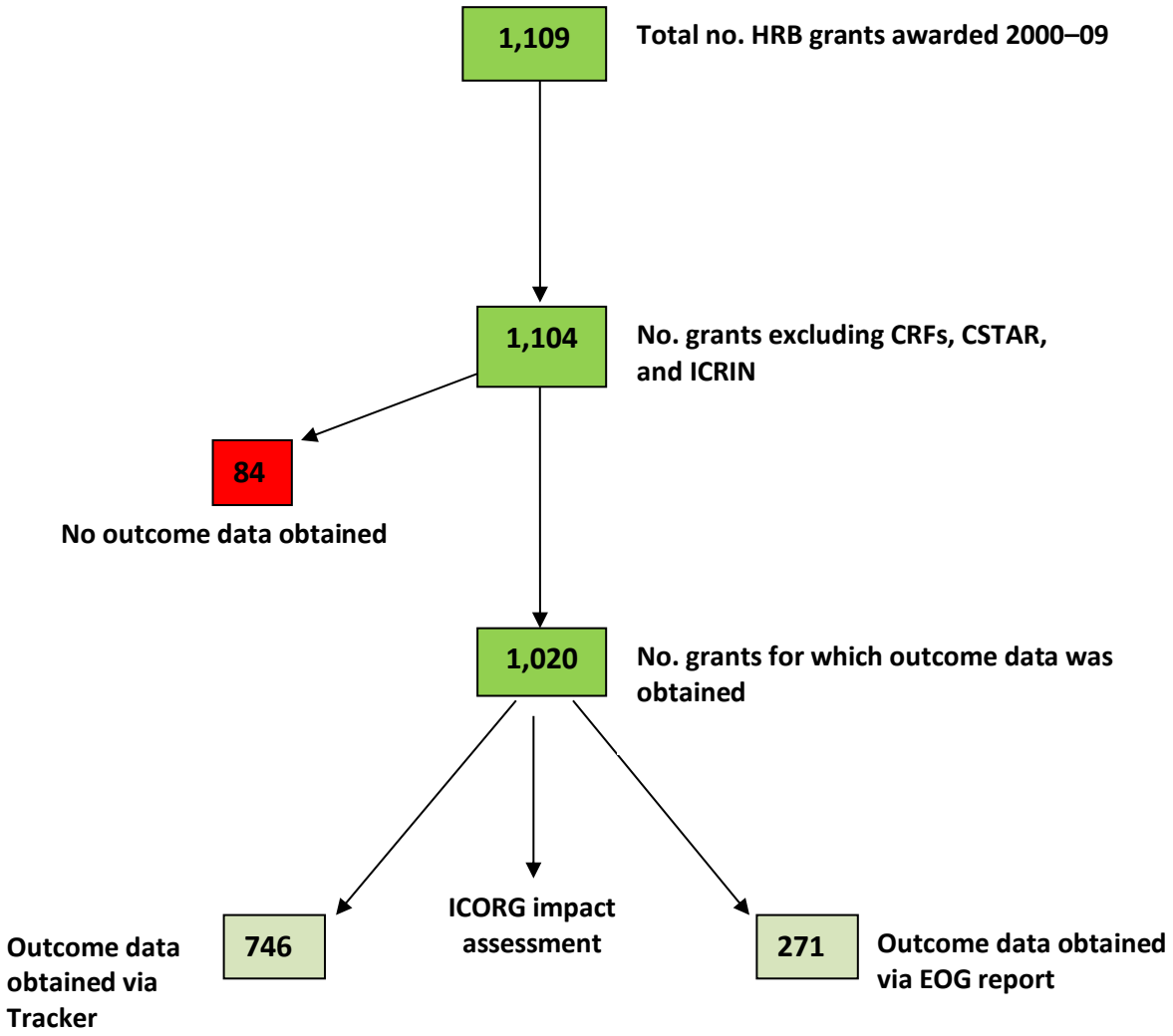
Overview of the 1,104 grants included in the project

The 1,104 grants included in the analysis were awarded to 695 unique grant-holders. Of the 1,104 grants, at least some outcome data were obtained for 1,020 (or 92%) grants. For the remaining grants, no outcome data could be obtained, either because the grant-holder did not respond to the Outcomes Tracker survey, or because no end-of-grant report was ever received.

