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hefcw



The impacts of research from Welsh universities

*A comprehensive review of the REF 2021
impact case studies*

Full report

October 2023

WRITTEN BY:

THE
POLICY
INSTITUTE



Different Angles

ELECTRIC DATA
solutions

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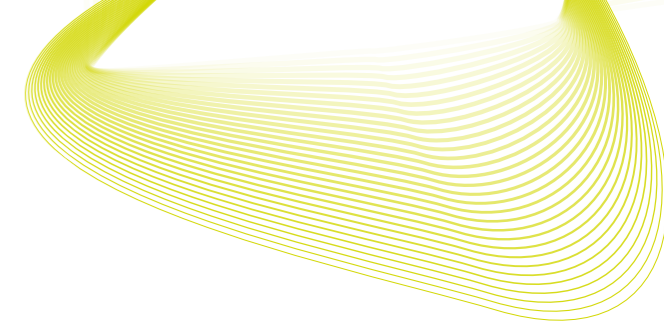
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Executive summary



This study was commissioned by the Learned Society of Wales to better understand, promote and communicate the contribution that Welsh Higher Education Institutions (HEIs) make to wider society. In doing so it takes all 280 publicly available impact case studies (ICS) submitted by Welsh HEIs to the 2021 Research Excellence Framework (REF 2021) and – through complementary quantitative and qualitative approaches – explores the nature of the impacts produced, the mechanisms supporting this and the groups of people that benefit. The case studies present a compelling and inspirational picture of the contributions made by Welsh HEIs beyond academia and Wales’s borders.

After the assessment of impact was introduced as part of the REF in 2014 (alongside the assessment of outputs and the institutional environment supporting research), the weighting of this component was increased from 20% to 25% in 2021. HEIs were required to submit impact case studies (ICS) describing the impact of research conducted across (up to) 34 subject-based units of assessment (UOAs), arranged under four main disciplinary panels. For each UOA, expert panels assessed the contribution of research – as described in the ICS – in producing an “effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia”.

While the analysis reported here is comprehensive in its coverage of the ICS submitted, it is important to note that these 280 examples represent a portion of the research taking place in Welsh HEIs and the impacts they produce (albeit, by definition, including the most high-impact work). For that reason, this report should not be taken as a picture of the sector as a whole – there will be many other contributions not captured as part of the REF exercise. It does, however, reveal the many strengths and varied impacts of research undertaken in Welsh HEIs. Assessing impact across the disciplinary spectrum also shines a light on those research areas that might typically have a lower-profile or in which less “traditional” conceptualisations of impact might be more common.

Key findings from the analysis are set out below.

Key findings

Welsh HEIs have a significant impact on society

The ICS submitted as part of REF 2021 form a rich dataset. They are useful for both demonstrating the scale and nature of impacts arising from Welsh HEIs, as well as exploring in detail the range of groups involved and diverse approaches to engaging with and benefiting the world outside academia. The opportunity to focus on HEIs in Wales in a geographically distinct analysis allowed us to read and analyse every ICS submitted, rather than relying on a limited sample, and enables us to build a nuanced picture across disciplines of the impact arising from HEIs in Wales. In doing so we are able to explore in more detail the various “pathways” by which impact is produced – for example, who is involved and the activities that are undertaken. This is particularly valuable in those areas that might have fewer “standardised” routes to impact (such as patenting or commercialising a technology) and we hope it can both help demonstrate the value to society of such research and inspire others to pursue novel ways of creating impact. It is also worth noting that the diversity of pathways and approaches documented in the ICS mean that impacts are realised over a longer-term period. Our analysis of these “time lags” between research outputs and impact (see Section 5.3) shows some variation both within and between disciplines, but across all research provides further evidence that generating impact is not a short-term endeavour.

Impact from Welsh HEIs emerges from multiple disciplines and its creation is a bespoke activity involving many possible pathways.

Although some impact topics are more strongly associated with some REF Panels – as we would expect – it is notable that in general each impact topic comprised contributions submitted to a variety of UOAs (see Figure 7) and drew on underpinning research from a wide range of research fields (see Figures 13 and 14). This illustrates the many possible routes to creating impact that were reported. We also examined cross-discipline collaboration in the research underpinning the reported impacts within individual ICS and how this varied by REF Main Panel. This analysis is reported in section 3.4.

Partnerships with non-academic stakeholders featured prominently in the creation of impact

The vast majority of ICS from Welsh HEIs – 94% – reported collaboration with non-academic partners (see Section 3.2). Most commonly this involved public sector bodies in Wales or the UK more widely (43% of partnerships described), including UK and Welsh national and local government as well as arm’s-length bodies and departments. A further 29% of collaborations were with industry partners, leading to impacts in areas including education, media and communication, healthcare, and digital environments. International partnerships with non-academic stakeholders were reported in 22% of ICS.

Welsh HEIs produced impact in a wide range of areas, with comparatively more ICS than UK HEIs as a whole in topics including “Environmental conservation” and “Energy”

We find that Welsh HEIs contributed across all 79 impact topics identified in the UK-wide analysis. This similarity to the UK as a whole is in itself an impressive achievement, given that this diversity was achieved within a much smaller number of HEIs and hence far fewer ICS. While the distribution across topics was similar for Welsh HEIs and for the wider UK, there was some slight variation in the relative proportions (see Figure 3 and Table 5). The analysis showed that comparatively more ICS from Welsh HEIs were classified in the impact topics “Environmental conservation” and “Energy”, and comparatively fewer in “Media and communication” and “Training and skills”. It is important to note that this latter observation is not an indication of either lower “quality” or of a small contribution in absolute terms – rather it is a reflection of the specific landscape of research impact in Wales and, indeed, both topics were in the five impact topics for Welsh HEIs with the greatest volume of submissions. Overall, the most prominent impact topic was “Wales”, a topic for which the associated ICS were distributed across all four broad disciplinary panels (further information on this topic is provided in Box 1). ICS associated with the second most common topic, “Training and skills”, also came from all four panels, but with larger numbers in Panels A and C.

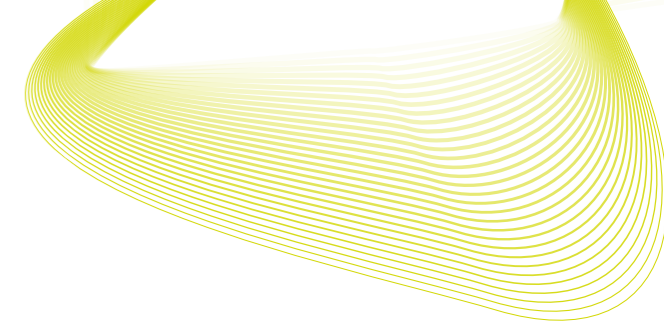
The sectors in which Welsh HEIs most often reported impact were “human health and social work activities”, “education” and “public administration and defence”

The qualitative coding revealed that impacts reported in ICS from Welsh HEIs occurred across 30 different sectors of the economy, as defined by the condensed version of the UK’s Standard Industrial Classification. Across the full set of ICS, 35% reported an impact in “human health and social work activities”, 25% in “education” and 22% in “public administration and defence” (see Table 7).

In addition to the 70% of ICS that documented impact in Wales, research carried out in Welsh universities has impact globally. Over 60% of ICS described research that had an impact internationally

Research carried out in Welsh HEIs reaches far beyond Wales in its impact, with over 90% of ICS reporting an impact in the wider UK and more than 60% describing international impact (see Sections 2.4 and 2.5). The

1. Introduction



top four sectors in which impact was reported were identical in each geographical area, although this is perhaps not surprising given the substantial overlap between ICS reporting impact in each region.

85% of ICS from Welsh HEIs reported impact in changing processes or practices, although there was significant overlap with other types of impact - in particular changing policy and governance (51%) and economic impacts (42%). Multiple types of impacts were reported in 77% of ICS.

The most commonly reported type of impact was that research created some kind of change in processes or practices, which featured in 85% of ICS from Welsh HEIs (see Section 2.6). This included changing practitioner knowledge or behaviour, informing new procedures and practices, and the creation and adoption of new products and services, as well as modifications to existing processes, procedures and guidelines (see Table 10). As we would expect, the sectors in which these impacts occurred reflect the sectors benefiting more widely from Welsh research, with “human health and social work”, “education” and “public administration and defence” featuring most prominently. It is worth noting, however, that 77% of ICS reported multiple types of impact, with 121 of those that reported changes in processes or practice also reporting impact on policy, while 100 ICS reported both impact on practice and economic impacts. This demonstrates how research has impact in multiple areas of social and/or economic life and how individual case studies often have multiple pathways to impact.

Over half of ICS informed policy or governance, while 42% had an economic impact, particularly in the manufacturing sector

While changes in processes and practices were most frequently reported, other types of impact were also widespread in the ICS. Over half of ICS described changes in policy or governance, while one-third reported changing public debate or perceptions – again, predominantly in sectors reflective of the overall set of ICS. Economic impact was reported in 42% of ICS, but here the sectoral profile was slightly different, with manufacturing featuring most prominently – overall, 9% of all Welsh ICS reported an economic impact in the manufacturing sector (25 of the 118 – or 21% – of the ICS that reported any economic impact).

The beneficiaries of research from Welsh HEIs were widespread and varied, including both those who benefited in a professional capacity and the wider public, in Wales, the UK and internationally

A wide array of people and groups benefited from the impacts reported by Welsh HEIs, with two-thirds of ICS reporting an impact on decision-makers and influencers, and just under half describing impacts on various groups within the wider public (see Section 4.1). Among decision-makers, government departments featured most prominently – overall around 20% of ICS benefited a Welsh Government department – while other groups mentioned include politicians, local government and sector-specific bodies in areas such as health and justice. Within the wider population, 25% of ICS reported benefiting children and young people, most commonly within Wales through direct engagement in schools or impacts on education policies and materials, for example. Other demographic groups referred to frequently included local and regional populations, and women and gender-based groups.

The United Kingdom’s 2021 Research Excellence Framework (REF 2021) was the second nationwide assessment of academic research to formally evaluate non-academic impact. This section provides an overview of REF 2021, how impact was assessed, and an outline of the aims and objectives of the report, which highlights and enumerates the impacts of research from Wales.

1.1. Overview of the Research Excellence Framework 2021

The REF is a system for assessing the quality of research undertaken in UK higher education institutions (HEIs) and since its introduction in 2014 – as a replacement for the previous Research Assessment Exercise – has been used as a means of allocating research funding over the subsequent time period. The 2021 exercise took place a year later than intended, following delays arising from measures to combat the Covid-19 Pandemic in 2020.

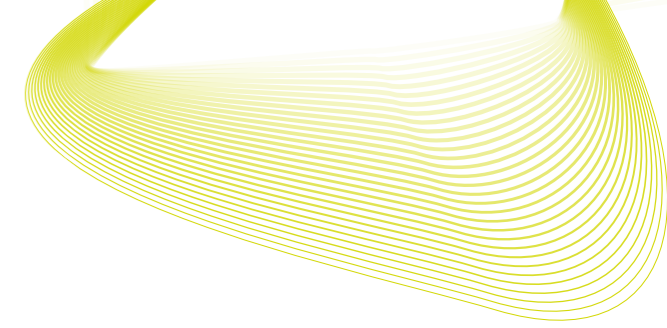
REF 2021 involved the four UK higher education funding bodies - Research England (RE), the Scottish Funding Council (SFC), the Higher Education Funding Council for Wales (HEFCW), and the Department for the Economy, Northern Ireland (DfE NI) – and was managed by the REF team based at RE.

157 UK HEIs made submissions to 34 units of assessment (UOAs) in REF 2021. These submissions were assessed by expert sub-panels within each UOA. Sub-panel membership comprised academics and research user members from outside of academia, including impact assessors. The sub-panels worked under the guidance of four Main Panels labelled A to D (Table 1) following broad disciplinary groupings, as was the case in 2014. Research was assessed on the quality of research outputs (which counted for 60% of the assessment), the vitality of the research environment (15%), and the wider impact of research (25%). The weighting for impact was increased from 20% to 25% between REF 2014 and REF 2021, with a relative reduction in weighting for quality of research outputs from 65% to 60% (although it should be noted the “impact template” from 2014 was dropped in the 2021 edition).

Impact was defined in REF 2021 as “the effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia” (REF, 2019).

Institutions were required to report on their research impact in the form of four-page narrative “impact case studies” (ICS). These outline the non-academic changes and benefits arising from academic research. A total of 6,781 impact case studies were submitted to REF 2021. The number of ICS submitted by individual HEIs varied according to the number of FTE of the submitted staff, with a minimum of two case studies being required for the smallest units. It was possible to submit ICS based on continuing impact from REF 2014, although such cases were not handled consistently across the panels. Panel A noted that “[it wished] to receive information on how any continued case study relates to that submitted in REF 2014. Panel members will have access to the REF 2014 database and may refer to this to understand the context of the 2021 case study”, whilst Panels B, C and D said the opposite - ie “do not wish to receive information on how any continued case study relates to that submitted to REF 2014”.

Impact case studies were assessed against “reach and significance”. Reach was defined as “the extent and/or diversity of the beneficiaries of the impact, as relevant to the nature of the impact” and was measured “in terms of the extent to which the potential constituencies, number or groups of beneficiaries have been reached”. Significance was defined “as the degree to which the impact has enabled, enriched, influenced, informed or changed the performance, policies, practices, products, services, understanding, awareness or well-being of the beneficiaries”.



Each ICS comprised five sections: “summary”, “underpinning research”, “references to the research”, “details of the impact”, and “sources to corroborate impact”. Impact had to have occurred between 1 August 2013 and 31 December 2020 – an extended period following the Covid-19 pandemic – and the underpinning research between 1 January 2000 and 31 July 2020.

