University of Strathclyde Glasgow

Fraser of Allander Institute

The economic impact of university research funding in Scotland

October 2023

UNIVERSITY of STRATHCLYDE
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The Fraser of Allander Institute

Disclaimer

The analysis in this report has been conducted by the Fraser of Allander Institute (FAI) at the University of Strathclyde. The FAI is a leading academic research centre focused on the Scottish economy.

The report was commissioned in January 2023 by the Scottish Funding Council.

The analysis and writing-up of the results was undertaken independently by the FAI. The FAI is committed to informing and encouraging public debate through the provision of the highest quality analytical advice and analysis. We are therefore happy to respond to requests for factual advice and analysis. Any technical errors or omissions are those of the FAI.

Executive summary

The research conducted by universities makes an important contribution to the Scottish economy and society. Such research advances knowledge, develops new products and processes, and increases productivity and economic growth.

University research is also a strategic investment. Scotland has more than a population share of the UK's researchers and is often cited as "punching above its weight" in terms of research impact and quality.

Universities are also cited as a key reason for foreign direct investment in Scotland, highlighting their contributions to the goals of the National Strategy for Economic Transformation (NSET).

The Scottish Funding Council (SFC) is one of the largest funders of Scottish university research, providing £286m in research and knowledge exchange funding during the 2019-20 academic year (27% of the total).

In the following report, we evaluate the impact of research funding on Scotland's economy. As we emphasise below, the estimates are the "narrowest" expression of economic impact, reflecting only the economic activity and jobs directly supported by investment in research. We estimate the economic contribution of:

- SFC grants for research and knowledge exchange to universities;
- All university research funding; and
- All R&D spending.

We estimate that in 2019, SFC research and knowledge exchange funding supported:

- Over 8,500 full-time equivalent jobs;
- £570 million in output; and,
- £400 million in gross value-added (GVA).

All R&D spending supported nearly 60,000 jobs, over £5,300 million in output, and £3,225 million in GVA.

We also compare multipliers for research spending to other sectors in the Scottish economy. We find that output, GVA, and employment multipliers for university research funding are typically higher than the average sector in Scotland, particularly when wage spending by employees is taken into account.

These input-output results are narrow estimates that account for the effects of spending on research, but they do not capture spillovers like productivity gains, innovation, and agglomeration, nor do they include wider societal benefits.

We review the literature and find an estimate of 20% return on investment (ROI) for public R&D in the UK. In other words, this figure suggests that for every £1 spent on public R&D, there are productivity spillovers worth an additional £0.20.

After benchmarking Scotland against other regions of the UK on metrics related to ROI for R&D, we posit that Scotland's ROI to public R&D may be higher than the average for the UK.

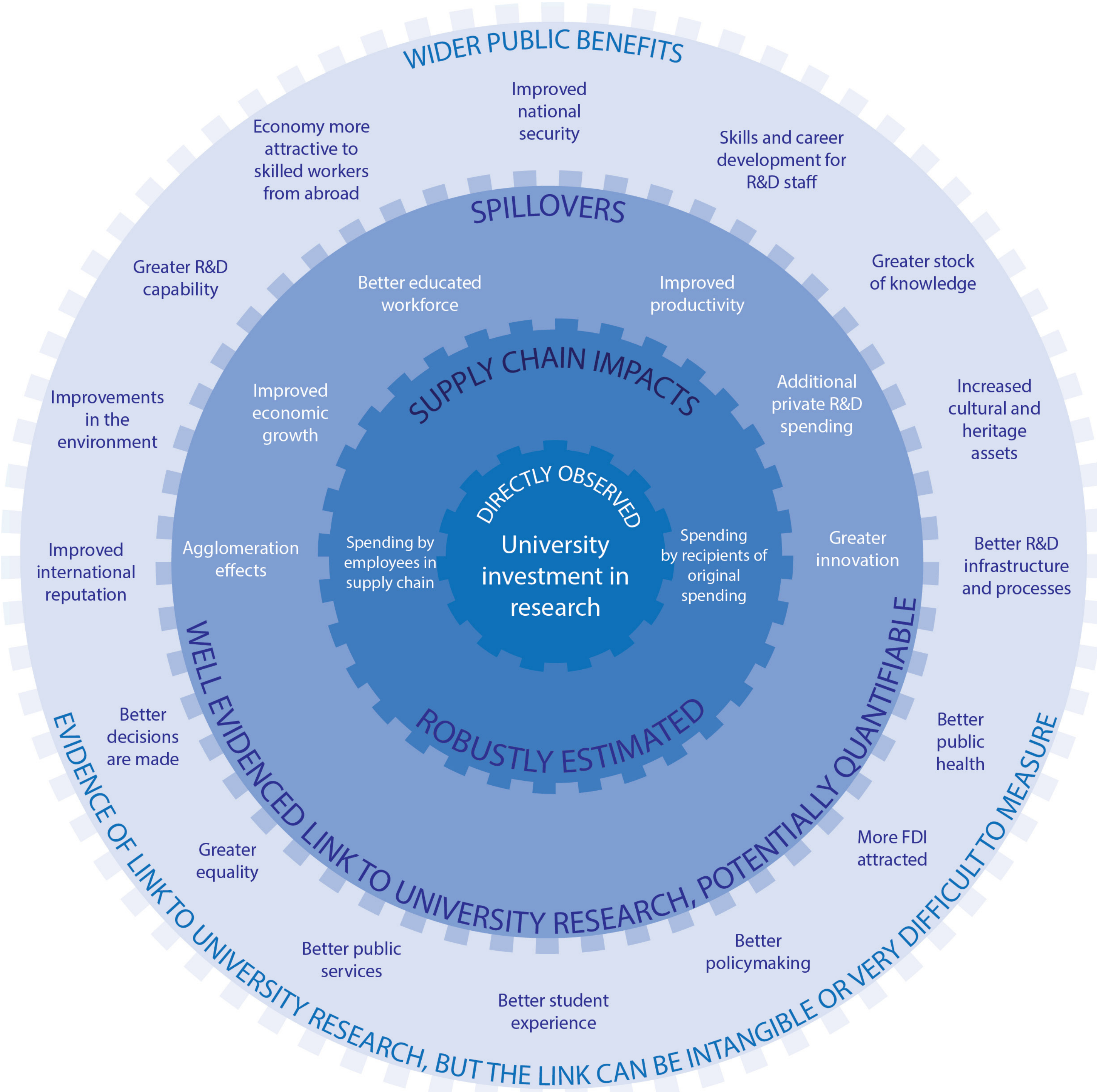
There are also a number of social benefits to research that cannot be appropriately measured or monetised.

We conclude the report by discussing approaches to estimating the return on investment in research.

Although these approaches can provide an estimate of the value of R&D spillovers to productivity and knowledge beyond that provided by the input-output modelling, they will still likely not capture other benefits such as international reputation, policy influence, and other less tangible impacts. In these cases, case studies and consideration of the less tangible impacts are useful for understanding the impact of research in a given field.

THE VALUE OF UNIVERSITY RESEARCH

The diagram below shows the different kinds of benefits that research can generate – from the **narrow** benefits generated from spending on research in the **supply chain**, to the **more intangible** benefits to society, such as contributing to the country's international reputation, increasing the stock of knowledge, or helping to ensure better decisions are made.



The Scottish Funding Council (SFC) invested **£286m** in unversity research in Scotland in 2019-20

In 2019-20, in addition to SFC funds, Universities received **£791m** in other income for research – the next-biggest chunk from research councils (£270m)

Across the economy, including businesses, government and universities, **£2.8bn** was invested in R&D in Scotland in 2019

SUPPLY CHAIN IMPACTS

SFC Funding supported over **8,500** full-time equivalent jobs and **£400m** in GVA

All R&D spending supported nearly **60,000** FTE jobs, and **£3,225m** in GVA

Output, GVA, and employment multipliers for university research funding are **typically higher** than the average sector in Scotland

SPILLOVERS

Recent literature on potential spillovers from University research in the UK indicates that an **additional 20% impact** can be generated from productivity improvements which can result from research spillovers

Scotland's productivity spillover effect may be **greater than the UK average**, given the type and nature of research carried out here, including:

- More impactful research in technology
- More research outputs in science, technology, engineering and maths (STEM) subjects
- More research council funding for medical research

WIDER PUBLIC BENEFITS

Various social benefits to research also exist but these cannot be appropriately measured or monetised. Approaches in the literature can provide an estimate of the value of R&D spillovers to productivity and other outcomes, however will **not capture other benefits** such as international reputation, policy influence, and other less tangible impacts.

In these cases, **case studies** and consideration of intangible impacts are useful for understanding the impact of research in a given field.

Introduction

Higher education institutions (HEIs) form an important part of the Scottish economy: they train students, employ many people, and perform instrumental research in a number of areas.

More broadly, research and development (R&D) across different sectors of the economy spur innovation, productivity gains, and economic growth.

Scotland's National Strategy for Economic Transformation highlights entrepreneurship, innovation, and productivity as key areas of growth for Scotland, along with further development of a skilled workforce.

Research and other HEI activities, as well as R&D in general, are key contributors to these goals.

Through funding provided by the Scottish Government, the Scottish Funding Council (SFC) is one of the largest funders of Scottish HEI research.

Other sources include UK Research and Innovation (UKRI), government departments, business/industry, and third-sector organisations such as the Wellcome Trust and the British Heart Foundation.

Higher education accounted for 41% of R&D spending in 2019, and businesses accounted for 51%; the rest was made up of government-funded R&D and R&D funded by private non-profits.