Table D2: Summary of the dataset

Data source	No. grants	Value (€ million)	No. grant-holders
Outcomes Tracker	746	€205.5	427
End-of-grant report	271	€57.1	207
ICORG impact assessment	3	€26.6	11
Total dataset	**1,020**	**€289.2**	**645**
No data available	84	€11.4	50
Overall total	**1,104**	**€300.6**	**695**

Figure D1: Flowchart showing no. grants included in dataset



Appendix E: Breakdown of grants included in analysis by funding scheme

In relation to grant type, Table E1 shows the breakdown of the 1,104 grants by grant type (i.e. funding scheme), grouped according to funding mode. As can be seen, three-year Project grants accounted for both the largest proportion of spend (€100.2 million or 33.3% of total spend) and the largest number of grants (559 or 51% of total number). The various types of Fellowship grant[10] accounted for the second largest proportion of spend (€41.2 million or 14% of total spend) and number of grants (259 or 23.5% of total number). Other schemes that accounted for significant funding commitments included the PhD Scholars Programmes, ICORG, Programme grants, Translational Research Awards, Clinician Scientist Awards, Strategic Health Service R&D Awards, Health Research Centres, and the Imaging Awards.

Table E1: Breakdown of the awards included in the analysis by strategic mode/grant type

Funding mode	Grant type	No. grants	Average grant value	Total funding (€ million)
Projects and programmes	Project grant	559	€179,316	€100.2m
	Medical Research Charity Group co-funded project	53	€91,083	€4.8m
	Partnership co-funded award	30	€60,461	€1.8m
	Programme grant	18	€921,838	€16.6m
	Strategic Health Services R&D award	11	€962,630	€10.6m
	Translational Research Programme	9	€1,399,281	€12.6m
	Interdisciplinary project grant	7	€114,301	€0.8m
Career funding	Fellowship award	259	€159,201	€41.2m
	Clinician Scientist award	7	€1,637,574	€11.5m
	Junior Clinician Scientist in nursing and midwifery	2	€87,500	€0.18
	PhD Scholars Programme	6	€4,644,459	€27.9m

[10] The Fellowship category comprised Post-Doctoral Research Fellowships (n=72), Research Training Fellowships for medical graduates (n=62), Health Service Research Fellowships (n=36), Nursing and Midwifery Fellowships (n=30), Cochrane Training Fellowships (n=30), Health Professionals Fellowships (n=14), Clinical Therapy Professional Fellowships (n=9), Research Fellowships in Rare Diseases (n=3), Primary Care Fellowships (n=3).

Funding mode	Grant type	No. grants	Average grant value	Total funding (€ million)
Targeted initiatives	North-South cooperation co-funded grants	19	€140,462	€2.7m
	Co-funded seed grant in Health Services Research	21	€15,371	€0.3m
	Cancer Consortium projects and fellowships	14	€214,762	€3.0m
	Global Health Research award	11	€355,458	€3.9m
	Blood utilisation and transfusion research	4	€372,029	€1.5m
	Autism research	3	€1,730,133	€5.2m
	Nursing and midwifery Research Priorities Study	2	€338,540	€0.7m
Infrastructure and networks	ICORG clinical trials	3	€8.9m	€26.6m
	Equipment grant	44	€154,000	€6.8m
	Health Information Systems award	18	€192,171	€3.5m
	Health Research Centres	2	€4,979,695	€10.0m
	Imaging award	2	€4,200,539	€8.4m
Total		**1,104**		**€300.6m**

Appendix F: Breakdown of grants included in analysis by host institution

Figure F1 shows the host institutions of the 1,101 grants awarded between 2000 and 2009. Note that the number for universities includes any grants awarded to their affiliated teaching hospitals – e.g. the figure of 277 grants for TCD includes 13 grants awarded to Tallaght Hospital and St James's Hospital, including the Haughton Institute. Similarly, the figure of 260 grants associated with UCD includes 13 grants awarded to St Vincent's University Hospital and the Mater Hospital; the figure of 145 for UCC includes grants hosted by Cork University Hospital; and the figure of 126 for RCSI includes 11 grants hosted by Beaumont Hospital and Connolly Hospital (none of the 115 grants for NUI Galway were hosted by its affiliated hospitals). The 'Other' category comprises 21 grants awarded to 18 separate institutions, such as the Economic and Social Research Institute (ESRI, and the charities GROW, RehabCare, Irish Cancer Society, and Headway). Of interest is that this category also includes MRCG grants that were awarded to PIs based in four overseas institutions (e.g. Stanford University, University of Aberdeen).

