Department for Business, Energy & Industrial Strategy

Enabling a World-Leading Regional Digital Economy through Data Driven Innovation

Edinburgh & South East Scotland City Region
A Science and Innovation Audit Report sponsored by the Department for Business, Energy & Industrial Strategy
APPENDICES

Appendix 1: Regional Data Science Innovation Cluster - Economic Impact Analysis by BiGGAR Economics

1. Summary

The Regional Data Science Innovation Cluster (RDSIC) will have a positive impact on the Scottish economy, increasing productivity and levels of innovation in the personnel and organisations that it works with. The RDSIC will contribute towards Scotland becoming a more digitally skilled and data driven economy and all the economic opportunities that such an economy would be able to take advantage of.

This study considered how the RDSIC would have an impact on the economy over the first 20 years. Two scenarios were considered: the RDSIC operating as a standard research centre (the Conservative Scenario) and the RDSIC at the centre of a cluster delivering a step change in the Scottish economy (the Transformative Scenario). The economic impacts come from five sources:

- **Core Impacts** - the direct, supply chain, employee spend and capital impacts associated with the core operations of the RDSIC;
- **Public Sector** - from the efficiency savings and enhanced tax collection abilities of a public sector with enhanced Big Data usage and a digitally up-skilled workforce;
- **Digital Skills** - the increased productivity of the Digital Skills continued professional development (CPD) courses run through the RDSIC;
- **Digital Employment** - the increased propensity of companies to locate in Scotland as a result of a high digital skills talent pool; and
- **Industrial R&D** - the benefits to the companies who invest in R&D programmes with the RDSIC.

The net present value (NPV) of the economic impacts (Gross Value Added, GVA) within the first 20 years could range from **£2.9 billion (Conservative Scenario) to £5.2 billion (Transformative Scenario)**.

Table 1.1: Sources of Impact [Source: BiGGAR Economics]

	CORE	PUBLIC SECTOR	DIGITAL SKILLS	DIGITAL EMPLOY'T	INDUSTRIAL R&D	TOTAL
Conservative Scenario						
NPV (£m GVA)	473	552	796	476	609	**2,906**
% of total	16.3%	19.0%	27.4%	16.4%	21.0%	100%
Transformative Scenario						
NPV (£ GVA)	473	1,133	1,592	1,320	731	**5,249**
% of total	9.0%	21.6%	30.3%	25.1%	13.9%	100%

Drivers & Further Details on Impacts:

Key Driver	Daily operations	Big Data sharing	CPD students	CPD students	Income from partners
Section	2.3	2.4	2.6	2.7	2.5

The economic impacts of the RDSIC will be long term and the wider economic impact in both scenarios is significantly greater than the initial capital investment impact. In the Conservative Scenario the RDSIC could support additional GVA across Scotland of up to **£414 million** *per year* by Year 20 (Figure 1 1).

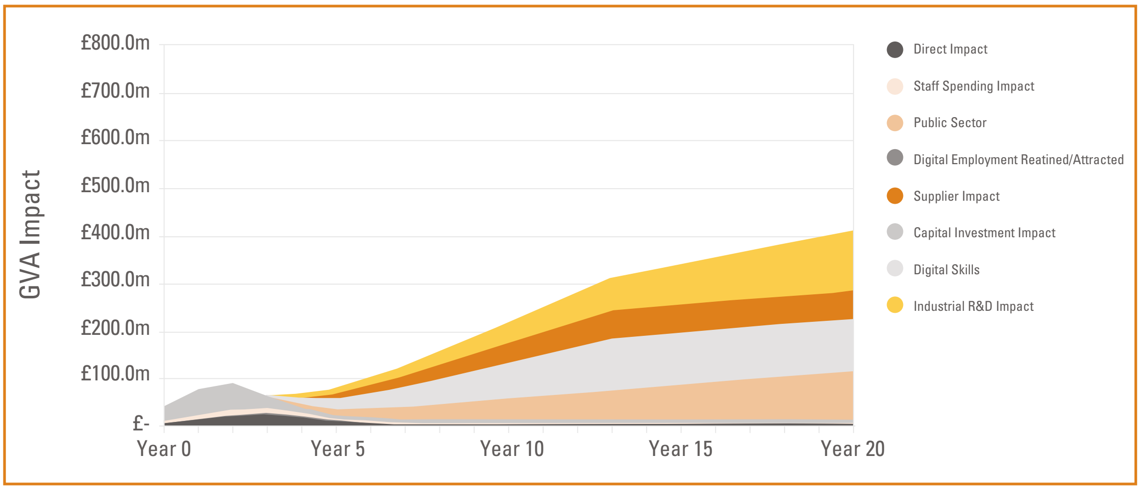

Figure 1-1: GVA Impact over 20 years by source - Conservative Scenario [Source: BiGGAR Economics]

In the Transformative Scenario the RDSIC could support additional GVA across Scotland of up to **£767 million** *per year* by Year 20 (Figure 1-2).

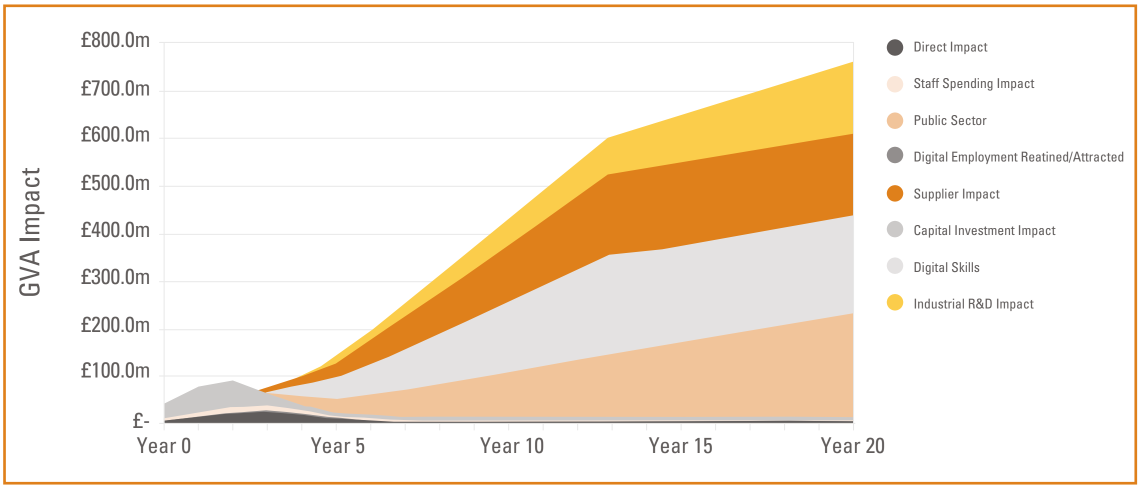

Figure 1-2: GVA Impact over 20 years by source - Transformative Scenario [Source: BiGGAR Economics]

Both of the scenarios would represent a strong return to investment. The Economic Rate of Return over the first 20 years could range from **54%** to **74%**.

2. RDSIC Economic Impact Assessment

This study considers the quantifiable economic impact associated with the three nodes of the Regional Data Science Innovation Cluster (RDSIC) and the digital skills training activities.

2.1 Approach

This analysis has been carried out by BiGGAR Economics, which has undertaken economic impact assessments of innovation and academic programmes throughout Scotland, the UK and Europe.

The economic impacts considered in this analysis are reported in terms of the Gross Value Added (GVA) and employment (job headcount). The analysis has been undertaken for a 20-year appraisal period, which shows how the cumulative impacts could have a significant effect over time.

The assumptions that underpin the analysis are based on evidence of the returns to digital skills and innovation investments elsewhere. It is also recognised that the scope of the RDSIC proposals goes beyond what has typically been done in the past collaborative university-industry initiatives and so the scale of the impacts could far exceed what has been achieved in the comparator examples on which the evidence base draws.

This analysis has therefore considered two impact scenarios:

- **Conservative scenario** – the growth stimulated by the activity of the RDSIC is in line with what has been achieved by typical university-industrial engagement programmes; and
- **Transformative scenario** – the growth stimulated by the activity of the RDSIC is above average for typical university-industrial engagement programmes and has a transformational effect within the industries in which it operates.