This report estimates the economic contribution to Scotland's economy of SFC core research and knowledge exchange funding for HEIs, all HEI research funding, and R&D overall in Scotland.

We focus on 2019 both based on available data and to avoid distortions in the economy introduced by the Covid-19 pandemic in 2020.

The contribution modelled here represents a conservative but robust estimate of the additional spending in the Scottish economy generated by research investment. The true impact, however, is much broader and difficult to measure.

We conclude the report by characterising the broader impacts of research funding and the extent to which they can be measured or estimated. In doing so, we highlight important areas for future research.

The report proceeds as follows:

- Section 2 provides a summary of research funding in HEIs and other R&D in Scotland;
- Section 3 evaluates the economic contribution of SFC core research and knowledge exchange funding, all HEI research funding, and all R&D spending in Scotland in terms of output, jobs, and gross value-added (GVA); and,
- Section 4 discusses spillovers from R&D and international evidence on the wider impact of R&D, as well as approaches to considering the value of the intangible benefits of university research.

Higher education research and other R&D in Scotland

Who funds university research in Scotland?

Public funding for university research in Scotland is delivered via a dual support mechanism comprising a block grant given by the SFC alongside competitively awarded grants from UK Research and Innovation (UKRI), incorporating the UK-wide Research Councils. Other funding comes from the UK government, charities, private businesses, and international sources.

For the 2019-20 academic year, the largest research funding source for Scottish HEIs was the SFC, which contributed 27% (£286 million) of the total. **See Chart 1.**

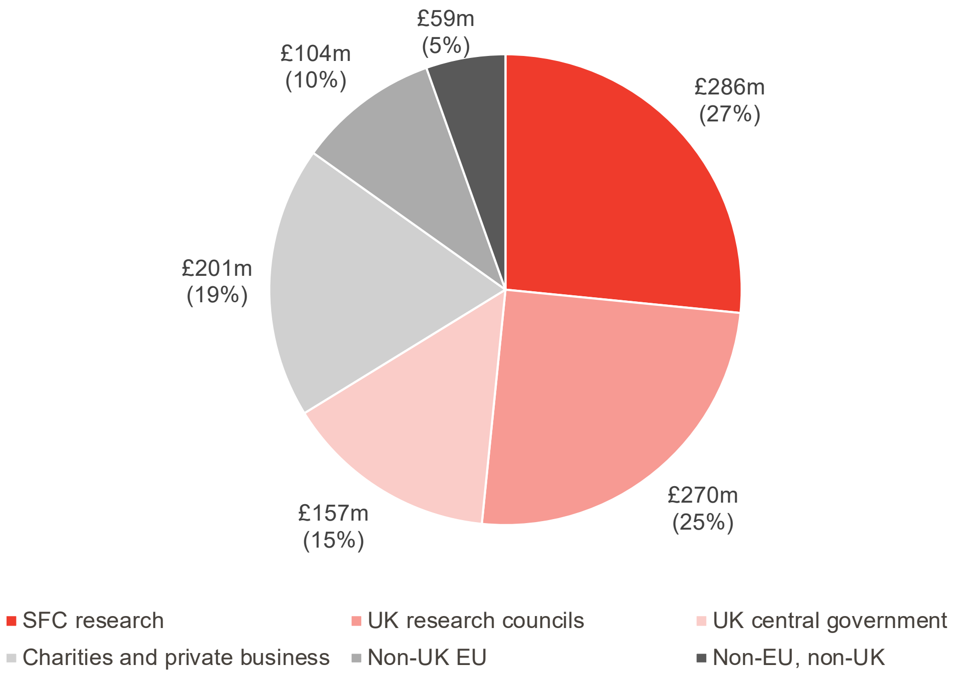
SFC funding was followed closely by UK Research Councils providing 25% (£270 million).

The UK government (including central government, devolved governments, local authorities, and health and hospital authorities) accounted for 15% of total funding (£157 million), and charities, industries, and other sources for 19% (£201 million) of the funds.

Non-UK EU sources contributed 10% (£104 million), while other non-EU, non-UK sources accounted for the remaining 5% (£59 million).

This distribution illustrates a diverse mix of Scottish, UK and international funding sources underpinning Scotland's university research activities.

Chart 1: Scottish university research funding breakdown, 2019–20



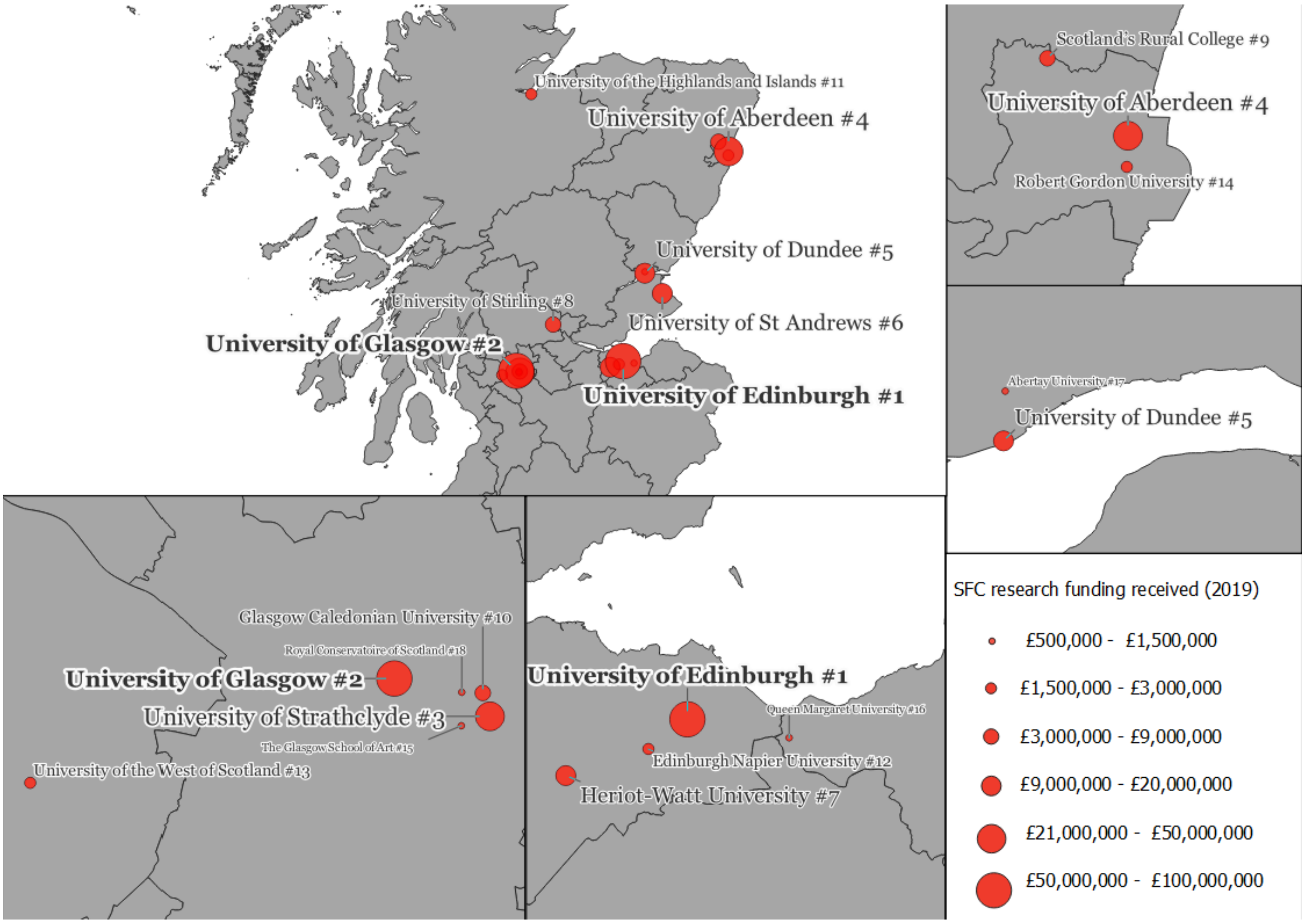
Source: *HESA, SFC*

Where does the SFC fund research?

SFC core research and knowledge exchange funding for universities amounted to £290 million in 2019.[1] These grants are distributed across Scottish HEIs, with a notable focus on key institutions in Edinburgh and Glasgow. **See Figure 1.**

Funding is distributed according to a funding model shaped in consultation with the higher education sector based on supporting excellence wherever it is found.

Figure 1: SFC core research and knowledge exchange funding by HEI, Scotland, 2019



Note: *Numbers may not sum perfectly due to rounding. The Open University receives approximately £280,000 in knowledge exchange funding from SFC but does not appear on the map because it does not have a physical campus.*

Source: *SFC*

Funding for 2019 ranges from around £660k for the Royal Conservatoire of Scotland to nearly £90 million allocated to the University of Edinburgh.

Almost 60% of the total funding is allocated to three universities: the University of Edinburgh, the University of Glasgow, and the University of Strathclyde.

Furthermore, the City of Edinburgh, Glasgow City, and Aberdeen City emerge as the top three authorities with the highest concentration of funding, accounting for 37%, 31%, and 11% of total funding, respectively.

1 This figure represents a weighted average for the 2019 calendar year of spending on SFC's Research and Innovation Grants for 2018-19 (£296 million) and 2019-20 (£285 million).

How does university research fit into Scottish R&D?

