University of Glasgow

CANCER RESEARCH AT GLASGOW

THE ECONOMIC IMPACT OF THE CANCER RESEARCH UK SCOTLAND INSTITUTE AND THE UNIVERSITY OF GLASGOW'S SCHOOL OF CANCER SCIENCES

WORLD CHANGING GLASGOW

LE London Economics

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Executive Summary

London Economics were commissioned to assess the **economic impact of the Cancer Research UK Scotland Institute (formerly Beatson Institute) and the University of Glasgow's School of Cancer Sciences (SCS) in the United Kingdom**. Working in close collaboration, the CRUK Scotland Institute and the School of Cancer Sciences constitute the core cancer research institutions in the West of Scotland, providing world-leading academic and clinical expertise that is deeply rooted within the region and responds to the specific health needs and challenges of its population. To capture the economic impact associated with the institutions' activities (focusing on the 2021-22 financial year[1]), we estimate the economic contribution associated with the SCS's and the CRUK Scotland Institute's wide-ranging cancer **research activities**, their **operating and capital expenditures**, and their **teaching and learning activities**.

The report outlines some of the regional factors that have influenced the two institutions' approaches to cancer research. Key among these are the size and composition of the patient base in the West of Scotland. As well as accounting for around half of Scotland's patient base, the region has some of the most deprived communities in the country according to the Scottish Index of Multiple Deprivation and has been marked historically by the existence of stark inequalities, particularly in relation to health outcomes. These disparities are also evident in cancer incidence and outcome statistics: a person living in the most deprived areas of Scotland is 30% more likely to develop cancer than someone living in the least deprived areas, and 74% more likely to die from cancer compared with the least deprived[2]. Cancer is the most common cause of death, and of premature death, in Scotland, with four sites, lung, breast, prostate, and colorectal, accounting for approximately half of all cases and deaths. Scotland experiences higher rates of cancer incidence and mortality than the rest of the UK, with the burden particularly high in the West of Scotland[3]. In response to these regional drivers, Glasgow has established itself as a key location for the operation of clinical trials, the translation of research for patient benefit and the testing of cancer prevention strategies, particularly for cancer types that are at a high incidence among the Scottish population. These factors have also strongly influenced the development of cancer research within the West of Scotland, which is characterised by a patient-centred approach to science developed in partnership with stakeholders such as the NHS, that reflects the region's unique health challenges and patient base.

Excellence is a further feature of cancer research within the region. One of the report's key headlines is the extent to which the two institutions' research is responsible for the economic impact that they generate collectively, underpinned by the high-quality research environment in which they operate. The Beatson Institute built a reputation for the strength of its basic cancer research and the University of Glasgow was assessed as being one of the top institutions in the UK for Clinical Medicine in the most recent Research Excellence Framework (REF) results. The University's College of Medical, Veterinary and Life Sciences – home of the School of Cancer Sciences – is investing significantly in its existing strengths as well as in relatively new areas, such as spatial biology, which will ensure that it continues to be at forefront of life sciences research internationally.

[1] The CRUK Scotland Institute's financial year 2021-22 ran from April 2021 to March 2022. The School of Cancer Sciences' financial year matches the University of Glasgow's academic year (August to July), but data for the School of Cancer Sciences was apportioned across the 2020-21 and 2021-22 academic years for consistency, to match the CRUK Scotland Institute's financial year.
[2] https://www.gov.scot/publications/cancer-strategy-scotland-2023-2033/
[3] Glover, M., Buxton, M., Guthrie, S., Hanney, S., Pollitt, A., & Grant, J. (2014).

The University of Glasgow also has one of the broadest research bases of any university in the UK, marked by its excellence across a range of disciplines and its role as one of only two Russell Group universities in Scotland. This depth and breadth of expertise enables it to take a whole-systems approach to addressing socioeconomic inequalities and poor health outcomes within the Glasgow City Region, Scotland and beyond. Such an approach reflects the University's civic mission, which aims to ensure that the institution's research strengths deliver benefits for the region's patients, communities and the wider economy.

The strength of this commitment is evidenced by the significant investments that the University has made in its research infrastructure and environment. Two recent major investments that highlight this are the Mazumdar-Shaw Advanced Research Centre (ARC) and the Clarice Pears Building:

- The £116.5 million ARC opened in 2022 and brings together researchers and ideas from a variety of disciplines and sectors. Initially, this is focused on five thematic areas: Creative Economies and Cultural Transformation; Digital Chemistry; Global Sustainable Development; Quantum and Nanotechnology; and Technology Touching Life. Through this cross-disciplinary approach, the University is enabling transformational programmes of innovative research, which have the potential to deliver a high level of societal and global impact. In the life sciences, researchers from the University's School of Cancer Sciences are collaborating with world-leading academics within the Digital Chemistry team in the ARC to co-develop new approaches to drug development for complex diseases like cancer.

- The Clarice Pears Building, opened in 2023, brings together researchers from the University's School of Health & Wellbeing with social scientists, economists and experts from across the University to better understand health outcomes and inequalities. The building has also been designed to facilitate community engagement and partnership working, which will support the translation of health-focused research into policy and practice. The work being done within the Clarice Pears Building forms part of the University's wider cross-institutional focus on addressing the most pressing health inequalities across the globe. The report also showcases the region's capacity for innovation and the impact this could have on Glasgow City Region's economy. This innovative capability was most effectively demonstrated during the COVID-19 pandemic through the rapid establishment of the Glasgow Lighthouse Lab in April 2020, Scotland's only mass-scale testing lab. The report provides examples of how this legacy is being built upon, through projects such as INCISE which is part of the £100 million UK Innovation Accelerator Programme announced in the Levelling Up White Paper, and the McNab Centre for Cancer Innovation.

Finally, the importance of partnership and collaboration features strongly in the report. This is most clearly symbolised by the close and effective working relationship between the University of Glasgow's School of Cancer Sciences and the CRUK Scotland Institute, but the report also highlights the extent to which the region's academics, clinicians and industry partners collaborate to drive improvements in prevention, diagnosis and treatment options for the benefit of cancer patients in Glasgow and beyond. Furthermore, the report highlights examples of collaboration between these two institutions with academic partners and supporters across the UK and internationally, via for example the Cancer Research UK Scotland Centre, which is co-creating innovative new approaches to cancer research and catalysing opportunities for knowledge exchange between world-class scientists.

The aggregate economic impact of the CRUK Scotland Institute and the School of Cancer Sciences

The total economic impact on the UK economy associated with the CRUK Scotland Institute's and the School of Cancer Sciences' activities in 2021-22 was estimated at approximately **£503 million** (see Table 1). Of this total, the impact generated by the **operating and capital spending** of the CRUK Scotland Institute and the School of Cancer Sciences stood at **£77 million** (**15%**); the impact of the institutions' **research activities** stood at **£407 million** (**81%**); and the economic contribution of the institutions' **teaching and learning activities** stood at **£19 million** (**4%**).

Table 1 Total economic impact of the CRUK Scotland Institute's and the School of Cancer Sciences' activities in the UK in 2021-22 (£m and % of total)

Type of impact	£m	%
Impact of expenditure	**£77m**	**15%**
Direct impact	£50m	10%
Indirect and induced impacts	£27m	5%
Impact of research	**£407m**	**81%**
Net direct research impact	£35m	7%
Net QALY[4] impact	£273m	54%
Crowding-in impact	£99m	20%
Impact of teaching and learning	**£19m**	**4%**
Students	£9m	2%
Exchequer	£10m	2%
Total economic impact	**£503m**	**100%**

Note: All estimates are presented in 2021-22 prices and rounded to the nearest £1m. Totals may not add up precisely due to rounding. ***Source: London Economics' analysis***

Compared to the CRUK Scotland Institute's and School of Cancer Sciences' total operational costs of approximately **£51 million** in 2021-22[5], the total impact of the institutions' activities on the UK economy was estimated at **£503 million**, which corresponds to a **benefit to cost ratio of 9.8:1**.

The impact of the institutions' expenditure

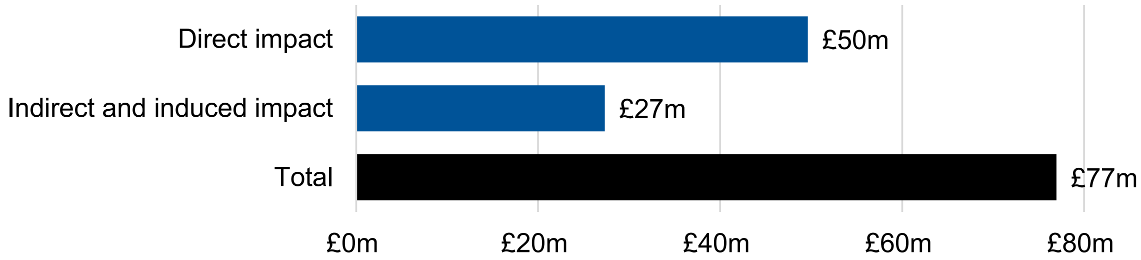
The institutions' physical footprint supports jobs and promotes economic growth throughout the UK economy. This is captured by the **direct, indirect, and induced impact** associated with the CRUK Scotland Institute's and the SCS's expenditures.

The **direct impact** of the institutions' physical footprint was based on their operating and capital expenditures. In 2021-22 the CRUK Scotland Institute and School of Cancer

[4] Quality-adjusted life years.
[5] This relates to the operating expenditures of the CRUK Scotland Institute and School of Cancer Sciences, including depreciation costs and movements in pension provisions.

Sciences incurred a total of **£50 million** of expenditure[6]. The direct increase in economic activity resulting from these expenditures generates additional rounds of spending throughout the economy (through the institutions' supply chains, and the spending of their staff). Applying relevant economic multipliers, the **total direct, indirect, and induced impact** associated with the expenditures of the CRUK Scotland Institute and School of Cancer Sciences in 2021-22 was estimated at **£77 million**. The majority of this impact (**£56 million**, **73%**) was accrued in **Scotland**, with **£21 million** (**27%**) occurring in **other regions** across the UK.

Figure 1 Impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' expenditure in 2021-22, £m



Note: All estimates are presented in 2021-22 prices and rounded to the nearest £1m. Totals may not add up precisely due to rounding. ***Source: London Economics' analysis.***

The impact of the institutions' research

To estimate the (**net**) **direct impact** of the institutions' research activities on the UK economy, we used the total research-related income accrued by the institutions in 2021-22 (**£40 million**), and deducted the costs to the public purse of funding their research activities (**£5 million**). This resulted in a **net direct research impact** of **£35 million**.

The existing academic literature indicates that investments in cancer research lead to **improved patient outcomes through both improved treatment and prevention**. These benefits can be quantified by estimating the impact on **quality-adjusted life years** (QALYs), which measure the additional life years gained from cancer research, adjusted for health-related quality of life. Applying estimates from the core existing literature[7], our analysis implies a QALY multiplier of **8.78**, which indicates that every **£1 million** of UK publicly funded or charity funded cancer research results in **£8.78 million** of future QALY benefits across the UK (net of the NHS treatment costs of delivering the improved health outcomes). Applying this multiplier to the CRUK Scotland Institute's and the School of Cancer Sciences' research income, we estimate that the future net QALY benefits of this research throughout the UK stand at approximately **£273 million**.

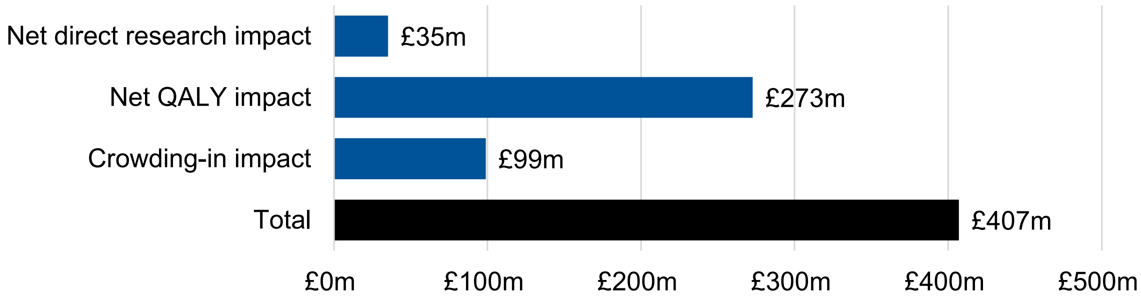
Another strand of academic literature suggests that publicly funded and charity funded expenditure in research and development **'crowds in' additional private sector research funding**. Using estimates derived from the key existing literature[8], we estimate a monetary multiplier of **1.52**, indicating that every **£1 million** of UK publicly funded or charity funded

[6] The total operational expenditure (excluding capital expenditure) of the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22 stood at **£51 million**. From this, for the purpose of the analysis, we excluded **£0.4 million** in depreciation costs (from non-staff expenditure) and **£1.6 million** in movements in pension provisions (from staff expenditure), as it is assumed that these are not relevant from a procurement perspective (i.e., these costs are not accounted for as income by other organisations).
[7] See Glover et al. (2014).
[8] See Sussex et al. (2016).

cancer research results in an additional **£1.52 million** of privately funded cancer research. This multiplier was applied to the SCS's and the CRUK Scotland Institute's relevant research income, to estimate the privately funded cancer research that is 'crowded in' as a result of the institutions' primary research. As with the institutions' own expenditures, the additional crowded-in research activity is expected to generate additional **indirect and induced economic impacts** throughout the UK economy. Based on this approach, the total direct, indirect, and induced economic impact associated with this crowded-in R&D stands at **£99 million**.

Combining these effects, the total impact of the research conducted by the SCS and the CRUK Scotland Institute in 2021-22 was estimated at **£407 million**. Compared to the total research income received by the institutions in 2021-22 (**£40 million**), this suggests that **for every £1 million of research income received, the institutions' research activities generate a total of £10.2 million in economic impact across the UK**.

Figure 2 Impact of the CRUK Scotland Institute's and the School of Cancer Sciences' research activities in 2021-22, £m



Note: All values are presented in 2021-22 prices, rounded to the nearest £1 million, and may not add up precisely to the total indicated. ***Source: London Economics' analysis***

The impact of the institutions' teaching and learning activities

The impact of the CRUK Scotland Institute's and the School of Cancer Sciences' teaching and learning activities estimates the **enhanced employment and earnings benefits to graduates**, and the **additional taxation receipts to the Exchequer** associated with the attainment of postgraduate research qualifications (i.e. Doctorate degrees) at the institutions.

Incorporating both the expected costs associated with qualification attainment and the labour market benefits expected to be accrued by students/graduates over their working lives, the analysis estimates that the **net graduate premium** achieved by a representative Scottish domiciled student in the 2021-22 cohort completing a **full-time** Doctorate degree at the SCS or the CRUK Scotland Institute (with a first degree as their highest level of prior attainment) stands at approximately **£293,000** in today's (i.e., 2021-22) money terms. Taking account of the benefits and costs to the public purse, the corresponding net Exchequer benefit was estimated at **£344,000**.

The net graduate premiums and net Exchequer benefits were combined with information on the number of students starting Doctorate degrees at the SCS and the Institute in 2021-22 and expected completion rates. The **aggregate economic impact** of the teaching and learning activities at the SCS and the CRUK Scotland Institute associated with the 2021-22 cohort of UK-domiciled student starters stands at approximately **£19 million**. Of this total,

£9 million (**46%**) is accrued by students in the cohort, while the remaining **£10 million** (**54%**) is accrued by the Exchequer.