Figure F1: Breakdown of 2000–09 grants by host institution

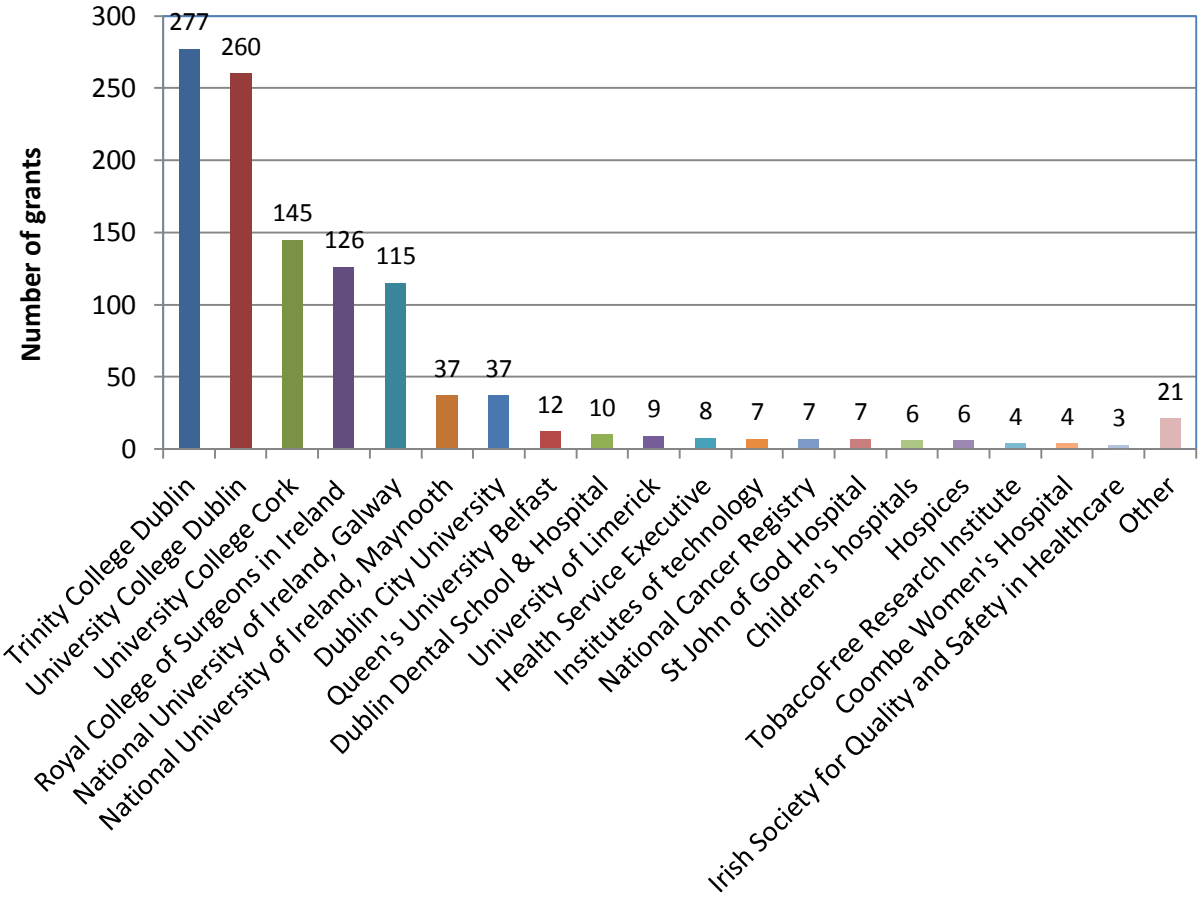


Figure F1 indicates four tiers of institutions in terms of the number of HRB grants hosted between 2000 and 2009 – the first tier comprised the two biggest institutions TCD and UCD, which between them hosted almost 50% of the total number of grants; the second tier comprised UCC, RCSI and NUI Galway, which between them hosted almost 35% of grants; the third tier comprised DCU and NUI Maynooth, which between them hosted almost 7% of grants; and the fourth tier comprised a large number of institutions, which between them hosted 9% of grants.

Appendix G: Analysis by UK Health Research Classification System

The UK Health Research Classification System (HRCS) is a two-dimensional classification framework for health research which was developed in 2005 by the UK Clinical Research Collaboration and is becoming increasingly used by health research funders internationally as well in the UK. The HRCS comprises two dimensions:

- Health Categories, to classify the type of health or disease being studied (e.g. neurological, renal, infection). There are 21 categories that encompass all diseases, conditions and areas of health.
- Research Activity Codes, to classify the type of research being undertaken (from basic to applied biomedical). There are 48 codes, which are divided into eight groups:

    1. Underpinning (including biological, behavioural and socio-economic factors)
    2. Aetiology (including biological, behavioural and socio-economic determinants)
    3. Prevention
    4. Detection and diagnosis
    5. Treatment development
    6. Treatment evaluation
    7. Disease management
    8. Health services and systems

The HRCS codes are assigned to capture the main objective(s) of a particular study – so that the system provides a broad overview of the *centre of gravity* of a set of research awards. Defined percentages are assigned to all HRCS codes, which means that the associated funding is analysed exactly, with no double counting.

Classification of HRB grants with the HRCS

In order to provide strategic insight into the types of research funded by the HRB in the 2000–09 period, the HRCS was used to code grants awarded at three time points: 2001, 2006 and 2009. The total number of grants awarded across these three years was 383, with a combined expenditure of €85 million.