The impacts in both of these scenarios are measured against a **Do Nothing scenario** in which there is **zero investment** and **zero additional economic activity**. However, this could be seen as understating the impacts because without such investment key sectors in Scotland could see a **long-term decline**, as the region becomes a less competitive area to do business with a **widening digital skills gap and decreasing levels of innovation**.

2.2 Quantitative Impacts by Source

The analysis of the programme approach considered the financial projections for the RDSIC and the anticipated areas of income and expenditure.

The impacts associated with the development and programmes are:

- core impacts of the RDSIC investment, including:
    - capital investment impacts;
    - direct impacts;
    - supply chain impacts;
    - staff spending impacts;
- public sector savings;
- impacts associated with industrial returns to R&D investment; and
- impacts associated with increased digital skills of the workforce.

The impacts associated with the core activities, namely capital investment, direct, supplier and staff spending, will be the same in both scenarios. However the impacts associated with the wider impacts of the activity, namely public sector savings, industrial returns and increased digital skills will vary between the two scenarios.

2.3 Core Impacts

2.3.1 Capital Investment Impacts

The **Capital Investment Impact** is the additional economic activity that is associated with the construction of the buildings and the supply of the new equipment needed in the three spokes.

The capital investment impact has been calculated based on the amount of money that will be spent on capital investment for this project. The majority of the expenditure in the first three years will be spent on the capital costs associated with the development of the three nodes and the other infrastructure.

The economic impacts associated with this expenditure were estimated based on the number of jobs and additional GVA that could be supported from this additional turnover in the companies supplying the construction or equipment. This has been done by considering the economic ratios of the appropriate sectors[1] and applying the economic multipliers for these sectors[2].

The economic impacts associated with the capital investment peak in Year 1 in line with the investment schedule. At its peak, the capital investment will generate £55 million GVA in Scotland and support 854 jobs in Year 1. However, capital investment continues throughout the ten-year project plan.

2.3.2 Direct Impacts

The day to day activities of the staff employed in the RDSIC is the **Direct Economic Impact** of these spokes.

The direct economic impacts were calculated by initially estimating the number of individuals who would be employed directly through the RDSIC. This was estimated by considering the turnover associated with the programmes being run through the RDSIC and the number of staff who would be supported by this turnover. In 2013/14 the average turnover per employee within the University of Edinburgh was £63,000 and therefore this figure was applied to the programme costs to generate an estimate for the number of people who would be employed as a result of RDSIC programmes. Similarly, the GVA of the directly employed staff was assumed to be in line with the wider University. In 2015, BiGGAR Economics undertook a study of the economic impact of the University of Edinburgh[3] and this found that the **average direct GVA per employee was £38,400**. This figure was applied to the number of employees estimated for each year to give an estimate for their direct GVA contribution.

As with the capital investment, the direct employment in the RDSIC peaks in the early stages of the development as the programmes are being established. In Year 2 the RDSIC is estimated to employ **635 people** directly who will generate **£27 million GVA**. By the end of the ten-year period the RDSIC will be in a steady state and employing **159 people** who will generate **£6 million GVA**.

2.3.3 Supplier Impacts

The RDSIC will have an economic impact on the companies that it purchases goods and services from as this will lead to an increase in turnover and activity within these companies. This is the **Supplier Impact**.

The economic impact within the companies of the RDSIC supply chain will be dependent on how much money is spent on goods and services and the types of goods and services that are procured. At this stage details on these levels of expenditure are not available and therefore the supplier impacts were calculated based on the anticipated level of employment at the RDSIC and the average supply chain impact per member of staff for the wider University of Edinburgh. In the 2015 study of the University of Edinburgh's impact it found that the **supplier impact in Scotland was equivalent to £4,900 GVA per member of staff** at the University. This figure was applied the direct employment estimated in Section 2.3.2 to give an estimate for the economic impact associated with the increased activity of companies that will supply the RDSIC with goods and services.

[1] ONS (2016), Annual Business Survey 20142

[2] Scottish Government (Jul 2015), Scottish Input-Output Tables 1998-2012

[3] BiGGAR Economics (May 2015), Economic Impact of the University of Edinburgh 2013-14

The supplier impact will peak in Year 2 because this is when the number of directly employed staff at the RDSIC will also peak. In this year the spending on goods and services by the RDSIC is estimated to **support 66 jobs** and **generate £3.5 million GVA** in Scotland. By the end of the ten-year period the RDSIC will be in a steady state and its expenditure on goods and services will support **15 jobs** who will generate **£0.8 million GVA**.

2.3.4 Staff Spending Impacts

The staff of the RDSIC have an impact on the businesses in which they spend their wages as this will lead to an increase in turnover and activity within these companies. This is the **Staff Spending Impact**.

The economic impact within the wider economy where staff spend their wages will be dependent on how many staff there are and how much these staff are paid. At this stage details on anticipated staff costs are not available and therefore the staff spending impacts were calculated based on the anticipated level of employment at the RDSIC and the average staff spending impact per member of staff for the wider University of Edinburgh. In the 2015 study of the University of Edinburgh's impact it found that the **staff spending impact in Scotland was equivalent to £14,300 GVA per member of staff** at the University. This figure was applied the direct employment estimated in Section 2.3.2 to give an estimate for the economic impact associated with the increased spending in the wider economy as a result of the purchasing power of these new members of staff.

The staff spending impact will peak in Year 2 because this is when the number of directly employed staff at the RDSIC will also peak. In this year the spending of staff employed by the RDSIC is estimated to **support 207 jobs** and **generate £10.2 million GVA** in Scotland. By the end of the ten-year period the RDSIC will be in a steady state and the spending of staff in the wider economy is estimated to support **46 jobs**, which will generate **£2.3 million GVA**.

2.4 Public Sector Returns

The public sector could gain from enhanced digital skills, Big Data and the Internet of things through the potential cost savings and efficiencies that these could offer. A 2012 report by Policy Exchange,[4] estimated that if the UK Government were to fully capture the benefits of the big data opportunity it could save between £16 billion and £33 billion a year, equal to a saving of 2.5-4.5% per year. About two-thirds of this benefit would arise from improved operational efficiency, with the remaining third resulting from increased tax collection and a reduction in fraud and error. The report also cautions that complementary investments are needed to fully realise the potential of big data, such as leaders who can understand and interpret the findings of big data.

One of the key proposals of the RDSIC is to facilitate the collation, integration and analysis of high volumes of public data across different sectors, including the public sector. Therefore the RDSIC has the potential to have an impact on the £68.6 billion[5] public sector expenditure in Scotland. Of this expenditure, approximately £56.4 billion was attributable to areas that could benefit form the public data projects facilitated by the RDSIC. In order to quantify the magnitude of this saving potential, this level of expenditure was projected forward for the next 20 years.

The RDSIC would be one of the many actors that would need to be effective in order for the public sector to achieve the 4.5% efficiency saving. In the Conservative Scenario it was assumed that the **RDSIC contributed towards 5%** of this target. It was assumed that the 4.5% efficiency saving across the Scottish public sector is achieved within the 20 year time period. Therefore, in this scenario the data sharing activities of the RDSIC would result in the public sector in Scotland saving more than £100 million by Year 20. The total **NPV[6] of these savings is £832 million**.

[4] Policy Exchange (2012), The big data opportunity

[5] Scottish Government (Aug 2016), GERS 2015-16

[6] Calculated based on a discount rate of 3.5% as recommended by HM Treasury

In the Transformative Scenario it was assumed that the RDSIC contributed towards 10% of this target. Therefore, in this scenario the data sharing activities of the RDSIC would result in the public sector in Scotland saving more than £210 million by Year 20. The total NPV of these savings is £1.7 billion.

2.5 Industrial Returns to R&D Investment

The companies that engage with the RDSIC and invest in research and development (R&D) through their programmes would expect to see a return to this investment. The benefits to these companies would come from increased turnover or profits. This is the **Industrial Impact**.

There are many different processes through which investment in research and development within a company can increase the economic performance of that company. For example, through:

- development of new or improved products;
- development of new or improved processes;
- accessing new markets;
- competitive advantage over other companies within their sector;
- attracting top talent and contracts through reputation as innovator; and
- improved access to finance through proof of concept.