Table 2 Impact of the CRUK Scotland Institute's and the School of Cancer Sciences' teaching and learning activities associated with the 2021-22 cohort, £m

Beneficiary	Full-time students	Part-time students	Total
Students	£8.7m	£0.3m	**£8.9m**
Exchequer	£10.1m	£0.3m	**£10.4m**
Total	**£18.7m**	**£0.5m**	**£19.3m**

Note: All estimates are presented in 2021-22 prices, discounted to reflect net present values, rounded to the nearest £0.1m, and may not add up precisely to the totals indicated. ***Source: London Economics' analysis***

1 Introduction

1.1 Background

London Economics were commissioned to assess the **economic impact of the Cancer Research UK Scotland Institute (formerly Beatson Institute) and the University of Glasgow's School of Cancer Sciences (SCS) in the United Kingdom**, incorporating an assessment of their contribution to the UK's national prosperity through their wide-ranging cancer **research activities**, their **operating and capital expenditures**, and their **teaching and learning activities**. Working in close collaboration, the CRUK Scotland Institute and the University of Glasgow constitute the core cancer research institutions in the West of Scotland. This work builds on our previous analysis of the economic impact of the University of Glasgow as a whole (London Economics, 2021), and focuses on the 2021-22 financial year.[9]

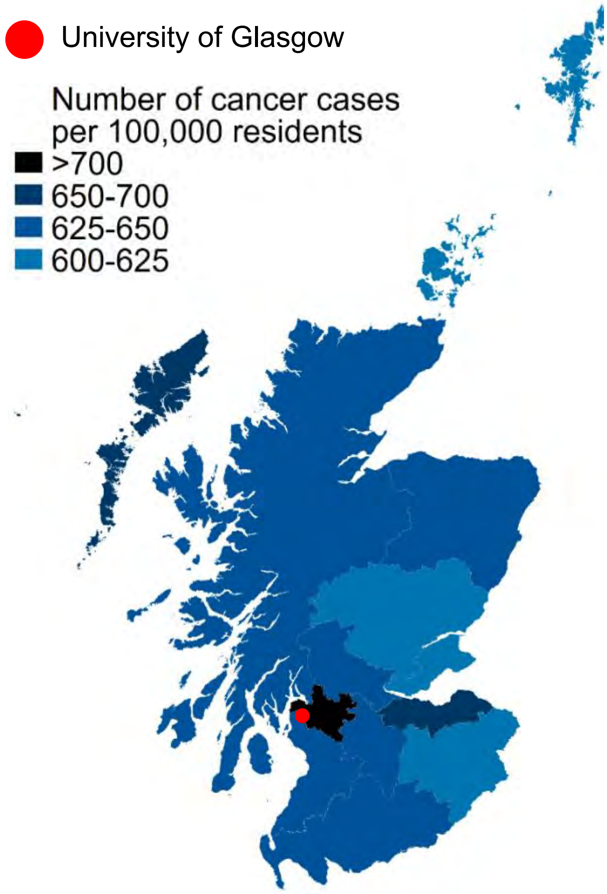
For over a century, cancer sciences have been a significant part of the fabric of Glasgow's research ecosystem. From the establishment of the Glasgow Cancer and Skin Hospital in 1886 until the present day, Glasgow has been at the heart of the global effort to further our understanding of cancer, developing new ideas, techniques, and practices and delivering benefits to patients across Scotland and beyond. The contribution of these advances to our collective understanding of cancer has led to improvements in the identification and treatment of the disease and declining cancer mortality rates. However, despite this progress, cancer remains the largest burden of disease across Scotland, and incidence rates have continued to increase over time. In 2021, there were over 35,000 new cancer diagnoses registered in Scotland (Public Health Scotland, 2023), and this is projected to increase in the future as the country's population ages. This is a particular issue for the West of Scotland, with Greater Glasgow and Clyde exhibiting the highest cancer incidence of any health board in Scotland in 2021, with 702 cancers[10] per 100,000 residents (see Figure 1).

Studies also show that the burden of cancer is not the same for all groups in society. Data referenced in the Scottish Government's 2023 Cancer Strategy (Scottish Government, 2023) highlights the disproportionate impact of socioeconomic deprivation on cancer incidence and survival rates. The data shows that a person living in the most deprived areas of Scotland is 30% more likely to develop cancer than someone living in the least deprived areas, and 74% more likely to die from cancer compared with the least deprived. Scotland also has a relatively unique geography, as it encompasses large urban centres, rural areas, and island communities. As the Scottish Government's strategy highlights, this poses additional challenges for Scotland in ensuring that patients across the country benefit equitably from advancements in the diagnosis and treatment of cancer.

[9] The CRUK Scotland Institute's financial year 2021-22 ran from April 2021 to March 2022. The School of Cancer Sciences' financial year matches the University of Glasgow's academic year (August to July), but data for the School of Cancer Sciences was apportioned across the 2020-21 and 2021-22 academic years for consistency, to match the CRUK Scotland n Institute's financial year.

[10] Using the European age-standardised rate for all cancers excluding non-melanoma skin cancer.

Figure 3 Cancer incidence in Scotland by Scottish Health Board, in 2021



Note: Cancer incidence refers to the European age-standardised rate for all cancers excluding non-melanoma skin cancer.
Source: London Economics' analysis based on Public Health Scotland (2023) data. Copyright Scottish Government, contains Ordnance Survey data © Crown copyright and database right (2023).

This diversity of need and diversity of patient base has resulted in an emergence of different strengths in cancer sciences across Scotland's regions. This is reflected in the development of different research specialisms across Scotland's world-class universities, such as remote and rural medicine, drug discovery and precision medicine, and the use of artificial intelligence (AI) and other technologies. Glasgow serves as a key example of the benefits of the development of different cancer research specialisms that derive from local needs, challenges, and strengths.

As Scotland's largest city, Glasgow and the surrounding areas in the West of Scotland account for a patient base of around 2.8 million patients (Invest Scotland, 2023), which represents more than half of the Scottish population. The city is home to the largest health board in Scotland and the largest cancer centre – the Beatson West of Scotland Cancer Centre – which sees more than 8,500 new patients and over 60,000 return patients every year (Beatson West of Scotland Cancer Centre, 2023). The size of the patient base in the region serves as an ideal location from which to undertake clinical trials and test prevention strategies for cancer and other chronic diseases.

As well as its size, the health needs and prevalence of disease within the region's population base are complex, with longstanding health disparities and comparatively high incidence of chronic diseases. Glasgow's industrial heritage has also left a mark in terms of the prevalence of certain types of cancer within the region. The West of Scotland has some of the highest incidence rates of malignant mesothelioma in the world, due to the previous widespread use of asbestos in key industrial sectors such as shipbuilding. Unfortunately, current treatment options are limited, and those diagnosed with malignant mesothelioma have very poor survival rates. Academics and clinicians in Glasgow have been central to efforts to change this situation and play a leading role in several national and international networks and projects aimed at developing more effective treatment options. For example, Glasgow's REMIT programme, which builds on the University's PREDICT-Meso & IAMMED-Meso projects, is seeking to develop a comprehensive strategy for early detection, risk stratification and more effective treatments for mesothelioma patients, and received a portion of £2.1 million of funding from Cancer Research UK in March 2023. This serves as a key example of how a particular need has spawned world-leading academic and clinical expertise that is rooted in the West of Scotland.

The patient base in the West of Scotland is also differentiated by its high level of engagement with local cancer research initiatives. Research groups from the University of Glasgow's School of Cancer Sciences and the CRUK Scotland Institute are well-integrated within the region's hospitals and with local patient groups, thus supporting the rapid translation of scientific research into clinical settings. Local residents have also provided generous donations to cancer sciences research, to ensure that the legacy of this work continues to benefit the city's residents, for example through the Beatson Pebble Appeal which generated £10M in public donations to build the University's Wolfson Wohl Cancer Research Centre. This level of engagement has served as a key differentiator of the region's approach to cancer sciences and plays an important role in attracting some of the world's leading cancer researchers to work in Glasgow.

As this report highlights, Glasgow's strengths in, and approach to, cancer sciences provide a range of benefits to the region's economy. Healthcare and precision medicine were highlighted in the Glasgow City Region Economic Strategy (Glasgow City Region, 2021) as core areas of comparative advantage for the region, with strong potential for future growth through the use of advanced technology within healthcare. This was further exemplified by the awarding of Levelling Up Innovation Accelerator funding to a bowel cancer screening and risk stratification tool, highlighting the potential for the region's expertise in cancer sciences to further accelerate its flourishing innovation economy. Moreover, a number of major MedTech, pharmaceutical and healthcare companies have based themselves within the region to better integrate with the thriving life sciences ecosystem built within the Glasgow Riverside Innovation District.

Cancer remains one of the biggest health challenges facing Scotland, and the evidence suggests that this will remain the case in the future. However, Scotland's leading role in life sciences and health innovation provides hope that this is a challenge that can be tackled collectively. This is signalled by the willingness of major players in this sphere to collaborate to drive benefits for patients. The University of Glasgow, for example, works closely with the NHS and its major industry partners, such as GE Healthcare, on innovative, people-centred solutions to improve healthcare treatment and outcomes. This approach is in evidence across different parts of the country, which have developed expertise and specialisms that reflect the particular needs of, and challenges faced by, local patient bases. As the West of Scotland's core cancer research institutions, together, the CRUK Scotland Institute and the SCS constitute two key drivers of Scotland's leadership in cancer sciences.

1.2 Structure of this report

The remainder of this report is structured as follows:

- In **Section 2**, we provide further background on Glasgow's cancer sciences ecosystem, and the many ways in which the CRUK Scotland Institute and the SCS have been working together to support and use the West of Scotland's cancer sciences infrastructure;
- In **Section 3**, we outline our assessment of the impact of the institutions' operating and capital expenditures;
- In **Section 4**, we discuss our findings on the impact of the CRUK Scotland Institute's and the SCS's research activities;
- In **Section 5**, we assess the economic impact associated with the institutions' teaching and learning activities for postgraduate research students who are taught at the SCS and the CRUK Scotland Institute; and
- In **Section 6**, we combine these different strands of impact to analyse the total economic impact associated with the CRUK Scotland Institute and the SCS.

2 Cancer sciences in Glasgow

2.1 The relationship between the University of Glasgow and the Cancer Research UK Scotland Institute

The University of Glasgow and the Cancer Research UK Scotland Institute are critical to the establishment of the cancer sciences ecosystem within the West of Scotland, and, together, form the core of the region's cancer research.

The University of Glasgow was established in 1451 and is a world top 100 university. It has one of the broadest research bases in the UK, with a wide range of disciplines reflected across its academic community. It was recognised in the most recent Research Excellence Framework (REF) for its world-leading research and positive impact on society, with 93.1% of the University's research recognised as 'world-leading or internationally excellent' (University of Glasgow, 2022)

A particular area of strength for the University is its expertise in clinical medicine and health-related disciplines, as reflected in its strong results for these subjects in both the Times Higher Education (49th) and QS (44th) World University rankings (Times Higher Education, 2023; QS Top Universities, 2023). The School of Cancer Sciences, which is part of the University's College of Medical, Veterinary and Life Sciences, plays a significant role in the strength of the University's reputation in this discipline.

The School of Cancer Sciences carries out a programme of world-class science, with internationally renowned expertise in cancer metabolism, tumour microenvironment, immuno-oncology, radiobiology, pre-clinical murine and fly patient avatars, and genomic testing. The School's research is directed at understanding the molecular changes that cause cancer and translating these scientific discoveries into new drugs and diagnostic and prognostic tools that benefit cancer patients. The focus on "bench-to-bedside" research is a key differentiator of the approach to cancer sciences in Glasgow. A key enabler of this is the School of Cancer Sciences' strength in clinical research – with roughly half of its research groups led by clinical academics – helping to foster excellent links with NHS clinicians and ensuring that its research is informed by close engagement with patients. Around 1 in 5 publications from the School are in top 5% cited worldwide, demonstrating that research conducted by Glasgow's cancer researchers is recognised for its excellence by peers across the globe.

The School of Cancer Sciences is located at the University of Glasgow's Garscube Campus, which is also home to the Cancer Research UK Scotland Institute (formerly Beatson Institute). The CRUK Scotland Institute has long-standing roots in Glasgow and has been located at Garscube since the late 1970s. Such close proximity with the University of Glasgow has allowed the two institutions to form a close association, the strength of which has increased significantly in the past few years, as evidenced by the extent to which staff from both institutions formally collaborate. Moreover, many of the staff within the Institute share joint appointments with the University of Glasgow through the School of Cancer Sciences.

The CRUK Scotland Institute, which is core-funded by Cancer Research UK (CRUK), is a highly collaborative research institute focused on making discoveries that increase our collective understanding of cancer as a whole-body disease, and drive improvements in treatment and prevention. The Institute has developed an excellent reputation for basic cancer research, particularly for its renowned *in vivo* modelling. Its research focuses predominantly on cancers defined by Cancer Research UK as those of unmet need, which generally have poor survival outcomes. This includes mesothelioma, hepato-pancreato-biliary cancer, and metastatic colorectal cancer. Several of these cancer types are also at a particularly high incidence in the Scottish population, and the CRUK Scotland Institute's work in this area has helped set the stage for the broader cancer research landscape in Scotland over the last five years.

The University of Glasgow is one of the CRUK Scotland Institute's key partners. The symbiotic relationship between the two institutions has been supported and strengthened in recent years, aided by the signing of a new Memorandum of Understanding (MoU) in 2022. All group leaders within the Institute now have hybrid University of Glasgow contracts and positions within the School of Cancer Sciences. Similarly, several members of the School of Cancer Sciences have the title of 'Beatson Associate', which is assigned to staff who are physically located within the CRUK Scotland Institute and are aligned with its strategic scientific themes. All of the Institute's PhD students are enrolled at the University, with international students being eligible for discounted tuition fees, which has helped the Institute attract and support the highest calibre students from across the world to study in Glasgow. The MoU also enables an integrated strategy for infrastructure investment in state-of-the-art technology and equipment, ensuring that cancer sciences in Glasgow remain joined-up and at the cutting edge of innovation.

The strengthening of the relationship between the CRUK Scotland Institute and the SCS has also resulted in improved outcomes for both institutions:

- For the **CRUK Scotland Institute**, formal links with University of Glasgow colleagues have increased its scientific critical mass – with several Beatson Associate and SCS staff members obtaining prestigious fellowships or programme grants – and allowed it to benefit from the breadth of the University's inter-disciplinary research expertise. This arrangement also allows for the more efficient use of resources and joint bids for capital equipment, thereby ensuring greater value for money. Crucially, closer links with University colleagues have allowed the CRUK Scotland Institute to fully harness the West of Scotland's excellent pathology infrastructure, which includes one of the largest pathology laboratories in Western Europe. This has enhanced the Institute's renowned *in vivo* models by ensuring that they more accurately reflect the progression and subtypes of cancer within patients.
- For the **University**, the benefits of the relationship can be seen in the growth of its research portfolio. In 2022, the value of the School of Cancer Sciences' research awards increased to around £25 million, up from around £16.5 million in 2018. The quality and reputation of the School of Cancer Sciences' research are further evidenced by its performance within the recent Research Excellence Framework (REF) results, as a significant contributor to the College of Medical Veterinary and Life Sciences submission which saw over 95% of its research recognised as 'world-leading' or 'internationally-excellent'. Of the nearly 170 FTE staff returned in Unit of Assessment 1 (UoA1), around 33% were attributable to School of Cancer Sciences staff, and almost 29% of that proportion related to staff with joint University-CRUK Scotland Institute contracts. Similarly, of the 425 outputs returned to UoA1, more than 41% were attributable to School of Cancer Sciences staff, and more than 26% of that proportion related to staff with joint contracts.

The strengthening of the two institutions through their close collaboration has, in turn, created an environment that both **attracts established world-leading scientists to Glasgow and provides an excellent training ground for early career clinician**

scientists, with both cohorts attracted by the opportunity to translate their discovery research into relevant cancer models and patient samples.

2.2 Key characteristics of the West of Scotland's cancer sciences ecosystem

The CRUK Scotland Institute and the SCS sit at the centre of the West of Scotland's cancer sciences and life sciences ecosystem, the development of which has been shaped by several key factors.

2.2.1 Size and composition of the patient base

The size of the patient base in the region is around 2.8 million (Invest Glasgow, 2023), which accounts for more than 50% of the Scottish population, and makes the region an ideal location for clinical studies and trials of new treatments. In addition to its size, the population is also complex from a health perspective. The region has well-documented and longstanding health inequalities and is marked by the continuing prevalence of chronic diseases and multiple morbidities. Deprivation is a key factor influencing these disparities in health outcomes: recent research conducted by the University of Glasgow highlights the large and persistent inequalities in health between the most and least deprived neighbourhoods in Scotland (Miall et al., 2022). These inequalities also manifest in cancer incidence rates and outcomes. Given that NHS Greater Glasgow and Clyde health board comprises the highest proportion of the most deprived data zones in Scotland (Cancer Research UK, 2022b), this is a particular issue for the region.

2.2.2 Breadth and depth of academic expertise in the region

The development of some of the region's key areas of research strength has been informed by its unique health challenges. At the University of Glasgow, this includes expertise in health inequalities, multi-morbidity, and chronic diseases, such as cancer, heart disease, stroke, arthritis, and diabetes. The breadth of expertise that exists across the University, as evidenced by the recent Research Excellence Framework, enables the formation of interdisciplinary teams from diverse disciplines to tackle the region's biggest health challenges. In relation to cancer sciences, for example, the University can draw on the expertise of clinical oncologists, pathologists, computer scientists, chemists, and clinical trials specialists, as well as public health experts and health economists. For example, in June 2023 two University of Glasgow-led projects received £12million from the Engineering and Physical Sciences Research Council (EPSRC) to engineer novel science and research tools to better understand and predict leukaemia. The University of Glasgow team – who have been supported to success by a range of industry and academic partners, and by Blood Cancer Research UK and Leukaemia Care – straddle multiple disciplines, including the College of Science and Engineering and the College of Medical, Veterinary and Life Sciences. This cross-disciplinary approach allows the University to take a whole-systems view of health outcomes within the region and across the UK, seeking to understand not just the biology of disease but the impact of socio-economic factors on health outcomes.

2.2.3 Close collaboration between academia, the NHS, and industry

In addition to the symbiotic relationship between the SCS and the CRUK Scotland Institute themselves, the work of both institutions is supported and enhanced by their close integration with other organisations within this network.