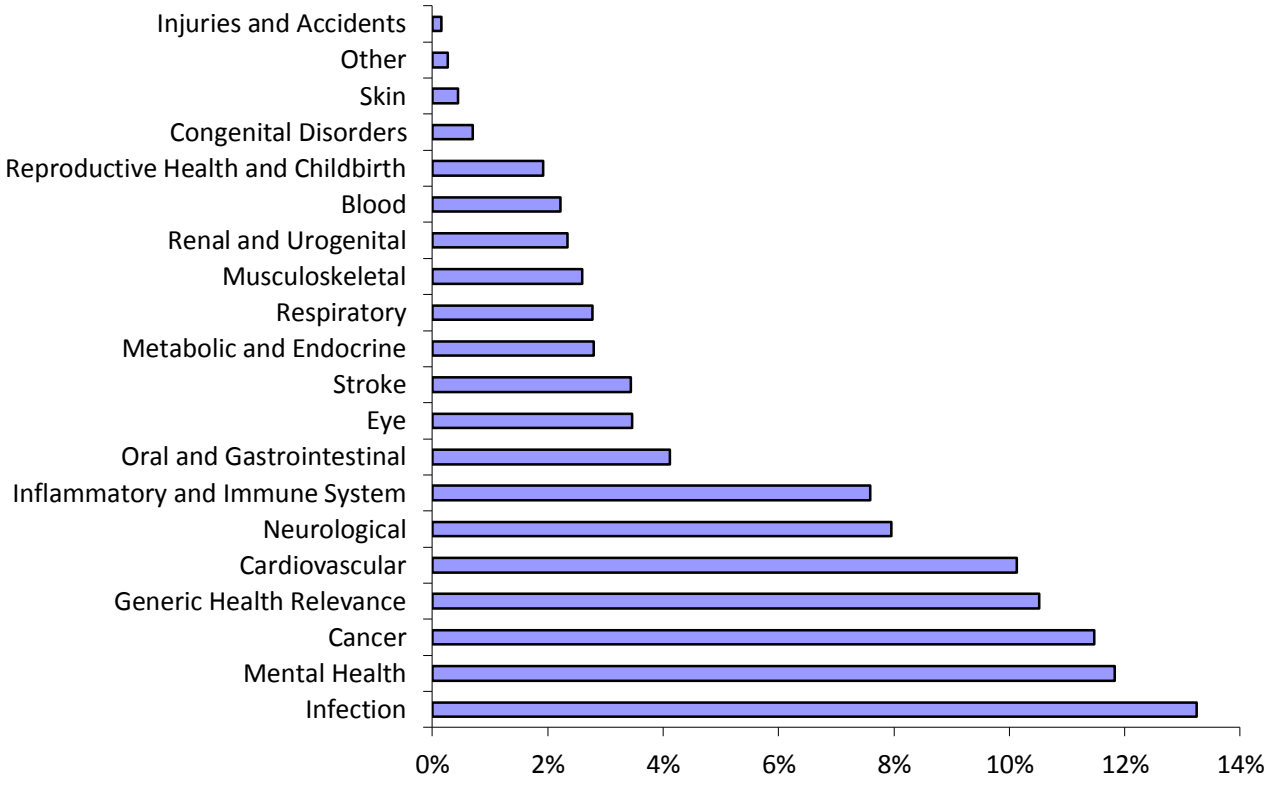
Process

Grants were coded internally by HRB staff, and grants were internally double-coded as a quality assurance measure. HRB staff attended a formal HRCS training workshop delivered by a professional UK-based HRCS coder, and as an additional quality control measure, a sample of grants was sent to an external coder in order to verify the accuracy of internal coding.

Health categorisation

As shown in Figure G1, the health areas with the highest proportion of HRB spend were infection, mental health, and cancer, respectively, while research of a 'generic health relevance' (i.e. not specific to any physiological system or disease, or applicable across a range of diseases) and cardiovascular research also had high relative spends.

Figure G1: Health categorisation of 2001, 2006 and 2009 grants combined



Research Activity Codes

From the analysis of the HRCS Research Activity Codes for the individual HRB funding years[11] 2001 (Figure G2), 2006 (Figure G3) and 2009 (Figure G4), the following observations can be made:

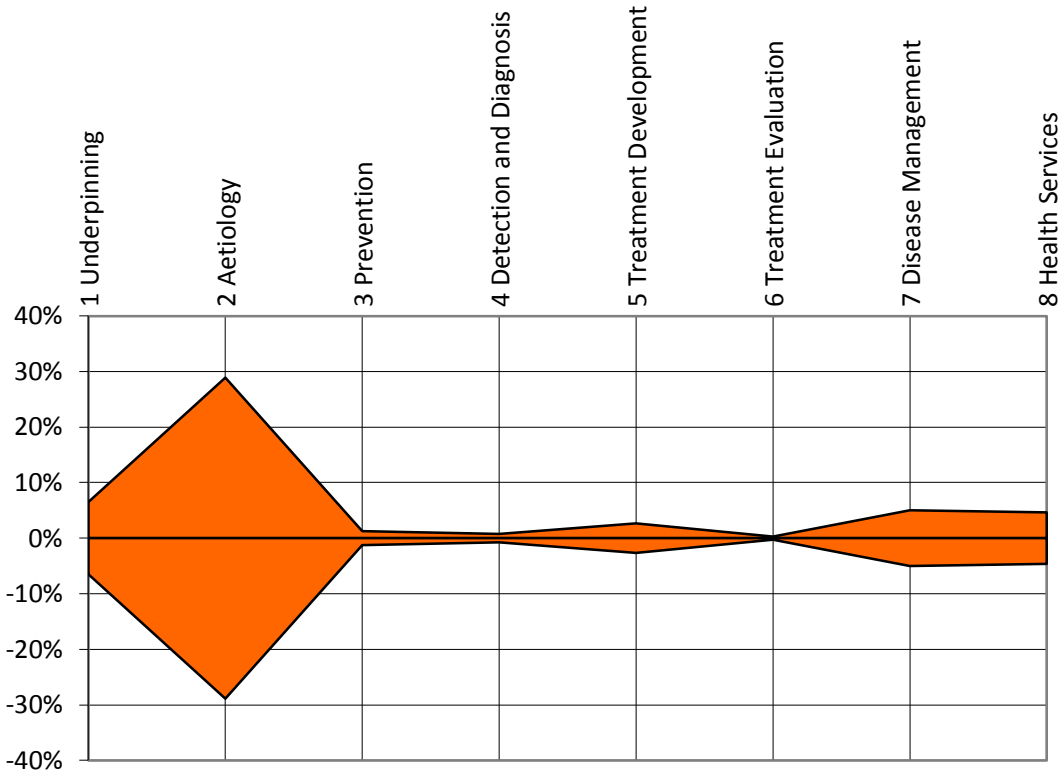
- The balance of HRB funding over the 10-year period shifted away from " basic" research (i.e. underpinning and aetiology research) towards a greater emphasis on translational, clinical and health services research (categories 3-8).
- In 2001, well over 70% of new funding went on 'Underpinning/Aetiology' research, mainly of a biomedical nature. Some funding went to Health Services Research (towards the right

[11] Note: the figures illustrate the *proportionate* value of new funding commitments by activity code. The absolute value of total new funding commitments was €27 million in 2001, €42.5 million in 2006, and €15 million in 2009

end of the spectrum) but very little on prevention, pre-clinical research and clinical trials (i.e. Treatment Development and Treatment Evaluation).

- By 2006, however, as new initiatives under *Making Knowledge Work for Health* were introduced, the relative proportion of funding for 'Underpinning/Aetiology' research had decreased by about 20%, while the proportion allocated to pre-clinical/translational research (i.e. Treatment Development) had increased significantly.
- This trend continued, so that by 2009 less than 50% of funding was allocated to 'Underpinning/Aetiology' research, and there was a more balanced distribution of funding across the spectrum.
- ICORG cancer clinical trial grants are omitted from these figures (the three Clinical Research Facility grants were awarded in 2007, so they are also excluded) – the approximately €3.5 million annual funding for ICORG would significantly increase the point for 'Treatment Evaluation' in the 2006 and 2009 kite diagrams.
- As was the case for many of the UK health research funders when they undertook a similar analysis in 2006,[12] the HRB diagrams show a very low level of investment by the HRB in 'Prevention' Research across all three years.