The economic benefits to the companies that undertake research and development with the RDSIC was estimated based on the amount of money that these companies invest in this R&D and the anticipated annual returns to this investment. The income from partners that is described in the project schedule of costs is used as a proxy for the level of private sector investment in research and development that occurs through the RSDIC, reaching **£20 million annually**.

The economic impact associated with this investment was calculated based on a study[7], which found that the private returns to R&D investment were between 20% and 30%.

For the Conservative Scenario, the mid-point of 25% was used, meaning that for every £1 that a company invests in R&D, they would expect to see £0.25 in benefit annually while they use the knowledge gained from this R&D. With the cumulative returns over time, this would mean that by Year 20, those partners that had invested in the RDCIS would generate an additional **£124 million GVA** for the Scottish economy and support an **additional 2,210 jobs** (Figure 2-1).

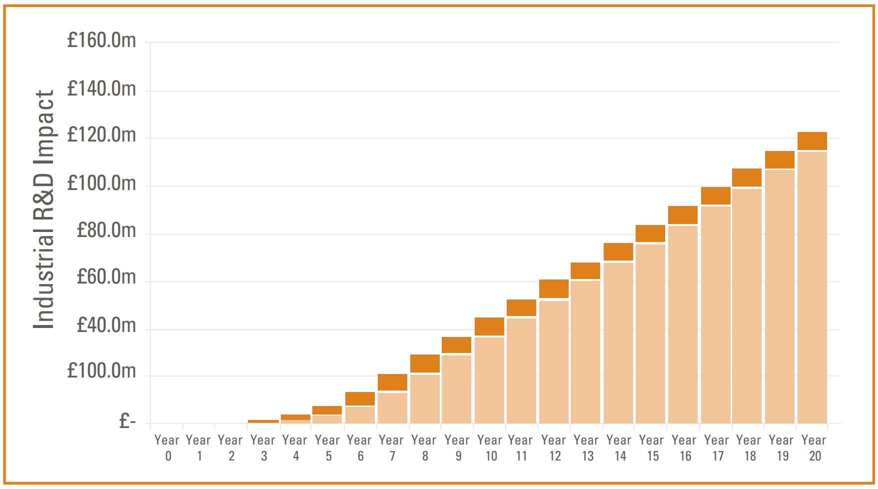

Figure 2-1: Industrial R&D impact over time - Conservative Scenario [Source: BiGGAR Economics]

[7] Frontier Economics (2014), Rates of Return to Investment in Science and Innovation

For the Transformational Scenario, the higher end of the range, 30% was used, giving a cumulative impact by Year 20, of an additional **£149 million GVA** for the Scottish economy and support an **additional 2,650 jobs** (Figure 2-2).

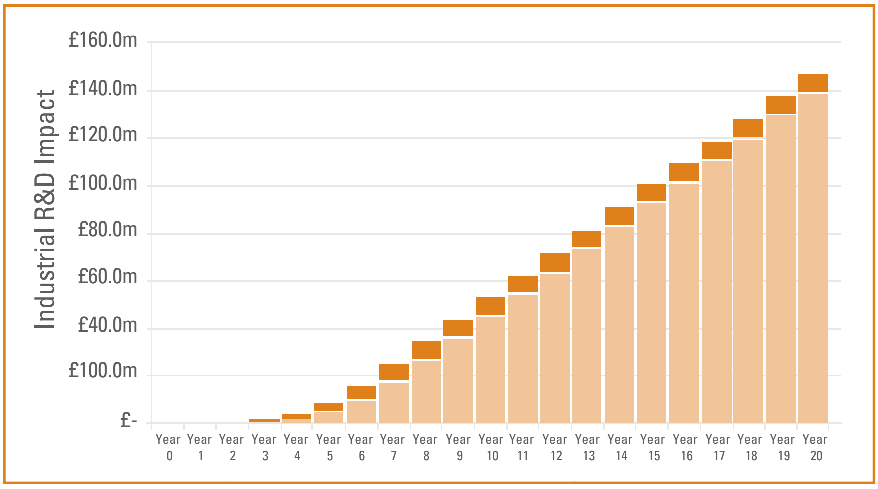

Figure 2-2: Industrial R&D Impact over time - Transformational Scenario [Source: BiGGAR Economics]

In summary, the NPV of these impacts over 20 years could range from **£610 million** (Conservative Scenario) to **£730 million** (Transformational Scenario).

2.6 Workforce Digital Skills Impacts

The Digital Science courses that will be run through the RDSIC will have an impact on the organisations that the participants work for through the increased abilities of the members of staff who go through these courses. This is the **Digital Skills Impact**.

The University aims to **engage 100,000 individuals** in these courses over a ten-year period. It was assumed that the courses would begin in Year 3, after the majority of the capital investment had occurred and that for each of the ten years in which the Digital Science course took place there were 10,000 participants and all would be based in Scotland. It was assumed that these courses would commence on completion of the initial capital investment (i.e. in year 3) and that it would take 10 years to meet the 100,000 target.

The economic impact associated with these courses was estimated based on the number of anticipated participants for these courses and the level of increased productivity that could be achieved above their current level. Analysis by the University of Twente[8] has found that those with higher education qualifications were **3.0% less productive** due to inadequate computer skills.

For the Conservative Scenario, the economic benefit was estimated by considering a 3.0% increase in productivity of the members of the graduate workforce throughout their working lives. This meant that on average participants of the Digital Science programme would produce £1,000 additional GVA each year following their completion of the course. On this basis it was estimated that by those workers who had participated in the Digital Skills programme would generate an additional **£106 million GVA** annually for the Scottish economy.

[8] Van Duersen et al (Jan 2012) CTRL ALT DELETE Lost Productivity due to IT problems and inadequate computer skills in the workplace, University of Twente

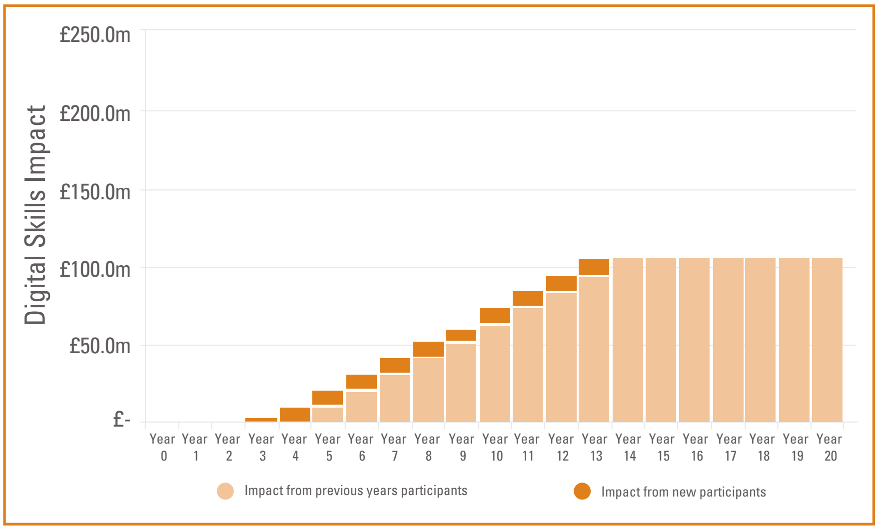

Figure 2-3: Digital Skills Impact over time - Conservative Scenario [Source: BiGGAR Economics]

In the Transformational Scenario the Digital Science productivity gain was increased from 3.0% to 6.0%. The Digital Skills programme proposed through RDSIC aims to equip professionals with an edge and the ability to take advantage of the opportunities that big data and data driven innovation will provide in the future. This is significantly more ambitious than just overcoming the day to day ICT difficulties that affect the graduate workforce. This assumption would result in the impact associated with Digital Science increasing to **£210 million GVA** annually across Scotland.