Table 1: Units of assessment (UOAs) and respective Main Panels for REF 2021

Main Panel A: Medicine, Health and Life Sciences	UOA1	Clinical Medicine
	UOA2	Public Health, Health Services, and Primary Care
	UOA3	Allied Health Professions, Dentistry, Nursing, Pharmacy
	UOA4	Psychology, Psychiatry, Neuroscience
	UOA5	Biological Sciences
	UOA6	Agriculture, Veterinary and Food Sciences
Main Panel B: Physical Sciences, Engineering, and Mathematics	UOA7	Earth Systems and Environmental Sciences
	UOA8	Chemistry
	UOA9	Physics
	UOA10	Mathematical Sciences
	UOA11	Computer Science and Informatics
	UOA12	Engineering§
Main Panel C: Social Sciences	UOA13	Architecture, Built Environment and Planning
	UOA14	Geography and Environmental Studies
	UOA15	Archaeology
	UOA16	Economics and Econometrics
	UOA17	Business and Management Studies
	UOA18	Law
	UOA19	Politics and International Studies
	UOA20	Social Work and Social Policy
	UOA21	Sociology
	UOA22	Anthropology and Developmental Studies
	UOA23	Education
	UOA24	Sport and Exercise Sciences, Leisure and Tourism
Main Panel D: Arts and Humanities	UOA25	Area Studies
	UOA26	Modern Languages and Linguistics
	UOA27	English Heritage and Literature
	UOA28	History
	UOA29	Classics
	UOA30	Philosophy
	UOA31	Theology and Religious Studies
	UOA32	Art and Design: History, Practice and Theory
	UOA33	Music, Drama, Dance and Performing Arts
	UOA34	Communication, Cultural and Media Studies, Library and Information Management

1.2. Assessing research impact: methods & objectives

All the impact case studies submitted to REF 2021 that are available for analysis are made available as a searchable database.¹ As with the REF 2014 database, this repository provides a rich resource of text showcasing research that has led to benefits to society beyond the academy.²

This report makes use of this repository to investigate the impact created by Welsh HEIs by analysing the 280 case studies submitted by these institutions for REF 2021. We also analyse a sub-sample of these – 78 case studies that received Welsh Government funding. These analyses are placed comparatively within the wider context of the 6,361 publicly available case studies submitted to REF 2021 by UK institutions overall, inclusive of Wales.

In REF 2021 Wales performed particularly well on impact with 89% of Welsh research considered internationally excellent or world-leading. This is higher than the proportion for the UK as a whole and, among the UK nations, is joint highest alongside Northern Ireland. It is important to note, however, that in this report we make no comment on the “quality” of impacts reported in the ICS and the scores they received, instead focusing on the nature of the impacts coming from research in Welsh HEIs, the mechanisms that support this and the various groups benefiting.

This report follows a previous report published in 2016 by the Policy Institute at King’s College London, commissioned by The Learned Society of Wales, which presented an in-depth analysis of the impact case studies submitted by Welsh universities to REF 2014 in order to better understand and communicate the contribution of research from HEIs in Wales to wider society.³ The present report replicates and extends this analysis, examining the 280 impact case studies submitted by Welsh universities to REF 2021 as well as the sub-sample of those case studies reporting impacts from research funded by the Welsh Government.

The study comprises two interlinked workstreams to ensure both breadth and depth of analysis:

1. Large-scale quantitative text mining of the complete dataset.
2. Reading, coding and qualitative analysis of all ICS from Welsh HEIs.

Our quantitative, automated analysis is contextualised and extended by the qualitative analysis of all the ICS submitted by HEIs in Wales. Each case study was read and analysed, guided by the following questions:

- What are the characteristics of the research underlying the impact?
- What sector does the impact occur in and what are the main types of impact?
- What were the activities or mechanisms that enabled impact to take place?
- Who are the beneficiaries of the research and what is the nature of their engagement?
- What were the specific benefits to Wales?

¹ Impact case study database (2021). Available at: <https://results2021.ref.ac.uk/impact>

² Impact case study database (2014). Available at: <https://impact.ref.ac.uk>

³ Hinrichs-Krapels, S. & Hewlett, K. (2017) Impacts of academic research from Welsh universities: A comprehensive review of the REF 2014 impact case studies. The Policy Institute at King’s.

2.2. Comparative overview of the “impact topics” of Welsh REF impact case studies

Using all 6,361 publicly-available ICS submitted by UK HEIs, we developed a topic model to create a taxonomy of the kinds of impacts described in the REF 2021 ICS, based on the text provided in Section 4 of the ICS – “Details of the impact”.⁶ Topic modelling is a language processing technique applied to document-sets to understand the different combinations of words or phrases (topics) that are present. This method seeks to develop results derived directly from the data it analyses and to avoid, as much as possible, a dependence on subjective notions of structure or conceptual categorisations of impact. The purpose of this method is to create a data-driven map of the key details of the case studies analysed.

In doing this, we identified 79 impact “topics”, as listed in Table 3, from the UK dataset and identified 12 cognate impact topic clusters, as listed in Table 4.

Table 2: Top 10 primary impact topics of Welsh ICSs

PRIMARY TOPIC	NUMBER OF ICS FROM WELSH UNIVERSITIES
WALES	86
TRAINING AND SKILLS	39
APPLIED TECHNOLOGY	28
DIGITAL ENVIRONMENTS	25
MEDIA AND COMMUNICATION	24
TREATMENT AND DISEASE	21
SOCIAL SERVICES AND PRIMARY CARE	20
STUDENTS AND EDUCATION	19
ENVIRONMENTAL CONSERVATION	17
TEACHING AND EDUCATION	17

Table 2 shows the top 10 primary impact topics of ICS from Welsh HEIs. This shows the prominence of “Wales” as an impact topic (see Box 1 for discussion of this), as well as topics such as “Training and skills”, “Applied technology”, and “Media and communication”, among others.

In Figure 2, the left-hand panel maps the 6,361 ICS for the whole of the UK, the middle panel the 280 ICS from Welsh HEIs, and the right-hand panel the 78 ICS that report Welsh Government funding support and come from Welsh HEIs. In this figure, each “dot” represents an ICS, the topics are numbered (as per the numbering in Table 3), and we have also used colouring to indicate the clusters – which can be considered to be groupings of closely-related topics (as described in Table 4).

It is interesting to note that some clusters are positioned more closely to one another. For example, “Energy, environment and engineering” (purple) and “Food, environment and ecology” (dark blue) can be found close together in the bottom right-hand corner of the figure. This is a result of the topics within those clusters being more similar than others in terms of vocabulary used. Compared to the majority of the 79 topics, the three topics that sit within the “Devolved nations” cluster (“Scotland”, “Wales”, and “Northern Ireland”) are slightly unusual in the sense that they don’t target a traditional impact area like the others.

IMPACT TOPICS: THE MAIN TOPICS OF IMPACT DESCRIBED BY CASE STUDIES AS DERIVED FROM A TOPIC-MODELLING ANALYSIS OF THE ‘DETAILS OF THE IMPACT’ SECTION IN REF IMPACT CASE STUDIES

Figure 2 also demonstrates that the impacts outlined within those specific ICS do not sit within one impact area and are likely to be related to a range of health, environmental and social impacts. It should be stressed that the topic modelling and clustering is entirely driven by the underlying content of the case studies; the topics are based on the text within Section 4 of the ICS “Details of the impact”. As a result, we can see that the topics and resulting clusters go beyond typical discipline areas and cover a wide range of impacts relating to health, society, and the environment.

Box 1. The “Wales” impact topic

What does the ‘Wales’ topic represent?

The topic modelling algorithm discovered three topics that are directly related to devolved nations in the UK – topic 5 (‘Northern Ireland’), topic 17 (‘Scotland’), and topic 23 (‘Wales’). These are grouped together in cluster 10 (‘Devolved nations’). This means that a sufficient number of ICS use terms relating to specific nations (such as place names, parliaments, government departments or programmes) for the algorithm to identify a coherent set of documents for each. Although mentions of the other UK nation – England – also feature in the ICS texts, they appear far more frequently (since most case studies are submitted by English HEIs) and are not significant enough to distinguish them from other case studies. For this reason, an England topic is not produced by the algorithm.

Essentially, the nation-specific topics identify ICS that are highly relevant to a particular nation, although they may have been submitted by any HEI in the UK. Indeed, it is not uncommon for impact to be exported across regions. For example, a total of 101 case studies were assigned to topic 23 (‘Wales’), of which 86 were submitted by Welsh HEIs and the remaining 15 by HEIs in other parts of the UK.

Table 3: The 79 impact topics, derived from the UK set of ICS (n=6,361)

Topic No	Label	Topic No	Label	Topic No	Label	Topic No	Label
0	Public Health	20	Drug discovery and clinical trials	40	Dementia and Alzheimer’s	60	Social services and primary care
1	Treatment and disease	21	International development	41	Domestic abuse and gender-based violence	61	Museums and cultural heritage
2	Computing and software development	22	Film and documentary	42	Energy	62	Media and communication
3	Applied technology	23	Wales	43	Employment conditions	63	Marine environment and fishing
4	Teaching and education	24	Procurement and supply chains	44	Mental health	64	Ethics and artificial intelligence
5	Northern Ireland	25	Gender equality	45	Genetic testing and diagnostics	65	Farming and animal welfare
6	History and cultural heritage	26	Dentistry	46	Climate resilience	66	Gambling
7	Music and live performance	27	Theatre and performing arts	47	Young people and youth support	67	Hate crime and criminal activity
8	POlicing	28	Viruses and vaccination	48	Poetry and literature	68	Performance and dance
9	Communities and urban planning	29	Stroke and brain injury	49	Students and education	69	Intelligence and cyber security

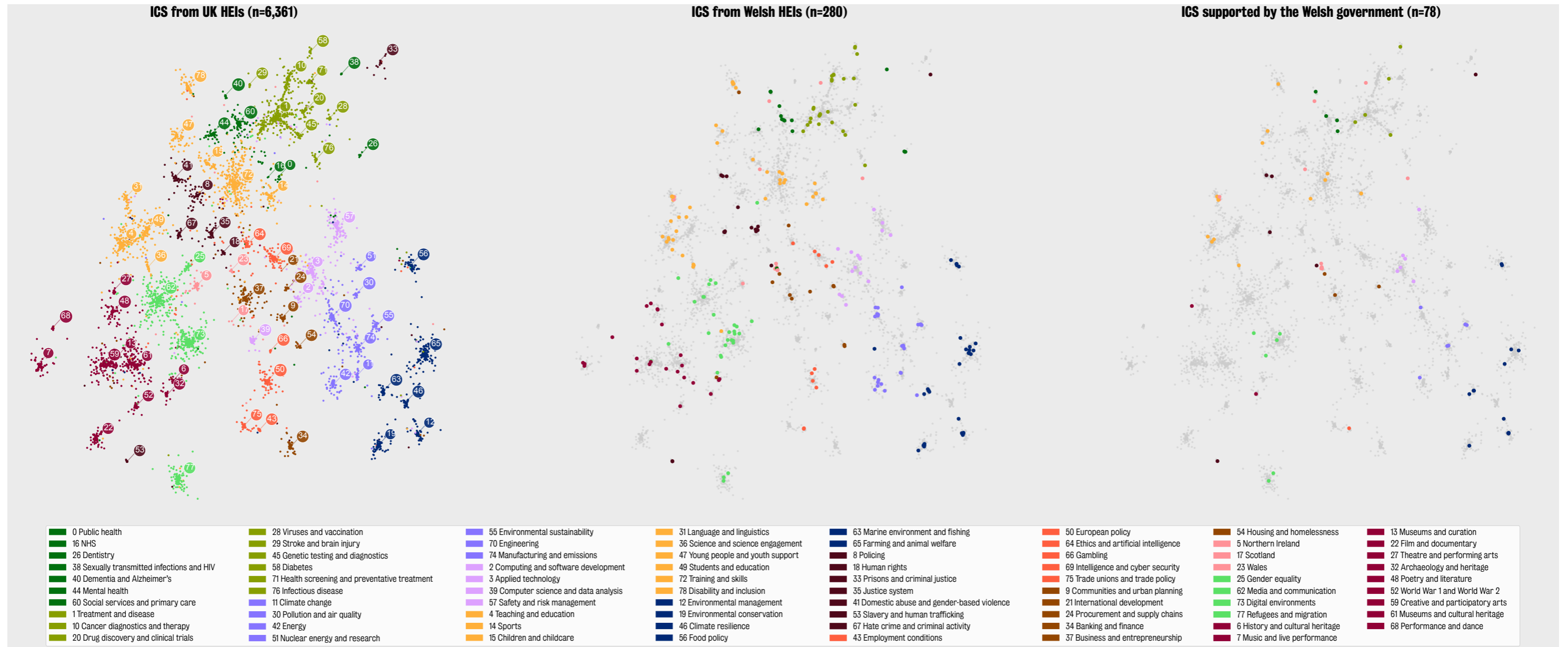
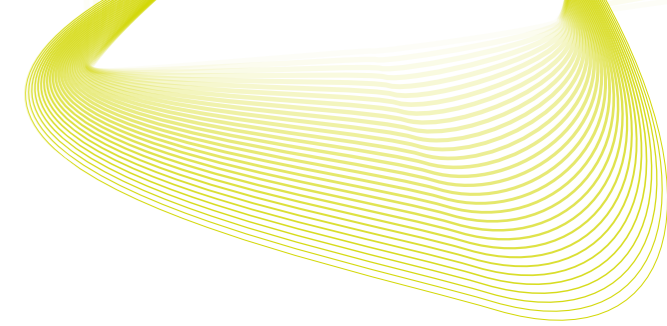
⁶ More details on the topic modelling approach can be found in Annex A

Topic No	Label	V	Label	Topic No	Label	Topic No	Label
10	Cancer diagnostics and therapy	30	Pollution and air quality	50	European policy	70	Engineering
11	Climate change	31	Language and linguistics	51	Nuclear energy and research	71	Health screening and preventative treatment
12	Environmental management	32	Archaeology and heritage	52	World War 1 and World War 2	72	Training and skills
13	Museums and curation	33	Prisons and criminal justice	53	Slavery and human trafficking	73	Digital environments
14	Sports	34	Banking and finance	54	Housing and homelessness	74	Manufacturing and emissions
15	Children and childcare	35	Justice system	55	Environmental sustainability	75	Trade unions and trade policy
16	NHS	36	Science and science engagement	56	Food policy	76	Infectious disease
17	Scotland	37	Business and entrepreneurship	57	Safety and risk management	77	Refugees and migration
18	Human rights	38	Sexually transmitted infections and HIV	58	Diabetes	78	Disability and inclusion
19	Environmental conservation	39	Computer science and data analysis	59	Creative and participatory arts		

Table 4: The 12 impact clusters, derived from the UK set of ICS (n=6,361)

Number	Cluster Label
1	Public health and health services
2	Clinical medicine
3	Energy, environment and engineering
4	Information, applied technology and analytics
5	Training, education and skills
6	Food, environment and ecology
7	Criminal justice and human rights
8	Policy, ethics and security
9	Business, planning and economics
10	Devolved nations
11	Culture and society
12	History, heritage and creative arts

Figure 2: The relationship of the 79 impact topics, for the UK dataset, ICS submitted by Welsh HEIs, and ICS supported by the Welsh Government



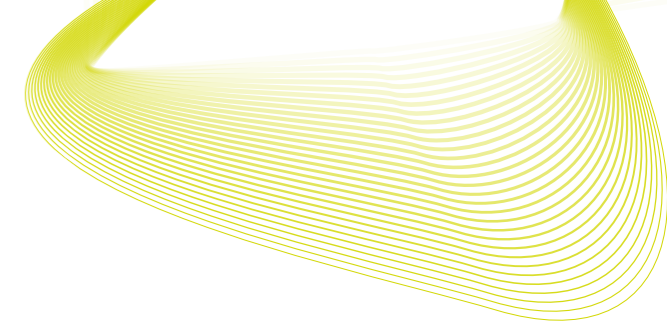


Figure 3 compares the proportion of case studies classified in different impact topics by HEIs in Wales compared to those of HEIs in the rest of the UK. Each circle represents the total number of submissions by HEIs in Wales for that impact topic, with the size of the circle indicating the absolute number of case studies submitted. Circles positioned above zero indicate that Wales submitted proportionally more ICS (as a proportion of the total number of submissions from Wales) for that topic, compared to the rest of the UK.⁷

As can be seen in the upper panel, the “Wales” topic is the dominant impact topic – that is, Welsh HEIs submitted more ICS classified in the impact topic “Wales” than for all UK HEIs. Given this dominance, the lower panel illustrates the same data but with the “Wales” topic removed. The data for the “top 10” and “bottom 10” impact topics are provided in Table 5. Along with Figure 3, this shows where Welsh HEIs have a comparative advantage and comparative disadvantage when it comes to impact.