Figure G2: Research Activity Codes for 2001



[12] UK Health Research Analysis (2006), UK Clinical Research Collaboration

Figure G3: Research Activity Codes for 2006

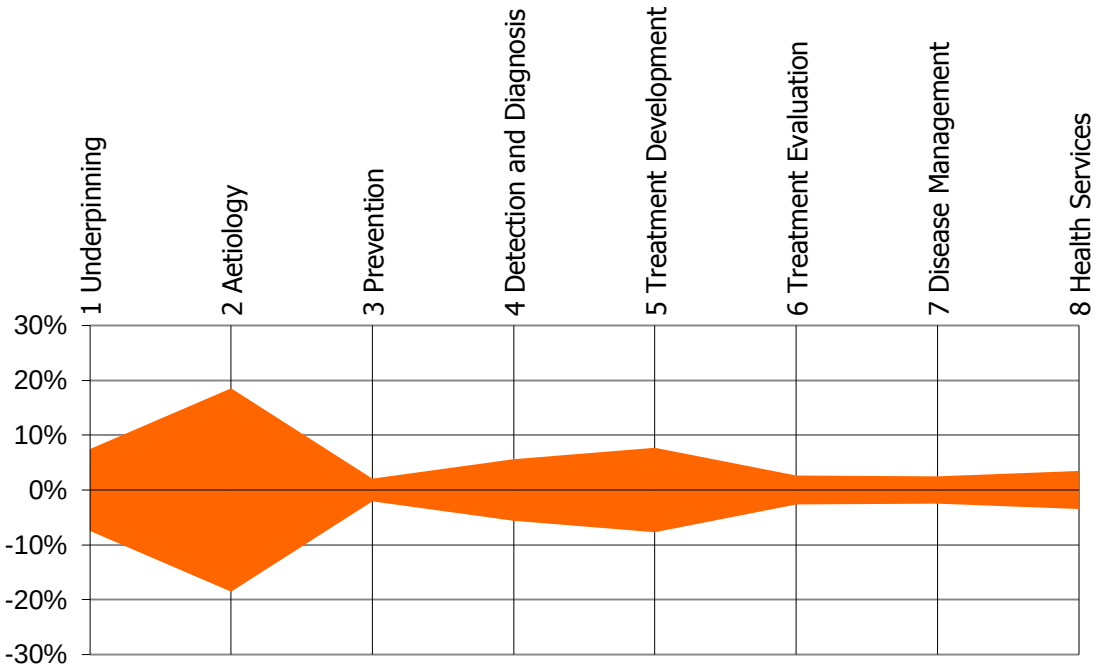
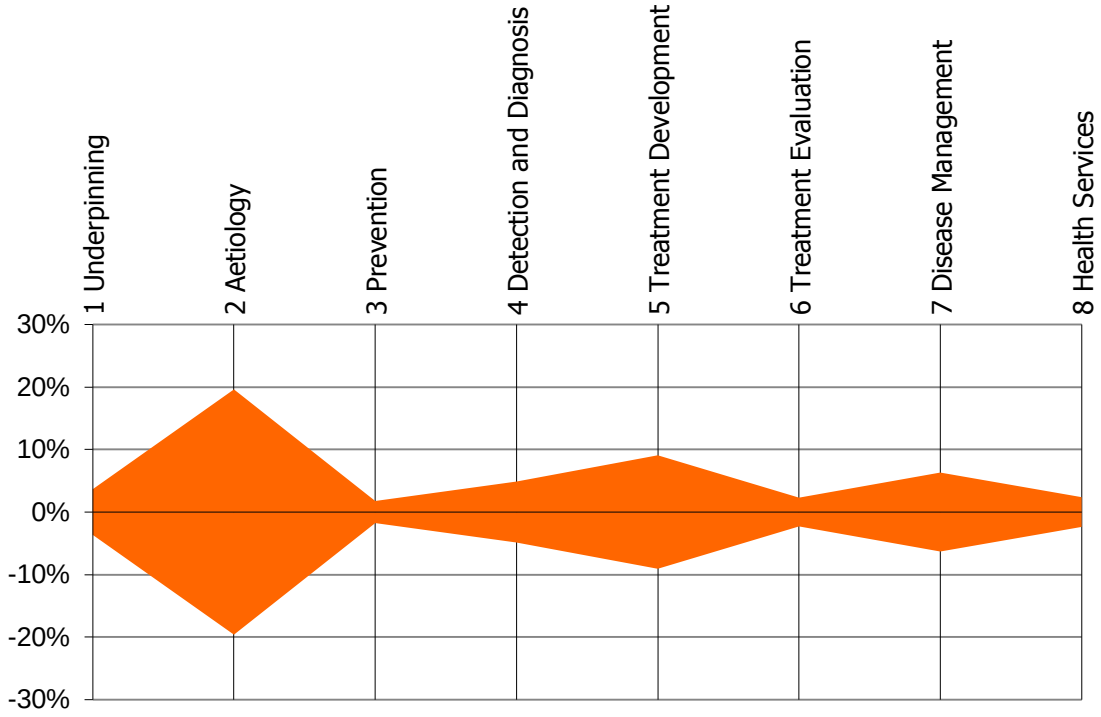


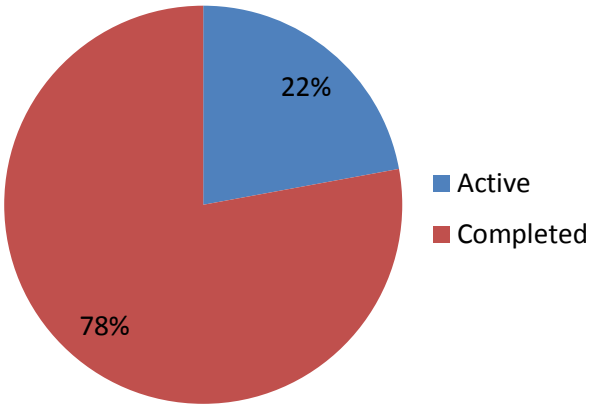
Figure G4: Research Activity Codes for 2009