Defining R&D

Total R&D spending is estimated every year as part of Scotland's national accounts. R&D expenditure is measured in accordance with the globally recognised Frascati methodology for collecting and reporting on research and experimental development (ONS, 2017; OECD, 2015).

The Frascati Manual uses the following definition of R&D:

> *"…creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge."*

Under this definition, an activity can only be considered R&D if it has an appreciable novelty.

Components of R&D

R&D expenditure within an organisation or sector can be approached in two ways:

- The **source of funding** allocated for R&D, or
- Who **performs** the R&D.

Consequently, the amount of R&D carried out by an organisation or sector does not always match the funding they allocate for it.

For instance, the Scottish higher education sector carried out R&D valued at approximately £1.15 billion in 2019, yet the majority of funding for this research originates from other sectors, including the government.

Gross Expenditure on Research and Development (GERD) measures all the R&D **performed** in Scotland and is the preferred metric for measuring and comparing R&D. In 2019, total Scottish GERD was £2.79 billion, a 34% increase since 2011.

The following four R&D components make up total GERD:

- Businesses (BERD)
- The public sector (GovERD)
- Higher education institutions (HERD)
- Private non-profit organisations, such as research charities (PnP)

University research funding, including funding from SFC and other research councils, is included in the total R&D figure under HERD.

Although methods of accounting for HERD and BERD have recently changed, this report uses statistics calculated using methods in place in 2019. **See Box 1.**

Our approach maintains consistency with the data used to create the underlying 2019 input-output tables, although the use of the revised data would likely result in larger estimates of total economic impact. The composition of GERD has changed considerably over the past decade. **See Chart 2.**

The share of R&D done by businesses (BERD) has risen consistently from 39% in 2011 to 51% in 2019. At the same time, the contribution of HERD has declined from 51% to 41%. GovERD declined slightly from 9% to 7% over this period, while PnP fluctuated slightly but remained at around 2% of total R&D.

These trends suggest a growing prominence of business enterprises in performing R&D in Scotland.

While the relative contribution of HEIs has declined, it still contributes a large proportion of total R&D spending and has increased in absolute value over time.

Box 1: Accounting for higher education R&D

The ONS introduced new methods of accounting for R&D carried out by HEIs (HERD) and by businesses (BERD) in 2021, alongside new estimates for 2018-2020.

HERD

Instead of the Higher Education Statistics Authority (HESA), HERD data now come from the Transparent Approach to Costing (TrAC) data, collected by the Office for Students. The revised HERD figure for Scotland in 2019 is £1,603 million, a 39% increase from the original estimate.

The uplift in the figure comes from including cross-subsidised R&D expenditure and indirect costs, which were previously omitted.

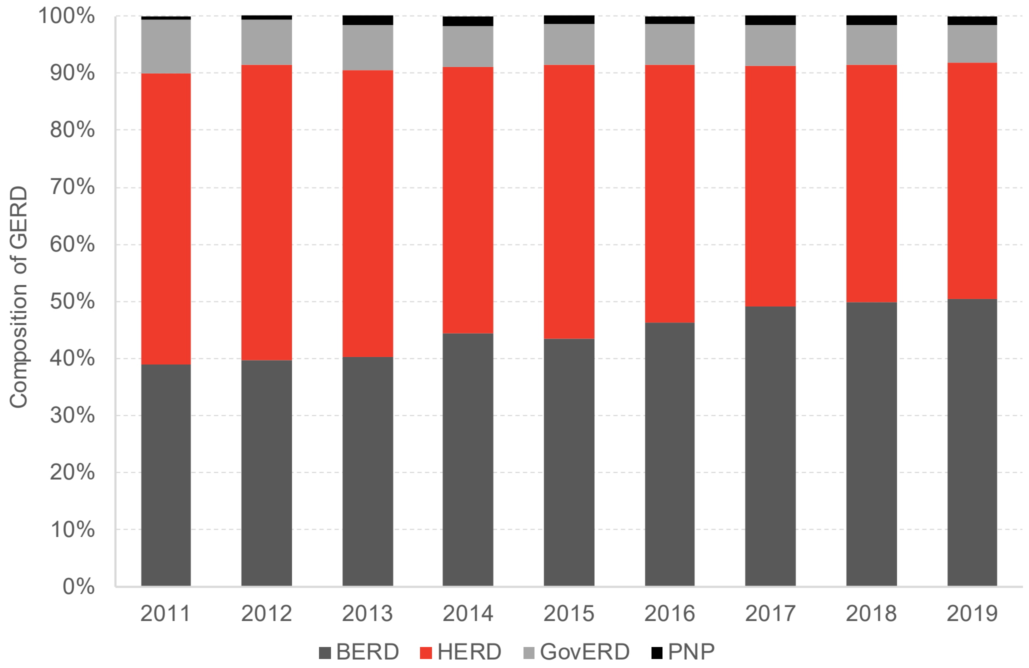
Cross-subsidisation – or cross flows – refers to the R&D work that was performed and funded internally, such as activities funded by surpluses from other non-R&D related operations like tuition fees. The indirect costs include activities that, although not directly a part of the R&D work itself, are necessary for its execution, such as libraries and human resource departments, research offices, and elements of central administration.

BERD

By comparing ONS BERD expenditure statistics to HMRC R&D tax credit statistics, the ONS discovered that many small businesses were missing in their calculations. The BERD methodology has now been improved to better represent these smaller businesses performing R&D.

The better inclusion of smaller businesses resulted in an estimate of BERD that is twice that of the previous estimate (£2.9 billion rather than £1.4 billion).

Chart 2: Components of Scottish GERD, 2011–2019



Source: *Scottish Government*

How does Scottish R&D stack up?

Rest of the UK

While Scotland lags behind the rest of the UK (rUK) in terms of overall R&D expenditure per capita (GERD), it outperforms rUK significantly in higher education R&D expenditure per capita (HERD), demonstrating a clear strategic emphasis on academic research and development.

These investment patterns reflect the importance of university research in Scotland's economy. Scotland had 11% of the UK's FTE research staff in 2021, more than its population share ('Ref 2021', 2023).

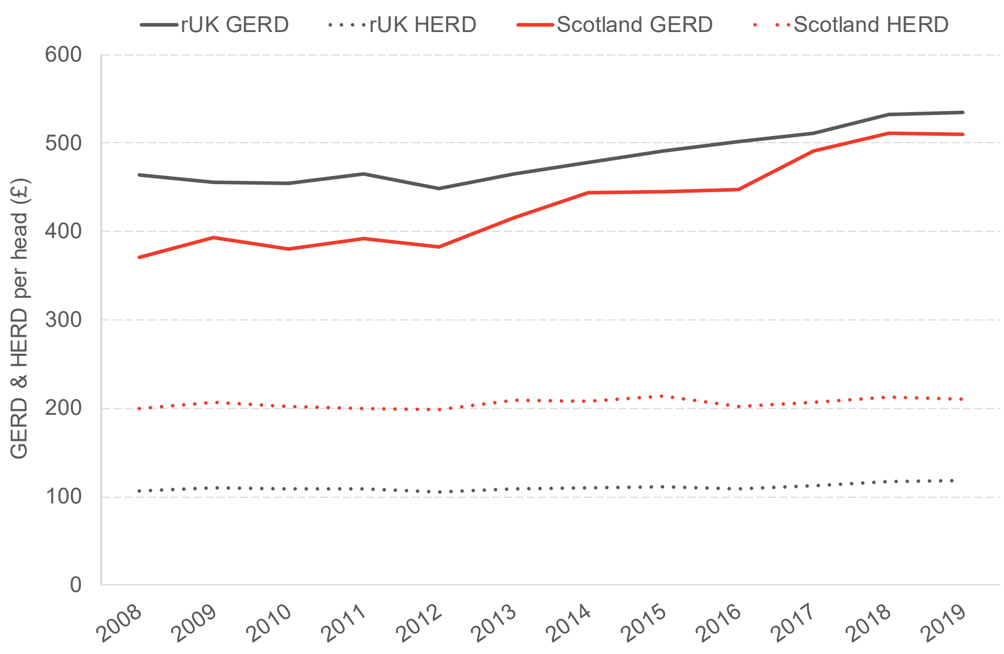
The number of research-active institutions and researchers relative to population is also higher in Scotland than in rUK, requiring greater investment to maintain the sector.

Chart 3 shows the changes in GERD & HERD per head in Scotland and the rest of the UK (rUK) from 2008 to 2019.

GERD per capita in Scotland started at a lower level than the rest of the UK in 2001 (£371 versus £464). Since then, R&D per capita has risen faster, reaching £510 per head compared to £535 in rUK in 2019.

In contrast, Scotland's HERD per capita in 2001 (£200) exceeded that of the rest of the UK (£107). This gap has stayed similar over time, with Scottish HERD per capita reaching £210 compared to rUK's £119 in 2019.

Chart 3: GERD and HERD per capita, Scotland and rUK (2008-2019)



Notes: *R&D per head is expressed in constant prices.*

Source: *Scottish Government; ONS*

University research also plays a notable role in attracting more investment.