Specifically, a distinctive feature of Glasgow's life sciences ecosystem is how academia, the NHS, and industrial partners collaborate. This has been exemplified by the development of key infrastructure at the Queen Elizabeth University Hospital (QEUH), which is one of the largest acute hospitals in Europe and the first clinical-academic-industry campus worldwide designed around the clinical implementation of precision medicine (Department for Business, Energy & Industrial Strategy, 2019). QEUH hosts world-class R&D centres of excellence, including the University of Glasgow-led Imaging Centre of Excellence and Clinical Innovation Zone. It also has one of the largest pathology laboratories in the UK and Europe, as well as a large biorepository that provides academics, clinicians, and industry with access to high-quality clinical data and samples. Such infrastructure is fundamental to the work of both the SCS and the CRUK Scotland Institute. Several other key infrastructure assets are listed in Table 6 in Annex A2.1. This collaboration between industry, academia and the NHS has been characterised as the 'triple helix' approach, drawing on the strengths of each partner to catalyse innovative solutions for patient benefit[11].

The excellent discovery research carried out by the CRUK Scotland Institute and the University of Glasgow, the close collaboration between academics, clinicians and industry, and the supporting infrastructure within the region (particularly in relation to tissue sampling, genomics, and precision oncology) are **crucial to the region's strengths in cancer sciences**. Together, these factors facilitate the translation of research discoveries made in laboratories into clinical pathways, ultimately **delivering better outcomes for patients in Glasgow, Scotland, and beyond**.

[11] Scottish Government (2021).

CASE STUDY 1

BENEFITS TO PATIENTS BROUGHT BY THE 'TRIPLE HELIX' APPROACH

Benefits to patients brought by the 'triple helix' approach

Patients in the West of Scotland benefit enormously from the specific cancer sciences expertise that exists within the region's universities, research institutes, health sector, and life sciences companies. But patients themselves also play an important role in shaping the world-leading research and innovation carried out by these organisations.

This is highlighted by **efforts to improve the treatment options for malignant mesothelioma**, an incurable form of cancer that is also known as the 'asbestos cancer', due to its prevalence among those exposed to asbestos. The West of Scotland currently has one of the highest incidences of mesothelioma in the world (and significantly higher incidence rates than the Scottish average), due to the previous widespread use of asbestos in the region's main industrial sectors, notably in shipbuilding. In addition, given the widespread use of asbestos throughout the UK before its ban in 1999, there are concerns that it is still present in large quantities in municipal buildings (such as schools and hospitals) built before 1999.

Unfortunately, current treatment options for mesothelioma are limited, and those diagnosed with the disease have very poor survival rates. The disease usually appears after decades of exposure, and early symptoms, such as chest pain, fatigue, and constant coughing, can be overlooked because they are similar to other illnesses. The average life expectancy after diagnosis is 18 months (Boggan, 2023).

In response to this significant health challenge, researchers from the University of Glasgow and the CRUK Scotland Institute have recently been awarded £2.1 million by Cancer Research UK to lead the **REMIT programme.** The programme aims to analyse what happens in the decades between initial exposure to asbestos and diagnosis, and to make it easier to diagnose and treat mesothelioma earlier (University of Glasgow, 2023). REMIT builds on substantial previous Cancer Research UK funding for the world-leading Glasgow-led projects **IAMMED-Meso** and **PREDICT-Meso**. The latter uses AI and advanced laboratory and imaging techniques to inform decisions on patient treatment and reduce barriers to the development of new treatments in clinical trials, which are critical for the discovery of new, more effective treatments (University of Glasgow, 2020 and 2021). Together, the three projects help form a comprehensive strategy for **early detection, risk stratification, and more effective treatments for mesothelioma patients**. This work has been supported by the CRUK Scotland Institute's unparalleled expertise in cancer modelling, which focuses on cancers of unmet need, including mesothelioma.

Mesothelioma patients in the West of Scotland will benefit enormously from being at the frontline of this research, but its impact will spread beyond Glasgow. Whilst the UK battles with the historic legacy of asbestos use, many countries still do not regulate its use, and the global incidence of mesothelioma will likely continue to increase.

3 The impact of the CRUK Scotland Institute's and the School of Cancer Sciences' expenditures

In this section, we outline our analysis of the **direct, indirect, and induced impacts associated with the operational and capital expenditures of the** CRUK Scotland **Institute and the School of Cancer Sciences**. Analyses of these impacts consider institutions as economic units creating output within their local economies by purchasing products and services from their suppliers and hiring employees. Specifically, these direct, indirect, and induced economic impacts are defined as follows:

- **Direct effect**: This considers the economic output generated by the CRUK Scotland Institute and the School of Cancer Sciences, by purchasing goods and services (including labour) from the economy in which it operates.
- **Indirect effect**: The CRUK Scotland Institute's and the School of Cancer Sciences' purchases generate income for the supplying industries, which they in turn spend on their own purchases from suppliers to meet the institutions' demands. This again results in a chain reaction of subsequent rounds of spending across industries, i.e., a 'ripple effect'.
- **Induced effect**: The employees of the institutions and businesses operating in the CRUK Scotland Institute's and School of Cancer Sciences' supply chain use their wages to buy consumer goods and services within the economy. This in turn generates wage income for employees within the industries producing these goods and services, who then spend their own income on goods and services – leading to a further 'ripple effect' throughout the economy as a whole.

3.1 Methodology

To measure the **direct economic impact** of the purchases of goods, services, and labour by the CRUK Scotland Institute and the School of Cancer Sciences, we used information on their operating expenditures (including staff and non-staff spending), capital expenditures, as well as the number of staff employed (in terms of full-time equivalent (FTE) employees) by the institutions in 2021-22[12].

The assessment of the **indirect and induced economic impacts** associated with these operating and capital expenditures were estimated using **economic multipliers** derived from an Input-Output analysis (capturing the degree to which different sectors within the UK economy are connected, i.e., the extent to which changes in the demand for the output of any one sector impact on all other sectors of the economy).[13] In particular, we applied the estimated average economic multipliers associated with organisations in Scotland's **professional and support activities sector** to estimate the total direct, indirect, and induced economic impacts associated with the CRUK Scotland Institute's expenditures, and the multipliers associated with organisations in Scotland's **government, health, and education sector** to assess the impact associated with the expenditures of the School of Cancer Sciences[14].

[12] Based on staff and financial data provided by the University of Glasgow. Again, the analysis is based on the CRUK Scotland Institute's 2021-22 financial year (i.e., April 2021 to March 2022).
[13] Please refer to Annex A2.2.2 for more detail on the underlying methodological approach.
[14] The use of different multipliers here effectively categorises the School of Cancer Sciences as an institution within the Scottish education sector, whereas the CRUK Scotland Institute is categorised as part of the Scottish scientific, research, and

To arrive at the total direct, indirect, and induced impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' institutional spending, we then deducted the total research income accrued by the institutions, as well as their fee waivers and bursary spending, to avoid double-counting with other strands of impact included here.

Public support for cancer research in Glasgow

There is a **long-established culture of public engagement with, and community support for, the work of the School of Cancer Sciences and CRUK Scotland Institute.** Both institutions undertake a variety of public engagement activities with charity partners, local politicians, supporters, volunteers and local schools, to promote the important cancer research being done in Glasgow.

The esteem and affection in which both are held is most clearly demonstrated by the generosity and commitment shown by supporters, who have donated and raised significant funds to ensure that Glasgow continues to be recognised as the home of ground-breaking developments in the understanding and treatment of cancer.

The **Beatson Pebble Appeal** successfully raised around £10 million in public donations to fund the construction of the Wolfson Wohl Cancer Research Centre in 2014, which is home to the School of Cancer Sciences and neighbour of the CRUK Scotland Institute. The Beatson Pebble Appeal continues to support the ongoing work of the School, which helps it to maintain a high-quality research environment and continue to attract the best cancer scientists from around the world.

Public donations also helped to fund the building of the Paul O'Gorman Leukaemia Research Centre in 2008, which is based at Glasgow's Gartnavel Hospital and is part of the School of Cancer Sciences. This support has continued through the **Friends of The Paul O'Gorman Leukaemia Research Centre**, which was established in 2009 by a group of patients, volunteers and donors. The group organises a range of events, such as this year's POG15 Summer Challenge, which help to raise awareness of the centre's work and contribute directly to supporting its important research programme.

3.2 Impact of the institutions' spending

The total direct, indirect, and induced impacts on the UK economy associated with the operating and capital expenditures incurred by the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22 was estimated at **£77 million** in economic output terms (see Figure 4):

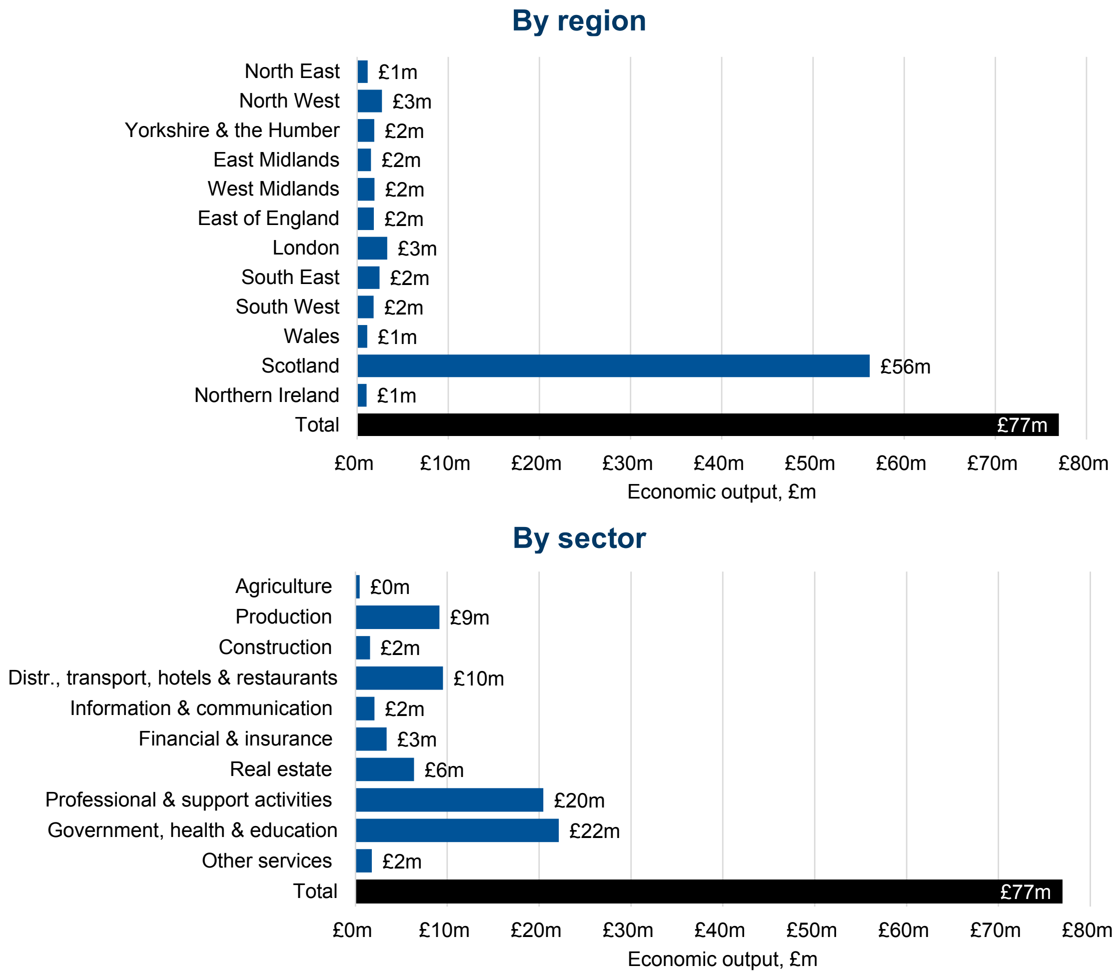
- In terms of impact type, **£50 million** (**64%**) of the total impact was attributable to the direct effect of this expenditure, while the remaining **£27 million** (**36%**) was associated with the indirect and induced effects of this spending.
- In terms of region, the majority of this impact (**£56 million**, **73%**) was generated in **Scotland**, with **£21 million** (**27%**) occurring in **other regions** across the UK.
- In terms of sector, in addition to the impacts occurring in the **government, health, and education sector** (**£22 million**, **29%**) and the **professional and support activities sector** (**£20 million, 27%**) itself, there are also large impacts felt within

development sector (which is included in the wider 'professional and support activities' sector within the relevant Input-Output tables). In other words, this approach asserts that the spending patterns of the CRUK Scotland Institute and the School of Cancer Sciences reflect the average spending patterns across organisations operating in Scotland's professional and support activities sector, and Scotland's government, health, and education sector, respectively.

other sectors, e.g., including the **distribution, transport, hotel, and restaurant sector** (**£10 million**, **12%**), and the **production sector** (**£9 million**, **12%**)[15].

In terms of the number of jobs supported (in FTE), the results indicate that the expenditures of the CRUK Scotland Institute and the School of Cancer Sciences supported a total of **560** FTE jobs across the UK economy in 2021-22 (of which **445** were located in Scotland). In addition, the impact in terms of gross value added (GVA) was estimated at **£49 million** across the UK economy as a whole (with **£37 million** generated within Scotland).[16]

Figure 4 Total economic impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' expenditure in 2021-22, by region and sector (economic output, £)



[15] For more detail on which specific industries are included in this high-level sector classification, please refer to Table 8 in Annex A2.2.5.
[16] Full results in economic output, GVA, and employment terms (by region and sector) are provided in Figure 9 and Figure 10 in Annex A2.2.4.

CASE STUDY 2

TRANSFORMING BOWEL CANCER SCREENING

Transforming bowel cancer screening

Bowel cancer is the second-most common cause of cancer-related deaths in the UK and is particularly prevalent in Scotland (Cancer Research UK, 2022a).

Consequently, **bowel cancer is a key area of research focus within Scotland,** particularly within the University of Glasgow’s School of Cancer Sciences and the CRUK Scotland Institute. The two institutions work together closely on bowel cancer research and collectively possess expertise that helps yield insight into how the disease progresses at its earliest stages, develop innovative screening tools, and investigate new treatments to improve late-stage cancer patients’ quality of life. This wide-ranging expertise is evidenced by several prominent bowel cancer research networks that are led from Glasgow, including the **ACRCelerate Colorectal Cancer Stratified Medicine Network**, the **Cancer Research UK RadNet Glasgow Centre**, and the **Integrated Technologies for Improved Polyp Surveillance (INCISE) collaboration**.

INCISE, which is led by Professor Joanne Edwards at the University of Glasgow, aims to **transform bowel cancer screening in the UK**. The collaboration has led to the INCISE project, a £3.37 million project led by the University of Glasgow in partnership with NHS Greater Glasgow and Clyde and several industry partners. The project team is developing a diagnostic tool that predicts which patients are at risk of developing pre-cancerous lesions (polyps) and tumours.

Currently, patients who test positive for blood in their stool are invited for a colonoscopy. Approximately 5% of those patients will have cancer, whilst over 30% will have polyps. These polyps are removed in a procedure called polypectomy; however, approximately half of those patients will go on to develop new polyps. Presently, all patients found to have polyps are scheduled for repeated colonoscopies, meaning that many people undergo unnecessary and invasive procedures.

INCISE seeks to transform polyp surveillance by developing a comprehensive risk stratification tool that will, for the first time, predict polyp recurrence by utilising the latest developments in digital pathology, machine learning, and next generation sequencing. The project has the potential to help the NHS realise significant cost savings and improve outcomes for patients, by focusing resources on individuals with a higher risk of polyp recurrence. This will minimise the extent to which those patients who do not develop further polyps have to undergo unnecessary, invasive, and time-intensive treatment.

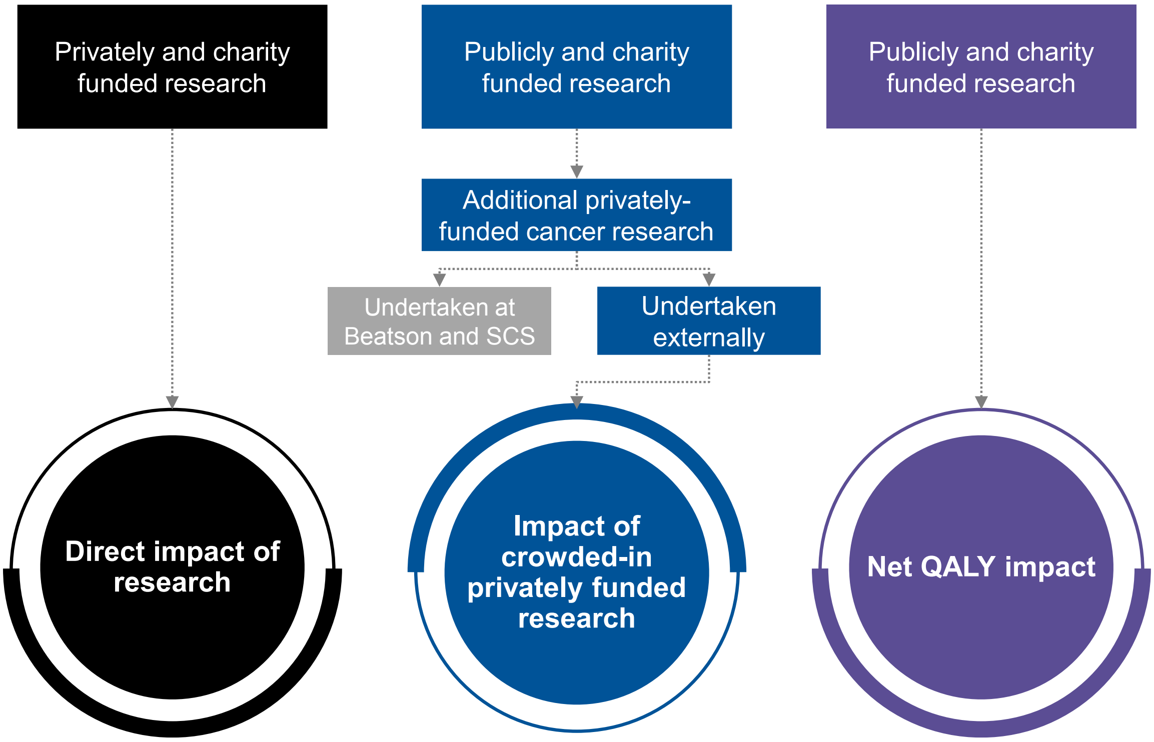
As well as delivering benefits for patients and the NHS, INCISE also has the potential to contribute to the growth of Glasgow’s innovation economy. It is one of eleven projects, six of which are linked to the University of Glasgow, that will receive support from Glasgow City Region’s share of £100 million Levelling Up funding to further accelerate the growth of the region’s high-potential innovation clusters. The project is also this year’s recipient of the Innovative Collaboration Award at Scotland’s Life Sciences Awards 2023, further highlighting the impact of the project to date and its potential to transform bowel cancer screening in Scotland and beyond.