Appendix H: Status of grants included in the analysis

An important point to consider when evaluating the outcomes of HRB grants awarded between 2000 and 2009 is the current stage of activity of the funded research. There is a well-recognised time lag between the completion of research activity and the peak manifestation of outputs (up to two years post-completion), outcomes and impacts (possible 17+ years for final impacts). An analysis of the 1,101 grants awarded by the HRB in 2000–09 showed that 77 grants (or 7% of the total number) were still active on 1 October 2012, the mid-point of the two-month data collection exercise for this project. However, the same 77 grants accounted for €60.6 million of HRB funding, or 22% of the HRB's total investment in the 2000–09 period (Figure H1). This is because the grants that were still active were longer-term (5-7 years), large-scale investments in initiatives such as the Health Research Centres, PhD Scholars Programmes, Imaging Awards, Clinician Scientist Awards, and Translational Research Programmes. These grants would be expected to produce outcomes with potential impacts on health, policy and practice in the years to come, and the HRB will continue to track these outcomes as they emerge.

Figure H1: Proportion of funding allocated to still active grants versus completed grants (as of 1 October 2012)



Grant type	No. active awards
Research project	30
Fellowship award	18
MRCG project	10
Clinician Scientist Award	5
PHD Scholars Programme	4
Translational Research Programme	4
Strategic R&D	2
Nursing Programme	1
Health Research Centre	2
Imaging Award	1
Total	**77**

Appendix I: Analysis of survey respondents and non-respondents

Outcomes Tracker invitation emails were sent to 632 grant-holders who held 1,036 awards. Bounced email notifications and out-of-office responses to the initial HRB survey invitation found that 59 grant-holders either did not receive the email invitations, or were unable to complete the Outcomes Tracker for various reasons (e.g. sick leave, maternity leave, annual leave/sabbatical, retired, moved abroad etc.). This meant that the participant pool was reduced to 573 grant-holders (who held 965 awards). Completed Outcomes Tracker reports were received from 428 grant-holders in relation to 746 grants, representing a very respectable grant-holder response rate of 75% (or 77% of all grants).

Figure I1 plots the response rate by funding scheme, while Figure I2 plots the response rate by year of grant award. As can be seen, the response rate was at least 50% for all schemes and, generally speaking, there was an increasing response rate for more recent years. Five schemes achieved a 100% response rate to the Outcomes Tracker. These were the PhD Scholars Programmes (N=6), Autism Projects (N=3), Nursing and Midwifery Awards (N=2), Health Research Centres (N=2), and the Imaging awards (N=2).

Figure I1: Percentage of grants per scheme that completed the Outcomes Tracker survey