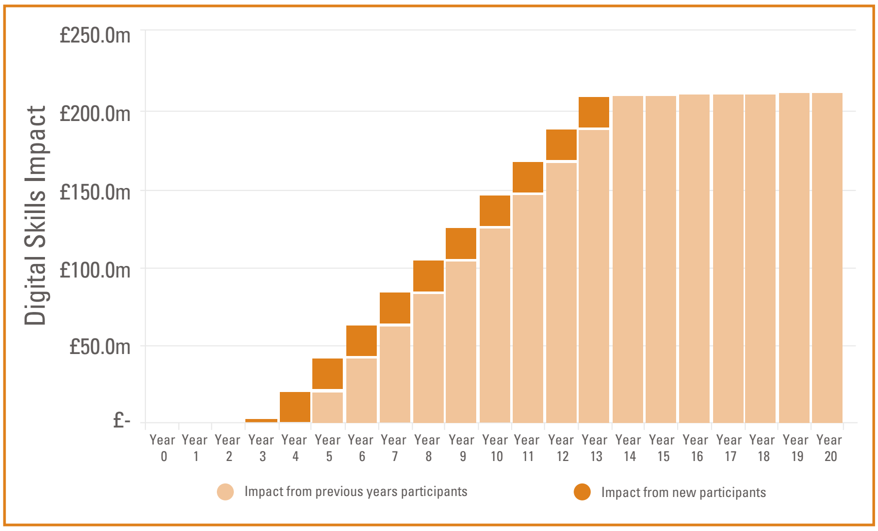

Figure 2-4: Digital Skills Impact over time - Transformational Scenario [Source: BiGGAR Economics]

The NPV of these impacts over 20 years **could range from £800 million** (Conservative Scenario) to **£1.6 billion** (Transformational Scenario).

2.7 Retention and Creation of Digital Skills Employment

In addition to being more productive in within their organisations, supporting the creation of a workforce with high levels of digital skills will encourage more mobile private sector organisations to either establish operations in Scotland or retain their Scottish operations. Therefore, while the additional marginal productivity associated with the Digital Science courses would apply to all participants, there may be some participants who would not be able to find employment in Scotland without the existence of these courses run through the RDSIC. In these instances the entire economic activity associated with these jobs would be attributable to the RDSIC.

In both scenarios, the number and the timing of the participants of the course remains the same, however the variation would be between the public and private sector split of those participants of the course and the impact that the RDSIC has on the choice that the private sector companies chose to make regarding relocation.

In the Conservative Impact Scenario it was assumed that **57%[9] of the participants in the Digital Science courses would be from within the private sector in Scotland**. In this scenario it was assumed that **1.0% of the private sector participants** of these courses would end up working for such mobile organisations. This would result in 570 jobs within the Digital Sector being directly generated or retained in Scotland as a result of the Digital Skills CPD at the RDSIC. This represents a small proportion of the employment growth envisaged by ScotlandIS, which aims to double the number of people working in digital technologies in 5 years, to 150,000[10].

The economic activity associated with 0.57% of all participants of the Digital Science courses would be attributable to the RDSIC and would be equivalent to 880 jobs by the end of the 20-year study period and these jobs would directly generate £63 million GVA.

Table 2.1: Digital Skills Employment Impact - Conservative Scenario [Source: BiGGAR Economics]

	YEAR 5	YEAR 10	YEAR 15	YEAR 20
Employment	180	610	880	880
GVA (£m)	13	44	63	63

In the Transformational Impact scenario it was assumed that **79% of the participants in the Digital Science would be from within the private sector in Scotland**. This would mean that private sector employees were just as likely to participate in this course than their public sector counterparts. It was also assumed that **2.0% of the private sector participants** of these courses would end up working for companies that would not otherwise be in Scotland. This is double the rate of the Conservative Impact scenario and would imply that by Year 20 there would be an additional 1,580 people directly employed in the digital sector in Scotland.

The economic activity associated with 1.58% of all participants of the Digital Science courses would be attributable to the RDSIC and would be equivalent to 5,770 jobs by the end of the 20-year study period and these jobs would directly generate £175 million GVA.

[9] Public Sector employment accounts for 21% of Scottish jobs (Scottish Govt (2016), Public Sector Employment in Scotland - Statistics for 1st Quarter)

[10] ScotlandIS (2016), Creating the climate for growth

Table 2.2: Digital Skills Employment Impact - Transformative Scenario [Source: BiGGAR Economics]

	YEAR 5	YEAR 10	YEAR 15	YEAR 20
Employment	490	1,700	2,430	2,430
GVA (£m)	35	122	175	175

The NPV of these impacts over 20 years could range from £480 million (Conservative Scenario) to £1.3 billion (Transformational Scenario).

2.8 Summary of Assumptions

The key assumptions used in this analysis are summarised in Table 2.3, which also includes the sources of these assumptions.

Table 2.3: Summary of assumptions

	VALUE	SOURCE
Public Sector Returns - Total Efficiency Savings		
Conservative Scenario	0.225%	5% of total savings, Policy Exchange (2012)
Transformative Scenario	0.45%	5% of total savings, Policy Exchange (2012)
Industrial Returns to R&D Investment		
Conservative Scenario	25%	Mid point from Frontier Economics (2014)
Transformative Scenario	30%	Higher limit from Frontier Economics (2014)
Workforce Digital Skills Impacts - Increased Productivity		
Conservative Scenario	3.0%	University of Twente (2012) study
Transformative Scenario	6.0%	Double above assumption
Retention and Creation of Digital Skills Employment - Private Sector CPD Clients		
Conservative Scenario	57%	Double Scottish public sector employment %
Transformative Scenario	79%	Scottish private sector employment share
Retention and Creation of Digital Skills Employment - Mobile Private Sector Jobs		
Conservative Scenario	1.0%	BiGGAR Economics Assumption
Transformative Scenario	2.0%	

2.9 Summary of Impacts

The total economic impacts including the core impacts and those associated with the wider industrial and skills development are given in Table 2.4. This shows that in the Conservative Scenario by Year 20, the RDSIC would support 3,420 jobs and £414 million GVA across Scotland. In the Transformational Scenario, the RDSIC would support 5,410 jobs and £767 million GVA across Scotland.

Table 2.4: Total Economic Impact - Conservative Scenario [Source: BiGGAR Economics]

	YEAR 5	YEAR 10	YEAR 15	YEAR 20
Conservative Scenario				
Employment	870	1750	2,720	3,420
GVA (£m)	79	222	343	414
Transformational Scenario				
Employment	870	1750	2,720	3,420
GVA (£m)	79	222	343	414

The combined Net Present Value (NPV) of these GVA impacts over 20 years **could range from £2.9 billion** (Conservative Scenario) to **£5.2 billion** (Transformational Scenario).

2.10 Costs and Return to Investment

The total costs associated with the RDSIC amount to £735 million over the 20-year time period[11]. The majority of this investment would occur within the first five years of the project and the NPV of this investment is **£578 million.**

Within the first ten years of the RDSIC, the economic returns in the Conservative Scenario would be greater then the associated investment costs. The Economic Rate of Return (ERR) from the total investment would be 49% over the first 10 years and **54% over the first twenty years** (Table 2.5). The Conservative Scenario GVA impacts and investment costs are summarised over 20 years in Figure 2 5.

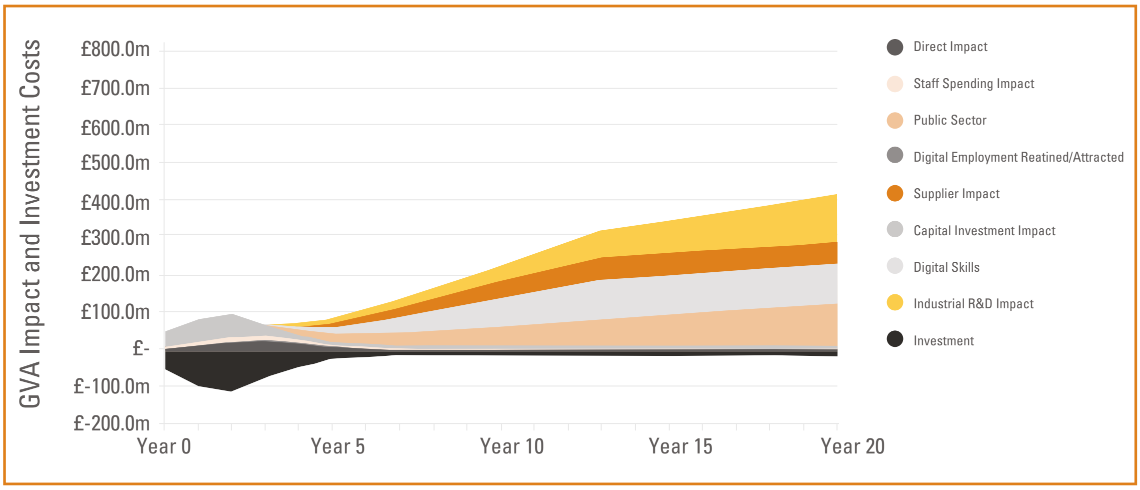

Figure 2-5: Annual GVA Impact by source (£m) - Conservative Scenario [Source: BiGGAR Economics]

[11] This includes the £515 million investment over the first 10 years of its life, plus ongoing annual costs of £20 million thereafter, assuming that programmes continue after the initial 10 year period.