4 The impact of the CRUK Scotland Institute's and the School of Cancer Sciences' research

In this section, we outline our analysis of the **economic impact of the CRUK Scotland Institute's and School of Cancer Sciences' research activities** (see Figure 5). This impact accounts for:

- The **direct effects** of this research (captured by the research income accrued by the institutions, net of any public funding);
- The impact of this research on improved health outcomes (measured in terms of **net quality-adjusted life year (QALY)** benefits (net of the public NHS treatment costs of delivering the improved health outcomes)); and
- The economic impact associated with privately funded research that is '**crowded in**' as a result of the research undertaken by the Institute and the SCS.

Figure 5 Overview of the analysis of the impact of research



Source: London Economics

The Institute's and the School of Cancer Sciences' world-leading research

Together, the CRUK Scotland Institute and the SCS **produce world-leading research relating to a wide range of cancers**.

In terms of publications, between April 2017 and March 2022, staff from the Institute and SCS collectively produced **1,280** outputs. In addition, the CRUK Scotland Institute and SCS work closely with industry to translate their research into clinical settings and ensure that patients benefit from it. In the same timeframe, for example, the CRUK Scotland Institute worked closely with **12** companies, in turn receiving **£18.4 million** of industry funding, and filing **10** patents and **23** disclosures based on its research. The SCS received funding from **36** different companies, with a combined value of **£20.5 million**, and filed **4** disclosures based on its research.

Cancer research plays a key role in the University of Glasgow's total research activities more broadly. Cancer-related research awards made up **10%** (**547** of **5,367**) of the total number and **11%** (**£119.8 million** of **£1,092.7 million**) of the total value of research awards to the University of Glasgow's College of Medical, Veterinary & Life Sciences between April 2017 to March 2022.

The close collaboration between the School of Cancer Sciences and the Institute is particularly important, with **58** research awards (with a total value of **£22.8 million**) awarded to staff with joint University of Glasgow and CRUK Scotland Institute contracts over the same timeframe.

The high quality of the University of Glasgow's research is demonstrated by its strong performance in Clinical Medicine in the Research Excellence Framework (REF) 2021 results. The University ranked **6th** (out of 31 institutions) in the UK overall in Clinical Medicine, and ranked top in Scotland. The University also ranked **3rd** in the UK in Clinical Medicine in terms of research outputs, **8th** in terms of impact, and **16th** in terms of environment.[17]

4.1 Methodology

4.1.1 Direct impact

To estimate the **direct impact** generated by the CRUK Scotland Institute's and the School of Cancer Sciences' research activities, we used information on the total research-related income accrued by the institutions in 2021-22[18] (**£40 million**). To arrive at the **net direct impact** of the institutions' research activities on the UK economy, we then deducted the costs to the public purse of funding their research activities in 2021-22 from this total research income.[19]

4.1.2 Net QALY impact

In addition to the direct impact of research, the wider academic literature indicates that investments in cancer research lead to **improved patient outcomes through both improved treatment and prevention**. These benefits can be quantified by estimating the impact on QALYs, which measure the additional life years gained from cancer research, adjusted for health-related quality of life. We measured the QALY patient benefit (net of

[17] Based on the number of 4* submissions to the REF.
[18] Again, the analysis is based on the CRUK Scotland Institute's 2021-22 financial year (i.e., April 2021 to March 2022).
[19] For more information on the calculation of the direct impact, please refer to Annex A2.3.1.

public treatment costs) using estimates derived from a core study by Glover et al. (2014) on the returns to UK publicly funded and charity funded cancer-related research in terms of the net value of improved health outcomes. Based on the study's results, we converted these returns into a monetary multiplier of **8.78**, which indicates that every **£1 million** of UK publicly funded or charity funded cancer research results in **£8.78 million** of future net QALY benefits in the UK. We then applied this multiplier to the CRUK Scotland Institute's and the School of Cancer Sciences' UK publicly funded and charity funded cancer research income, to estimate the future net QALY benefits of this research throughout the UK.[20]

4.1.3 Impact of 'crowding in' of privately funded research

Alongside the QALY benefits, another strand of the academic literature suggests that publicly funded and charity funded expenditure in research and development (R&D) **'crowds in' additional private sector research funding** (i.e., public and charity research funding encourages private funders to invest in additional research, e.g., to further develop and commercialise the fundamental/basic R&D undertaken). We quantified the economic impact of this crowding-in effect using estimates from Sussex et al. (2016), who found that, in the UK, a 1% increase in government and charity funded biomedical and health R&D expenditure is associated with a 0.81% increase in private sector pharmaceutical R&D spending. Using data from the Office for National Statistics (2022c), we converted this elasticity into a monetary multiplier of **1.52**, indicating that every **£1 million** of UK publicly funded or charity funded cancer research results in an additional **£1.52 million** of privately funded cancer research. Again, this multiplier was then applied to the CRUK Scotland Institute's and the School of Cancer Sciences' UK publicly funded and charity funded research income, to estimate the privately funded cancer research that is 'crowded in' as a result of the institutions' research.[21]

As with the expenditures of the CRUK Scotland Institute and the SCS (see Section 3), the additional crowded-in research activity is expected to generate **indirect and induced economic impacts** throughout the UK economy. Again, these additional knock-on effects were estimated by applying relevant economic multipliers from the above-discussed Input-Output analysis.

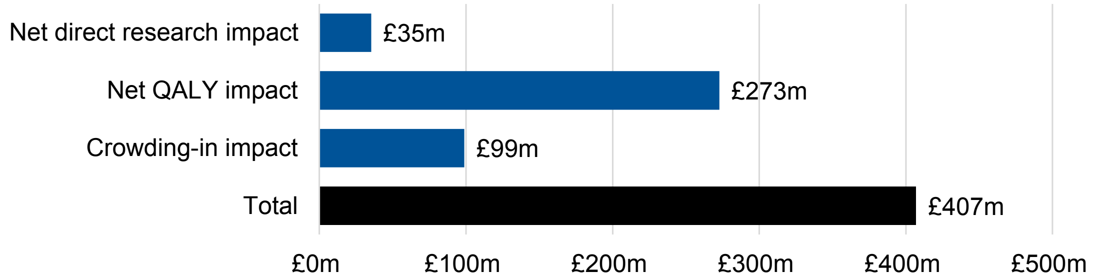
4.2 Impact of the institutions' research

Combining the above effects, we estimate that the total economic impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' research activities in 2021-22 stood at approximately **£407 million** (see Figure 6). This includes **£35 million** associated with the direct economic impact of the institutions' research; **£273 million** associated with improved future patient outcomes (i.e., net QALY benefits); and **£99 million** in direct, indirect, and induced economic activity associated with the additional private sector funded research that is crowded in as a result of the institutions' research.

Comparing this impact to the **£40 million** of total research income received by the institutions in 2021-22, this suggests that **for every £1 million of research income received, the CRUK Scotland Institute's and the School of Cancer Sciences' research activities generate a total of £10.2 million in economic impact across the UK**.

[20] Please refer to Annex A2.3.2 for a detailed description of how the net QALY multiplier was derived. Also see here for a summary of Glover et al. (2014)'s methodological approach and findings.
[21] Please refer to Annex A2.3.3 for further methodological details. Note that we deducted any privately funded research undertaken at the CRUK Scotland Institute and School of Cancer Sciences itself (to avoid double-counting).

Figure 6 Total impact of the CRUK Scotland Institute's and the School of Cancer Sciences' research activities in 2021-22, £m



Note: All values are presented in 2021-22 prices, rounded to the nearest £1 million, and may not add up precisely to the total indicated.
Source: London Economics' analysis

CASE STUDY 3

THE ROLE OF INNOVATION IN TACKLING CANCER'S BIGGEST CHALLENGES

The role of innovation in tackling cancer's biggest challenges

Glasgow's Garscube Campus is home to the newly established **McNab Centre for Cancer Innovation (MCCI)**. The MCCI is a ground-breaking research centre that aims to **revolutionise cancer treatment and improve patient outcomes**, combining innovative technologies and out-of-the-box thinking to tackle the most challenging cancers, many of which continue to evade treatment. Led by Professor Ross Cagan, Professor Jim Norman, and Dr Chiara Braconi, the MCCI was established through a very generous bequest made to the Institute by Ms Annie McNab, to support cancer research in Glasgow and the West of Scotland. Consequently, a primary focus for the MCCI is on those cancers that are particularly prevalent or problematic for the patient base in the West of Scotland.

At the core of the MCCI's research agenda are **two cutting-edge approaches to cancer therapeutics** which utilise and build upon the region's strengths and assets in healthcare innovation, including its expertise in precision medicine and excellent pathology infrastructure.

The first approach involves the development of human-on-a-chip 'assembloids', which faithfully capture the crucial elements of cancer, including the immune system, key organs, and the tumour itself. These assembloids provide a unique platform for studying cancer more holistically, enabling researchers to better understand the complex interactions between tumours and the whole body, and the impact of these interactions on patient treatment.

The second approach centres around a pioneering unique approach to medicinal chemistry to develop new cancer drugs through a process called 'Chemical Evolution'. This represents a paradigm shift in drug discovery, leveraging the power of artificial intelligence and chemical automation to rapidly synthesise and screen a 'smart' library of chemical compounds. This technology, which has been developed by Professor Lee Cronin and is unique to the University of Glasgow, enables researchers to explore a wide range of molecular structures and identify potential drug candidates with enhanced precision and efficiency.

The MCCI aims to combine these exciting technologies to **develop a new generation of cancer drugs that can effectively treat tumours within the context of the whole body**. By leveraging the comprehensive understanding provided by the assembloids, researchers at the MCCI can design drug compounds that specifically target tumour cells while minimising harm to healthy tissues and organs. This integrated approach holds tremendous potential for personalised medicine and tailored cancer treatments that consider the unique characteristics of each patient's cancer and physiological makeup, whilst radically reducing the time and cost of producing cancer drugs.

The MCCI's establishment signifies an important milestone in cancer research and treatment in Glasgow and the UK. It is poised to drive health innovation within the Glasgow City Region, foster collaboration among experts in the field, and pave the way for ground-breaking discoveries that will shape the future of cancer care.

CASE STUDY 4

LEADING THE WAY IN THE APPLICATION OF PRECISION MEDICINE

Leading the way in the application of precision medicine

The University of Glasgow is **leading the way in developing new precision medicine techniques**, which aim to treat patients earlier and more effectively. Cancer sciences have played a significant role in the development of the region's expertise in precision medicine, which has the potential to transform patients' treatment, generate substantial savings for the NHS, and contribute to the Glasgow City Region's economic development.

Precision medicine is the tailoring of medical treatments to patients' specific characteristics. This means patients can be treated faster and more effectively, while avoiding unnecessary side effects. Precision medicine is made possible by using cutting-edge medical tools, such as more precise diagnostics, imaging, genomics, and artificial intelligence.

In 2019, a University of Glasgow-led UK Government BEIS Science and Innovation Audit[22] highlighted the **potential for Scotland's unique health infrastructure to develop world-leading precision medicine innovations and enable the UK to become a leader in the field**. According to the report, Scotland is differentiated by its combination of world-class clinical research, high-quality patient data, patient samples, a single healthcare provider, and large cohorts of patients with chronic disease.

The strength of this opportunity is **particularly evident in relation to the diagnosis and treatment of cancer**. Academics from the University of Glasgow's School of Cancer Sciences and the CRUK Scotland Institute are playing a leading role in several exciting precision medicine projects and trials, including **Precision-PANC**, **INCISE**, and **PREDICT-Meso**, which focus on pancreatic cancer, bowel cancer and mesothelioma (respectively).

This opportunity is underlined by the fact that much of the inward investment in precision medicine in Scotland has been focused on Glasgow, with investors attracted by the presence of one of the largest acute hospital complexes in Western Europe, a world top 50 university for clinical medicine and health in the University of Glasgow, and several world-class centres of excellence in research. This includes the University of Glasgow's Precision Medicine Living Laboratory, which represents a collaborative effort by public and private partners to create a dynamic network for Glasgow's precision medicine sector through establishing innovation pathways in a real-world clinical setting.

These factors have **contributed to the growth of the region's burgeoning life sciences sector**. Recent figures estimate that there are more than 380 life sciences companies located in Glasgow, turning over around £325 million annually and employing over 10,000 people. Almost 75% of the region's life sciences activity involves human healthcare, as do more than 25% of Glasgow's top innovative firms (Invest Glasgow, 2023). The region has more than 120 health start-ups, which have attracted £124 million in funding since 2015 (Dealroom, 2023). All of this indicates the region's strong future potential to grow its health sector and exploit synergies in underpinning technologies and related industries, such as data science and health economics.

[22] Department for Business, Energy & Industrial Strategy (2019).

5 The impact of teaching and learning activities

As a final core strand of economic impact associated with the activities of the CRUK Scotland Institute and the SCS, we estimate the impact of the institutions' teaching and learning activities. Specifically, we estimate the net benefits to students/graduates and the Exchequer associated with postgraduate research students (i.e., Doctorate degree students) who are taught at the CRUK Scotland Institute and the SCS.[23]

5.1 Methodology

The analysis of the economic impact of teaching and learning activities focuses on the **2021-22 cohort of UK domiciled students enrolled at the School of Cancer Sciences**, i.e., on the **39** UK domiciled students who started postgraduate research qualifications at the SCS in 2021-22. This includes students in the cohort who were taught in collaboration with the CRUK Scotland Institute (i.e. whose Doctorate degree is supervised by Institute staff). Using the same methodological approach that was applied to estimate the economic impact of teaching and learning activities across the University of Glasgow as a whole[24], the analysis captures the enhanced labour market benefits and taxation receipts (minus the costs of attendance/provision) associated with students completing Doctorate degrees at the School of Cancer Sciences.