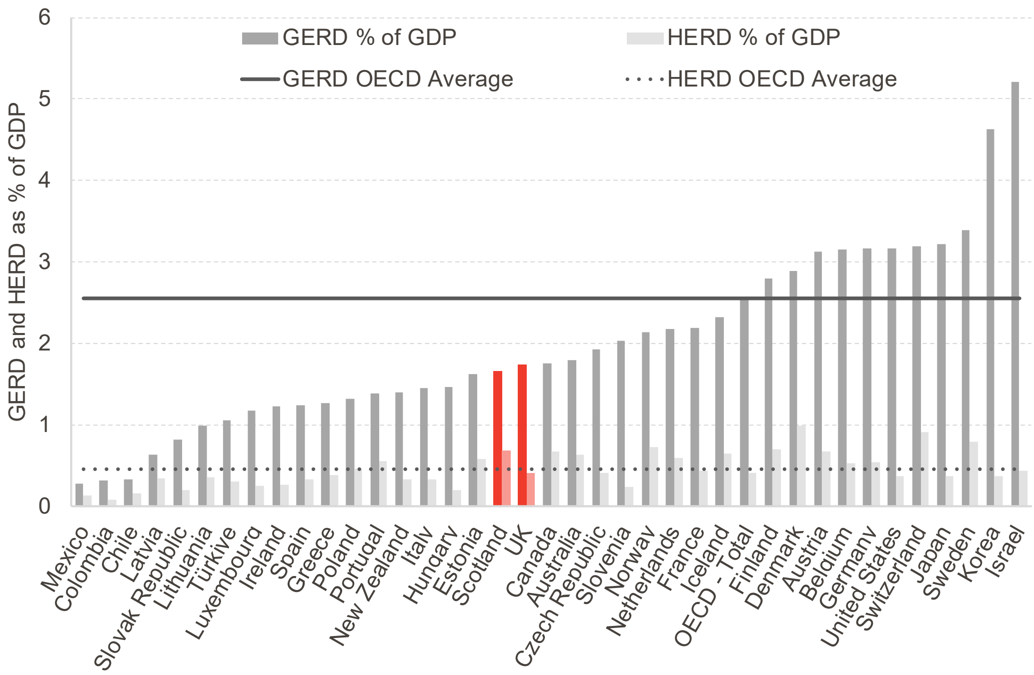
Universities Scotland report that almost half of the incoming foreign direct investment (FDI) projects cited universities as a deciding factor for choosing Scotland, while Ernst and Young find Scotland has the next-highest share of FDI projects in the UK after London.

OECD countries

Scotland's GERD constitutes 1.66% of GDP, situating it below the OECD average of 2.56% (**Chart 4**). It outperforms several countries, including Greece, Spain, and Ireland, but falls short of the UK as a whole at 1.74% of GDP.

Overall, Scotland's investment in R&D relative to GDP is near the middle of the spectrum among OECD nations, suggesting room for growth in this area.

Chart 4: GERD & HERD as proportions of GDP across the OECD (2019)



Source: *OECD*

In contrast, Scotland's HERD spending as a proportion of GDP is higher than the OECD average (0.69% compared to an average of 0.46%).

This pattern is noted in several reports as evidence that Scotland "punches above its weight" in terms of international research (Department for Business, Innovation, and Skills, 2013; Scottish Government, 2018; Campaign for Science and Engineering, 2019; Elsevier Analytical Services, 2019; Kemp and Lawton, 2021; Scottish Funding Council, 2022).

Scotland's high level of HERD per capita when compared internationally also reflects the make-up of our publicly funded research system. In Scotland, there is a focus on universities as the most significant research-performing institutions, whereas other countries undertake more research in independent research institutes and public sector research establishments (PSREs). Scotland's focus on the HE sector reflects the world-class excellence within our university research system.

Modelling the contribution of R&D in Scotland

Universities play an incredibly important role in Scotland's economy by creating a skilled workforce, which is key to business productivity and economic prosperity.

However, it is not their only achievement. Research carried out by universities makes a substantial contribution to the economy, supporting economic activity and jobs across the whole of Scotland as well as boosting productivity and innovation through new knowledge.

Likewise, while R&D is commonly associated with advanced, high-tech companies and pioneering ground-breaking technologies, it is important to recognise that a range of firms regularly spend large sums of money to improve existing products and processes. In turn, this also contributes significantly to the economy, promoting Scottish economic activity and job creation.

In this section, we use a detailed model of the Scottish economy to estimate the economic impact of three different levels of research: SFC funding, all HEI research funding, and all R&D spending in Scotland.

We focus on the impacts of spending on supply chains and jobs in the UK. Notably, estimates in this section do not include the significant beneficial impacts of:

- The value of research towards addressing societal issues such as climate change and social inequality.
- The positive knowledge and innovation spillovers of research within the private, public and third sectors which drive long-term economic growth.
- The long-term value of research outputs that are created as a result of the research, e.g., patents and new technologies.

The results of the input-output modelling presented below are therefore likely to underestimate the true value of R&D in Scotland by a significant margin.

The results provide an evidence-based, robust estimation of the economic impact of spending in the sector, but miss the broader benefits, economic and beyond, that undoubtedly result from R&D. We discuss these issues in more detail in Section 4.

Data sources

This modelling utilises multiple data sources to model the economic impacts of research in Scotland.

We rely on the Research Grant figures from the SFC's 2019 and 2020 Annual Reports as a measure of total SFC research funding.

Statistics on overall HEI research funding (HERD) and Scottish R&D expenditure are taken from the Scottish Government's Gross Expenditure on Research and Development (GERD) 2019 tables.

A detailed sectoral distribution of BERD is not available, therefore we make use of additional data on businesses and growth sectors to distribute business R&D across sectors.

We further supplement these sources with data from the Office for National Statistics (ONS) R&D datasets, particularly where Scottish breakdowns were not available.

The methodology in the Appendix outlines our approach and explains how to interpret our results in more detail.

In 2021, the ONS revised their methodologies for calculating HERD and BERD, and re-estimated statistics for 2018-2020.

Both revisions significantly increased estimated R&D spending for 2019. We use the original statistics in our analysis because the Scottish input-output table for 2019 does not currently account for the higher revised estimates. This approach likely under-estimates the overall impact of HERD and BERD spending, but is more reliable given current data availability.

However, if the revised estimates were modelled, our results would reflect that higher R&D spending had a larger impact on the Scottish economy. The sectors experiencing the highest surge in R&D spending when including the small business uplift at the UK level are:

- Wholesale and Retail Trade;
- Repair of Motor Vehicles and Motorcycles;
- Information and Communication; Financial and Insurance Activities;
- Professional, Scientific and Technical Activities; and Real Estate Activities.

Results

Interpreting our results

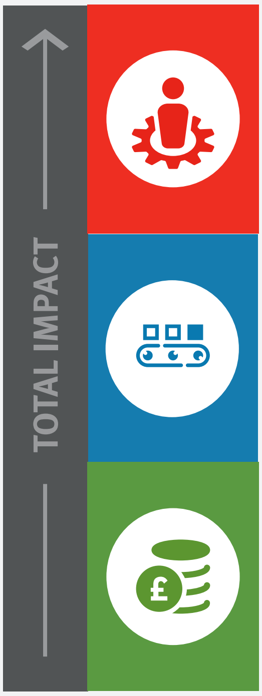
Our results are expressed in terms of output, gross value added (GVA), and employment.

Output refers to the value of sales of all goods and services produced in an economy, similar to turnover. GVA is typically smaller than output because it discounts the value of intermediate goods used in production and counts only the value of all final goods and services produced.

Employment refers to the number of full-time equivalent (FTE) jobs supported by a given amount of spending.

The results highlight the direct, indirect, and induced impacts of research expenditure in Scotland. **Diagram 1** explains each of these impacts.

Diagram 1: Direct, indirect and induced impacts



Direct impacts

SFC, other research councils, and other organisations fund university research and R&D in Scotland. To perform R&D, universities and others purchase goods and services from suppliers. The reaction of suppliers to meet this demand generates output, GVA and employment.

+

Indirect impacts

Their suppliers make purchases from their own suppliers who, in turn, have their own suppliers. The indirect impact measures the output, GVA and employment generated throughout the national supply chain.

+

Induced impact

The employment gained due to the direct and indirect impacts leads to additional wages. These wages are spent on goods and services around the nation, further boosting the economy.

Source: *Fraser of Allander Institute*

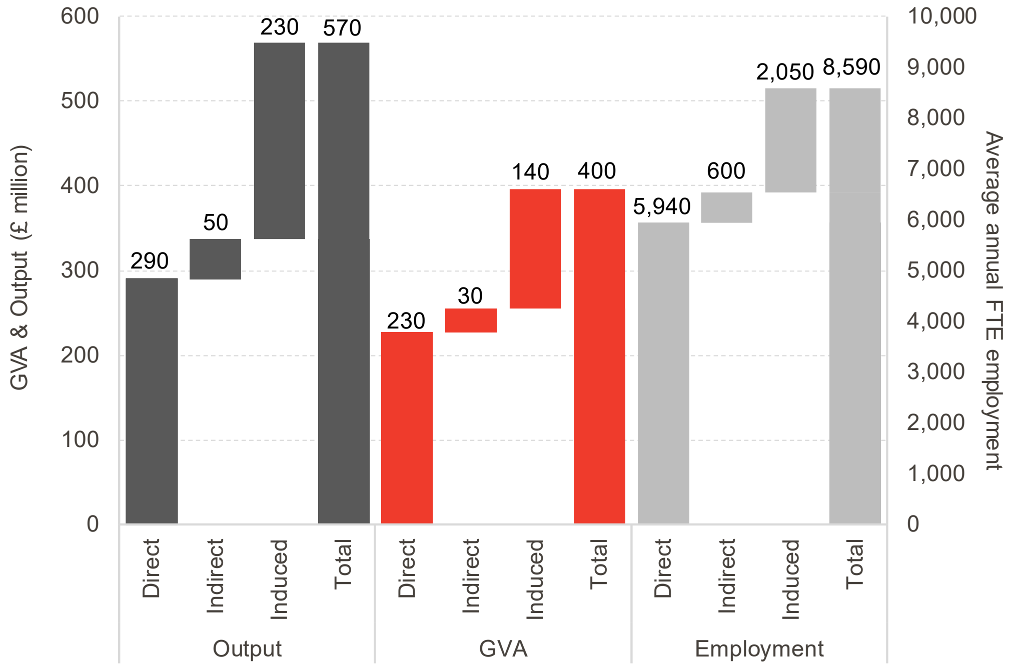
Impact of SFC research and knowledge exchange funding

SFC research funding to Scottish universities directly contributes around £290m in output, 5,940 FTE jobs, and £230 million in GVA to the Scottish economy. **See Chart 5.**

When spill-over effects are accounted for – the indirect and induced impacts – SFC research funding is associated with a net contribution of approximately £570m in output, £400m in GVA and supports 8,590 jobs across the Scottish economy.