Table 2.5: Economic Analysis results - Conservative scenario [Source: BiGGAR Economics]

	YEAR 10	YEAR 20
NPV of Economic Benefits (£ billion)	1.0	2.9
NPV of total investment (£ billion)	0.5	0.6
ERR from all investment	49%	54%

The returns to investment in the Transformational Scenario would be greater. The ERR from the total investment would be 71% over the first 10 years and **74% over the first twenty years** (Table 2.6). The Transformational Scenario GVA impacts and investment costs are summarised over 20 years in Figure 2 6.

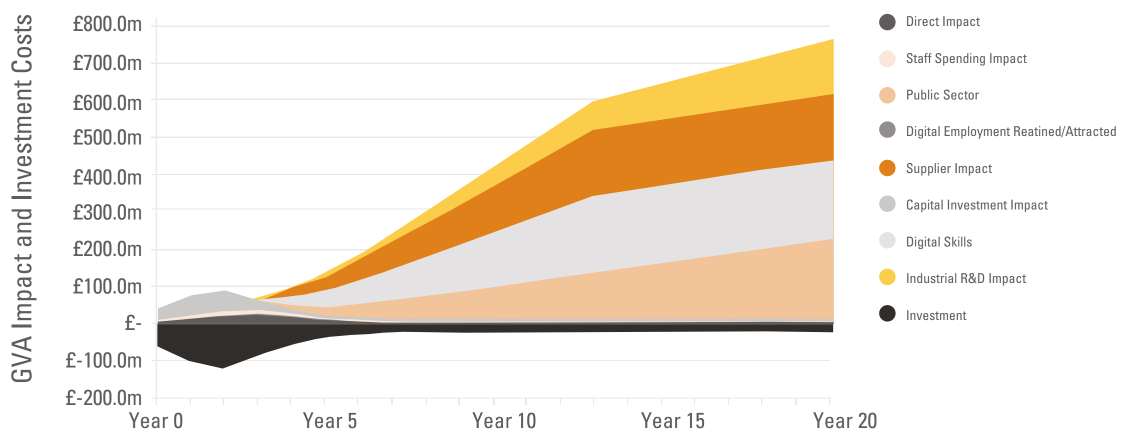

Figure 2-6: Annual GVA Impact by source (£m) - Transformational Scenario [Source: BiGGAR Economics]

Table 2.6: Economic Analysis results - Transformational scenario [Source: BiGGAR Economics]

	YEAR 10	YEAR 20
NPV of Economic Benefits (£ billion)	1.6	5.2
NPV of total investment (£ billion)	0.5	0.6
ERR from all investment	71%	74%

2.11 Summary and Conclusion

The RDSIC will have a positive impact on the Scottish economy, increasing productivity and levels of innovation in the personnel and organisations that it works with. These NPV of the economic impacts within the first twenty years of the project could **range from £2.9 billion to £5.2 billion**, which is greater than the NPV of the total investment required to create and support the RDSIC. The Economic Rate of Return (ERR) over the first twenty years from the investment required to support the RDSIC could range from **54% to 74%.**

Appendix 2: Excellence in Science and Research in DDI

Scientific production and quality

Scientific and research production in the region is dominated by Higher Education Institutions (HEIs). We first outline the leading areas for research power in the region, and then focus on research power associated with data driven innovation specifically. In much of the following, we use research power, as defined on data from the Research Excellence Framework 2014 (REF2014), as the primary metric, since it requires us to bring together both **production** quantity, in terms of the numbers of researchers in an area, and their **quality** profile, in terms of the proportions of their output judged to be world leading (4*) or internationally excellent (3*).

There are six HEIs of varying scale: University of Edinburgh (UoE), Heriot Watt University (HWU), the University of St Andrews (UStA), Edinburgh Napier University (ENU), Queen Margaret University Edinburgh (QMU), and Scotland's Rural College (SRUC). In REF2014, the region did well, with strengths in research outputs, research impact and research environment.[12]

The University of Edinburgh did best overall due to its size and willingness to submit large numbers of excellent staff. Submission in 31 of the 36 possible units of assessment reflects its wide subject base, with 20 schools and significant levels of interdisciplinary working.

HEI	UNITS OF ASSESSMENT SUBMITTED
The University of Edinburgh	31
The University of St Andrews	20
Heriot Watt University	12
Edinburgh Napier University	9
Queen Margaret University Edinburgh	5
Scotland's Rural College	1

Table 1: Total Units of Assessment submitted to in REF2014 by each Higher Education Institute in the Region.

HEI	The University of Edinburgh	The University of St Andrews	Heriot Watt University	Edinburgh Napier University	Queen Margaret University Edinburgh
Staff submitted to REF	83.28 %	82.46 %	81.75 %	18.84 %	22.36 %
FTE Staff submitted	1,753.08	518.69	352.36	98.9	42.7
Staff FTE 3*/4*	1,446.45	426.53	288.79	52.79	24.56
Research Activity 3*/4*	83.0 %	82.0 %	82.0 %	53.0 %	58.0 %
Quality Index	53	49	45	24	29
Research Power	0.63	0.17	0.11	0.02	0.01
Rank in the UK	4th	29th	43rd	97th	118th

Table 2: Institutional profiles in terms of quantity (Category A staff numbers submitted) and quality (3*/4*). Quality index is a weighted sum of 4* and 3*; Research Power is the product of these expressed as a ratio of the top score in the ranking.

[12] Many of the research analyses in this report were produced using the Elsevier REF2014 Analysis Tool: https://ref2014tool.analytics.elsevier.com/

The University of Edinburgh ranked 4th in the UK, by Research Power, after the Universities of Oxford and Cambridge, and University College London. There is a strong tradition of collaboration in the region, fostered by the Scottish Funding Council's research pooling initiative, and continuing joint work around specific projects and facilities. Partnerships were evidenced in REF2014, with six joint submissions by the University of Edinburgh: three with Heriot Watt, two with St Andrews and one with SRUC.

PARTNER HEI	UNIT OF ASSESSMENT SUBJECT
Heriot Watt University	10 – Mathematical Sciences
Heriot Watt University	15 – General Engineering
Heriot Watt University	16 – Architecture, Built Environment and Planning
The University of St Andrews	8 – Chemistry
The University of St Andrews	9 – Physics
Scotland's Rural College	6 – Agriculture, Veterinary and Food Science

Table3: Joint submissions with the University of Edinburgh in REF2014 by Unit of Assessment.

Finally, to put the Edinburgh City region in an a UK context, with 4.8% of overall Research Power, the City of Edinburgh takes 4th place, just outside the Golden Triangle of London, Oxford and Cambridge.[13]

HEI	OVERALL	SCIENCES	ENGINEERING	SOCIAL SCIENCES	CLINICAL SUBJECTS
London	22.2 %	22.2 %	19.6 %	21.3 %	36.9 %
Oxfordshire	6.8 %	8.6 %	4.4%	6.7 %	7.0 %
Greater Cambridgeshire	5.5 %	7.8 %	7.8 %	3.8 %	5.8 %
City of Edinburgh	4.8 %	7.6 %	5.2 %	4.0 %	5.1 %
Leeds City Region	4.5 %	4.8 %	3.6 %	4.9 %	3.2 %
Greater Manchester	4.1 %	4.2 %	4.5 %	4.0 %	3.0 %
West of England	3.9 %	4.9 %	4.8 %	4.3 %	3.2 %

Table 4: Regional strengths in selected research areas, by proportion of the UK's overall Research Power, which shows the competitiveness of the Edinburgh City region.