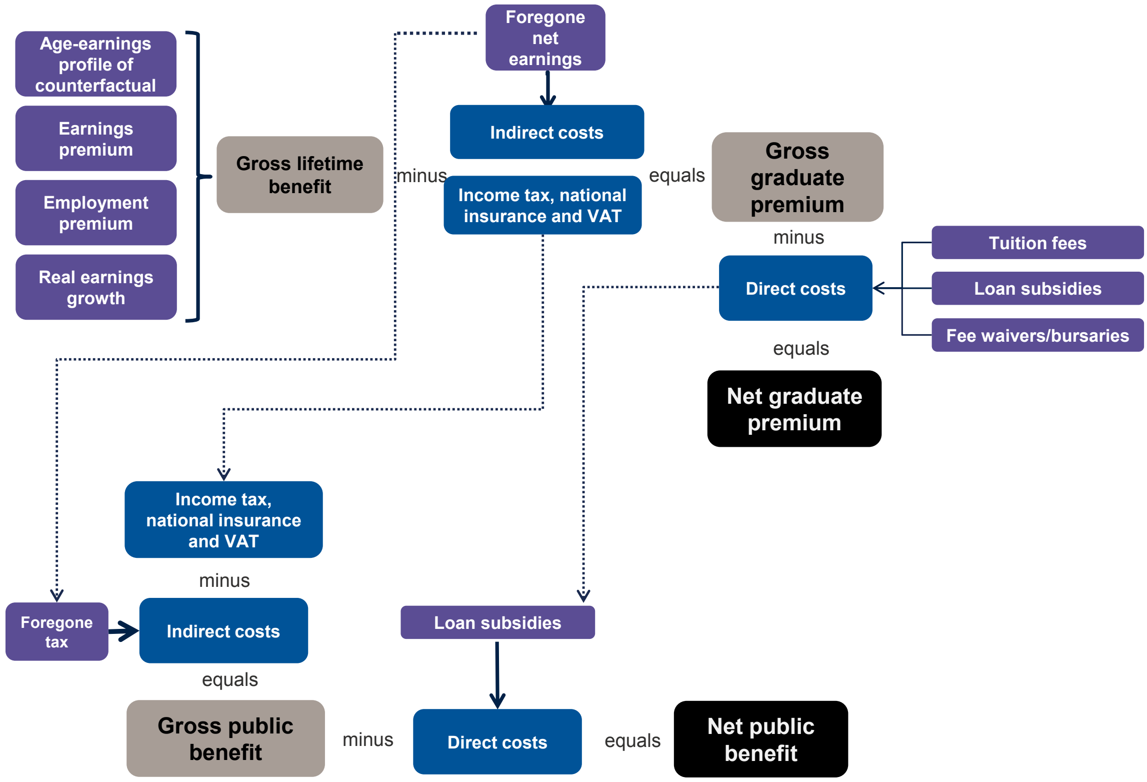
Specifically, the fundamental objective of the analysis is to estimate the **gross and net graduate premium** to the individual and the **gross and net public purse benefit** to the Exchequer associated with higher education qualification attainment (i.e., postgraduate research qualifications in this instance), defined as follows (and presented in Figure 7):

- The ***gross* graduate premium** associated with qualification attainment is defined as the **present value of enhanced after-tax earnings** (i.e., after income tax, National Insurance and VAT are removed, and following the deduction of any foregone earnings during study) relative to an individual in possession of the counterfactual qualification. Here, reflecting the prior attainment levels of students in the 2021-22 cohort of SCS students, all results are estimated relative to individuals in possession of **first degrees** as the relevant counterfactual;
- The ***gross* benefit to the public purse** is defined as the **present value of enhanced taxation** (i.e. income tax, National Insurance and VAT, following the deduction of the costs of foregone tax earnings during study) relative to an individual in possession of the counterfactual qualification;
- The ***net* graduate premium** is defined as the gross graduate premium *minus* the present value of the direct costs associated with qualification attainment; and
- Similarly, the ***net* benefit to the public purse** is defined as the gross public purse benefit minus the direct Exchequer costs of provision during the period of attainment.

[23] All students in the relevant cohort were undertaking postgraduate research qualifications; specifically, all of these students were enrolled in Doctorate degrees. Throughout this report, we therefore use the terms 'postgraduate research qualifications' and 'Doctorate degrees' interchangeably.

[24] See London Economics (2021) and Annex A2.4 for a detailed description of the methodology used to estimate the impact of teaching and learning activities.

Figure 7 Overview of gross and net graduate premium, and gross and net Exchequer benefit



Source: London Economics' analysis based on Department for Business, Innovation and Skills (2011)

5.2 Impact of the institutions' teaching and learning activities

5.2.1 Estimated net graduate premium and net Exchequer benefit

Table 3 presents the net graduate premiums and net Exchequer benefits achieved by Scottish domiciled students starting Doctorate degrees at the School of Cancer Sciences (including students supervised at the CRUK Scotland Institute) in the 2021-22 cohort (by study mode, on average across men and women).

The analysis indicates that the **net graduate premium** achieved by a representative Scottish domiciled student in the 2021-22 cohort completing a **full-time** Doctorate degree at the SCS (with a first degree as their highest level of prior attainment) is approximately **£293,000** in today's (i.e., 2021-22) money terms. The corresponding net graduate premium per **part-time** student was estimated at **£243,000**.[25]

The public purse benefits associated with students completing postgraduate research qualifications at the School of Cancer Sciences are even more substantial than the above net graduate premiums. The analysis indicates that the **net Exchequer benefit** for a representative Scottish domiciled **full-time** Doctorate degree student at the SCS stands at

[25] We assume that part-time students are able to combine work with their academic studies and thus do not incur any *opportunity costs* in the form of foregone earnings. However, the fact that part-time students tend to complete their studies later in life (resulting in fewer years spent in the labour market post-graduation) results in a relative reduction in the net graduate premiums for part-time students compared to full-time students (again, see Annex A2.4 for more information). Note again that most students in the 2021-22 cohort of SCS students were undertaking their qualifications on a full-time basis.

approximately **£344,000** in 2021-22 money terms, while the corresponding net Exchequer benefit per **part-time** student was estimated at **£278,000**.

Table 3 Net graduate premium and net Exchequer benefit per Scottish student completing a postgraduate research qualification at the SCS or the CRUK Scotland Institute, by study mode

Type of benefit	Full-time students	Part-time students
Net graduate premium	£293,000	£243,000
Net Exchequer benefit	£344,000	£278,000

Note: All estimates constitute weighted averages across men and women (weighted by the estimated number of student completers in the 2021-22 cohort), and provide the net graduate premium and net Exchequer benefit relative to individuals in possession of first degrees as the counterfactual level of qualification. The estimates are presented in 2021-22 prices, discounted to reflect net present values, and rounded to the nearest £1,000.
Source: London Economics' analysis

Wider impacts of teaching and learning on cancer sciences graduates

Beyond the economic benefits quantified in this chapter, the School of Cancer Sciences and the CRUK Scotland Institute support the career paths of their students.

For example, approximately **75%** of students at the CRUK Scotland Institute progress to a postdoc fellowship in academia or industry. Beyond this, around **20%** of its postdocs progress to become group leaders or lecturers, around **31%** undertake a second postdoc and around **24%** become a scientist in industry.

Both institutions also support clinicians to transition into research through a jointly run training scheme. Since 2020, the institutions have hosted **3** MB-PhD students (a qualification supporting the transition of medical students into research careers), and since 2012, has hosted **14** clinical research training fellows and **5** clinical group leaders. More widely, the scheme also provides support and mentoring to clinicians.

5.2.2 Total impact of teaching and learning activities at the SCS and CRUK Scotland Institute

Combining the information on the number of UK domiciled students in the 2021-22 SCS cohort, expected completion rates, and the estimated net graduate and public purse benefits per student, the analysis estimates that the **aggregate economic impact** of the teaching and learning activities at the SCS and the CRUK Scotland Institute associated with the 2021-22 cohort of UK-domiciled students stands at approximately **£19 million** (see Table 4). Of this total, **£9 million** (**46%**) is accrued by students undertaking Doctorate degrees at the School of Cancer Sciences (including students whose work is supervised by staff at the Institute), and the remaining **£10 million** (**54%**) is accrued by the Exchequer.

Table 4 Aggregate impact of the SCS's and the CRUK Scotland Institute's teaching and learning activities associated with the 2021-22 cohort (£m)

Beneficiary	Full-time students	Part-time students	Total
Students	£8.7m	£0.3m	**£8.9m**
Exchequer	£10.1m	£0.3m	**£10.4m**
Total	**£18.7m**	**£0.5m**	**£19.3m**

Note: All estimates are presented in 2021-22 prices, discounted to reflect net present values, rounded to the nearest £0.1m, and may not add up precisely to the totals indicated. ***Source: London Economics' analysis***

6 Total economic impact of the CRUK Scotland Institute and School of Cancer Sciences

Combining the above strands of impact, the total economic impact on the UK economy associated with the CRUK Scotland Institute's and School of Cancer Sciences' activities in 2021-22 was estimated to be approximately **£503 million** (see Table 5). Of this total:

- The impact generated by the **operating and capital spending** of the CRUK Scotland Institute and the School of Cancer Sciences stood at **£77 million** (**15%**);
- The impact of the institutions' **research activities** stood at **£407 million** (**81%**); and
- The value of the CRUK Scotland Institute's and the School of Cancer Sciences' **teaching and learning activities** stood at **£19 million** (**4%**).

Table 5 Total economic impact of the CRUK Scotland Institute's and the School of Cancer Sciences' activities in the UK in 2021-22 (£m and % of total)

Type of impact	£m	%
Impact of expenditure	**£77m**	**15%**
Direct impact	£50m	10%
Indirect and induced impacts	£27m	5%
Impact of research	**£407m**	**81%**
Net direct research impact	£35m	7%
Net QALY impact	£273m	54%
Crowding-in impact	£99m	20%
Impact of teaching and learning	**£19m**	**4%**
Students	£9m	2%
Exchequer	£10m	2%
Total economic impact	**£503m**	**100%**

Note: All estimates are presented in 2021-22 prices and rounded to the nearest £1m. Totals may not add up precisely due to rounding.
Source: London Economics' analysis

Compared to the CRUK Scotland Institute's and School of Cancer Sciences' total operational costs of approximately **£51 million** in 2021-22[26], the total impact of the institutions' activities on the UK economy was estimated at **£503 million**, which corresponds to a **benefit to cost ratio of 9.8:1**.

[26] Compared to the **£50 million** of direct impact of the CRUK Scotland Institute's and School of Cancer Sciences' expenditures included in Section 3, the **£51 million** of operating expenditure here *excludes* capital expenditure (**£0.5 million**) but *includes* depreciation costs (**£0.4 million**) and movements in pension provisions (**£1.6 million**).

CASE STUDY 5

THE CRUK BEATSON INSTITUTE'S WORLD-LEADING IN VIVO MODELS

The CRUK Scotland Institute's world-leading *in vivo* models

Rapid diagnosis of cancer at an early stage is vital for improving response and survival rates. To date, this has been limited both by our collective understanding of how the disease develops in its earliest stages and a lack of reliable and non-invasive techniques for diagnosis. Closing this knowledge gap has been a key focus of the work of the Institute since 2017 (Cancer Research UK Scotland Institute, n.d.), which has developed a **suite of *in vivo* cancer models to better understand the development of cancer in its early stages**. In the process, the CRUK Scotland Institute has established a reputation as the pre-eminent institute for *in vivo* cancer modelling in the UK.

The Institute's *in vivo* models focus primarily on key tumour types that relate to cancers of unmet need (such as liver, pancreas, and lung cancer); that are significant contributors to cancer-related deaths (such as colorectal cancer); or that have a particularly high incidence in the West of Scotland (such as malignant mesothelioma). The models accurately recapitulate critical events in the progression of cancer, such as tumour initiation, growth, and metastasis (when cancer cells spread from one part of the body to another). Understanding these processes is key to preventing cancer initiation, detecting cancers early, assessing their potential lethality, and developing treatments for metastatic disease.

To ensure that the models are as accurate as possible, the Institute undertakes extensive and rigorous benchmarking against the appropriate human cancers, their pathology, and co-morbidities – a discipline that is termed 'disease positioning'. Aligning the models to patient populations enables researchers in SCS and the CRUK Scotland Institute to translate their discoveries from the lab into a clinical setting, ultimately delivering improved outcomes for patients.

The CRUK Scotland Institute's integration within the West of Scotland's cancer sciences landscape has played an important role in the development of its world-leading *in vivo* models. The region has an excellent pathology infrastructure, much of which is centred around the Queen Elizabeth University Hospital. Additionally, the University of Glasgow's School of Cancer Sciences' clinical research strengths and close relationships with NHS clinicians have helped improve access to clinical expertise, critical clinical cohorts, and patient samples. These developments, facilitated by the increasingly strong and integrated relationship between the CRUK Scotland Institute and the University, have played a significant role in improving the accuracy of these unique models of cancers of unmet need.

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Annex 2 Technical Annex and supplementary information

A2.1 Cancer sciences in Glasgow

As outlined in Section 2.2, there is a wide range of key life sciences infrastructure assets within Glasgow that are fundamental to the work of both the School of Cancer Sciences and the CRUK Scotland Institute. Examples of such infrastructure are provided in Table 6, which highlight Glasgow's strengths in cancer sciences, precision medicine, tissue sampling, advanced imaging, clinical trials and omics.

Table 6 Key life sciences infrastructure in Glasgow

Name	Summary	Location
Genomics Innovation Alliance	Building on the successes of past genomics innovation partnerships (e.g. Glasgow Precision Oncology Laboratory), the Genomics Innovation Alliance (GIA) is a partnership between the University of Glasgow and NHS Greater Glasgow and Clyde (NHSGGC) that capitalises on existing expertise, leadership and clinical infrastructure to enable the development and clinical and economic evaluation of potential new genomics innovations. Piloted in Glasgow, underpinned by the Lighthouse Lab/Living Laboratory infrastructure with University and NHS working together, GIA offers the opportunity develop a national platform for diagnostics and the application of Precision Medicine, as a key building block of Scotland's life sciences ecosystem. GIA delivers a platform that will underpin a co-creation model to drive translation and implementation of genomics innovations to improve healthcare outcomes, deliver efficiencies for the NHS and foster innovation. By working in partnership with NHSGGC molecular diagnostics laboratory GIA offers a co-development environment where industry and academics can access resources integrated with NHS systems to validate and evaluate potential genomic diagnostics. GIA provides a framework under which potential genomic innovations are assessed for suitability and readiness for adoption into the NHS, including consideration of potential barriers such as integration into existing NHS platforms and workforce implications. This model will support the delivery of Scotland's genomic ambitions, smoothing the pathway for testing and translation and enabling ready implementation into NHS workflows to enable sustainable delivery for the NHS.	Queen Elizabeth University Hospital
Glasgow Tissue Research Facility (GTRF)	The GTRF facilitates the collection of and access to tissues collected from consenting patients participating in clinical trials or studies. The GTRF offers a wide range of services, including digital pathology, image analysis, Tissue Microarray construction, and histology services. These services help to bridge the gap for tissue-based research between the NHS, the University of Glasgow, and industry. For example, GTRF has played an important role in the continued development of the I's renowned *in vivo* models by helping to transform researchers' access to human tissues.	Queen Elizabeth University Hospital
Imaging Centre of Excellence (ICE)	ICE is a facility that hosts world-leading imaging clinical research facilities, which provide a nexus for academic, NHS and industrial expertise into advanced imaging. It is home to	Queen Elizabeth

Name	Summary	Location
	the 7 Tesla (7T) MRI scanner, an ultra-high-resolution scanner which was the first of its kind to be fully integrated within a clinical site in the UK underpinned by world-leading clinical expertise in stroke, cardiovascular disease and brain imaging.	University Hospital
Precision Medicine Living Laboratory	The Precision Medicine Living Laboratory is the result of a £38 million award by the UKRI Strength in Places Fund in 2020, designed to build on Glasgow's existing leadership and infrastructure in precision medicine and cement the region's status as a world leader in this field. Through the development of cutting-edge tools and innovations such as medical imaging, genomics, and artificial intelligence, precision medicine can be used to help treat people quickly and more successfully whilst avoiding unnecessary side effects from ineffective treatments.	Queen Elizabeth University Hospital
Glasgow Molecular Pathology Node[27] (Medical Research Council/ Engineering and Physical Sciences Research Council)	The Glasgow Molecular Pathology Node was a partnership between the University of Glasgow, the NHS, and industry to create a multi-disciplinary centre of excellence in the research and development of molecular diagnostic tests for cancer and other chronic diseases.	Queen Elizabeth University Hospital
Industrial Centre for Artificial Intelligence Research in Digital Diagnostics (iCAIRD)[28]	iCAIRD was a world-class centre of excellence focusing on the application of AI to digital diagnostics. As with much of the region's other life sciences infrastructure, it helped facilitate collaboration between research-active clinicians and innovative SMEs to better inform clinical questions and ultimately solve healthcare challenges more quickly and efficiently. iCAIRD promoted two distinct eco-systems for AI development - one focused on the needs of AI in radiology, and the other on AI in pathology.	Queen Elizabeth University Hospital
Beatson West of Scotland Cancer Centre	The Beatson West of Scotland Cancer Centre is an internationally renowned cancer centre and the busiest in the UK in terms of clinical activity and patient numbers. It is also the second largest cancer centre in the UK, delivering all radiotherapy and much of the chemotherapy to the population of the West of Scotland, with a catchment area that accounts for roughly two-thirds of Scotland's population.	Gartnavel General Hospital
Glasgow Clinical Trials Unit	The Glasgow Clinical Trials Unit (GCTU) supports all aspects of clinical trial research from concept through to analysis & reporting. The GCTU is established within the University of Glasgow and Greater Glasgow & Clyde Health Board, with specialist services provided by the Robertson Centre for Biostatistics, Glasgow Clinical Research Facility and Greater Glasgow & Clyde NHS R&I.	Gartnavel General Hospital
West of Scotland PET/CT Centre	The West of Scotland PET/CT Centre is a purpose-built facility with space for 2 PET/CT systems, a cyclotron and associated laboratory facilities. It serves as one of two bases in Glasgow from which the Translational Molecular Imaging (TMI) centre, which is operated by the CRUK Scotland Institute, operates. TMI advances novel imaging technologies and is as a shared resource for the CRUK Scotland Institute and Cancer Research UK Scotland Centre researchers.	Gartnavel General Hospital

[27] Refers to legacy infrastructure.
[28] Refers to legacy infrastructure.