This total includes employment in SFC-funded research as well as employment in other parts of the Scottish economy through the effects of the initial spending on the supply chain.

Chart 5: Economic impact of SFC research and knowledge exchange funding, 2019



Notes: *Amounts are expressed in current prices. Totals may not sum due to rounding.*

Source: *FAI calculations*

Impact of HEI research funding

The sector has a direct contribution of £1,150 million in output, employs 23,570 FTE jobs, and adds £900 million in GVA. **See Chart 6.**

Once spill-over effects are accounted for, in total, university research funding supports a total of £2,600 million in output, 34,070 FTE jobs, and £1,570 million in GVA in the Scottish economy.

For every 1 job created through university research funding in the higher education sector, an additional 0.4 jobs are created in the wider Scottish economy.

Chart 6: Economic impact of higher education R&D spending (HERD), 2019

Notes: *Amounts are expressed in current prices. Totals may not sum due to rounding.*

Source: *FAI calculations*

Impact of all R&D

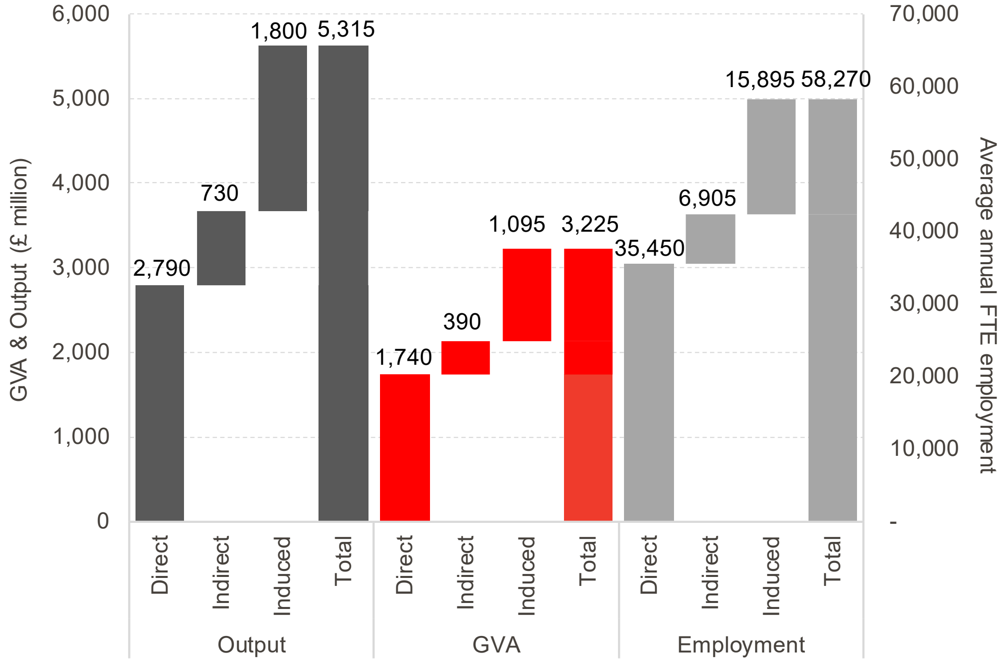
Gross expenditure on R&D in Scotland directly contributes £2,790 million in output, 35,450 FTE jobs, and adds £1,740 million in GVA. **See Chart 7.**

When spillover effects are considered, the net economic contribution amounts to a total of £5,315 million in output, supports 58,270 FTE jobs, and adds £3,225 million in GVA to the Scottish economy, with nearly half attributed to induced effects.

Notably, for every 1 job created through R&D expenditure, an additional 0.6 jobs are created in the wider Scottish economy.

Moreover, for every £1 spent on research and development in Scotland, the economy generates almost £2. Given the narrowness of the impacts modelled here, this is an approximate lower bound for the full economic impact.

Chart 7: Economic impact of all R&D spending, 2019



Notes: *Amounts are expressed in current prices. Totals may not sum due to rounding.*

Source: *FAI calculations*

Our main results model the effects of R&D spending when business R&D (BERD) is distributed among the sectors performing R&D (see the appendix for a full description).

However, it is possible that R&D expenditure in each sector looks very different to that sector's other spending, and that R&D spending is more similar to that of the R&D sector.

To check the sensitivity of our results, we estimate an alternate model of the effects of Scottish R&D with all BERD allocated to the R&D sector. A comparison of these results is shown in **Table 1**.

Table 1: Sensitivity analysis for the economic impact of gross R&D spending

	GVA		Output		Employment	
	Main	**Alternate**	**Main**	**Alternate**	**Main**	**Alternate**
Direct	1,740	1,590	2,790	2,790	35,450	35,990
Indirect	390	505	730	885	6,905	9,990
Induced	1,095	1,190	1,800	1,950	15,895	17,245
Total	3,225	3,285	5,315	5,625	58,275	63,220

Source: *FAI calculations*

The decision to model BERD as more similar to spending in the sector which conducts it tends to produce slightly smaller estimates of GVA, output, and employment than modelling BERD as most similar to spending in the R&D sector.

The largest difference is for employment, where the alternate model produces an estimate of total employment supported that is approximately 5,000 FTE jobs (8%) greater than the main model. This difference is likely driven by the more employment-heavy spending patterns in the R&D sector relative to other sectors.

Economic multipliers

While large industries often have significant impacts, economic multipliers can be used to understand the value for money that an industry supports in the economy.

Economic multipliers tell us the amount of output, GVA and jobs supported by a £1 million expenditure on final demand. High multipliers typically describe industries that are strongly integrated with Scottish supply chains and spend significant amounts on wages.

Type I and Type II multipliers are shown in **Table 2**. Type I sum together direct and indirect effects while Type II multipliers also include induced effects (the impact of employee wage spending).

Table 2: Estimated multipliers for £1m by source, Type I and Type II

		SFC/all HEI research funding	R&D (Main)	R&D (Alternate)	Average for all spending in Scotland
Output (£m)	Type I	1.16	1.26	1.31	1.34
	Type II	1.96	1.90	2.02	1.85
GVA (£m)	Type I	0.88	0.76	0.75	0.66
	Type II	1.37	1.16	1.18	0.97
FTE jobs	Type I	23	15	16	12
	Type II	30	21	23	16

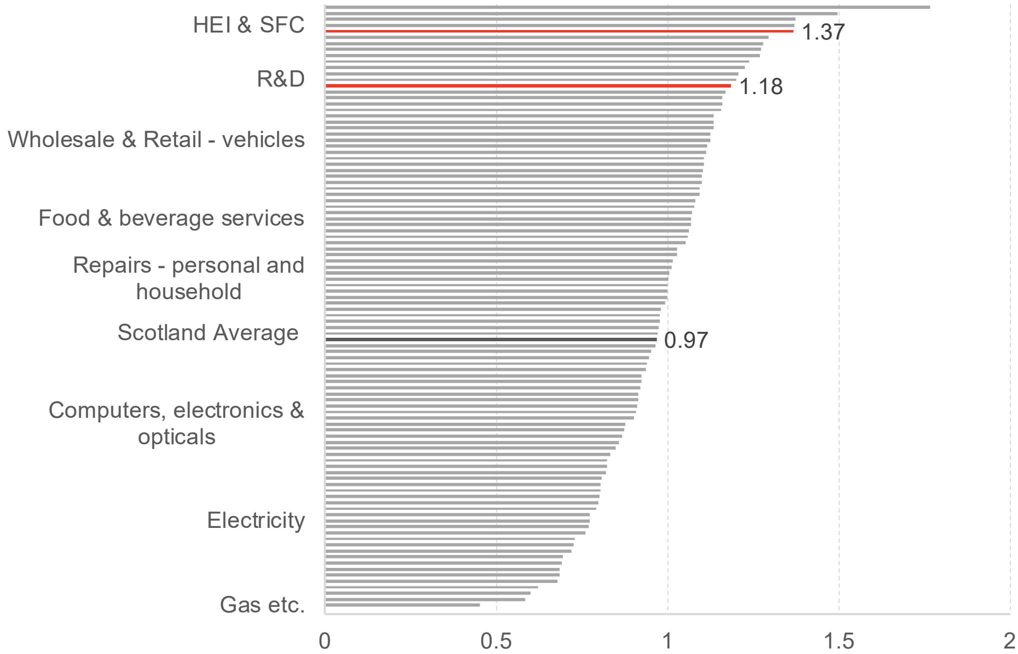
Notes: *Output and GVA are rounded to the nearest 0.01; full-time equivalent jobs are rounded to the nearest whole number. FTE jobs multipliers represent the number of FTE jobs supported by £1m of spending.*

Source: *FAI calculations*

The estimated Type I effect of £1m spent on university research or R&D is higher than the average £1m in Scotland for GVA and employment, but lower for output. University research in particular has a larger Type I effect on all three measures.