[13] An interactive map can be viewed at http://www.hefce.ac.uk/analysis/maps/research/

Scientific Specialisation

With this background in place, we turn to the scientific specialisation associated with data-driven innovation (DDI). DDI is the use of data to shape, develop and deliver innovative digital propositions to consumers and citizens. It arises from the development and exploitation of data science, engineering and technology. Data science itself is the study of the computational principles, methods, and systems for extracting knowledge from data. Research and innovation here are driven by the need to deal with data that is 'big' in at least one sense: vast, fast, or complex. Data driven innovation can only arise when an industry is sufficiently digital: when many of the vital information flows are captured, transformed and shared via networked devices.

The science and research which underlies digital and data-driven innovation is sited primarily in the intellectual area of computer science and informatics, as defined in REF2014, and four of the six HEIs in the region return groups in this unit of assessment (UoA 11). However, it is important to note two key provisos: first, digital and data science-based technologies are also developed and reported in other units of assessment, especially in this case, general engineering, but also in mathematics; secondly, an important regional (and national) source of expertise in data-driven innovation is the Edinburgh Parallel Computing Centre (EPCC).[14] EPCC is the University of Edinburgh's world-class supercomputing centre which provides services for the translation of scientific research into high performance, scalable, data-intensive software applications; its translational contribution is not captured in REF2014 submissions.

Based on Research Power, the University of Edinburgh is ranked 1st in the UK, given the combination of quantity and quality in the School of Informatics, with 98.8% of staff submitted. The Table displays UK rankings for Research Power in Unit of Assessment 11 with the top universities, those active in the SIA region and other noteworthy institutes.

UK RANK	HEI	POWER	CAT A FTE	4*	3*
1	University of Edinburgh	1.00	94.85	40%	45%
2	University College London	0.98	70.70	61%	35%
3	University of Oxford	0.91	73.50	53%	34%
5	University of Cambridge	0.65	54.60	48%	41%
17	University of Warwick	0.33	24.40	56%	41%
23	Heriot-Watt University	0.22	27.70	23%	55%
31	University of St Andrews	0.19	24.00	22%	55%
66	Edinburgh Napier University	0.04	10.70	3%	54%

Table 5: The rankings in the UK of selected Universities for Unit of Assessment 11 based on research power, including those in the region, along with members of the Alan Turing Institute.

[14] http://www.epcc.ed.ac.uk/

For overall strength, Informatics at Edinburgh[15] has been consistently ranked first in the UK in RAE 2001, 2008 and REF 2014. In terms of comparative critical mass, it houses 29% more Category A staff than its nearest rival in REF 2014. Examples of recent research-led successes include: the award of three EPSRC Centres for Doctoral Training (Data Science, Pervasive Parallelism, and (joint with Heriot Watt) Robotics and Autonomous Systems); its attraction of the only UK Centre of Excellence for ARM plc; and its status underpinning Edinburgh's founding membership of the Alan Turing Institute, along with Cambridge, Oxford, UCL and Warwick.

Connectivity among the computer science and informatics groups within the region is sustained by the Scottish Informatics and Computer Science Alliance (SICSA), and by The Data Lab innovation centre, which as well as supporting joint research hosts the Data Talent Scotland initiative, bringing together companies and HEIs with a common purpose to serve the talent, skills and employability agenda in the region to drive improved productivity.

THE UNIVERSITY OF EDINBURGH	HERIOT WATT UNIVERSITY	EDINBURGH NAPIER UNIVERSITY	THE UNIVERSITY OF ST ANDREWS	SICSA
Intelligent Systems & their Applications	Intelligent Systems	Emergent Computing	Artificial intelligence	
Computing Systems Architecture		Distributed Computing and Security	Computer systems	Next Generation Internet
			Systems engineering	Complex Systems Engineering
Language, Cognition & Computation	Interaction	Interaction Design	Human Computer Interaction	Human Computer Interaction
Perception, Action & Behaviour		Information and Software Systems		
Adaptive & Neural Computation				
Foundations of Computer Science	Rigorous Systems		Programming languages	Modelling and Abstraction

Table 6: The research themes of the computer science and/or informatics departments in the Edinburgh city region in REF2014, and the research themes of the Scottish Informatics and Computer Science Alliance research pool.

With some loss of resolution, the research foci within the diverse groups can be mapped onto the structure of the School of Informatics, which has six institutes, covering: theory, systems, language and speech interaction, artificial intelligence, robotics and computer vision, and machine learning and neural computation; software engineering is an additional focus. The largest groups by volume of activity are language and interaction, and machine learning, which – along with databases and computing-at-scale – provide the research and science which fuel data-driven innovation.

An aspect of the REF2014 was Impact. Impact concerns the ways in which research was used to make real changes in society, policy and economics. REF2014 assessed impact by examining evidence-based narrative case studies which described how important research results had affected a range of external actors, via activities ranging from commercialisation, to policy influence, to public engagement. By way of example, within the Edinburgh city region, the critical mass of language and interaction research carried out in the HEIs underpins several impact cases in Unit of Assessment 11:

- Clinical and commercial applications of text-to-speech synthesis technologies
- Speech Graphics Ltd: Audio-driven Animation
- The Moses Machine Translation Toolkit
- The Natural Language Toolkit (NLTK)

However, two important provisos should be noted. First, as noted in the main body of this report, there is room for improvement regarding the quality of impact attained. There, it was observed that the proportion of DDI-related impact achieving 4* (world leading) ratings fell some way behind that achieved by UCL, Cambridge and Warwick. If 3* (internationally excellent) ratings are included, as in Table 7, the gap is not so dramatic, but there is still headroom. Secondly, the impact of a toolkit such as Moses is significant and worldwide; but the effect within the region is less obvious, at least in terms of new products and services developed within the commercial sector.

HEI	CAT A FTE	No. Case Studies	4*/3*
University of Edinburgh	94.85	10	80%
University of Oxford	73.50	8	80%
University College London	70.70	8	100%
University of Cambridge	54.60	6	100%
University of St Andrews	24.00	3[15]	87%
University of Warwick	24.40	3	100%
Heriot-Watt University	27.70	4	100%
Edinburgh Napier University	10.70	2	90%

Table 7: The performance in the UK of selected Universities for Unit of Assessment 11 impact based on the quality and the number of case studies submitted (related to number of staff submitted), including those in the region, along with members of the Alan Turing Institute.

Within the region the case studies are varied in their approach to innovation and the pathways to impact are different based on the circumstances. Tables 8 and 9 list and link to relevant case studies, and illustrate the breadth of impact across sectors.

[15] Of these three, only one is publically accessible.

UNIVERSITY	CASE STUDY TITLE	
The University of Edinburgh	Actual Analytics Ltd: automated processing of video data to reduce the use of laboratory animals in scientific research	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23948
	Automatic detection of defects in multi-threaded enterprise Java codebases	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23950
	Clinical and commercial applications of text-to-speech synthesis technologies	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23943
	Milepost GCC and compiler research at Edinburgh	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23952
	Shaping the XML technologies used to manage the world's data	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23944
	Speech Graphics Ltd: Audio-driven Animation	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23946
	The EnCore Microprocessor and the ArcSim Simulator	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23945
	The Moses Machine Translation Toolkit	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23947
	The Natural Language Toolkit (NLTK)	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23951
	The Tegola Wireless Community Broadband Project	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23949
Heriot Watt University	Enhanced reservoir management in the oil/gas sector via new algorithms for large-scale optimization	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25841
	Heriot-Watt 3D texture capture system enable 'virtual' production of 210 million IKEA catalogues annually	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25843
	Pioneering Web Portals for Health Information	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25840
	Bringing Computer Science, Programming and Computational Thinking into the Classroom	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25842
Edinburgh Napier University	Standards for Taxonomic Classification of Biodiversity Data	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=43932
	Enabling greater citizen participation in governance: e-petitioning	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=43931
The University of St Andrews	Extending Open Virtual Worlds for Cultural Heritage and Education	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=35279

Table 8: The impact case studies from the region by title and university from REF2014 in Unit of Assessment 11.