Name	Summary	Location
Experimental Cancer Medicine Centre (ECMC) Glasgow	The Glasgow ECMC is a partnership between the University of Glasgow, the CRUK Scotland Institute, NHS Greater Glasgow and Clyde, and the Beatson West of Scotland Cancer Centre. The Glasgow ECMC forms part of a network of 17 ECMC adult centres, including one in Edinburgh, and 12 ECMC paediatric centres across the UK. ECMCs work in conjunction with local NHS facilities to provide access to cutting-edge trials and treatments to help find new ways to detect, monitor and treat the disease to help beat cancer sooner. In January 2023, it was announced that Glasgow's adult and paediatric ECMCs will receive up to £2.2 million to help doctors and scientists develop the cancer treatments of the future. The Glasgow ECMC has also been designated as a CRUK Biomarker of Excellence – one of four in the UK – with researchers from the ECMC working in partnership with Cancer Research UK's Centre for Drug Development on translational biomarker research for early-stage clinical trials.	University of Glasgow Garscube Campus
Glasgow Polyomics	Glasgow Polyomics brings together world-renowned experts in the field of omics research, with a focus on genomics, transcriptomics, proteomics, metabolomics and lipidomics, bioinformatics and data analysis. Glasgow Polyomics aims to understand the molecular processes of health and disease, facilitating and developing cutting-edge research across biology. Its expertise has been utilised in clinical projects, industrial biotechnology, drug discovery, and biomarker identification.	University of Glasgow Garscube Campus
Scottish Centre for Macromolecular Imaging	The Scottish Centre for Macromolecular Imaging (SCMI) was established in September 2018 to provide support to researchers across Scotland for cryo-electron microscopy of a wide range of scientific samples. As well as offering advanced instrumentation, the centre is staffed by experienced personnel who provide support and advice in the areas of sample optimisation, preparation and screening of cryo-grids and high-resolution data collection. SCMI is funded by the Medical Research Council, the universities of Glasgow, Edinburgh, Dundee and St Andrews, Scottish Funding Council, Scottish Universities Life Science Alliance, CRUK Scotland Institute and MJM Smith Trust.	University of Glasgow Garscube Campus

A2.2 The impact of the CRUK Scotland Institute's and the School of Cancer Sciences' expenditures

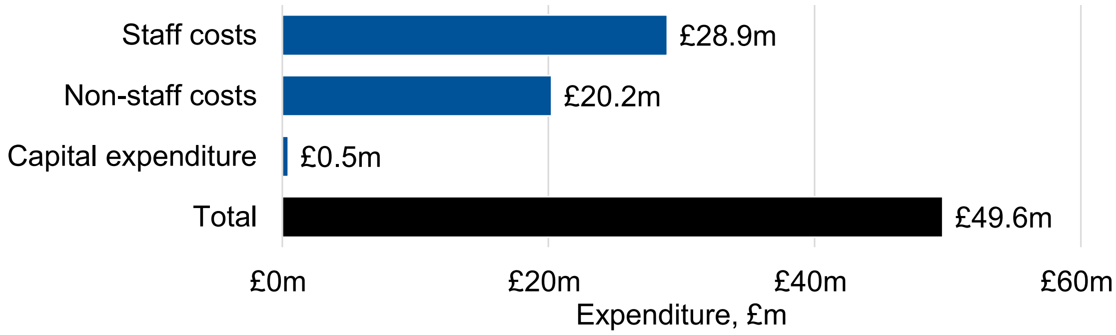
In Section 3, we outlined our analysis of the **direct, indirect, and induced impacts associated with the operational and capital expenditures of the CRUK Scotland Institute and the School of Cancer Sciences**. These impacts can be measured in terms of economic output, gross value added, and (full-time equivalent) employment. The following provides further methodological detail on how we arrived at the estimates.

A2.2.1 Direct impact of the institutions' expenditures

To measure the direct economic impact of the purchases of goods, services, and labour by the CRUK Scotland Institute and the School of Cancer Sciences, we used information on their operational expenditures (including staff and non-staff spending), capital expenditures, and the number of staff employed (in FTE), in 2021-22[29].

In terms of monetary economic **output** (measured in terms of expenditure), **the direct economic impact** associated with the CRUK Scotland Institute's and the School of Cancer Sciences' expenditures stood at approximately **£50 million** in 2021-22 (see Figure 8). This includes **£29 million** of staff costs, **£20 million** of other (non-staff) operating expenses[30], and **£0.5 million** of capital expenditure incurred in that year.

Figure 8 Direct economic impact (in terms of output) of the CRUK Scotland Institute and the School of Cancer Sciences expenditure in 2021-22, by type of expenditure



Note: We exclude a total of **£0.4 million** of non-staff costs associated with depreciation, and **£1.6 million** of staff costs associated with movements in pension provisions, as it is assumed that these are not relevant from a procurement perspective (i.e., these costs are not accounted for as income by other organisations). All estimates are presented in 2021-22 prices and rounded to the nearest £0.1m.
Source: London Economics' analysis based on data provided by the University of Glasgow.

A2.2.2 Indirect and induced impacts of the institutions' expenditures

The assessment of the indirect and induced economic impacts associated with the expenditures of the CRUK Scotland Institute and the School of Cancer Sciences were estimated using **economic multipliers** derived from Input-Output tables, which measure the total production output of each industry in the UK economy, and the inter-industry (and intra-industry) flows of goods and services consumed and produced by each sector. In other words, these tables capture the degree to which different sectors within the UK economy are connected, i.e., the extent to which changes in the demand for the output of any one sector impact on all other sectors of the economy. To be able to achieve a breakdown of the analysis by region, we developed a **multi-regional Input-Output model**, combining UK-

[29] Based on staff and financial data provided by the University of Glasgow.
[30] The total operational expenditure (excluding capital expenditure) of the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22 stood at **£51 million**. From this, for the purpose of the analysis, we excluded **£0.4 million** in depreciation costs (from non-staff expenditure) and **£1.6 million** in movements in pension provisions (from staff expenditure), as it is assumed that these are not relevant from a procurement perspective (i.e., these costs are not accounted for as income by other organisations).

level Input-Output tables (for 2016[31]) with a range of regional-level data[32] to achieve a granular breakdown by sector[33] *and* region[34].

Using this Input-Output model to derive economic multipliers by sector and region[35], we then applied the estimated multipliers as follows:

- To estimate the impact of the expenditures incurred by the CRUK Scotland Institute, we applied the estimated average multiplier associated with organisations in the Scottish **professional and support activities sector**; and,
- To estimate the impact of the SCS's expenditures, we applied the estimated average multiplier associated with organisations in Scotland's **government, health, and education sector**.[36]

The multipliers are expressed in terms of **economic output**, **gross value added**, and (full-time equivalent) **employment**, and are calculated as **total multipliers**, capturing the aggregate impact on all industries in the UK economy arising from an initial injection relative to that initial injection.

The resulting multipliers are presented in Table 7 (for Scotland and the UK as a whole[37]), indicating that:

- Every £1 million of operational or capital expenditure incurred by the CRUK Scotland **Institute** generates an *additional* **£1.19 million** of impact throughout the UK economy, of which **£0.63 million** is accrued in Scotland. In terms of employment, we assume that, for every **1,000** (FTE) staff employed directly by the CRUK Scotland Institute, an additional **720** staff are supported throughout the UK, of which **400** are located in Scotland; and
- Every £1 million of operational or capital expenditure incurred by the **School of Cancer Sciences** generates an *additional* **£1.54 million** of impact throughout the UK economy, of which **£0.83 million** is generated in Scotland. In terms of employment, we assume that, for every **1,000** (FTE) staff employed directly by the

[31] See Office for National Statistics (2023b).
[32] The fundamental idea of the multi-regional Input-Output analysis is that region *i*'s demand for region *j*'s output is related to the friction involved in shipments from one region to another (which we proxy by the distance between the two regions), and that cross-regional trade can be explained by the relative gross value added of the sector in all regions. The multi-regional Input-Output model was derived by combining UK-level Input-Output tables with data on geographical distances between regions; GVA and compensation of employees by sector and region (Office for National Statistics, 2019); employment by sector and region (Office for National Statistics, 2022a); gross disposable household income by region (Office for National Statistics, 2020); population by region (Office for National Statistics, 2022b); and UK imports into each region and exports by each region, by commodity (Office for National Statistics, 2018).
[33] In terms of sector breakdown, the original UK Input-Output tables are broken down into 64 (relatively granular) sectors. However, the (wide range of) regional-level data required to generate the multi-regional Input-Output model is not available for such a granular sector breakdown. Instead, the multi-regional Input-Output model is broken down into 10 more high-level sector groups (see Table 8 in Annex A2.2.5 for more information).
[34] While Input-Output analyses are a useful tool to assess the total economic impacts generated by a wide range of activities, it is important to note several key limitations associated with this type of analysis. Input-Output analyses assume that inputs are complements, and that there are constant returns to scale in the production function (i.e., that there are no economies of scale). The interpretation of these assumptions is that the prevailing breakdown of inputs from all sectors (employees, and imports) in 2016 is a good approximation of the breakdown that would prevail if total demand (and therefore output) were marginally different. In addition, Input-Output analyses do not account for any price effects resulting from a change in demand for a given industry/output.
[35] Specifically, the analysis makes use of *Type II* multipliers, defined as [Direct + indirect + induced impact]/[Direct impact].
[36] In other words, this approach asserts that the spending patterns of the CRUK Scotland Institute and the School of Cancer Sciences reflect the average spending patterns across organisations operating in Scotland's professional and support activities sector, and Scotland's government, health, and education sector, respectively.
[37] In addition to the impacts on Scotland and the UK as whole, the analysis estimates a full breakdown across all regions, as well as by sector. These detailed results are presented in Figure 9 and Figure 10 in Annex A2.2.4.

School of Cancer Sciences, an additional **1,020** staff are supported throughout the UK, of which **560** are located in Scotland.

Table 7 Economic multipliers associated with the expenditures of the CRUK Scotland Institute and the School of Cancer Sciences

Institution	Location of impact	Output	GVA	FTE employment
CRUK Scotland Institute	Scotland	1.63	1.59	1.40
	Total UK	2.19	2.06	1.72
School of Cancer Sciences	Scotland	1.83	1.81	1.56
	Total UK	2.54	2.46	2.02

Note: All multipliers constitute Type II multipliers, defined as [Direct + indirect + induced impact]/[Direct impact]. Multipliers for the CRUK Scotland Institute are based on the average multipliers associated with organisations in Scotland's professional and support activities sector, and multipliers for the School of Cancer Sciences are based on the average multipliers associated with organisations in Scotland's government, health, and education sector.
Source: London Economics' analysis

A2.2.3 Adjustments for double-counting and transfers

Before arriving at the total direct, indirect, and induced impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' institutional spending, it is necessary to deduct two income and expenditure items to avoid double-counting, and to take account of the 'netting out' of the costs and benefits associated with the Institute's and the SCS's activities between different agents in the UK economy. Specifically, we deducted:

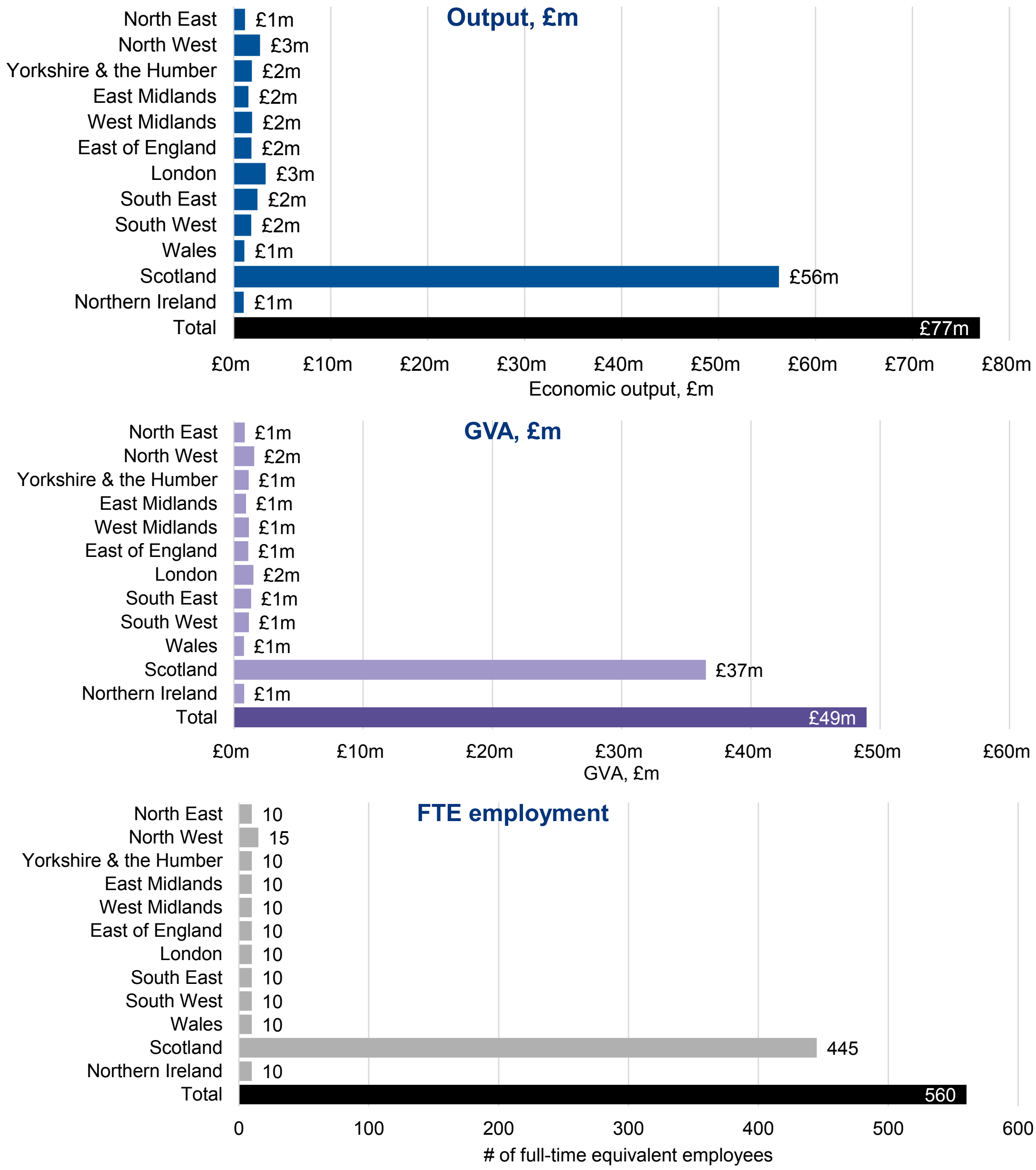
- The total research income received by the CRUK Scotland Institute and School of Cancer Sciences in 2021-22 (**£40 million**), to avoid double-counting with the estimated impact of the institutions' research activities (see Section 4); and
- **£0.1 million** in fee waivers and other bursary spending for UK domiciled students provided by the SCS[38], as this was included (as a benefit) in the analysis of the Institute's and SCS's teaching and learning activities (see Section 5).

A2.2.4 Aggregate impact of the institutions' spending

Figure 9 presents the estimated total direct, indirect, and induced impacts associated with the expenditures incurred by the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22 (after the above-described adjustments have been made), in economic output, GVA, and FTE employment terms, disaggregated by region. Figure 10 presents the corresponding results broken down by sector.

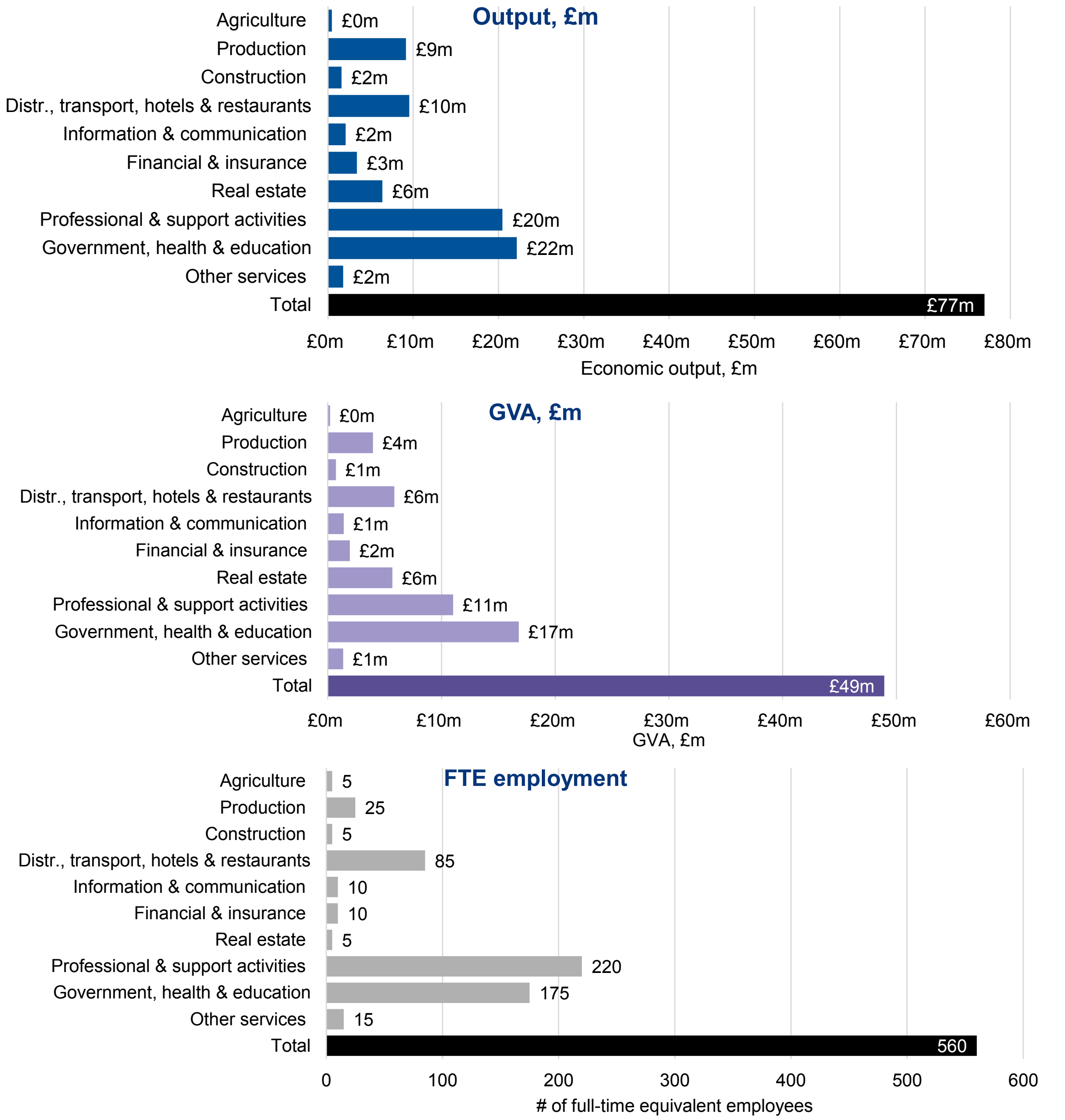
[38] The bursary support to UK domiciled students is considered as a benefit to the student in the analysis of the impact of teaching and learning (see Section 5). It was therefore necessary to deduct these bursaries from the direct impact of the CRUK Scotland Institute's and the School of Cancer Sciences' spending to correctly take account of the fact that these bursaries are a transfer from the institutions to students, and not an additional benefit to the UK economy.