Figure 3: Relative volume of submission by impact topic, Welsh HEIs vs UK HEIs



Table 5: Comparative advantage and comparative disadvantage (by volume of ICS) of impact topics for Welsh HEIs (top and bottom 10 listed for the 79 impact topics)

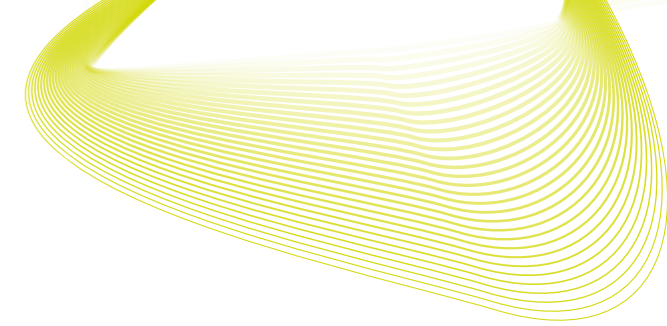
Primary Topic	% Difference compared to rest of UK	Number of ICS from Welsh HEIs
“Top 10”:		
Wales	29.1%	86
Environmental conservation	2.6%	17
Energy	2.5%	14
Applied technology	2.3%	28
Marine environment and fishing	1.9%	13
Language and linguistics	1.7%	11
Procurement and supply chains	1.6%	7
Sports	1.1%	10
Dementia and Alzheimer’s	1.0%	6
Social services and primary care	1.0%	20
“Bottom 10”:		
Communities and urban planning	-1.6%	7
Refugees and migration	-1.6%	5
Teaching and education	-1.7%	17
Children and childcare	-1.9%	8
Banking and finance	-2.1%	2
Creative and participatory arts	-2.5%	11
Trade unions and trade policy	-2.9%	1
Treatment and disease	-3.0%	21
Training and skills	-4.7%	39
Media and communication	-5.3%	24

2.3. The disciplinary areas underpinning the REF 2021 impact case studies

The distribution of submissions by UOA for the 280 Welsh ICS, 78 ICS supported by the Welsh Government and the 6,361 UK ICS is shown in the impact wheels in Figure 4. The four colours represent the four panels: Panel A: pink, Panel B: blue, Panel C: purple, and Panel D: green. Different shades of the same colour are used to represent the 34 UOAs that are associated with the four panels. The size of the spokes in the impact wheels indicates the proportion of submissions in that UOA.

There is very little difference between the Welsh and UK sets of ICS, with UOA7 (Earth Systems and Environmental Sciences) being the only unit that has relatively more submissions outside a ± 1 percentage point range. This is illustrated in Figure 5, where we have compared the relative volume of submissions between the two data sets, with UOA7 from Welsh HEIs accounting for 9.5% of the total (compared to the expected value of $280/6361 = 4.4\%$). Other UOAs where Welsh HEIs show a comparative strength, in terms of volume of submissions, are UOA26, Modern Languages and Linguistics, with 8% of all submissions and UOA6, Agriculture, Food and Veterinary Sciences, with 7% of all submissions. Interestingly, the comparative strength of Modern Languages and Linguistics is partly underpinned by Welsh Government support, with 9% of the 78 Government-funded ICS having been submitted in this UOA. Other areas where ICS are disproportionately supported by the Welsh Government are UOA3 (Allied Health Professions, Dentistry, Nursing and Pharmacy)

⁷ Note that for all the impact topic data presented, we have allowed each ICS to be allocated to up to three impact topics in the topic model.



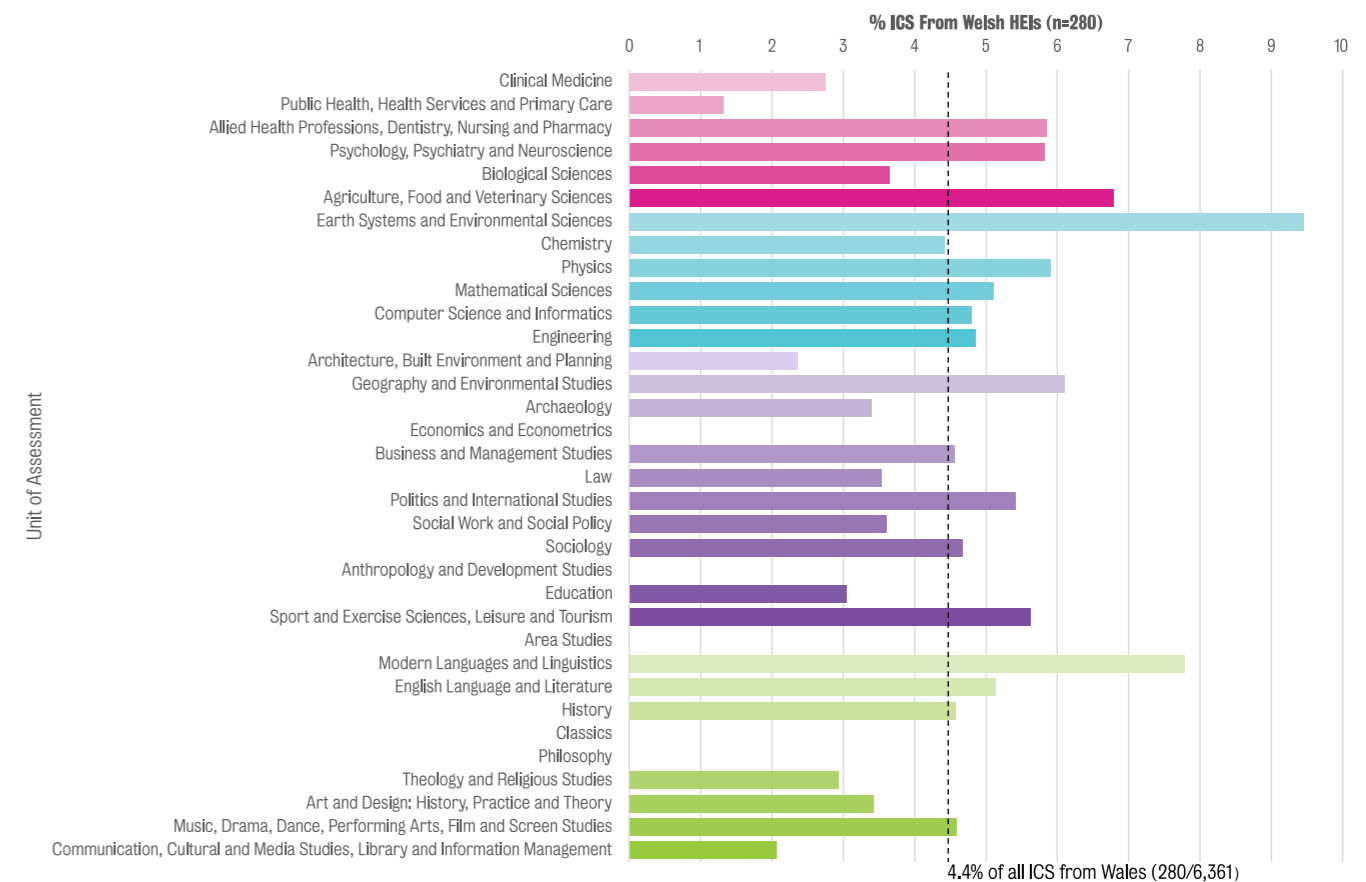
which accounts for 12% of the 78 ICS, UOA17 (Business and Management Studies; 10%) and UOA12 (Engineering; 8%).

The distribution of panels and UOAs within the 79 impact topics are illustrated by a further set of impact wheels, as shown in the examples provided in Figure 6 for the “top” four topics (by volume of ICS) submitted by Welsh HEIs. As expected, the level of contribution from each panel varies in relation to the impact topic. For example, the 86 ICS for the “Wales” impact topic are distributed across the four panels, with the largest contributions coming from UOA26, Modern Languages and Linguistics, (12%) and UOA17, Business and Management Studies, (16%). By contrast the 28 ICS for the “Applied technology” impact topic largely come from Panel B. We observed this diversity and mix of contributing UOAs across the majority of the impact topics, illustrating that impact is built from multiple research disciplines.

Figure 4: Distribution of ICS by UOA, for the UK, Wales and Welsh Government-supported ICS



Figure 5: Relative volume of submissions from Welsh HEIs by UOA



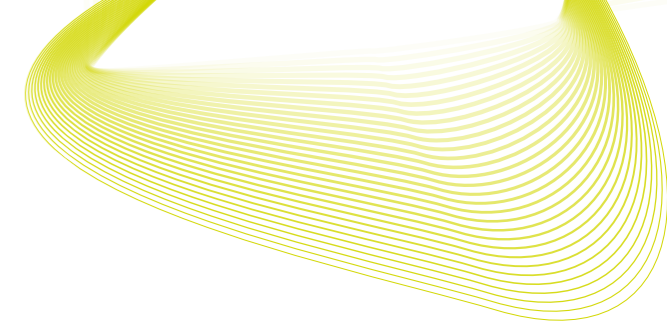
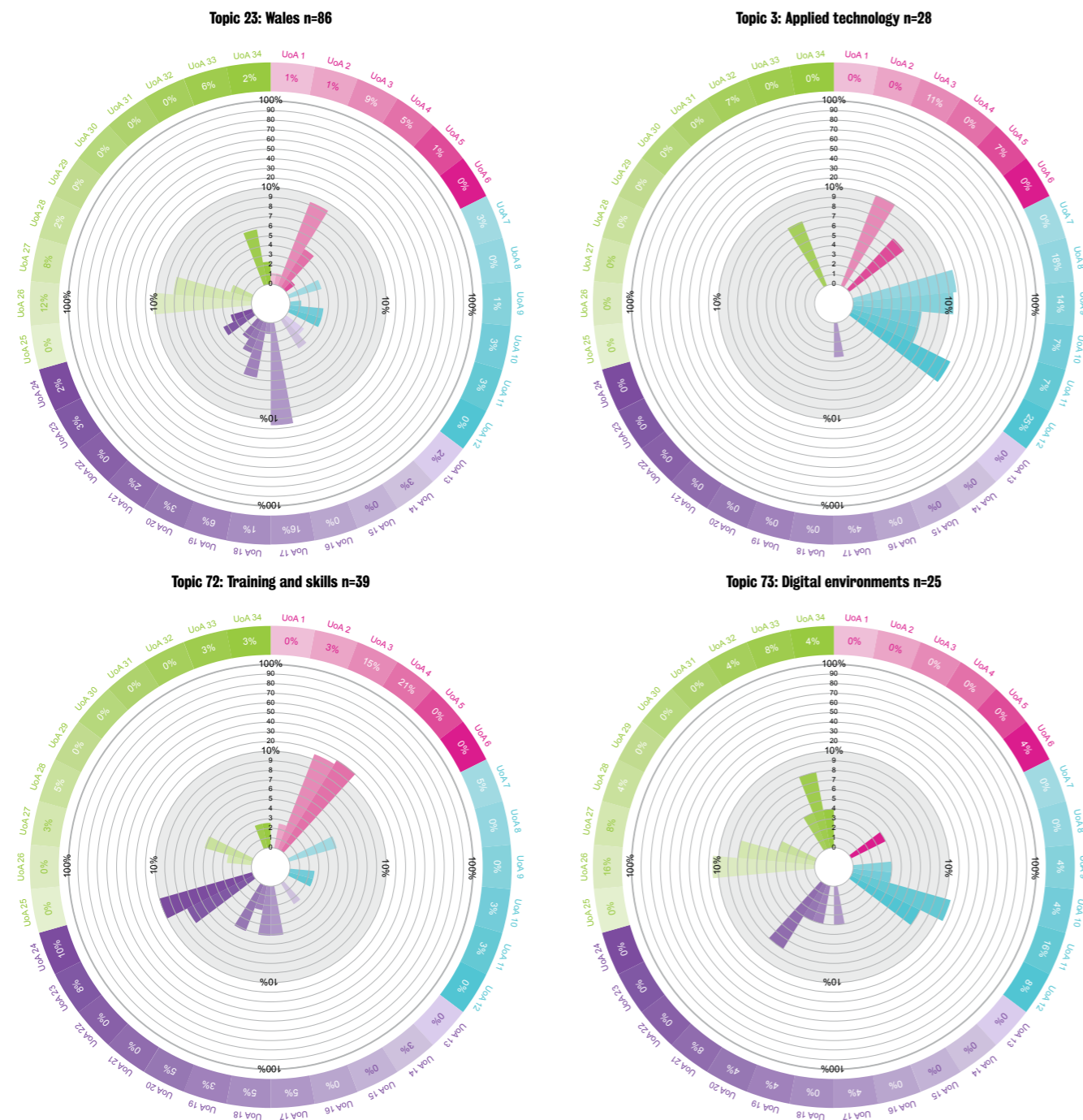


Figure 6: Impact wheels showing the UOAs contributing to impact topics for a sample of four topics



The relationship between impact topics and UOAs is summarised in Figure 7 and Figure 8. These bubble plots show the distribution of ICS across impact topics and UOAs, while the size of each bubble indicates the number of ICS it represents. This demonstrates a relationship between the type of impact (as represented by the impact topic) and the UOA. For example, we can see that within Panel A (illustrated by the pink bubbles), the topics are – unsurprisingly – predominantly associated with health impacts such as “Public health” (Topic 0), “the NHS” (Topic 16) and “Dentistry” (Topic 26), whereas within Panel D (illustrated by the green bubbles) the topics are more closely associated with impacts around culture and society, such as “Media and communication” (Topic 62) and “Museums and cultural heritage” (Topic 61). What is notable, though, is that topics do not emerge solely from the most obviously relevant panel or UOA – instead a variety of different disciplines contribute in each case. For example, while “Social services and primary care” (Topic 60) is most closely associated with the UOAs in Panel A, we also see this impact topic emerging from ICS in each of the other three panels.