The Type II effects include the impact of employees spending their wages. Since university research and other R&D are generally labour-intensive, the estimated Type II impacts are significantly larger than for average spending in Scotland.

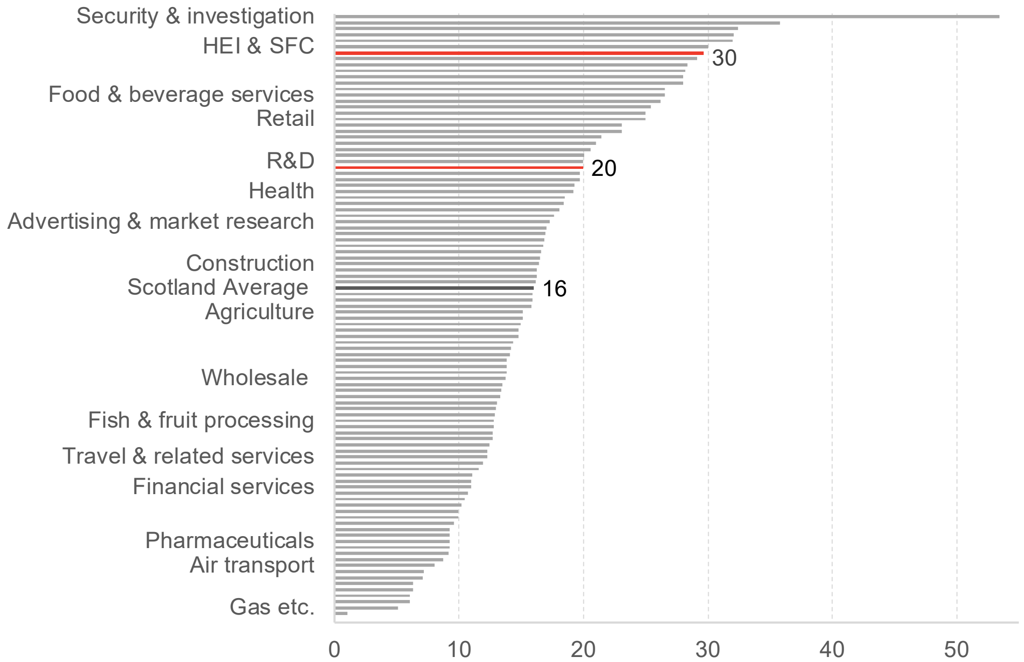
Chart 8: Type II GVA multipliers for Scotland (2019)



Notes: *Results are shown for 97 sectors of the Scottish economy. Only selected sectors are labelled.*

Source: *FAI calculations*

Chart 9: Type II FTE jobs-output multipliers for Scotland (2019)



Notes: *Results are shown for 97 sectors of the Scottish economy. Only selected sectors are labelled.*

Source: *FAI calculations*

Spillovers from R&D

Productivity and innovation

The previous section presented estimates for the economic impact of SFC research funding, total university research funding, and total R&D in Scotland. However, those impacts include only the supply chain effects of R&D spending.

In this section, we discuss the longer-term spillovers research can create in terms of innovation, productivity, and knowledge.

Productivity is generally defined as the output created per unit of input. Many studies use changes in total factor productivity (TFP) to assess spillovers where TFP measures the output produced from a specific range of inputs, for example, output per labour and capital inputs.

Evidence from the UK strongly suggests that public sector spending on R&D has a positive impact on private sector productivity. This funding can originate from various sources, including government budgets, charitable contributions, or UKRI (including Research Council) spending channelled through grants for university research.

Notably, there is evidence of a robust correlation between research council R&D spending and TFP growth in the UK (Haskel and Wallis, 2013). A positive relationship between TFP growth and both public and private R&D funding is also found (Haskel et al., 2014; Frontier Economics, 2014; Goodridge et al., 2015).

Haskel et al. (2014) estimate a 20% return on public R&D spending for the UK with respect to market sector TFP and note that this estimate is likely to represent a lower bound for the true effect. These findings are consistent with the 15-155% range of estimated social returns to R&D recorded by Frontier Economics and London Economics.

Moreover, Goodridge et al. (2017) find that links between R&D and TFP growth work at least partially through the effect of R&D on the stock of knowledge, not just on general spending.

Higher returns to medical and scientific research compared to other fields are also recorded by Frontier Economics, as well as higher returns to applied experimental research compared to basic research.

However, the productivity returns to public R&D spending are not evenly distributed across firms. For instance, Harris et al. (2011) find that UK firms that exhibit greater levels of collaboration with HEIs have higher TFP by as much as 12%.

Moreover, foreign-owned firms that maintain strong links with HEIs and specialise in non-production sectors appear to capitalise more effectively on their prior technological advantages and the support HEIs provide compared to production industries, which are typically technology-seeking enterprises.

HEIs also produce innovation spillovers when measured by patent applications. Evidence from the US shows that establishing a new HEI led to 62% more patents in the surrounding area compared to similar areas with no HEI, with only 12% of patents coming directly from university employees (Andrews, 2023).

There are also spillovers to private R&D spending. Aitken et al. (2021) find that private sector returns to R&D in the UK amount to a substantial productivity boost, with a return of £0.20 for every £1 invested in R&D.

Furthermore, firms engaged in R&D activities appear to generate a noteworthy spillover effect, resulting in a 1% increase in productivity for other firms within a local enterprise partnership.

The granting of new patents is also found to significantly boost productivity in manufacturing industries, while services industries experience notable productivity gains from introducing new-to-market products and services (Aitken et al., 2021).

The impact of knowledge spillover from new-to-market innovation is particularly pronounced in high-tech and intensive research industries.

Several more findings from the study relevant to this report stand out. Firstly, Scotland exhibits noteworthy productivity gains when embracing new-to-market innovative products and process innovation, surpassing several regions in the UK.

Moreover, R&D investment in new-to-market innovation in Scotland appears to yield particularly favourable returns relative to the rest of the UK, and the returns from publicly funded R&D prove to be notably larger despite the relatively lower intensity of R&D activities observed in Scotland compared to the rest of the UK.

Spending, agglomeration, and growth

In addition to raising private productivity, public R&D spending also increases private R&D expenditure – a phenomenon known as the "crowd-in" effect.

Oxford Economics estimate that £1 of additional public R&D spending increases private R&D by £0.41 to 0.74 in the short run and £1.96 to 2.34 in the long run averaged across 33 industries. When comparing across countries, they also find that the UK experiences a crowd-in effect greater than that of the US and five other countries, but below that of Japan, Finland, and Germany.

Focusing solely on biomedical and health research funding, Sussex at al. (2016) estimate a £0.83 to £1.07 rise in private R&D spending for every £1 increase in public R&D.

R&D spending on universities may also have spillovers in the form of agglomeration; that is, the positive effects that arise due to universities and industries clustering together in a specific geographic location.

For instance, evidence from the US shows that spending by HEIs later increases non-education sector labour income in the same area, with higher effects in industries that cited university patents more frequently (Kantor and Whalley, 2009).

University research has also been found to augment regional growth rates. Valero and Van Reenen (2016) study 1,500 regions across 78 countries from 1950 onwards and find that regions with more HEIs experience a rise in GDP per capita. The effects also reached other regions nearby and acted through innovation and human capital channels in addition to demand-side expenditures.

Implications for estimating the returns to R&D in Scotland

Estimates of the return on investment (ROI) to public R&D and spillovers to private R&D spending, agglomeration, and growth measure benefits of R&D that are not reflected in the input-output modelling presented earlier in this report.

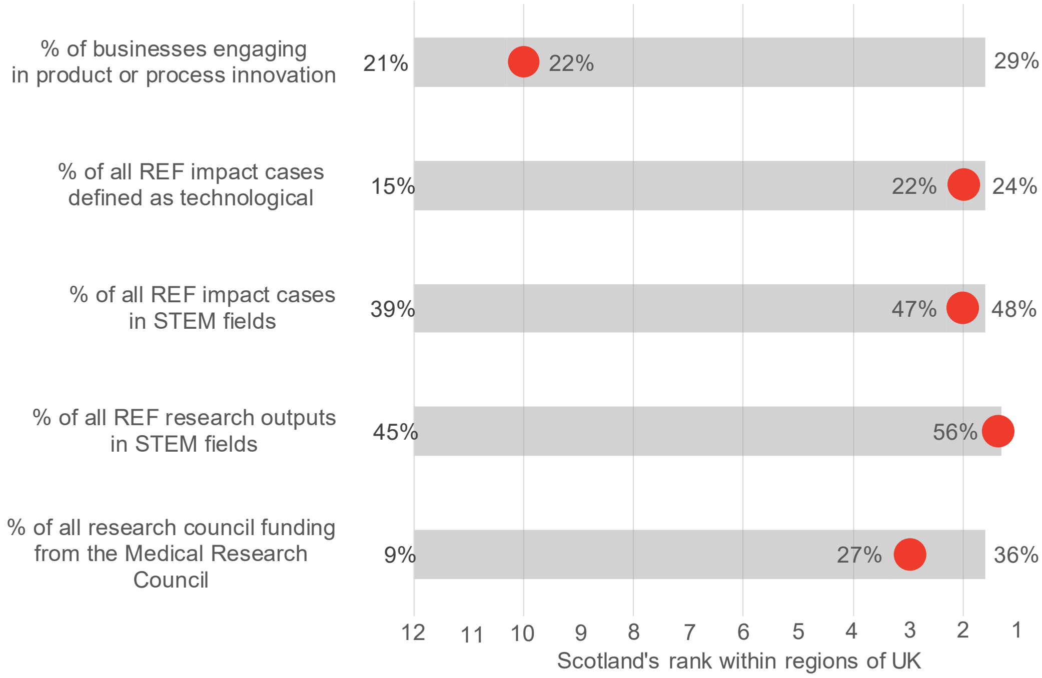
As explained above, the literature suggests that public R&D spending in the UK has an ROI of 20%. That is, for every £1 spent on public R&D, there are productivity spillovers worth an additional £0.20.