Figure 9 Total economic impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' expenditure in 2021-22, by region



Note: Monetary estimates are presented in 2021-22 prices, rounded to the nearest £1 million, and may not add up precisely to the totals indicated. Employment estimates are rounded to the nearest 5, and again may not add up precisely to the totals indicated.
Source: London Economics' analysis

Figure 10 Total economic impact associated with the CRUK Scotland Institute's and the School of Cancer Sciences' expenditure in 2021-22, by sector



Note: Monetary estimates are presented in 2021-22 prices, rounded to the nearest £1 million, and may not add up precisely to the totals indicated. Employment estimates are rounded to the nearest 5, and again may not add up precisely to the totals indicated.
Source: London Economics' analysis

A2.2.5 Industry breakdown

Table 8 provides an overview of the high-level industry classifications used throughout the multi-regional Input-Output analysis (described in greater detail in Annex A2.2.2).

Table 8 Industry grouping used as part of the multi-regional Input-Output analysis

Industries included in original UK Input-Output table	High-level industry group [and UK SIC Codes]
Crop and animal production, hunting and related service activities	Agriculture [1-3]
Forestry and logging	
Fishing and aquaculture	
Mining and quarrying	Production [5-39]
Manufacture of food products, beverages, and tobacco products	
Manufacture of textiles, wearing apparel and leather products	
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
Manufacture of paper and paper products	
Printing and reproduction of recorded media	
Manufacture of coke and refined petroleum products	
Manufacture of chemicals and chemical products	
Manufacture of basic pharmaceutical products and pharmaceutical preparations	
Manufacture of rubber and plastic products	
Manufacture of other non-metallic mineral products	
Manufacture of basic metals	
Manufacture of fabricated metal products, except machinery and equipment	
Manufacture of computer, electronic and optical products	
Manufacture of electrical equipment	
Manufacture of machinery and equipment n.e.c.	
Manufacture of motor vehicles, trailers and semi-trailers	
Manufacture of other transport equipment	
Manufacture of furniture; other manufacturing	
Repair and installation of machinery and equipment	
Electricity, gas, steam, and air conditioning supply	
Water collection, treatment and supply	
Sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities and other waste management services	
Construction	Construction [41-43]
Wholesale and retail trade and repair of motor vehicles and motorcycles	Distribution, transport, hotels, and restaurants [45-56]
Wholesale trade, except of motor vehicles and motorcycles	
Retail trade, except of motor vehicles and motorcycles	
Land transport and transport via pipelines	
Water transport	
Air transport	
Warehousing and support activities for transportation	
Postal and courier activities	
Accommodation and food service activities	
Publishing activities	Information and communication [58-63]
Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	
Telecommunications	
Computer programming, consultancy and related activities; information service activities	
Financial service activities, except insurance and pension funding	Financial and insurance [64-66]
Insurance, reinsurance and pension funding, except compulsory social security	
Activities auxiliary to financial services and insurance activities	
Real estate activities excluding imputed rents	Real estate [68.1-2-68.3]
Imputed rents of owner-occupied dwellings	
Legal and accounting activities; activities of head offices; management consultancy activities	Professional and support activities [69.1-82]
Architectural and engineering activities; technical testing and analysis	
Scientific research and development	
Advertising and market research	
Other professional, scientific, and technical activities; veterinary activities	
Rental and leasing activities	
Employment activities	
Travel agency, tour operator reservation service and related activities	
Security and investigation activities; services to buildings and landscape activities; office administrative, office support and other business support activities	
Public administration and defence; compulsory social security	Government, health & education [84-88]
Education	
Human health activities	
Social work activities	

Creative, arts and entertainment activities; libraries, archives, museums, and other cultural activities; gambling and betting activities	Other services [90-97]
Sports activities and amusement and recreation activities	
Activities of membership organisations	
Repair of computers and personal and household goods	
Other personal service activities	
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	

Note: 'n.e.c.' = not elsewhere classified ***Source: London Economics' analysis, based on Office for National Statistics (2023b) and UK SIC Codes (see Office for National Statistics, 2022d)***

A2.3 The impact of the CRUK Scotland Institute's and the School of Cancer Sciences' research

In Section 4, we outlined our analysis of the **economic impact of the** CRUK Scotland **Institute's and School of Cancer Sciences' research activities**, including:

- The **direct effects** of this research (captured by the research income accrued by the institutions, net of any public funding);
- The impact of this research on improved health outcomes (measured in terms of **net QALY** benefits); and
- The economic impact associated with privately funded research that is **crowded in** as a result of the publicly (and charity) funded research undertaken by the CRUK Scotland and the SCS.

A2.3.1 Direct research impact

To estimate the **direct impact** generated by the CRUK Scotland Institute's and School of Cancer Sciences' research activities, we used information on the total research-related income accrued by the institutions in 2021-22[39], including:

- Income from **research grants and contracts** provided by **UK sources** (including the UK Research Councils; UK-based charities; central government bodies, Local Authorities, and health and hospital authorities; industry and commerce; and other UK sources) and **overseas (EU and non-EU) sources**; and
- **Recurrent research funding** allocated to the School of Cancer Sciences by the Scottish Funding Council.

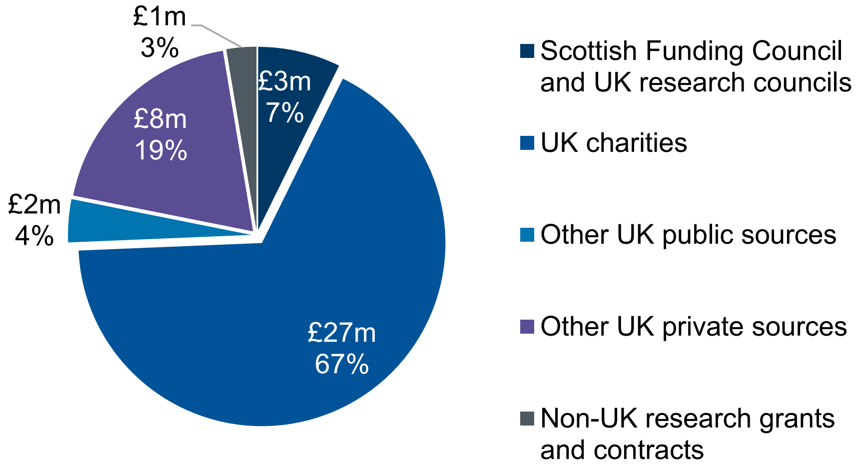
Aggregating across these sources, the combined total research-related income accrued by the CRUK Scotland Institute and the SCS in 2021-22 stood at **£40 million** (see Figure 11). The majority of this income (**£27 million**, **67%**) originated from UK charities (predominantly Cancer Research UK), with an additional **£3 million** (**7%**) received from the Scottish Funding Council and UK Research Councils, **£2 million** (**4%**) from other UK public sources[40], and **£8 million** (**19%**) from other UK private sources (e.g., pharmaceutical companies). In addition, **£1 million** (**3%**) of the institutions' research-related income was derived from non-UK research grants and contracts.

To arrive at the **net direct impact** of the institutions' research activities on the UK economy, we deducted the costs to the public purse of funding their research activities in 2021-22 from the above total research income. These public costs include funding from the Scottish Funding Council and UK Research Councils (**£3 million**) and research income from other

[39] Again, the analysis is based on the CRUK Scotland Institute's 2021-22 financial year (i.e., April 2021 to March 2022).
[40] I.e., UK central government bodies, Local Authorities, and health and hospital authorities.

UK public sources (**£2 million**, from UK central government bodies, Local Authorities, and health and hospital authorities). Deducting these total public purse costs (**£5 million**) from the above total research-related income (**£40 million**), we estimate that the **net direct impact** associated with the CRUK Scotland Institute's and SCS's research activity in 2021-22 stood at **£35 million**.

Figure 11 Research income received by the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22, £m by source



Note: All values are presented in 2021-22 prices, rounded to the nearest £1 million, and may not add up precisely to the totals indicated.
Source: London Economics' analysis based on data provided by the University of Glasgow

A2.3.2 Net QALY benefit

In addition to the direct impact of research, the wider academic literature indicates that investments in cancer research lead to **improved patient outcomes through both improved treatment and prevention**. These benefits can be quantified by estimating the impact on QALYs, which measure the additional life years gained from cancer research, adjusted for health-related quality of life.[41] This value places a monetary benefit on the wellbeing derived from improved quality and duration of life (rather than quantifying labour market benefits such as increased earnings from a longer life duration).[42]

To measure the QALY patient benefit, we relied on estimates derived from a core study by Glover et al. (2014) on the returns to UK publicly funded and charity funded cancer-related research in terms of the net value of improved health outcomes. The study assesses the net QALY benefit in the UK of UK publicly funded and charity funded cancer-related research conducted between 1976 and 1995, net of the public NHS treatment costs of delivering the improved health outcomes. The study assumes that it takes 15 years before cancer research impacts patient outcomes and that the impact of the research then lasts for 20 years, and estimates an internal rate of return (IRR) associated with public and charity funded cancer research of 10%. Based on the study's results, we converted this IRR into a monetary multiplier of **8.78**, which indicates that every **£1 million** of UK publicly funded or charity

[41] For more detail on the implementation of the QALY methodology within economic impact assessments, see HM Treasury's (2022) Green Book.
[42] Such labour market benefits have been quantified in other studies (e.g., Hilhorst and Lockey (2019)), but are not accounted for here. Therefore, the estimated benefits are likely to under-estimate the true economic impact benefits of the Institute's and the SCS's research.

funded cancer research results in **£8.78 million** of future net QALY benefit to the UK in present value terms.[43]

To estimate the net QALY benefit associated with the CRUK Scotland Institute's and School of Cancer Sciences' research activities, we apply this multiplier to the approximately **£31 million** of UK publicly funded and charity funded research income received by the Institute and the SCS in 2021-22 (again see Figure 11).[44] We thus estimate that the research conducted by the CRUK Scotland Institute and School of Cancer Sciences in 2021-22 will result in a future net QALY benefit to patients of **£273 million**.[45]

A2.3.3 Impact of crowded-in privately funded research

Alongside the net QALY benefits of publicly funded and charity funded cancer research, another strand of academic literature suggests that publicly funded and charity funded expenditure in research and development (R&D) also 'crowds in' additional private sector research funding. In other words, public and charity research funding encourages private funders to invest in additional research (e.g., to further develop and commercialise the initial fundamental R&D that was undertaken).

We have quantified the economic impact of this crowding-in of privately funded research using estimates from Sussex et al. (2016), who found that, in the UK, a 1% increase in government and charity funded biomedical and health R&D expenditure is associated with a 0.81% increase in private sector pharmaceutical R&D spending. This elasticity figure was converted to a monetary multiplier using data on total UK R&D expenditure by funding source (see Office for National Statistics, 2022c). The resulting estimated multiplier of **1.52** indicates that every **£1 million** of UK publicly funded or charity funded cancer research results in an additional **£1.52 million** of privately funded cancer research.[46]

As with the above-discussed net QALY benefits (see Section A2.3.2), we apply this multiplier to the **£31 million** of UK publicly funded and charity funded research income received by the CRUK Scotland Institute and the School of Cancer Sciences in 2021-22. Hence, we

[43] Glover et al. (2014)'s benefit figures use value of £25,000 per QALY (in 2011 prices), but the best practice QALY value has since been updated to £70,000 (in 2020 prices) (see HM Treasury's Green Book (HM Treasury, 2022)). Therefore, the study's original QALY benefit figures were re-calculated using a QALY value of £60,129 (which represents a £70,000 QALY figure converted to 2011 prices using CPI inflation (Office for National Statistics, 2023)).
The multiplier was then calculated based on the level of public and charity cancer research funding invested in 1976 and the resulting estimated total net QALY benefits associated with this funding (adjusted for the difference in QALY values) that were incurred between 1991 and 2010 (all in 2011 prices). In line with Glover et al.'s analysis, these calculations assume that it takes 15 years for cancer research to result in patient benefits, and that these benefits then last for 20 years (i.e., that the patient benefits associated with cancer research funding provided in 1976 occurred between 1991 and 2010). The benefits were aggregated over the 20-year period and discounted to net present value (NPV) terms using a 1.5% real discount rate (based on HM Treasury (2022) Green Book guidance on the best practice real discount rate to use for the estimation of QALYs in NPV terms). Dividing the benefits by the associated level of investment, this allowed us to calculate the QALY return on cancer research as a monetary multiplier.
We also undertook sensitivity checks in relation to model assumptions around time lags and effect duration, which did not substantially change the identified multiplier.

[44] The core relevant literature used here focuses exclusively on the net QALY benefits associated with UK publicly funded and charity funded cancer research but excludes privately funded research (and only limited research exists on any corresponding effects associated with privately funded research of this type). While it is likely that privately funded cancer research also carries substantial benefits, we interpret the literature conservatively, by estimating only the net QALY benefits associated with UK publicly and charity funded research (and assuming that the QALY benefits associated with other types of research funding are zero).

[45] Note that this benefit will take place over many years in the future, but is discounted to net present values in 2021-22 prices (using a 1.5% real discount rate (as per HM Treasury (2022) Green Book guidance)).

[46] Sussex et al. (2016) do not specify an exact timeframe over which the impact occurs. They report that 44% of the impact occurs within one year, with the remainder expected to occur over multiple subsequent decades. For this analysis, as there is no specific information on the timeframe for the remaining 56% of impact, we have assumed that the crowded-in research takes place within the same financial year as the CRUK Scotland Institute's and SCS's research. This assumption is likely to have a relatively minor impact on the estimated multiplier, given that nearly half of the impact occurs in the first year.

estimate that the CRUK Scotland Institute's and the School of Cancer Sciences' publicly funded and charity funded research crowds in **£47 million** of subsequent additional privately funded cancer research throughout the UK. To avoid double-counting[47], we then deduct the **£9 million** of private research income[48] received by the Institute and the SCS themselves, thus arriving at an estimated **£39 million** of external private sector research that is 'crowded in' as a result of the institutions' research.[49]

As with the expenditures of the CRUK Scotland Institute and the SCS, this crowded-in research activity is expected to generate indirect and induced economic impacts throughout the UK economy. In this instance, these additional knock-on effects were estimated by applying the relevant economic multiplier associated with the economic activities of the UK's scientific R&D sector as a whole (estimated at **2.56**).[50] Applying this multiplier to the estimated **£39 million** of external privately funded crowded-in cancer research as a result of the activities of the Institute and the SCS, we estimate that the direct, indirect and induced economic impact associated with this crowded-in R&D stands at **£99 million**.

A2.4 The impact of teaching and learning activities

As a final core strand of economic impact associated with the activities of the CRUK Scotland Institute and the SCS, we estimate the impact of the institutions' teaching and learning activities. Specifically, we estimate the net benefits to students/graduates and the Exchequer associated with postgraduate research students (i.e. Doctorate degree students) who are taught at the Institute and the SCS.[51] Using the same methodological approach that was applied to estimate the economic impact of teaching and learning activities across the University of Glasgow as a whole[52], the analysis captures the enhanced labour market benefits and taxation receipts (minus the costs of attendance/provision) associated with students completing Doctorate degrees at the School of Cancer Sciences, which includes students who are taught in collaboration with the CRUK Scotland Institute (i.e., whose Doctorate degree is supervised by Institute staff).