The difference between Figure 7 and Figure 8 is that the first illustrates the distribution of impacts submitted by Welsh HEIs (so could include international impacts or impacts in the rest of the UK) while the second illustrates impacts within Wales, so could include non-Welsh HEIs (as well as Welsh HEIs) which are having an impact in Wales.

Figure 7: Bubble plot mapping impact topics against UOA for Welsh HEIs

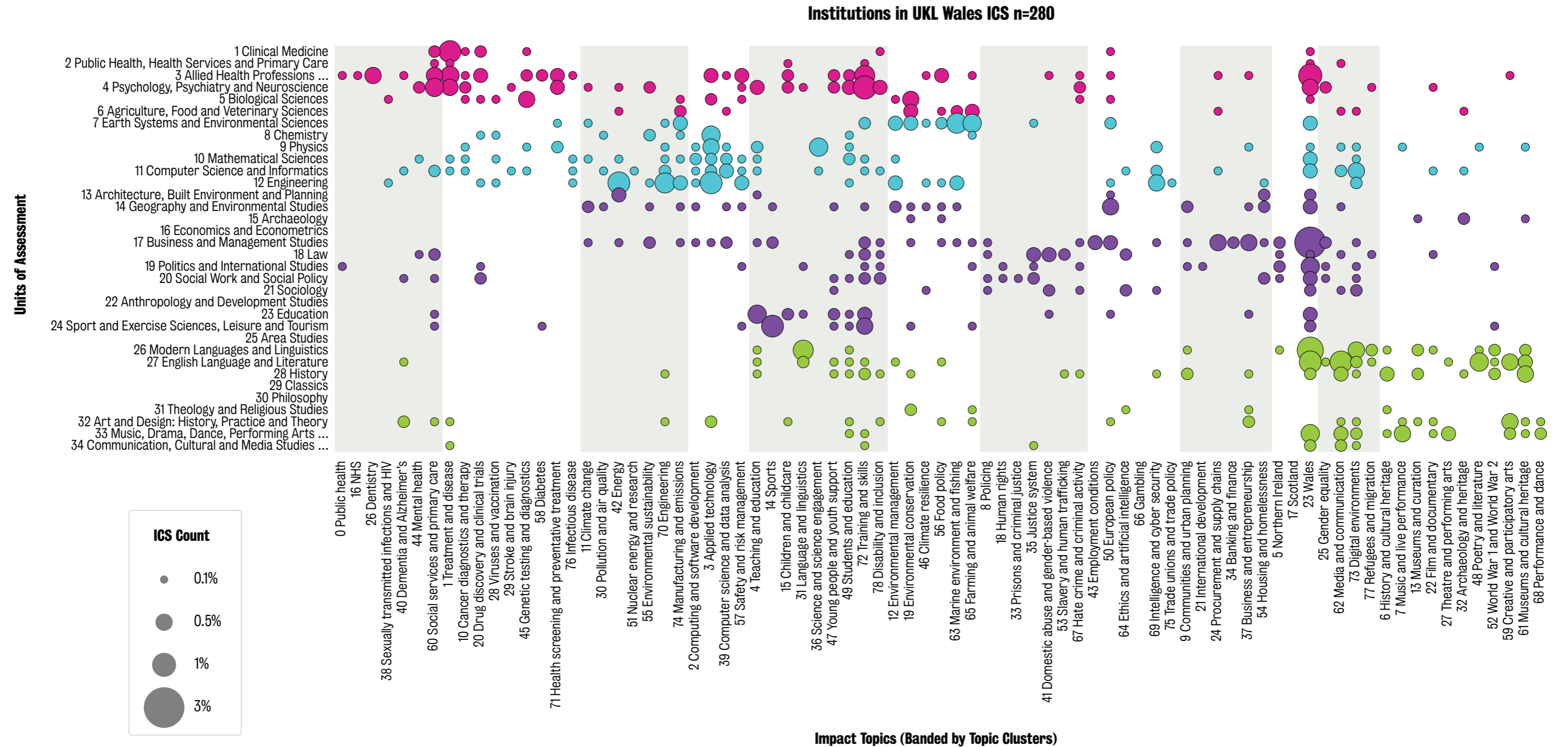
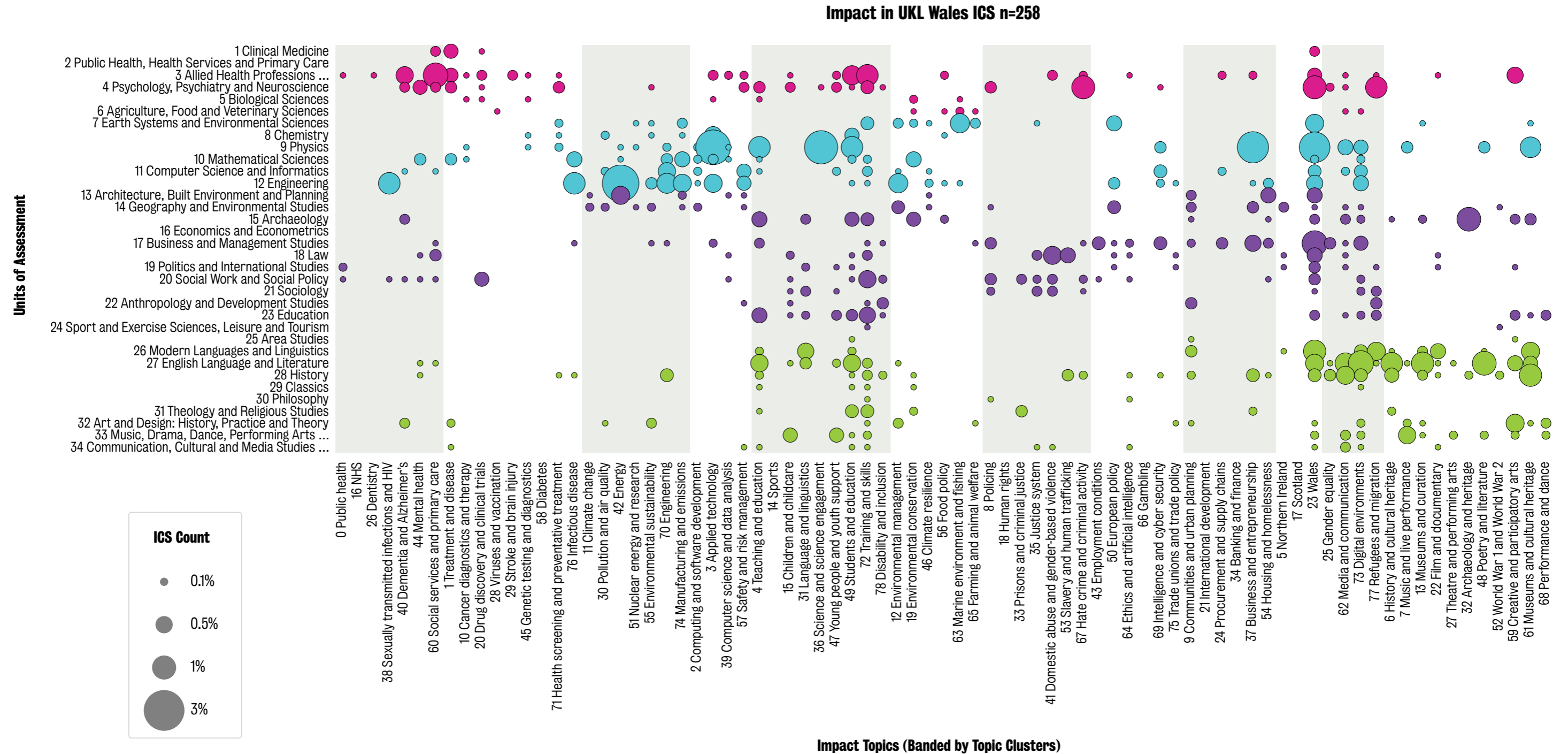
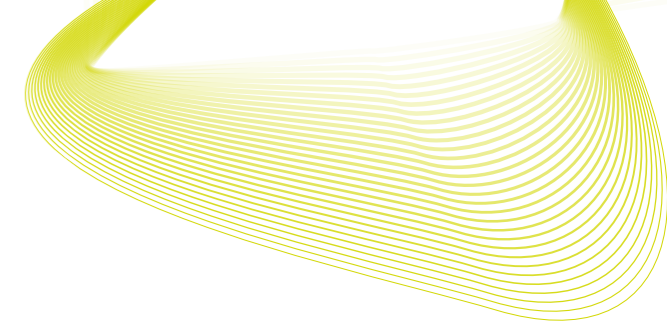


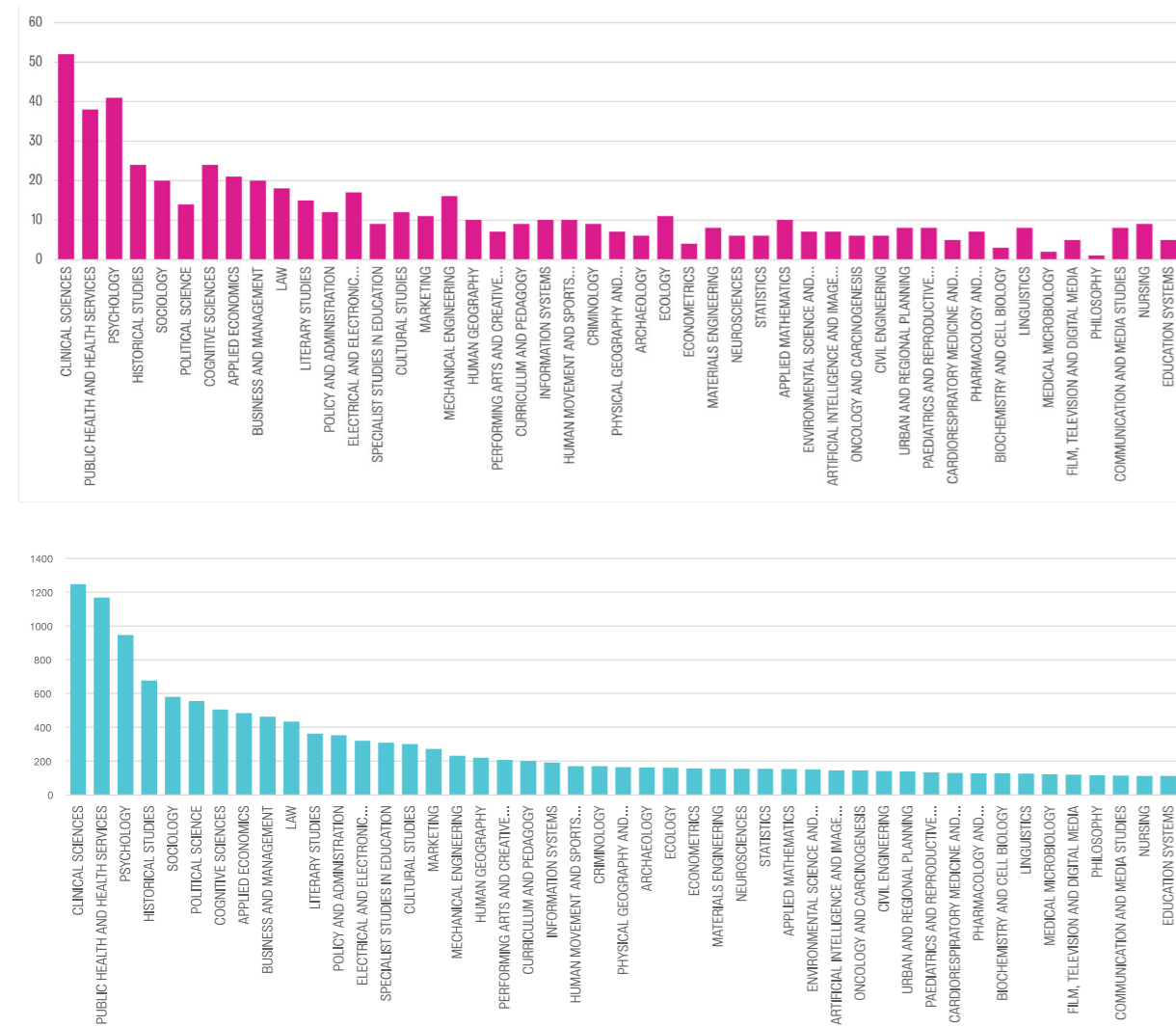
Figure 8: Bubble plot mapping impact topics against UOA for all ICS having an impact in Wales



Information submitted within the “Underpinning research” (Section 3) of the impact case studies was linked to Fields of Research (FoRs), a taxonomy developed by the Australian and New Zealand Statistical Bureaux. FoRs allow research activity to be categorised according to the methodology used in the research, rather than the activity of the unit performing the research as captured by the UOAs. The FoR is a hierarchical system with three levels: 22 divisions (two digits), 157 groups (four digits) and 1238 fields (six digits). The assignment of codes was made in an automated way and typically works well for underpinning research that is published in the peer reviewed literature. Further detail on the FoR taxonomy and its application in this study is provided in Annex A.