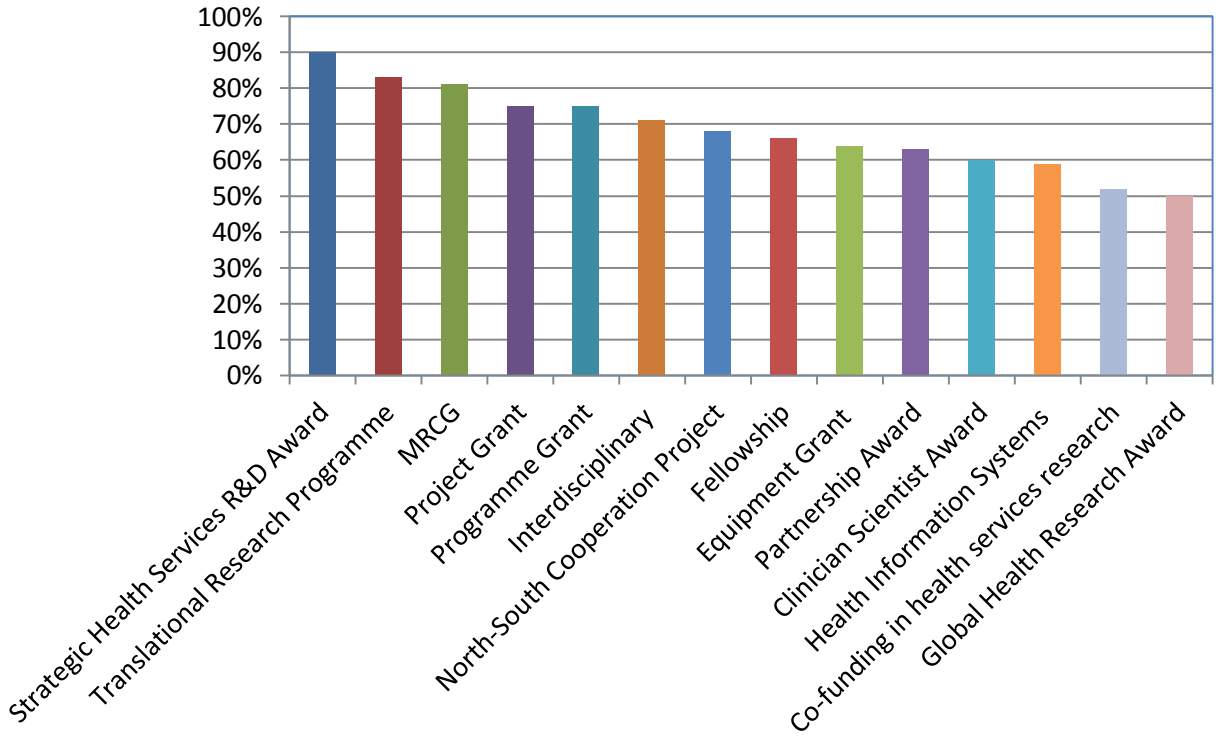
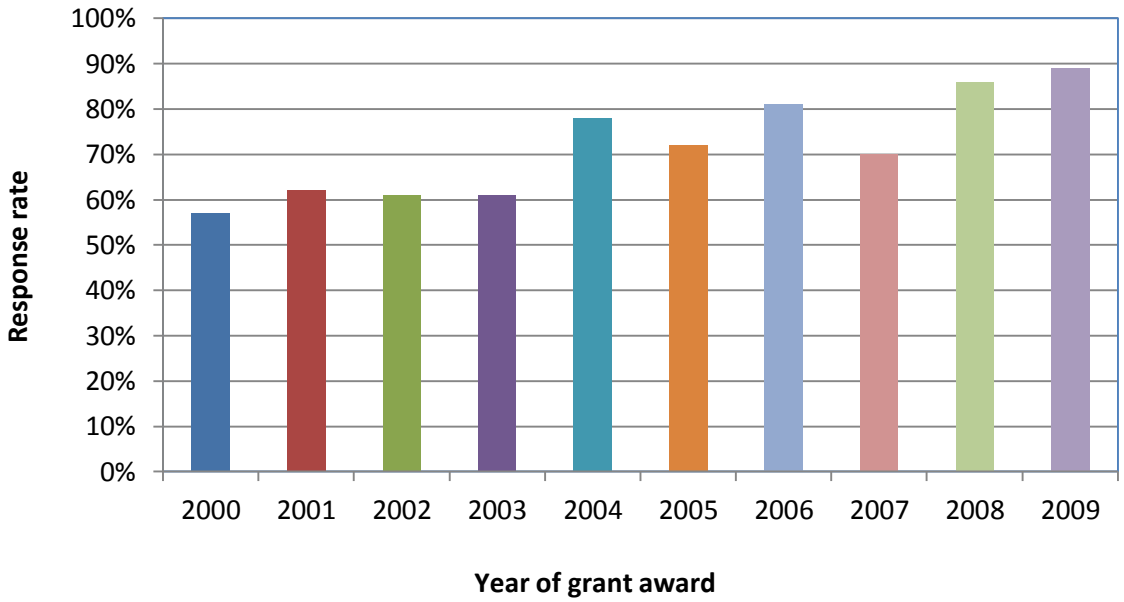


Figure I2: Response rate to Outcomes Tracker by year of grant award



Non-respondents

A total of 204 grant-holders who held 289 awards did not complete the Outcomes Tracker (Figure I3 shows the reasons for non-responses). As outlined above, 59 grant-holders either did not receive the HRB email invitation, as indicated by receipt of an automated delivery failure (i.e. no updated email address could be found), or an out-of-office notification was received stating that the person was on leave, sabbatical, retired, or no longer at this address. Of the remaining 145 grant-holders who held 215 awards and who did not complete the Outcomes Tracker, approximately 18% of this cohort actually logged in to the Outcomes Tracker but did not complete it for unknown reasons. A small number of additional grant-holders sent an email to say that they were too busy to complete the Outcomes Tracker. The vast majority of non-respondents (approximately 70%) who did not complete the Outcomes Tracker gave no reason for not doing so, nor did the HRB receive any notification that may have indicated a reason, such as an obsolete email address or the grant-holder was out of office. (The vast majority of the non-responder cohort was once-off grant-holders whose grant had concluded pre-2008). Where available, relevant data from end-of-grant reports held on file for those non-respondent grants was imported into the data spreadsheet.

In addition, 52 researchers (who held 65 grants) were not asked to participate in the Outcomes Tracker Survey. Reasons for this are listed below:

- PI had died and no suitable co-applicant could be located to complete the Outcomes Tracker in place of the PI (the relevant end-of-grant report (EOG) was used instead where this was available)
- The grant concluded in 2012 and an EOG request had recently been submitted or was due (hence the information submitted in the EOG could be used).
- Grant was a Cochrane Fellowship and grant-holder had responded to a recent outcomes survey relating to the review of that scheme (and the information submitted as part of that survey could be used).

Figure I3: Logged 'reason' for non-response to Outcomes Tracker