UNIVERSITY	CASE STUDY TITLE		UoA
The University of Edinburgh	A New Generation of Supercomputers results from the Co-Design of a Computer Chip for Lattice QCD Calculations	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=35273	9 Physics
	The Message Passing Interface (MPI): An International Standard for Programming Parallel Computers	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=35271	9 Physics
	Translational Biophysics - IBM Blue Gene Application Demonstrator Portfolio	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=35268	9 Physics
	Bayesian statistical methods applied to the quantification of forensic evidence	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23938	10 Mathematical Sciences
	Interior point methods adopted by leading optimization software	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23940	10 Mathematical Sciences
	New thermostatic controls adopted by molecular dynamics software providers	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23934	10 Mathematical Sciences
	Uplift modelling for improved customer targeting	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23933	10 Mathematical Sciences
	Phylogenetic analysis software BEAST informs public health responses to infection	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23898	5 Biological Sciences
	Dairy farm profitability is enhanced by the application of quantitative genetics	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23901	5 Biological Sciences
	Development of operational earthquake forecasting services	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23926	7 Earth Systems and Environmental Sciences
	Operational and strategic policy formation related to volcanic hazards in north-western Europe	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23923	7 Earth Systems and Environmental Sciences
	Commercial and clinical impact of speech synthesis	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=24042	28 Modern Languages and Linguistics
	Enhancing public understanding of human cognition	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23889	4 Psychology, Psychiatry and Neuroscience
	The Lothian Birth Cohorts: informing and changing policy and public perceptions on what is and is not associated with normal cognitive ageing	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23886	4 Psychology, Psychiatry and Neuroscience
	Delivering the Good Governance Framework of the Scottish Health Informatics Programme (SHIP)	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23972	20 Law

UNIVERSITY	CASE STUDY TITLE		UoA
Heriot Watt University	Statistical methods are helping to control the spread of epidemics	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23936	10 Mathematical Sciences
	Impact of a mathematical model of housing allocation on governmental policies	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23935	10 Mathematical Sciences
	Statistical models of mortality impact on the pricing and reserving of pensions	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23941	10 Mathematical Sciences
	Stochastic models of longevity risk adopted by the pension industry	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23942	10 Mathematical Sciences
	Valuing complex insurance liabilities using least squares Monte Carlo	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23937	10 Mathematical Sciences
	Increasing Oil Recovery by Advanced Reservoir Management	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25858	15 General Engineering
	Smart Software for Autonomous Maritime Systems	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25860	15 General Engineering
	Feature Recognition for Smart Design and Manufacture	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=25851	15 General Engineering
Edinburgh Napier University	The Power of Social Networks	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=43944	19 Business and Management Studies
Edinburgh Napier University	Animal-borne telemetry tags for conservation and weather forecasting	http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=35247	5 Biological Sciences

Table 9: DDI-related impact case studies from the region by title and university from REF2014 in Units of Assessment other than 11.

DDI research maps onto a subset of existing identified UK and Scottish priorities. In some sectors, computer science and informatics (and allied expertise in general engineering and mathematics and statistics) is critical; in other sectors, it is an enabler or only a subpart of a larger field. Among the latter cases, for example, quantum technologies (including computing) are one of several emerging technologies; robotics enables certain forms of high value manufacturing; and data science and technology pervade regenerative medicine, synthetic biology and agri-science.

EIGHT GREAT TECHNOLOGIES	INNOVATE UK PRIORITIES	UK INDUSTRIAL STRATEGY SECTORS
Data[16]	**Digital Economy**	**Creative Industries**
Robotics	**Enabling Technologies**	
Regenerative Medicine	*Emerging Technologies*	
Synthetic Biology	*Health and Care*	*Life Sciences*
Agriscience	*Agriculture and Food*	*Food and Drink*
Satellites	Space Applications	
Energy Storage	Energy	Energy
Advanced Materials	*High Value Manufacturing*	
	Transport	
	Urban Living	
	Built Environment	
		Financial/Business Services
		Sustainable Tourism

Table 10: Mapping onto identified priority sectors. Bold indicates that the research and science is a crucial enabler in that sector. Italics indicates that it is relevant to data driven innovation in the sector.

Strength in research competition, national and international

At a national level, the region competes effectively for funding, attracting 50% more than the University of Oxford, and double that secured by UCL.

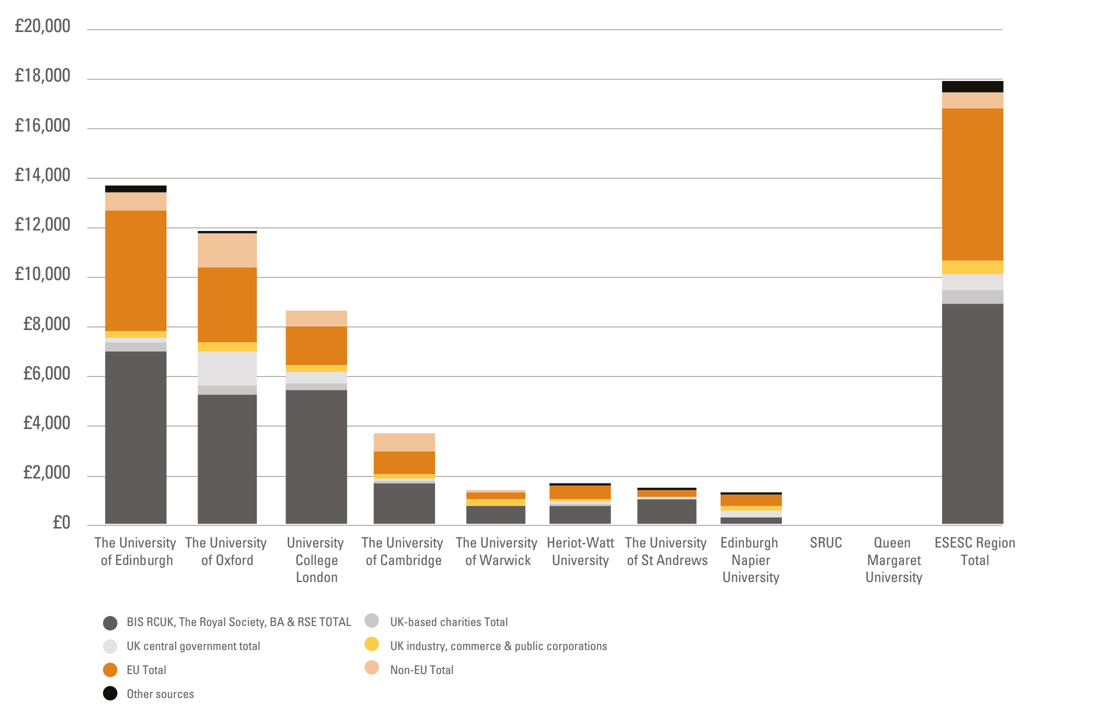

Fig 3: Finance Statistics Return - Research grants & contracts - breakdown of income in IT, systems sciences & computer software engineering research in the academic year 1415 (SRUC and QMU had zero income in this area).

[16] Including energy efficient computing.

The Engineering and Physical Sciences Research Council (EPSRC) is the most important RCUK funder for data driven innovation, though it is by no means the only relevant research council. The University of Edinburgh is counted as a Framework University with EPSRC, one of twelve. These framework universities account for 60% of EPSRC's portfolio and this is a highly valued and managed stakeholder relationship, on both sides. EPSRC also have strategic relationships with Heriot Watt University and the University of St Andrews.

HEI	NO. GRANTS	TOTAL GRANT VALUE / £
University of Edinburgh	128	£140,234,221
Heriot Watt University	79	£69,754,847
University of St Andrews	44	£56,386,955
Edinburgh Napier University	2	£347,801
Queen Margaret University	0	0

Table 10: Current EPSRC Grants to HEIs in the region based on the Grants on the Web database on the EPSRC website

Innovate UK funding can be used as a method of seeing knowledge exchange activity in the region as it requires collaboration with a private sector organisation. However, while the regional activity is low this is likely due to alternative industry engagement mechanisms being utilised.

	INNOVATE UK TOTAL	KTP	FEASIBILITY STUDY	COLLABORATIVE R&D	EUROPEAN
University of Edinburgh	2	1	0	1	0
Heriot Watt	13	8	2	3	0
University of St Andrews	6	0	1	4	1
Edinburgh Napier	10	8	0	2	0
Queen Margaret University	0	0	0	0	0

Table 11: Total active Innovate UK projects at the HEIs in the region, accessed from Gateway to Research. Table also includes the breakdown of the type of project.