Figure 9 illustrates the distribution of FoRs for the underpinning research of the 280 Welsh ICSs (upper panel) and the 6,361 UK ICS (lower panel). Broadly, the distribution in both datasets is similar – nine of the top ten FoRs are the same. FoRs where there are relatively fewer references in Welsh ICS include Public Health and Health Services, Political Science, and Policy and Administration.

Figure 9: Fields of Research for Welsh ICS (upper panel) and UK ICS (lower panel)

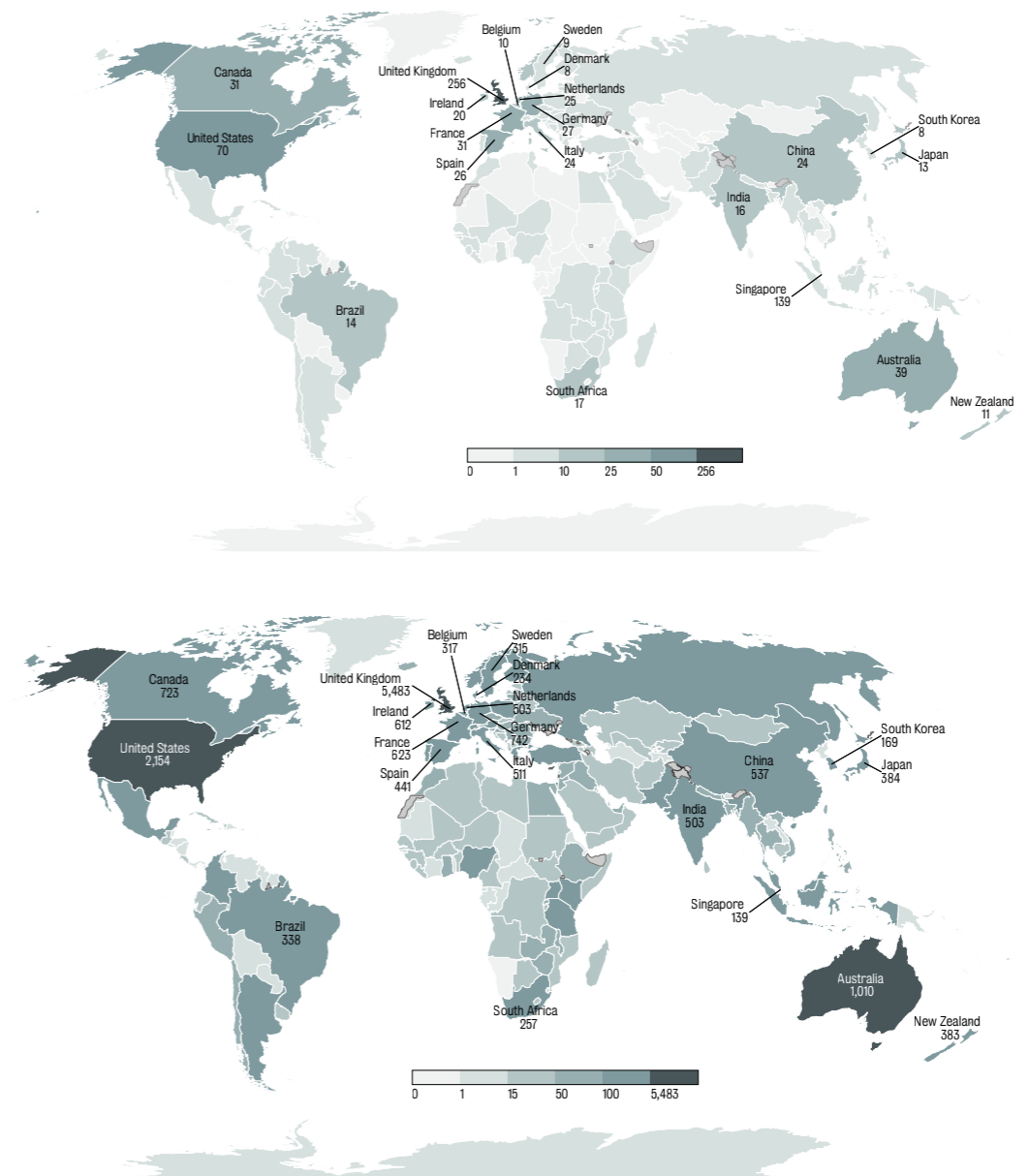


2.4. The geographical reach of research impact arising from Welsh HEIs

Using geotagging, we identified all mentions of different geographic locations in Section 4 of the ICS – “Details of the impact”.

Based on this analysis it is clear – as seen in the 2014 analysis – that UK and Welsh HEIs have a global impact, as shown in Figure 10. Exploring this in more detail, we find that the countries most frequently mentioned in Welsh ICS are the UK, United States and Australia (Table 6). When compared with the UK data, it is apparent that the overall distribution is similar (19 of the top 20 are the same), although Welsh HEIs report relatively more impact in Spain, Netherlands, and South Africa. As would be expected, the number of mentions of impact in locations in Wales is substantially higher in ICS from Welsh HEIs (71%).

Figure 10: The global reach of impact for Welsh HEIs (upper panel) and all UK HEIs (lower panel)



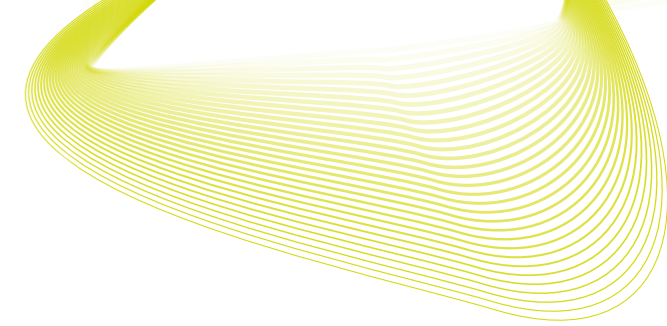


Table 6: Top 20 countries where impact has occurred for Welsh ICS (compared to UK when in top 20)

Country	Wales ICS Count	% Wales	Wales Country Rank (Top 20)	UK ICS Count	% UK	UK Country Rank (Top 20)
United Kingdom	256	91.4	1	5,483	86.2	1
UK (not Wales)	208	74.3		5,426	85.3	
Wales	200	71.4		862	13.6	
United States	70	25.0	2	2,154	33.9	2
Australia	39	13.9	3	1,010	15.9	3
Canada	31	11.1	4	723	11.4	5
France	31	11.1	4	623	9.8	6
Germany	27	9.6	6	742	11.7	4
Spain	26	9.3	7	441	6.9	12
Netherlands	25	8.9	8	503	7.9	10
China	24	8.6	9	537	8.4	8
Italy	24	8.6	9	511	8.0	9
Ireland	20	7.1	11	612	9.6	7
South Africa	17	6.1	12	257	4.0	20
India	16	5.7	13	503	7.9	10
Brazil	14	5.0	13	338	5.3	15
Japan	13	4.6	15	384	6.0	13
New Zealand	11	3.9	16	383	6.0	14
Belgium	10	3.6	17	317	5.0	16
Norway	10	3.6	17	311	4.9	18
Sweden	9	3.2	19	315	5.0	17
Singapore	9	3.2	19	139	2.2	

2.5 The sectors in which research from Welsh HEIs has impact

This section provides a further qualitative analysis of the sectoral impact of research from Welsh HEIs, drawing on our reading of the 280 ICS to establish:

- What are the main sectors of activity in which research from Welsh HEIs had an impact?
- Where did this impact occur, whether in the UK, including Wales, specifically in Wales, or internationally?

The qualitative assessment supports the findings of the quantitative analysis by demonstrating the significance of the impact topic of “Wales”, as well as topics such as “Health and disease”, “Training and skills”, and “Applied technology”. However, it also extends this analysis by focusing specifically on the sectoral beneficiaries of the research and their geographical location, offering a qualitative view of how Welsh research makes an impact on non-academic sectors.

Employing the categories provided by the UK’s “Standard Industrial Classification” (SIC), used to classify business and other organisations according to the type of economic activity in which they are engaged, the impact reported by researchers in Wales fell into 30 distinct sectors. The top 12 sectors represented among the 280 ICS are shown in Table 7. This provides us with a related but distinct analysis from the quantitatively

derived set of impact topics, by focusing specifically on the categories of industries and organisations on which case studies described making an impact.

Sectors of impact

The most prominent sector was “human health and social work activities”, a sector of impact reported in 35% of all case studies, followed by “education”, which encompasses adult, further, and higher education, as well as education for young people (25%), and “public administration and defence”, which accounts for impact on public policy as well as impact in the defence sector (22%).

SECTORS OF IMPACT: THE SECTORAL BENEFICIARIES AS DESCRIBED BY IMPACT CASE STUDIES, BASED ON THE UK’S STANDARD INDUSTRIAL CLASSIFICATION USED TO CLASSIFY BUSINESS AND OTHER ORGANISATIONS ACCORDING TO THE TYPE OF ECONOMIC ACTIVITY IN WHICH THEY ARE ENGAGED

Table 7: The top 12 sectors of impact of Welsh ICSs

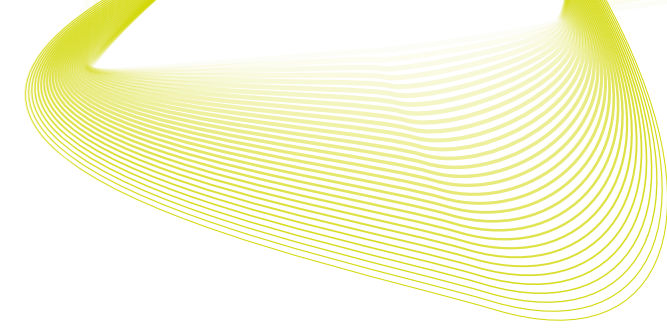
Sector (UK SIC)	No. case studies
Human health and social work activities	97
Education	70
Public administration and defence	62
Arts, entertainment and recreation	43
Heritage and tourism	33
Information and communications	33
Biodiversity, ecology and environmentalism	32
Manufacturing	32
Justice	22
Professional, scientific and technical activities	19
Agriculture, forestry, fishing	15
Electricity and gas supply	13

Other key sectors of impact include the related “arts, entertainment and recreation” sectors (reported by 15% of ICS) and ‘heritage and tourism’ and “information and communications” (each reported by 12%), as well as “biodiversity, ecology, and environmentalism”, “manufacturing”, “justice” and “professional, scientific and technical activities”.

Sectoral impact & geographical reach

According to our text-mining analysis, 70% (200 of 280) of ICS had an impact in Wales. Table 8 cross-references this with our qualitative data to reveal that, of these 200 case studies with Welsh impact, 38% (75 of 200) had an impact on the “health and social work” sector, 29% on “education” (57 of 200), and 27% on “public administration and defence” (53 of 200). Other key sectors of impact in Wales included the “arts, entertainment and recreation” (reported by 13% of ICS), “heritage and tourism” (12%) and “manufacturing” (11%).

This supports the text-mining analysis by highlighting the importance of these key sectors and, specifically, how “Wales” as a general topic of impact cuts across a range of sectors of activity. It also demonstrates that there is quite an even distribution of impact sectors across ICSs with Welsh impacts, UK-wide impacts, and international impacts. Although impacts on the health and social care sectors feature marginally more



prominently in ICS with impacts in Wales (38% in Wales versus 35% of the overall sample), the top four most prominent sectors are identical across both data sets. A notable difference when looking at impact beyond the UK is the relative prominence of the “biodiversity, ecology and environmentalism” sector, which was reported in 16% of ICS with international impact, compared with 11% in the overall sample.

Table 8: Top 10 sectors of impact according to their primary location of impact

Sectors	No. ICS with impact in UK (including Wales) (n=256)	Sectors	No. ICS with international impact (n=170)	Sectors	No. ICS with impact in Wales (n=200)
Human health and social work activities	93	Human health and social work activities	54	Human health and social work activities	75
Education	68	Education	43	Education	57
Public administration & defence	59	Public administration & defence	29	Public administration & defence	53
Arts, entertainment and recreation	35	Arts, entertainment and recreation	27	Arts, entertainment and recreation	26
Heritage and tourism	31	Biodiversity, ecology, environmentalism	27	Heritage and tourism	24
Manufacturing	29	Information and communications	25	Manufacturing	22
Information and communications	26	Heritage and tourism	22	Information and communications	19
Biodiversity, ecology, environmentalism	24	Manufacturing	19	Biodiversity, ecology, environmentalism	18
Justice	20	Professional, scientific and technical activities	14	Justice	17
Professional, scientific and technical activities	17	Justice	12	Professional, scientific and technical activities	15

Accepting that there is significant overlap between case studies that report UK-wide impact (including Wales) (256), specifically Welsh impact (200) and international impact (170) in a data set that contains only 280 case studies, it is nevertheless notable that despite some minor variation there is clear consistency across these contexts. This suggests that Welsh research has clearly defined sectoral strengths in relation to research impact, whether they are focused nationally, internationally, or within Wales.

Sectoral impact for Welsh Government-funded research

Does the sectoral impact of research funded by the Welsh Government differ from the overall sample of 280 case studies? Looking specifically at the subset of 78 ICS with Welsh Government funding, “human health and social work activities” is also the most-commonly cited sector of impact. This not only mirrors the picture of the overall sample, but also the trend across UK-wide and international impacts. “Education” and “public administration and defence” also feature prominently as the second and third most commonly reported sectors of impact, as in the other geographical areas.

Table 9: Top 10 sectors of impact for Welsh Government-funded ICS

Sector of impact	Welsh Government-funded ICS
Human health and social work activities	33
Education	25
Public administration & defence	18
Biodiversity, ecology, environmentalism	13
Manufacturing	8
Justice	7
Agriculture, forestry, fishing	6
Arts, entertainment and recreation	6
Information and communications	6
Construction	5

Indeed, there is significant consistency in the relative proportions of case studies’ sectoral impacts across the geographical reach of their impacts, UK-wide, internationally, and in Wales, as well as among those with Welsh Government funding. As is demonstrated by Table 8, the majority of the top ten most cited sectors of impact among Welsh Government-funded case studies are also present in the top sectors of impact across all geographical areas. The two exceptions are “agriculture, forestry and fishing” and “construction”. Further analysis of the 78 Welsh Government-funded ICS can be found in section 3.5.