It is possible to benchmark Scotland against the ROI estimate of 20% for R&D in the UK. A variety of factors have been identified as contributing to a higher ROI, including indicators of technological innovation, research in STEM fields, and alignment of research with business interests (Frontier Economics 2021; Aitken et al. 2021).

We compare Scotland to the rest of the UK (rUK) on a number of these indicators to see whether the ROI to public R&D spending is likely to be higher or lower than 20%.

When looking at the percentage of businesses engaging in product or process innovation across UK regions, Scotland ranks 10th. However, for metrics relating to the proportion of university research outputs and funding in STEM, technology and medical fields, Scotland ranks 1st and 3rd, respectively. **See Chart 10.**

Chart 10: Metrics for benchmarking Scotland's ROI on R&D



Notes: *Ranks are presented with 1st being the highest-performing and 12th the lowest-performing. Minimum and maximum values are labelled alongside the value for Scotland for each metric.*

Source: *FAI calculations from REF 2021 and Innovation UK survey data*

Several of these indicators are taken from the Research Excellence Framework (REF) 2021 report.

Every seven years, UK universities contribute to this report to measure their research outputs and impact. Scotland ranked first among the 12 UK regions for the percentage of research outputs that were submitted from STEM fields with 56%.

22% of the REF impact cases submitted by Scottish universities in 2021 were defined as technological, and 47% were in STEM fields. These percentages were exceeded only by Northern Ireland and Wales, respectively.

Finally, 27% of all Research Council funding in Scotland came from the Medical Research Council, making Scotland the third-ranking region in the UK behind the East of England (31%) and London (36%).

Overall, Scotland conducts a high proportion of its research and receives a high proportion of its Research Council funding in STEM fields compared to other regions of the UK.

These metrics suggest that the ROI to R&D in Scotland may be higher than the 20% return estimated for the whole of the UK.

Directions for future research

Previous estimates of productivity spillover effects

A number of studies modelling the economic impacts of research also estimate productivity and knowledge spillovers.

The most recent estimates for the UK come from Haskel and Wallis (2013) and Haskel et al. (2014) who correlate public R&D spending and private TFP growth. They find that research council funding in particular is highly correlated with private sector TFP growth, while civil and defence public sector R&D are not. The estimated correlation coefficients are similar when public R&D is lagged.

This supports the idea that publicly funded R&D increases private-sector productivity, and not vice versa. However, the estimated effect may also capture some of the crowding-in effect in which public R&D spending prompts greater private R&D. The results thus represent a correlation, not pure causation.

In their recent report, London Economics use estimates from Haskel and Wallis (2013) and Haskel et al. (2014) to evaluate the contribution of Scottish university research to the UK economy in 2019-20.

They apply a multiplier of 12.7[1] to UK Research Council and UK charities funding and 0.2 to all other sources to estimate the value of spillovers and arrive at a figure of £5,794 million in spillovers. This figure is then divided by the amount of public research funding to get an impact multiplier of £8.1 in additional economic activity per £1 spent on public research funding.

However, the 12.7 figure is the coefficient from a regression of TFP growth on lagged research council R&D funding, while the 0.2 (20%) is a calculated rate of return on public R&D spending.

While it is reasonable to use the 20% rate of return in this way to estimate spillovers, it is not clear whether the 12.7 can be appropriately applied as a multiplier, or why the multiplier for research council funding would be so much larger.

Frontier Economics replicate the approach of Haskel et al. (2013, 2014) using several data sources, including EU KLEMS, SET (science, engineering, and technology) statistics from BIS, ONS BERD estimates and data on internet access, and OECD productivity and GovERD statistics.

They estimate returns to R&D in different fields, including science and technology, as well as returns to spending by other research councils. Their estimates face the same limitations as those discussed above for the Haskel papers.

In their 2021 report, the National Institute of Economic and Social Research take a slightly different approach, compiling a dataset of innovation activities of UK firms and then aggregating to the regional and industry levels.

They use this information to test significant drivers of innovation, the types of innovation most tied to productivity growth, and the relationship between innovation and the inclusiveness of growth.

Their dataset covers Scotland, and their key findings include higher estimated returns to R&D in certain types of products and innovation in Scotland compared to the rest of the UK.

1 London Economics cites a working paper version of Haskel and Wallis (2013) from 2010. The 12.7 figure becomes approximately 15 in the published version of their paper.

Other approaches to demonstrating social returns

Several projects from the US and UK provide alternative methods for establishing the returns to university research funding. Both of the projects discussed here use a more bottom-up approach, leveraging information about individual research projects and individuals.

The first is the STAR METRICS project, a US-based federal and university partnership to develop an empirical framework for measuring the outcomes and public benefit of science investments.

The project used a number of data sources, including administrative records of research contracts, grant documents, human resources data from research institutions, and industry census data.

By employing language processing on grant documents and cross-referencing with other datasets, the researchers identified the nature of research (e.g., applied vs. basic), its direct and indirect employment impacts, employment effects and collaborations between institutions and vendors.

From the UK, the Industry Engagement Project at Imperial College London involved researchers creating a comprehensive database of approximately 10,000 college research staff, including their grants, teaching roles, and publications over a decade.

The data also contained information on patents, spin-off companies, industry affiliations, and media impact, allowing researchers to connect research investments with both academic achievements and economic impact.

The project provided insights into the research-to-output pipeline to guide thinking on different research investments.

Accounting for intangible returns to university research

Some of the social returns to university research are intangible and cannot be associated with a market value. Florio (2019) highlights a number of these in the UK R&D context, including:

- Increases in the stock of knowledge;
- Increased R&D capability, including better infrastructure and processes, agglomeration, equality, diversity, and inclusion, and more FDI attracted;
- Improved skills and career development for R&D personnel and students, as well as the ability to attract skilled workers from other countries;
- Improved societal outcomes like national security, public health, improved environment, more equality, increased cultural or heritage assets, and public enjoyment; and
- Better policymaking, public services, and international reputation.

These cannot be easily valued but are an important consideration of investments in research. Individual case studies can shed light on these impacts from university research, potentially using information from sources like REF impact cases or other university records of research impact.

It is clear from our research and discussions with experts in the field that this is a challenging area. However, the expression of benefits of research which are less tangible – even if they cannot be monetised – is becoming more accepted by government when a case is made for investment.

This is in line with changes made to The Green Book in 2022, which made it clear that the cost-benefit ratio was not the be-all and end-all. Although much of the academic research focuses on high-level macroeconomic impacts, which fit neatly in old-fashioned Green Book style calculations of a cost-benefit ratio, it is likely that tailored evidence – in the region, field and/or specific policy area of particular research – will be much more compelling.

With this in mind, investment in case study evidence is likely to be an effective way to generate a resource for capturing the benefits of investing in research.

This can add to the stock of understanding of the extent to which different programmes of research generate benefits particularly in Scotland, and to what extent they contribute to Scotland's international reputation, the attractiveness to investors, and so on.

Promising approaches for Scotland

The approaches discussed above tackle the wider benefits of university research from a number of angles, but so far have not been applied specifically to Scotland.

Additionally, each approach has associated challenges. Some possibilities for future research on the impact of university research in Scotland are discussed below.

Replicating Haskel: A top-down approach

Similar to the work of Haskel et al. (2013, 2014), one approach is to measure the association between worker productivity and public investment in university research or in R&D generally. This approach has the benefit of providing a concrete estimate of impact. However, it faces several challenges:

- **Data availability**: Scotland-specific measures of productivity and control variables may be difficult to obtain or may not exist for a long enough period of time.
- **Concluding causation**: Haskel estimates a correlation between public R&D spending and productivity, but likely also captures other elements like the impact of more private R&D spending as a result of crowding-in. It does not allow the researcher to conclude that public R&D directly causes the estimated increase in productivity.
- **Limited scope**: This approach expands on the input-output modelling used earlier in this report by estimating the productivity spillovers of research investment, but it still does not cover other elements of wider societal benefits from research.
- **"Big picture" focus**: This approach provides an overview of productivity spillovers, but due to limited data and spillovers between regions and sectors, disaggregated analysis would be difficult.

An alternative approach is to measure factors that determine the return on investment in research and use them to benchmark Scotland against ROI estimates for the rest of the UK (rUK), as we have done in this report. These factors include:

- Greater applied and experimental (rather than basic) research;
- Greater concentration of research in medical and science fields;
- Better alignment of research with businesses' interests;
- Stronger firm links with HEIs; and,
- Research outputs – for example, patents are associated with higher returns in manufacturing, but new-to-market products and services are associated with higher returns in services

There are a variety of ways to measure each factor, most imperfect but still informative.

Benchmarking Scotland against rUK then allows a conclusion to be drawn about whether the return on investment in research is likely to be higher or lower than for rUK.