A2.4.1 The 2021-22 cohort of postgraduate research students taught at the SCS and CRUK Scotland Institute

The analysis of the economic impact of teaching and learning activities focuses on the **2021-22 cohort of UK domiciled students enrolled at the School of Cancer Sciences**, i.e., on the **39** UK domiciled students[53] who started postgraduate research qualifications at the SCS

[47] Specifically, this adjustment is made to avoid double-counting with the indirect and induced effect associated with the Institute's and the SCS's expenditure that was funded through private research income (see Section 3).
[48] I.e., research income received from sources other than UK public sources or UK charities.
[49] Note that the figures here do not add up precisely due to rounding.
[50] Again, the relevant multiplier is based on the above-described Input-Output analysis (see Section 3 and Annex A2.2.2). We make use of the estimated economic multiplier associated with the UK scientific R&D sector as a whole (as opposed to a multiplier specifically associated with the economic activity of the *Scottish* scientific R&D sector), as it is not known where in the UK the additional crowded-in privately funded R&D takes place. In this case, compared to the multi-regional Input-Output analysis described in Section 3 and Annex A2.2.2, the multiplier here is based on the more granular industry breakdown available from the UK-wide Input-Output tables (also see Table 8 in Annex A2.2.3).
[51] All students in the relevant cohort were undertaking postgraduate research qualifications; specifically, all of these students were enrolled in Doctorate degrees. Throughout this report, we therefore use the terms 'postgraduate research qualifications' and 'Doctorate degrees' interchangeably.
[52] Again, see London Economics (2021).
[53] In addition, there were **29** non-UK domiciled students who started postgraduate research qualifications at the SCS in 2021-22. It is possible that a proportion of these international students will remain in the UK to work following completion of their studies (and, similarly, that UK domiciled students might decide to leave the UK to pursue their careers in other countries). However, given the uncertainty in predicting the extent to which this is the case, and the difficulty in assessing the net labour market returns for students not resident in the UK post-graduation, the analysis of teaching and learning focuses on UK domiciled students only. In other words, we assume that all UK domiciled students will enter the UK labour market upon graduation, and that non-UK students will leave the UK upon completing their qualifications at the SCS.

in 2021-22. This includes **14** students whose Doctorate degree was supervised by a staff member at the CRUK Scotland Institute[54], and **25** students supervised by SCS staff instead. In terms of **mode of study**, most students in the cohort were undertaking their studies on a full-time basis, with few students enrolled on a part-time basis. In terms of **domicile**, the majority of students in the cohort were from Scotland, with a small number of students domiciled in England or Wales instead.[55]

A2.4.2 Adjusting for completion rates

To aggregate the individual-level impacts of the SCS's and CRUK Scotland Institute's teaching and learning activities, we adjusted the above number of first-year students in the 2021-22 cohort (i.e., the number of 'starters') to account for expected **completion rates**.

To achieve this, we applied the same assumed completion rates as we did for our previous analysis of the economic impact of the University of Glasgow as a whole.[56] Specifically, the assumptions were based on the completion outcomes of the 2012-13 and 2013-14 cohorts of the University's students (i.e. 2012-13 and 2013-14 'starters', with their completion outcomes measured 8 years after the initial enrolment) - broken down by study mode, study intention, and study completion. These completion data capture the number of students (across the two cohorts) who completed their intended qualification, completed a different (usually lower) qualification, or discontinued their studies without being awarded a qualification (for students who originally intended to complete postgraduate degrees, this was modelled as completion at 'other postgraduate' level[57]).

Based on these completion rate data, we assume that, out of the total of **39** students in the 2021-22 cohort of students starting postgraduate research qualifications at the School of Cancer Sciences, **31** students are expected to complete their intended Doctorate degree, while **8** students are expected to complete only one or more modules associated with their degree before dropping out (modelled as completion at 'other postgraduate' level).[58]

A2.4.3 Estimating the returns to higher education qualifications

Our assessment of the returns to higher education qualifications attained at the SCS and the Institute (in the 2021-22 cohort) makes use of our previous estimates of these benefits as part of our analysis of the impact of teaching and learning across the University of Glasgow as a whole (which was based on the cohort of students starting higher education qualifications at the University in 2018-19). While the following provides a brief summary of the underlying methodological approach (including a number of core adjustments made for

[54] This includes Institute staff who were either the primary or secondary supervisor of the relevant students' postgraduate research degree work.
[55] Again, the analysis here focuses on UK domiciled students only.
[56] Again, see London Economics (2021).
[57] In other words, we assume that students who started but dropped out of postgraduate studies were assumed to at least complete one or several standalone modules associated with their intended qualification, so that these students' completion outcomes were modelled as completion at 'other postgraduate' level. As a result, the total assumed completion rates sum up to 100%.
[58] Note that the assumed completion rates here are based on University of Glasgow data for students in *any* subject of study, rather than focusing only on those relevant subjects taught at the SCS. Most students in the 2021-22 cohort of School of Cancer Sciences students were undertaking Doctorate degrees in Medicine (as compared to a much wider subject mix for student enrolled across the range of University of Glasgow schools and colleges). As we assume that the completion rates among Medicine students are typically higher than the average completion rates across all subjects of study taught at the University of Glasgow as a whole, it is expected that the assumed completion rates here somewhat underestimate the 'true' completion rates among students attending the SCS specifically.

the analysis here), for further detail, please see our previous report on the economic impact of the University[59].

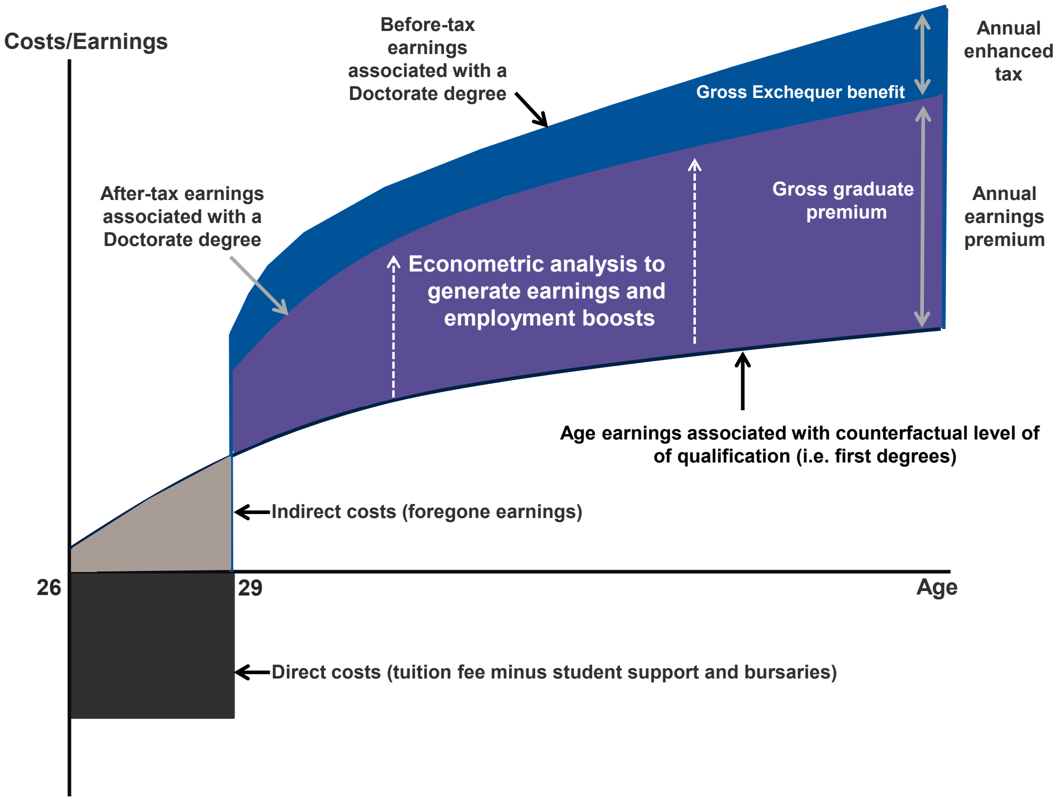
The fundamental objective of the analysis is to estimate the **gross and net graduate premium** to the individual and the **gross and net public purse benefit** to the Exchequer associated with higher education qualification attainment (i.e., postgraduate research qualifications in this instance[60]), defined as follows:

- The ***gross* graduate premium** associated with qualification attainment is defined as the **present value of enhanced after-tax earnings** (i.e., after income tax, National Insurance and VAT are removed, and following the deduction of any foregone earnings during study) relative to an individual in possession of the counterfactual qualification. Here, reflecting the prior attainment levels of students in the 2021-22 cohort of SCS students, all results are estimated relative to individuals in possession of **first degrees** as the relevant counterfactual;
- The ***gross* benefit to the public purse** is defined as the **present value of enhanced taxation** (i.e. income tax, National Insurance and VAT, following the deduction of the costs of foregone tax earnings during study) relative to an individual in possession of the counterfactual qualification;
- The ***net* graduate premium** is defined as the gross graduate premium *minus* the present value of the direct costs associated with qualification attainment; and
- Similarly, the ***net* benefit to the public purse** is defined as the gross public purse benefit minus the direct Exchequer costs of provision during the period of attainment.

As a core component of the analysis, we estimate the **labour market return associated with higher education qualifications**, rather than simply assessing the labour market outcomes achieved by individuals *in possession* of these qualifications. The standard approach to estimating this labour market return is to undertake an **econometric analysis** where the 'treatment' group consists of those individuals in possession of the qualification of interest (i.e., postgraduate research qualifications in this instance), and the 'counterfactual' group consists of those individuals with comparable personal and socioeconomic characteristics but with the next highest level of qualification (i.e., first degrees in this instance). The rationale for adopting this approach is that the comparison of the earnings and employment outcomes of the treatment group and the counterfactual group 'strips away' those other personal and socioeconomic characteristics that might affect labour market earnings and employment (such as gender, age, or sector of employment), leaving just the labour market gains attributable to the qualification itself (see Figure 12 for an illustration of this).

[59] Again, see London Economics (2021).
[60] As well as 'other postgraduate' learning, for those students in the 2021-22 cohort who are expected to only complete one or more module of their intended Doctorate degree at the SCS before discontinuing their studies.

Figure 12 Estimating the gross graduate premium and gross Exchequer benefit



Note: The analysis assumes that the opportunity costs of foregone earnings associated with higher qualification attainment are applicable to full-time students only. For part-time students, we have assumed that these students are able to combine work with their academic studies and as such, do not incur any opportunity costs in the form of foregone earnings. This illustration is based on an assumed average age at enrolment among full-time postgraduate research degree students at the SCS in the 2021-22 cohort of 26, and we have assumed that a full-time postgraduate research degree requires 3 years to complete.
Source: London Economics

Based on this econometric analysis, the **gross graduate premium** is then estimated as the **present value of the enhanced post-tax earnings** of individuals in possession of postgraduate research degrees (i.e., after income tax, National Insurance and VAT are removed, and following the deduction of foregone earnings) relative to an individual in possession of the counterfactual qualification (i.e., first degrees) – estimated separately by gender and mode of study.

The **gross benefits to the Exchequer** are derived from the enhanced taxation receipts that are associated with a higher likelihood of being employed, as well as the enhanced earnings associated with more highly skilled and productive employees. Based on the analysis of the lifetime earnings and employment benefits associated with postgraduate research qualification attainment, combined with administrative information on the relevant taxation rates and bands (from HM Revenue and Customs), we estimated the **present value of additional income tax, National Insurance and VAT associated with postgraduate research qualification attainment** (again relative to first degrees, and separately by gender and mode of study).

The difference between the gross and net graduate premium relates to **students' direct costs** of qualification acquisition[61]. These direct costs refer to the **tuition fees paid by the**

[61] Note again that the *indirect* costs associated with qualification attainment, i.e., foregone earnings during the period of study (for full-time students only), are already deducted from the gross graduate premium.

student net of any **fee waivers or other bursaries** provided by the University of Glasgow, and minus any applicable **Postgraduate Doctoral Loans** provided by the Student Loans Company (SLC, for students from England and Wales)[62,63]. In this respect, the student benefit associated with student loan support (where applicable) equals the **Resource Accounting and Budgeting charge** (RAB charge), capturing the proportion of the loan that is not repaid.

Conversely, this RAB charge constitutes the **direct costs**[64] **to the public purse** associated with funding postgraduate research students, in relation to the **interest rate or write-off subsidies** that are associated with Postgraduate Doctoral Loans. Again, the analysis tailors this cost to the student's specific Home Nation of domicile[65].

These direct costs associated with qualification attainment to both students and the Exchequer (by study mode and home nation domicile) are calculated from start to completion of a student's learning aim. Throughout the analysis, to ensure that the economic impacts are computed in **present value** terms, all benefits and costs occurring at points in the future were **discounted** using the standard HM Treasury Green Book real discount rate of **3.5%** (see HM Treasury, 2022). Deducting the resulting individual and Exchequer costs from the estimated gross graduate premium and gross public purse benefit, respectively, we arrive at the estimated **net graduate premium** and **net public purse benefit** per student.

Based on our previous analysis of the impact of teaching and learning associated with students studying at the University of Glasgow as a whole, for the assessment of the net graduate premium and net Exchequer benefit per student in the relevant 2021-22 SCS cohort, we **adjusted our previous estimates for**:

- The specific characteristics of students in the cohort. Specifically, the above-described econometric analysis of the labour market returns to higher education qualifications was **adjusted to account for the specific subject composition of SCS students**, to reflect the significant variation in post-graduation labour market outcomes depending on the subject of study.[66] We further adjusted the estimates

[62] Given the differing approach to public support funding for students from each of the UK Home Nations, the direct costs incurred by students were assessed separately for students from Scotland, England, and Wales. While English and Welsh domiciled students undertaking Doctorate degrees (anywhere in the UK) have access to Postgraduate Doctoral Loans (from the SLC) to help finance their tuition fees and/or living costs, there is currently no corresponding support scheme available to Scottish domiciled Doctorate degree students from the Students Awards Agency for Scotland (SAAS). As a result, we have assumed that there is no student support available for Scottish domiciled students in the relevant 2021-22 SCS cohort.
[63] Note again that there were no students in the 2021-22 cohort of SCS students that were domiciled in Northern Ireland.
[64] Again, any indirect costs to the public purse in terms of foregone income tax, National Insurance and VAT receipts foregone during the period of qualification attainment (applicable to full-time students only) are already deducted as part of the gross public purse benefits.
[65] Our previous analysis of the impact of teaching and learning of higher education qualifications attained at the University of Glasgow as a whole (London Economics, 2021) *also* took account of the additional Exchequer cost of teaching grant funding administered by the Scottish Funding Council (SFC). However, we assume that this teaching grant funding typically does not apply to students undertaking postgraduate research qualifications, so this cost was excluded from the analysis here.
[66] In other words, the marginal earnings and employment returns associated with postgraduate research qualifications here are adjusted for the fact that most students in the 2021-22 cohort of School of Cancer Sciences students were undertaking Doctorate degrees in Medicine (as compared to a much wider subject mix for student enrolled across the range of University of Glasgow schools and colleges), where the labour market returns associated with qualifications in Medicine subjects are typically significantly larger than the corresponding labour market returns to qualifications in other subjects.
Note that, as a conservative approach, the net graduate premiums and Exchequer benefits associated with completion at 'other postgraduate' level (i.e., for students in the SCS cohort who are expected to drop out of their studies after completing one or several modules associated with their intended Doctorate degree) have *not* been adjusted for the specific subject mix of SCS students. Instead, they are based on average marginal earnings and employment returns across all subjects of study (i.e., across all graduates included in the underlying Labour Force Survey data on which the analysis is based, irrespective of subject of study), to ensure that these returns for 'non-completers' are not overestimated.

for the **average age at enrolment**[67] and **study intensity**[68] among students in the 2021-22 SCS cohort (separately by mode of study); and

- **Inflation**, to convert the estimates (which were originally calculated in 2018-19 prices) to 2021-22 prices, using CPI inflation data published by the Office for National Statistics (2023a).

All other assumptions remained the same as in our analysis of the impact of the teaching and learning activities of the University of Glasgow as a whole.

[67] Specifically, based on the above-mentioned HESA student data provided by the SCS, we assumed an average age at enrolment of students in the 2021-22 SCS cohort of 26 for students enrolled in full-time Doctorate degrees, and 36 for students undertaking Doctorate degrees on a part-time basis (this compares to 27 and 39 for full-time and part-time postgraduate research students in the overall 2018-19 cohort of University of Glasgow students, respectively; see London Economics (2021)).

[68] The average study intensity (separately by study mode) was calculated by dividing the number of students in the cohort in full-time equivalents by the corresponding number of students in terms of headcount (again based on HESA data provided by the University of Glasgow). The resulting average study intensity assumptions then fed into the assumed average tuition fees for part-time students, as well as the estimated fee waivers and other bursaries for full-time and part-time students (again, see London Economics (2021) for further detail).

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