2.6. The nature of the impacts produced

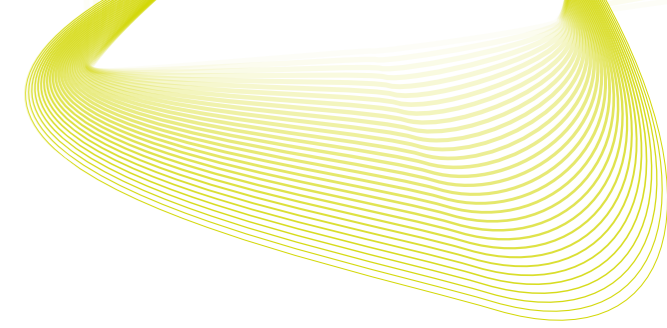
As well as examining the Welsh ICSs to establish their sectoral impacts and their location, our qualitative approach analysed the nature of the impacts made by Welsh research. In other words, if our sectoral analysis shows on what sectors of economic or social activity Welsh research had an impact, our analysis of the nature of these impacts shows the type of impact that occurred – whether, for example, they changed public behaviours or created economic benefits. Importantly, this differs from our analysis, in Chapter 3, on “mechanisms”, which focuses on the processes and interactions between stakeholders that lead to impacts later on.

To investigate the types of impact created by Welsh HEIs, we divided the impacts reported in case studies across four key categories:

- changing policy and governance
- changing processes and practices
- changing public debate and perceptions
- economic impact(s)

Each of these was divided into a number of pre-defined sub-categories (based on prior studies of ICS in Wales and other locations). These were then refined through an iterative process of coding and reviewing.

The following section enumerates the main types of impact coded in our analysis. However, it should be noted that throughout there is a significant level of overlap between the types of impact at a general level as well as the sub-categories within each impact type. For example, significant numbers of case studies – 77% overall – report more than one type of impact (eg policy impact and economic impacts) and, within that, may report



more than one type of sub-category of impact (eg changing policymaker attitudes and informing existing government policy).

The most reported type of impact in all case studies was “changing processes and practices” (85%), which included a variety of impacts on the way in which practitioners from a range of different sectors behaved or took on evidence, as well as on processes and services. Within this broad category, the most frequently reported type of impact was a change in practitioner knowledge (such as deepening understanding of museum collections or approaches to local news reporting by media organisations such as the BBC), which 148 out of the 237 relevant ICS (62%) described. This was followed by research informing new procedures, practices, or protocols (41%), including the creation of a new Framework for Action on Tackling Crimes for Wales, new signalling system implementation processes in use by Siemens, and a self-assessment tool now used by commissioners and providers of Appropriate Adult services.

However, other types of impact – from creating a service or product in use to modifying existing procedures or practices – were prominent too, as is demonstrated in Table 10. These included impacts such as changing data capture methodologies used by sport governing bodies, changing approaches to perinatal psychiatry, and changing pedagogical practices to enable greater learner experimentation in the classroom.

Table 10: Sub-categories of “changing processes and practices”

Changing processes and practices	No. ICS
Change practitioner knowledge	148
Inform new procedure, practice, protocol	98
Service or product regular use	76
Change practitioner behaviours	71
Improve workflow or processes	57
Impact practitioners’ attitudes	49
Inform new practice guidelines	43
Modification of existing procedure, practice, protocol	35
Inform existing practice guidelines	22
Replace procedure, practice, or protocol	6
End or stopping procedure, practice, protocol	5
Change practitioner behaviours	4

The next most prominent type of impact reported was “changing policy and governance”, with half of case studies (52%) reporting an influence on policy in a variety of contexts. This included 61% of these ICS changing policymaker knowledge (89 out of 145), for instance by delivering training in Welsh language policy development and implementation or by presenting research on women’s healthcare to officials in Australia. 53% of ICS with a policy impact helped advance wider policy debates (77 of 145), while 31% helped shape the attitudes of policymakers (45 of 145).

This grouping of impact types also included more direct forms of influence on the direction of policy or governance, with 53% of these ICS informing new government policies (77 out of 145) and 15% informing existing policies (22), as well as changing the behaviours of policymakers themselves (28). Examples of these include research leading to the employment by Welsh Government of specialist career advisors for refugees, the permanent ringfencing of health board funding for community nurses, and a change in behaviour by Literature

Wales, (the national company for developing literature in Wales), from being a funder of events to being an active facilitator and innovator of projects.

“Economic impacts” were reported in 42% of ICS. These included financial impacts, reported in a third of case studies (95 out of 280), impacts ranging from job creation and financial returns for the private and public sector, to further investment from government or private partners. Such investments enabled job creation, which was reported in 5% of case studies but represented more than 2,500 additional posts across the public and private sectors. In 15% of ICS, research was reported as enabling such innovations as improved supply chains, new company forecasting methods, and improved policies in use by the National Grid. Finally, 12% reported commercialisation of research leading to income generation in, for example, heritage projects and the sale of products and technologies such as trauma packs used in remote parts of continental Africa.

“Changing public debate and perceptions” was reported by 33% of ICS, the most prominent form of which was shaping or changing public knowledge (74 ICS or 26%), followed by influencing public attitudes (54 or 19%), and changing public behaviours (42 or 15%). Examples of these impacts included workshops on opera, exhibitions and heritage displays which transformed public knowledge and understanding of the Welsh copper industry, the creation of computing societies in Namibia devoted to the Python coding language, or schools-focused science and technology education programmes.

Type of impact and sectoral impact

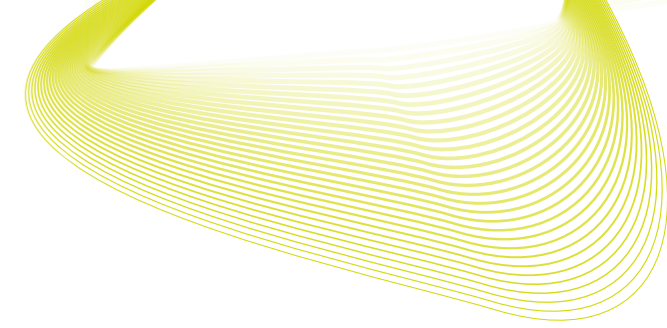
This section cross references our analysis of the sectoral impact of Welsh research with our analysis of the nature of those impacts.

Examining the most prominent form of impact in the overall sample, “changing processes and practices”, we see that most significant sectors are “human health and social work activities”, followed by “education”, and “public administration and defence” – the relative proportions of each reflecting the wider trends of sectoral impact as outlined in Section 2.5. These include projects such as the establishment of the first e-health service for student sex workers, improving nursing support for secondary breast cancer, and training nurses as diabetic foot-care officers. They also include widening access to classes in English for Speakers of Other Languages (ESOL) and the development of collaborative pedagogy in which researchers, teachers and learners worked together to plan, deliver and record lessons.

Table 11: Sectoral breakdown of impacts that changed processes and practices

Sector	No. ICS reporting changing processes and practices
Human health and social work activities	56
Education	37
Public administration and defence	23
Information and communications	20
Manufacturing	20

Regarding ICS that reported “changes on policy and governance”, “human health and social work activities” is again the most commonly reported sector of impact, with the “public administration and defence” sector representing the second largest proportion of impacts. Here too, “education” features prominently. Notably,



the sector of “justice” (policing, law, criminal justice) and the environmental sector (“biodiversity, ecology and environmentalism”) are the fourth most reported sectors for policy impact.

Table 12: Sectoral breakdown of impacts that changed policy and governance

Sector	No. ICS reporting changing policy and governance
Human health and social work activities	37
Public administration and defence	34
Education	19
Biodiversity, ecology and environmentalism	13
Justice	13
Information and communications	8

Within the set of ICS reporting “economic impacts”, the sectoral landscape looks similar to that of those with impacts on practice and policy. “Human health and social work activities”, “education”, “public administration and defence”, and “information and communications” remain significant sectors for this type of impact. However, one notable difference is the significance of the “manufacturing” sector, which is the most commonly reported amongst ICS citing economic impacts. Impacts reported here include the development of a new product pipeline for analgesics, a new LiDAR system for military and commercial use, and a modern fungicide used to improve crop yields.

Table 13: Sectoral breakdown of ICS that reported an economic impact

Sector	No. ICS reporting economic impact(s)
Manufacturing	25
Human health and social work activities	23
Public administration and defence	11
Education	10
Information and communications	8

In relation to “changing public debate and perceptions”, again, “education” and “human health and social work activities” feature prominently. Here, however, we see that the “heritage and tourism” sectors, as well as “arts, entertainment and recreation”, feature as significant sectors for this type of impact. This may reflect the salience of these cultural sectors among public attitudes and perceptions.

Table 14: Sectoral breakdown of impacts on public debate and perceptions

Sector	No. ICS reporting changing public debate and perceptions
Education	26
Human health and social work activities	18
Heritage and tourism	15
Arts, entertainment and recreation	8
Information and communications	7

The types of impact reported in Welsh Government-funded case studies

In Welsh Government-funded case studies, “changing processes and practices” is also the most reported type of impact, with 70 out of the 78 ICS (90%) in this sub-group citing an impact of this kind. Within this group of 70, the most prominent kind of impact is a change in practitioner knowledge, representing almost two-thirds (64%) of the impacts cited, such as a project that produced materials and trained health professionals in evidence-based, person-centred approaches to physiotherapy for people with Huntington’s Disease. Just under half of ICS in this grouping (47%) reported informing a new procedure, practice, or protocol, while one-third (33%) reported a change in practitioner behaviours.

Table 15: Impact types for Welsh Government-funded case studies

Type of impact	No. ICS with Welsh Government funding
Changing processes and practices	70
Changing policy and governance	46
Economic impact(s)	33
Changing public debate and perceptions	24

An impact on policy and governance was also among the most frequently reported kind of impact in Welsh Government-funded ICS, with 59% of the sample of 78 citing an impact of this sort, slightly higher than the proportion in the overall sample of 280 case studies (52%). The number of Welsh Government-funded ICS citing an economic impact was the same as in the sample as a whole (42%), while 31% reported changing public debate and perceptions, slightly below the proportion in the sample as a whole (33%). This suggests that, relatively speaking, Welsh Government-funded research in Welsh HEIs is slightly more likely to have had an impact on policy, processes or practices than research reported in Welsh ICS in general, but slightly less likely to have had an impact on public debate.

Further analysis of the impacts of Welsh Government-funded research can be found in Section 3.5.

3. Pathways to impact

This chapter provides an analysis of the “pathways to impact” of Welsh HEIs that submitted to REF 2021, via quantitative and qualitative means. First, it offers a detailed overview of the connection between impact topics – as established through the quantitative analysis –with UOAs and their disciplinary origins, mapping out the routes that case studies take in creating an impact. It shows this analysis for the UK-wide sample and for the Welsh HEIs sample, providing different levels of comparison for both.

This chapter also provides a qualitative analysis of pathways to impact, by identifying and enumerating the key activities and processes outlined in ICS which facilitated wider social, economic, and other forms of impact. This section focuses on key activities such as partnerships and co-production, as well as types of research dissemination, and codification of intellectual property.

Relatedly, this chapter also provides analyses of certain characteristics of the underlying research leading to impacts, including the prevalence of collaboration with non-academic partners, and the role of inter-disciplinary research.

3.1. The pathways to impact for different impact types and their variance according to discipline

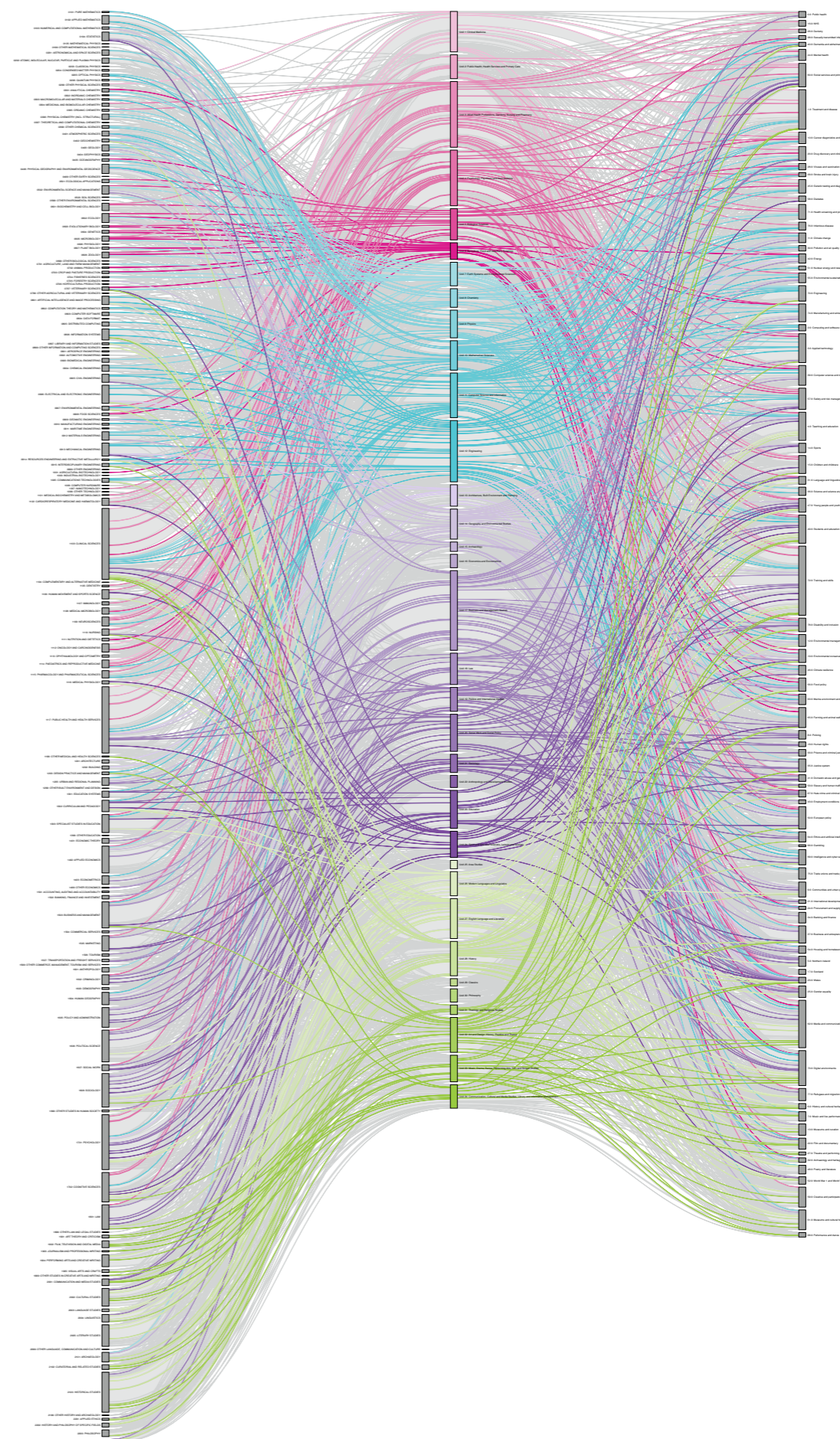
Combining the impact topics identified in the quantitative analysis with (i) the UOA of the related case studies and (ii) the fields of the underpinning research listed in those ICS allows us to build an overall picture of the pathways from research to impact. This is illustrated in the alluvial diagram in Figure 11. The coloured lines are for the 280 ICS that come from Welsh HEIs and the greyed-out lines from the remaining UK ICS. The total number of unique lines (impact pathways) for Welsh ICS is 1,217 (5,397 for UK); 75% of Welsh ICS have two or more FoR divisions (two digit) associated with them (slightly more than the UK figure of 72%).