However, this approach would not produce a specific ROI figure for Scotland and would also face the limitations discussed above for this type of top-down approach.

"Bottom-up" approaches

Other potential methods approach the returns to research by starting with individual pieces of research.

One option is to collect detailed information about the research conducted in Scotland to document its impact. This could be done over the long run with data collected every seven years for REF, but more data is needed between REF rounds to see shorter-term changes. Intangible benefits would also be difficult to aggregate.

Instead, case studies can also be used to examine returns to research for different fields and types of research. These studies would illustrate the types and size of impact generated from other areas and types of research, including effects that are difficult to measure.

While these approaches would likely not result in a specific numeric value or return on investment, they would capture more of the intangible benefits discussed above.

Conclusion

This report presents estimates of the economic impact of (1) SFC university research funding, (2) all HEI research funding, and (3) all R&D spending in Scotland.

We find that SFC university research and knowledge exchange funding support approximately £590m in output, £410m in GVA, and almost 9,000 full-time jobs in the Scottish economy through direct, indirect, and induced effects.

The Type II economic impact of £1m in university research funding is generally higher than the average for all spending in Scotland, likely because research is employment-heavy and has a large, induced effect through wage spending by employees.

However, these estimates are narrow and measure only the impact of how the money is spent, not the social return on investment to university research.

Existing estimates indicate around a 20% ROI to university research funding in the UK, which is likely larger for technological fields, applied research, and when research is closely aligned with industry interests.

Benchmarking Scotland against other regions of the UK using several metrics suggests that Scotland's ROI to university research may be higher than the rest of the UK.

Estimation of the ROI for university research in Scotland faces several challenges.

First, the data demands of robust estimation are high. Taking a top-down approach to correlate R&D spending with TFP growth (similar to Haskel et al., 2014) requires time-series data on productivity, R&D, and several control variables, some of which may not be available for Scotland.

A more bottom-up approach focusing on the impact of individual research projects requires a large amount of information provided by universities. However, this may be achievable by leveraging resources like those collected for REF.

Second, not all returns to research can be appropriately measured or monetised. While approaches like those discussed above can estimate the value of R&D spillovers to productivity and knowledge beyond that provided by the input-output modelling, they are still unlikely to capture other benefits such as international reputation, policy influence, and other less tangible impacts.

Therefore, case studies and consideration of intangible impacts are useful in understanding the impact of research in a given field.

Glossary

Agglomeration refers to benefits associated with firms and other entities forming geographic clusters.

Crowding-in describes how spending by one entity can cause others to spend more; it is typically used for the effects of public spending on private spending.

Direct effects in input-output modelling are the impact of spending in a sector on that sector; for instance, the direct impact of £1m spent in higher education is £1m.

Full-time equivalent (FTE) employment considers the importance of full-time and part-time employees. One FTE job equates to one full-time employee working for one year, or, alternatively, two part-time employees.

Gross value added (GVA) is the value of all final goods and services produced and is a measure of the contribution to an economy. GVA is a preferred measure to output as a firm could buy £1m of goods and sell these on for a further £1m – clearly, no additional value has been created. GVA can be expressed generally as the difference between revenue from sales and the cost of inputs.

Indirect effects in input-output modelling are the supply chain impacts of spending in a particular sector.

Induced effects in input-output modelling are the effects of wage spending by employees of the original sector and other sectors in the supply chain.

Multipliers are used in this report to refer to the amount of output, GVA, or FTE employment supported by a £1m change in spending. Type I multipliers include direct and indirect effects, and Type II multipliers add on induced effects.

Output refers to the value of sales of all goods and services produced in an economy. This is most easily thought of as similar to the turnover of firms. However, output is chosen over turnover because a large amount of activity is not undertaken by just firms (e.g. Public Sector Spending). The key difference between output and GVA is that the value of intermediate goods is included in the calculation of output whereas they are not included in the calculation of GVA.

Return on investment in research measures the benefit produced by the research relative to research funding. An ROI of 20% means that for each £1 of research funding, the research is estimated to create an additional economic benefit of £0.20.

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Appendix: Data and modelling

Data sources

SFC funding

Data on SFC spending comes from SFC annual reports, specifically the Research and Innovation Grants corresponding to the financial years 2018-19 and 2019-20. The figure of £301 million represents the weighted average of the SFC Research and Innovation Grants (i.e., the sum of the Research Excellence Grant, the Research Postgraduate Grant, and the University Innovation Fund) for these two financial years.

Higher education R&D

The total figure for higher education R&D (HERD) comes from the Scottish Government's Gross Expenditure on Research and Development (GERD) 2019 tables. HERD for 2019 amounts to £1,105 million. **Box 1** describes how estimates from later years would likely compare due to changes in the national accounting methods for HERD.

Gross R&D

Data for overall Scottish R&D comes from several sources.

The first source is the Scottish Government's GERD tables which provide detailed data on the total expenditure on R&D performed in Scotland. This provides the £2,789 million figure for total R&D expenditure in 2019, as well as the total figure for BERD (the largest component of GERD) at £1,409 million. Further insight on the original sources for each GERD component can be found in the background notes of the Gross Expenditure on R&D Scotland publication.

To model the effects of GERD, R&D spending must be distributed across the sectors where the R&D is performed. However, a sectoral distribution of BERD spending is unavailable. Therefore, we have adopted an alternative approach that makes use of additional data.

The first is information on sectoral turnover and BERD expenditure as a percentage of turnover by sector. These sources allow us to calculate a BERD figure for all but three sectors. We use data on growth sector R&D to assign BERD values to the remaining sectors. This process is described in greater detail in the next section.

These data are further supplemented by ONS R&D datasets. These provide information on UK-wide spending patterns where a Scottish breakdown is not available, including for government R&D (GovERD) and non-profits (PnP).

Data for constructing the model

Our economic models use input-output tables from the nations of the UK. These include the ONS UK input-output table, the Scottish Government's input-output table and NISRA's input-output table.

Input-output tables describe the flow of goods and services around the economy. They show how industries buy and sell from each other, compensate labour, and sell to sources of final demand such as Government, households and exports. Input-output tables are a simple transformation of Supply and Use tables.

While individual data sources can suffer heavily from accurate measurement, bias, definitions and other issues, supply and use tables (SUTS) are constructed from many government datasets. The inclusion of many datasets allows for (a) each dataset to act as a check for other datasets and (b) to place heavier weight on more reliable datasets. As a result, SUTS are considered the cornerstone of National Accounts. These, along with input-output tables, are produced by many advanced economies and are used to create significant economic statistics, such as GDP.

We have also introduced employment data to produce estimates of employment impacts. These data sources include the ONS Workforce Jobs dataset and the ONS Business Register and Employment Survey.

Modelling methodology

We use input-output modelling to generate the estimates. This modelling methodology is well established and dates back to 1951; Wassily Leontief received the Nobel Memorial Prize in Economics for his work on input-output modelling.

In this report, there are three separate modelling sections covering different levels of research expenditure in Scotland:

- SFC-funded university research
- All university research
- Total R&D

Our estimates model the impact of an uplift in research expenditure for each sector.

For the first and second model, we model the expenditure directly into education sector (SIC 85), as this clearly aligns with the nature of university expenditures.

However, the third model, total R&D, is more complex. This is because the SIC breakdown of R&D expenditure is currently unavailable, so it is more difficult to model how this spend is distributed across the economy.

Based on available data, we distribute R&D expenditure as follows:

- HERD – SIC 85 (Education)
- PnP – SIC 86 (Health)
- GovERD – SIC 84 (Public Administration and Defence), 85 and 86
- BERD – See below

The report includes results for two approaches, which are each based on different assumptions about the distribution of BERD spending:

- Main approach – Assume that BERD spending patterns most closely resemble the sector that conducts the R&D; use turnover data to estimate spending in each sector.
- Alternate approach – Assume that BERD spending patterns are closer to those of the R&D sector; assign all BERD spending to the R&D sector (SIC 72).

Further explanation

All PnP spending has been assigned to sector 86, representing the health sector, given the primary focus of most private non-profit R&D efforts.

The GovERD breakdown is a more nuanced, with spending divided among sectors 84, 85, and 86, encompassing public administration and defence, education, and health respectively. This allocation is derived from the UK's official spending breakdowns for GovERD, and assumes that Scotland GovERD follows a similar pattern. Spending by other devolved administrations (Northern Ireland and Wales) was removed from calculations.

Our main approach to modelling BERD spending is to distribute BERD spending to the sectors that perform it.

We first multiply total Scottish turnover by BERD expenditure as a percentage of turnover for each sector. This calculation yields a total BERD spend of £1017.89 million across all sectors, representing 72.24% of the total BERD figure.

Three sectors do not report R&D as a percentage of turnover: Financial and Insurance Activities; Water Supply, Sewerage, Waste Management and Remediation Activities; and Electricity, Gas, Steam and Air Conditioning Supply. A Scottish Government report gives a figure of £247 for financial services R&D (Scottish Government 2020). The remainder of BERD spending is split between the remaining two sectors by applying the sub-sector percentage of turnover that is available (for Waste Collection) to the two sectors, assuming it is broadly in line with these sectors R&D.

Our alternative approach assumes that BERD spending is more similar to spending in the R&D sector. For example, the R&D for an IT firm may be more similar in its spending pattern to firms that operate within the R&D sector, such as buying labs/equipment, rather than its normal spending pattern on computer inputs, etc.

Differences in estimates from the two methods are evident in the results, but do not substantially change the conclusions of this report.

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