Income in research competitions can also be identified by REF unit of assessment; as well as computer science and informatics, we include for comparison general engineering (which includes work on sensors, communication, and networks, for instance) and mathematics (which includes work on the statistical underpinnings of data science).

UNIT OF ASSESSMENT	2008	2009	2010	2011	2012
Computer Science and Informatics	£9,848,256	£9,994,081	£8,921,251	£7,760,405	£9,328,406
General Engineering	£15,606,110	£14,785,120	£16,219,980	£16,673,803	£15,296,151
Mathematical Sciences	£3,511,155	£4,522,130	£4,035,274	£5,003,179	£4,891,950

Table 8 REF Research Income - Annual value of income (£) in the Edinburgh City Region, domestic sources. Source: Research Excellence Framework (REF). Results. Higher Education Funding Council for England (HEFCE). At an international level too, the region also competes effectively for funding.

UNIT OF ASSESSMENT	2008	2009	2010	2011	2012
Computer Science and Informatics	£5,482,652	£4,197,926	£5,061,515	£5,720,347	£6,004,939
General Engineering	£3,710,822	£3,532,536	£4,708,555	£5,233,990	£6,200,178
Mathematical Sciences	£518,717	£674,778	£642,741	£813,499	£969,827

Table 9 REF Research Income - Annual value of income (£) in the Edinburgh City Region, international sources. Source: Research Excellence Framework (REF). Results. Higher Education Funding Council for England (HEFCE).

Within non-UK funding the majority, as seen in Figure 1, comes from EU funding. This source of funding is currently a large part of the research landscape, and so there is a risk given recent political events that the stability of the funding landscape is at risk.

The priority of European Research Council (ERC) grants is to fund scientific excellence. The UK outperforms the rest of Europe in this area.

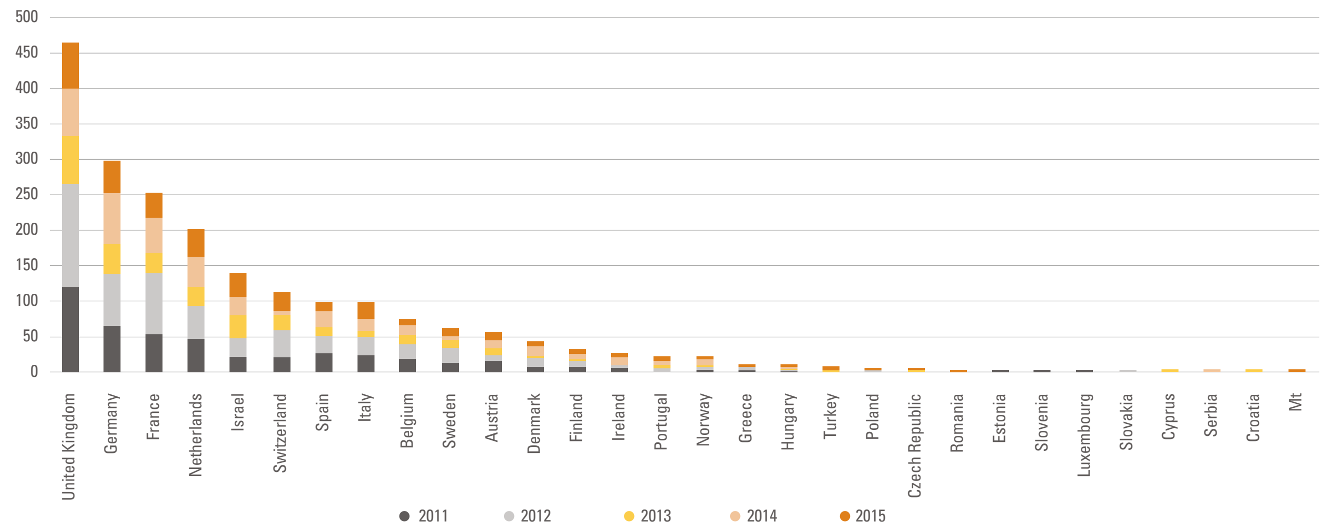

Fig 4: ERC Grants from the last 5 years by country. Accessed from erc.europa.e

Both the University of Edinburgh and the University of St Andrews are in the ERC's top 100 universities by applications to ERC[17].The regions of Edinburgh and St Andrews are also both in the top 50 for physical sciences and engineering awards, seen in Figure 5.

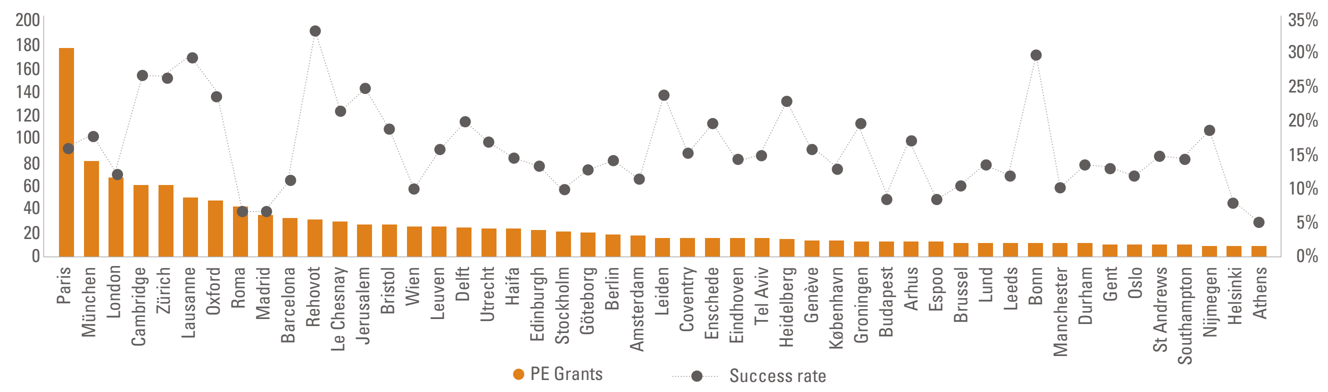

Fig 5: Funded applicants and success rates in top-50 localities in Physical Sciences and Engineering. Edinburgh is ranked 20th and St Andrews 45th. Graph taken from Reference 7.

[17] ERC Funding Activities 2007-2013. Accessible at https://erc.europa.eu/sites/default/files/publication/files/ERC_funding_activities_2007_2013.pdf

The East Scotland Region performs 13th best in Europe for ERC funding, and while this does not map directly onto the City Region, it is mostly attributable to the success of the Universities of Edinburgh and St Andrews. This again brings us in as the most successful UK region outside the golden triangle of London, Oxford and Cambridge.

RANKING BY NO. OF AWARDS	2nd	4th	6th	13th
NUTS Region	UKI1 Inner London	UKH1 East Anglia	UKJ1 Berkshire, Buckinghamshire and Oxfordshire	UKM2 East Scotland
Total Applications	1570	628	700	547
Total Awarded	265	148	129	73
Success Rate	16.9%	23.6%	18.4%	13.3%
Awarded Physical Sciences and Engineering	69	66	54	35
Awarded Life Sciences	112	55	37	20
Awarded Humanities and Social Sciences	84	27	38	18

Table 12: ERC Funding statistics 2007-2013demonstrate the competitiveness of the East Scotland Region in Europe.

It is clear therefore, both by the research quality review in REF2014 and by our research funding success, that the Edinburgh City region is highly valuable and internationally competitive.

Appendix 3: List of References

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The cover image is from the Turing Suite by Sir Eduardo Paolozzi (1924-2005), one of the most versatile artists from Britain after 1945. Educated mainly in London and Paris, he always had strong ties to his hometown Edinburgh. His father and uncle died in WWII when the convoy taking them to Canada was bombed.

Alan Turing was an informatician who, in the 1930s, worked on the theory that brains are computational devices. He developed the Universal Turing Machine, helping fix the limits of mechanical computation; modern computers directly descend from his ideas. As well as being a key figure during the Second World War at at Bletchley Park, Britain's code breaking centre, Turing is also considered the father of artificial intelligence, and the first computational biologist.

The Turing Suite portrays Turing's contribution at Bletchley Park. Paolozzi was interested in genius and wanted to depict Turing's work in deciphering the Enigma Code. The vivid colours evoke the intensity of Turing's inner vision of the natural world. Edinburgh's Informatics Forum houses one of the limited edition print suites.