This illustrates the multidisciplinary nature of impact and, from that, the fact there is no single pathway. In other words, impact is often a bespoke activity which suggests that the development of a balanced and comprehensive set of impact metrics that captures the range of activities illustrated in Figure 11 would be very challenging.

To aid interpretation of the alluvial diagram, Figure 12 shows the same data but this time using “two-digit” FORs (extreme left) with the 12 impact clusters, organised by panel (middle). As before, the coloured lines are for the 280 ICS that come from Welsh HEIs and the greyed-out lines from the remaining ICS for the UK. Finally, Figure 13 and Figure 14 again show the same data but this time only for the 280 Welsh ICS, plotted by both aggregations of the data (ie Figure 13 is similar to Figure 11 and Figure 14 to Figure 12).

Finally, to get a sense of whether the pattern of impact pathways was any different for Wales compared to other UK regions, we plotted the number of unique pathways for each NUTS1 region⁸ against the number of ICS in each region (Figure 15 and Table 16). In this figure, regions with a smaller number of ICS are likely to have fewer impact pathways hence a sublinear relationship is evident (as the number of ICS increases, the potential to include novel pathways reduces). As illustrated by the pink highlight in Figure 15, Wales appears to be on the same trendline as other regions – that is there is no discernible difference in the number of pathways for Wales compared to the other regions/countries in the UK.

Figure 11: Alluvial diagram illustrating pathways to impact



⁸ The NUTS classification (Nomenclature of territorial units for statistics; Eurostat, 2021) is a hierarchical system for dividing up the economic territory of the EU and the UK, with the NUTS1 level representing major socioeconomic regions.

Figure 12: Simplified alluvial diagram showing higher level impact pathways

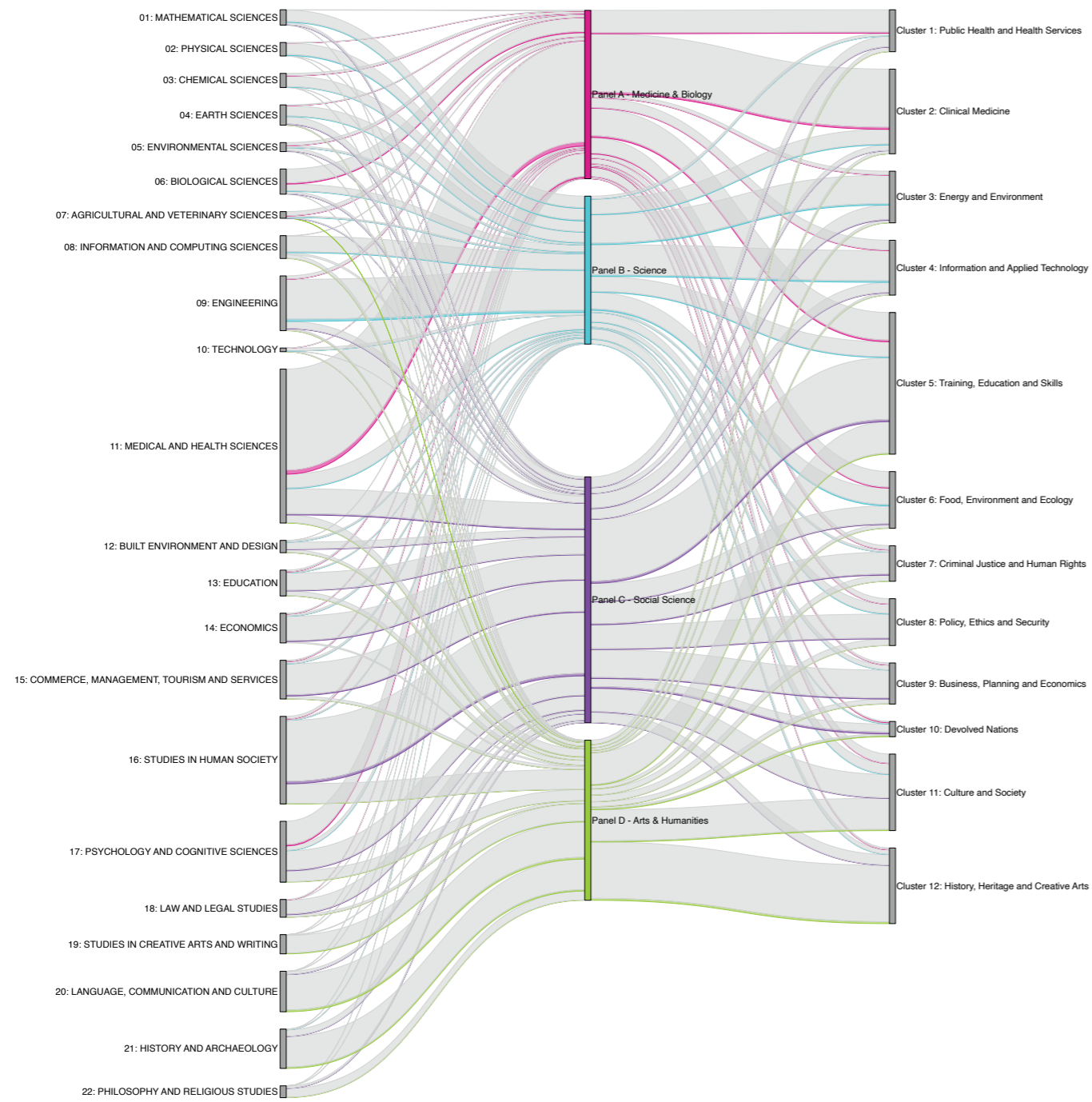


Figure 13: Alluvial diagram illustrating pathways to impact for Welsh ICS

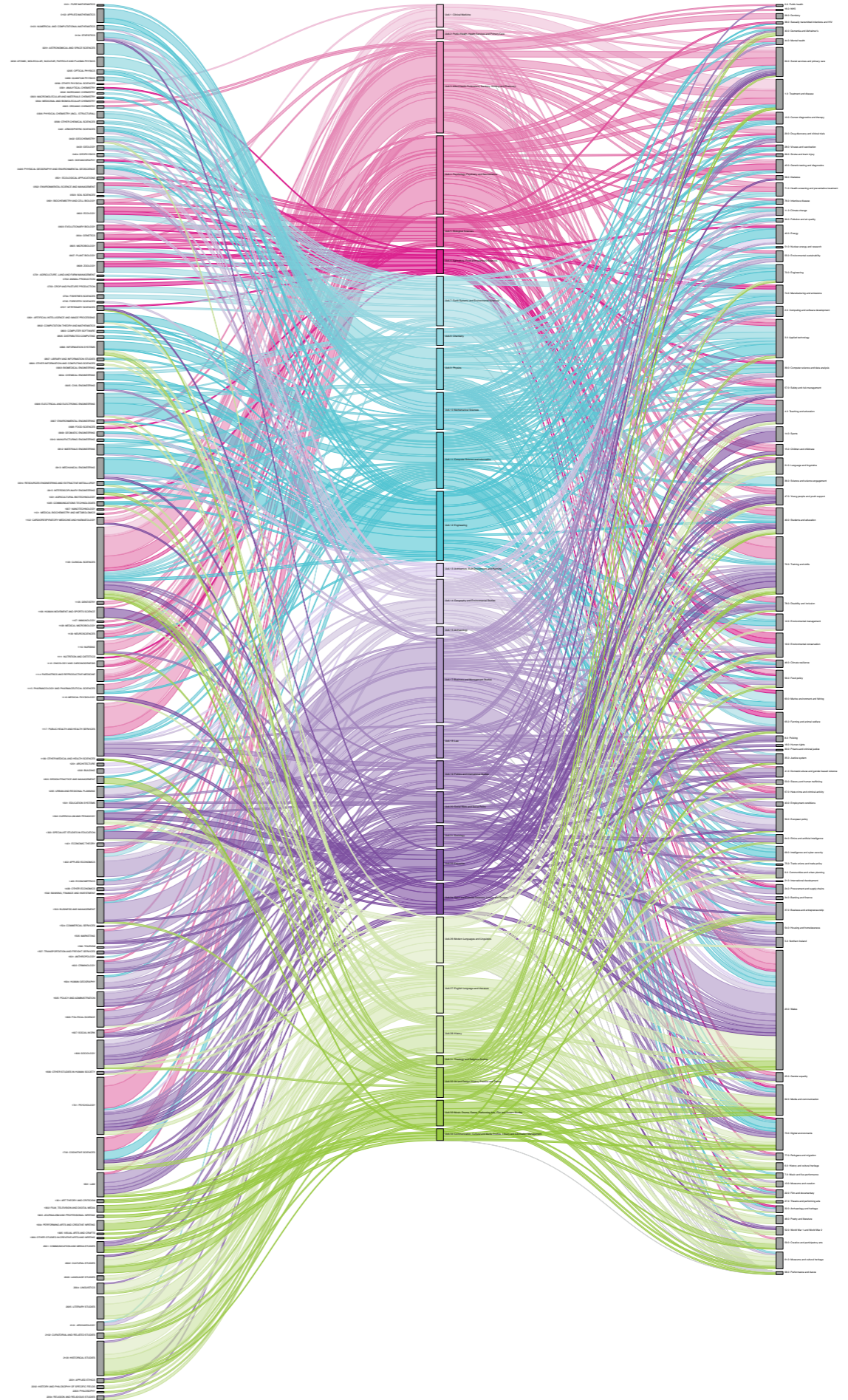


Figure 14: Simplified alluvial diagram showing higher level impact pathways for Welsh ICS

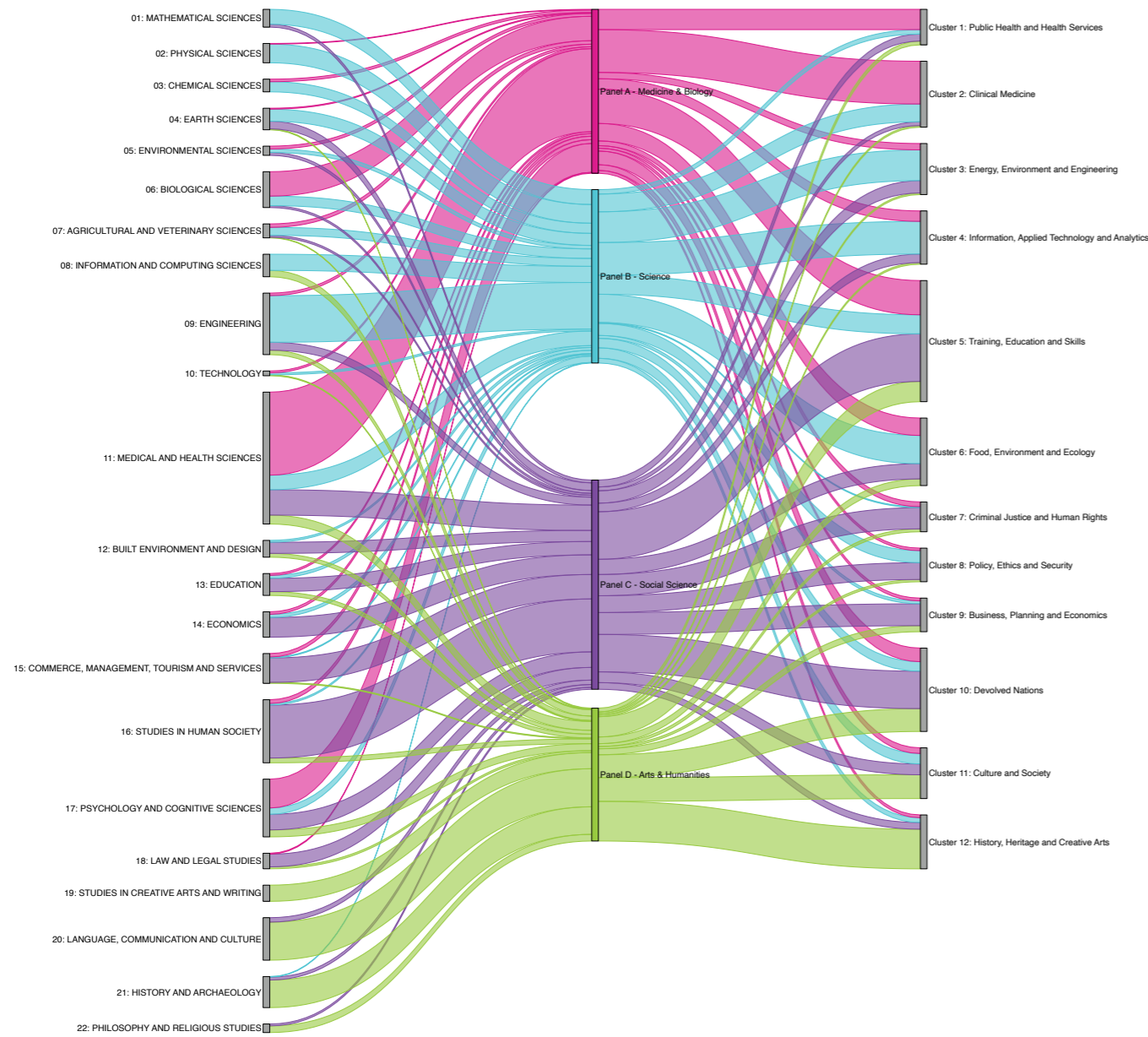


Figure 15: Number of unique pathways by number of ICS for UK NUTS1 regions

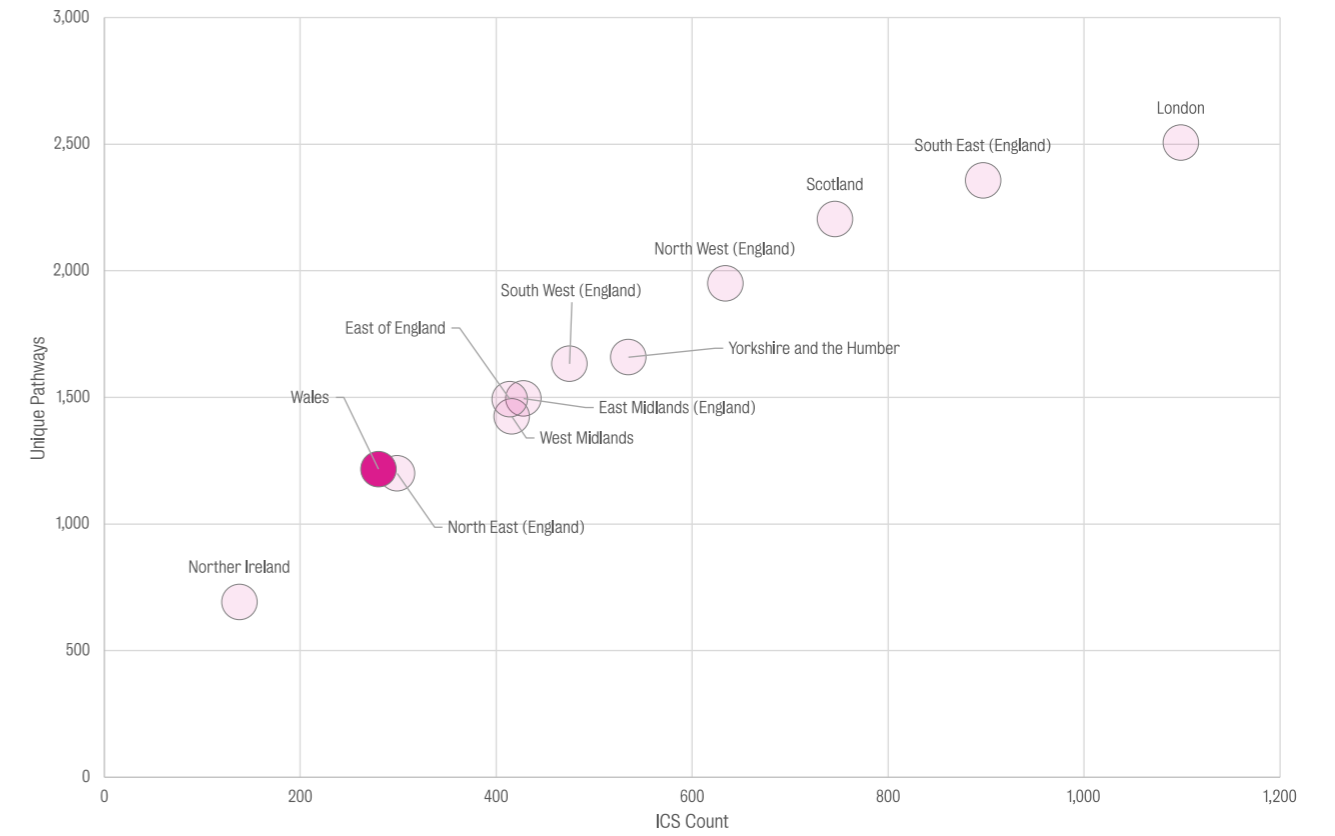
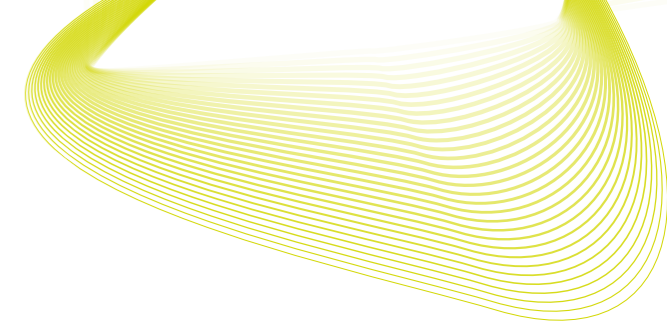


Table 16: Number of unique pathways and ICS for UK NUTS1 regions

Sample name	ICS count	% with 2/3 FoR divisions	Unique pathways
All ICS	6,361	72	5,397
Inst from UKI London	1,099	70	2,505
Inst from UKJ South East (England)	897	73	2,356
Inst from UKM Scotland	746	70	2,203
Inst from UKD North West (England)	634	71	1,949
Inst from UKE Yorkshire and the Humber	535	76	1,659
Inst from UKK South West (England)	475	75	1,632
Inst from UKF East Midlands (England)	428	74	1,496
Inst from UKG West Midlands (England)	416	69	1,425
Inst from UKH East of England	414	71	1,492
Inst from UKC North East (England)	299	77	1,199
Inst from UKL Wales	280	75	1,217
Inst from UKN Northern Ireland	138	71	692



3.2. The activities and mechanisms facilitating the impact of Welsh research

This section draws on the qualitative analysis of the 280 ICS from Welsh HEIs to establish the activities and mechanisms that enabled impact. This focuses on the interactions that take place between key stakeholders, collaborative partnerships, different forms of research dissemination, or formal codification of a product, idea, or service, which lead to the types of social, economic or other impact we report on in Section 2.6. Admittedly, there is some overlap between these “mechanisms” and the types of impact outlined earlier, as some types of impact (as defined in the REF) will also lead to subsequent impacts. For example, informing a policy change or commercialising IP as a product – both impacts in their own right – are interim points on a pathway that might create subsequent social or economic impacts.

MECHANISMS: THE MAIN ACTIVITIES AND FORMS OF ENGAGEMENT DESCRIBED BY CASE STUDIES WHICH LEAD TO FURTHER SUBSEQUENT SOCIAL, ECONOMIC, OR OTHER IMPACTS

Partnership types

To establish the mechanisms used to facilitate impact in the 280 ICS, we examined each case study to ascertain the kinds of non-academic partners and collaborators they reported, as well as the nature of these partnerships – for example, whether they involved deep forms of collaboration and co-creation or more light-touch engagement such as consulting with user groups or practitioners.

As might be expected of impactful research and knowledge exchange activities, almost all 280 ICS submitted by Welsh HEIs (94%) reported at least one clearly identifiable non-academic partner or collaboration. Exploring this data further we can see that the most common form of partnerships were those formed with the public sector in the UK (43%), inclusive of the Welsh public sector. Of these UK public sector partnerships, 74% were with Welsh public sector bodies, which includes a range of organisations and institutions, including the devolved Welsh Government to local government, and other arm’s-length bodies or departments, such as Public Health Wales. The other 26% (44 ICS) reported partnerships with public sector bodies in the UK located outside Wales, whether in other individual nations, such as the Social Care Board in Northern Ireland, or with bodies that represent the UK as a whole, such as the Food Standards Agency.

The next most prominent type reported in ICS were “academic-industry” partnerships which accounted for 29% of partnerships overall (80 ICS). These led to impacts in a UK-wide context (74 out of 80), in Wales (55 out of 80), and internationally (53 out of 80). They also facilitated impacts across a wide range of impact topics: cross-referencing our quantitative analysis on impact topics with academic-industry partnerships shows that they were most prominent in “Applied technology” (25) and the “Wales” topic (14), but also occurred in relation to “Engineering” (9), “Energy” (8), “Intelligence and cyber security” (8) and a range of other areas.

International partnerships were reported in 22% of ICS (61), of which 27 cited EU partners – for example, the Irish Government working on language policy, the Ministry of Research in France working on housing policy, and the European Commission working to operationalise Smart Specialisation – while 45 mentioned international partners from outside the EU.

Third sector and multi-sector partnerships (partnerships where multiple different sectors were involved in a single activity, as opposed to multiple partnerships across different activities) were the least common approaches, with the former being reported in just 33 of 280 ICS (12%).

The nature of partnerships

As well as identifying who research teams and researchers connected with, we coded these partners according to the type of partnership formed. The most frequently reported was “collaboration”, present in 30% of

ICS, which we defined as a “researcher or research team co-producing activities or mechanisms with a non-academic sector partner”. This was followed by researcher-led partnerships (29%), commissioned work (20%), and co-production of a product or technology (8%). Other forms involved the use of a published output, whether adopted by the sector partner (8%) or cited (5%), referencing researchers as experts or practitioners (13%), or a more general interaction (12%).

These figures may be further nuanced according to the broad disciplinary groupings of the four Main Panels. Co-production of products or technologies, for example, was most common in Main Panel B, which accounted for more than half of the mentions of this form of partnership (12 out of 23, or 52%). By contrast, those partnerships wherein researchers were referenced as experts or practitioners were most common in Main Panel C, accounting for 17 of the 35 mentions (49%), followed by Panel A (23%). Direct commissioning by a sector partner was also most common in Panel C (29 of 56 instances; 52%).

Of the 80 ICS that reported a partnership with an industry or commercial organisation, collaborative engagement was the most reported form of interaction: co-production and collaboration accounted for 39% of partnerships with the private sector, or 11% of partnerships overall. Outside of this, other kinds of interaction – from co-produced technologies and consultation to commissioned work – were spread quite evenly in industrial partnerships, as demonstrated in Table 17.

Within international partnerships, co-production and collaboration was also the main type of interaction reported (22 of 61). However, researchers being referenced as experts by partners also figured prominently, in a sixth of these interactions.

Table 17 shows the number of ICS that referenced different types of partnership, cross-referenced with the nature of those partnerships. While there is clear overlap between case studies, with 54 citing at least two types of partnership, this table shows that across all types of partnership – whether with public-sector, industry, third-sector, or international partners – the prominence of collaborative, co-productive engagement is consistent, underlining the importance of this type of interaction for facilitating impact. Another key point from this table is the importance of direct engagement with partners in the form of commissioned work, which is prominent for academic-public sector and academic-industry partnerships in particular.

Table 17: Partnership types and the nature of partnerships

	Academic-third sector	Multi-sector	International	Academic-industry	Academic-public sector
Published output cited by sector	3	1	5	2	7
Co-produced product or technology	3	2	3	12	7
Published output adopted by sector	4	3	7	8	9
Interaction with sector	4	2	6	11	18
Referenced as expert, practitioner	4	4	12	5	22
Commission by sector partner	5	7	12	15	37
Led by researcher or project team	8	18	18	17	33
Collaboration with sector	15	12	26	31	28

Dissemination

Dissemination of research findings – defined as “any method to communicate the research outputs” – is present in all of the 280 ICS from Welsh HEIs. This encompasses all forms of outputs which took original research and presented it in a format that would be accessible to a non-academic audience, including:

- Non-academic publication (occurring in 34% of ICS) through mediums such as reports, books, articles, and authoritative editions of music scores, as well as blogs, newsletters, pamphlets, and reference texts.
- Non-academic presentation (28% of ICS) delivered via public speaking or organising conferences, seminars and workshops based on themes generated by the research. A small number of official launch events (1% of ICS) also took place.
- Media coverage (21% of ICS) via coverage in broadcast and print media.
- Educational materials (16% of ICS) such as teaching resources and study guides.
- Data sharing (8% of ICS) and open source platforms (5%), examples of which include collections of digitised historical sources, scientific field data, and computing software.

DISSEMINATION: THE WAYS IN WHICH RESEARCH IS DISTRIBUTED, RECEIVED, AND ENGAGED WITH BY STAKEHOLDERS, INCLUDING PUBLICATION AND EVENTS

In addition to non-academic dissemination, almost all projects had some form of academic output for specialist audiences, whether in the form of presentations (15% of ICS) or academic publications (98%).

Codification of ideas, products or services

Some projects – 33 of the 280 (or 12%), and generally from Main Panels A and B – involved some form of codification, including patents, formal recommendation by a recognised body, trademarks, and registration. This reporting highlights commercialisation activities used by Research England in the Higher Education – Business and Community Interaction (HE-BCI) survey, which included indicators of commercialisation, such as spin-out companies, patents, royalties or licenses.

The most common form was formal recommendation by a recognised body, occurring in 16 of the 33 projects or approximately 50%. These ranged from a screening tool used in youth justice prevention in Ceredigion to post-partum blood product algorithms to brain injury outcome tools in use in Bangladesh.

Patents were reported in 13 of the 33 ICS involving codification. These included a trauma pack used in rural Zambia, various forms of biotechnology, photovoltaic devices, and chemicals. Five of the 33 ICS (15%) reported registration of an idea, product or service, including a new British Standard (BS) for head protectors used in cricket and International Standards (ISO) for 3D printed surgical implants.

3.3. Collaboration in the underlying research for Welsh impact case studies

To determine the types of collaboration that featured in the research underpinning Welsh ICS, we examined the author-affiliations listed in papers referenced in Section 3 of the ICS and explored two dimensions of collaboration:

- Collaboration mode – whether research was conducted solely at the submitting institution (none), with domestic collaborators (domestic), with international collaborators (international), or with a large number of international collaborators (multilateral – from at least five different countries).
- Collaboration sectors – whether collaboration organisations are from outside academia, namely healthcare facilities (eg hospitals and clinics), governmental labs, private companies, or non-profit organisations.

In Figure 16, for benchmarking purposes, the data are presented for ICS supported by the Welsh Government (right) and ICS submitted by Welsh HEIs (middle), alongside ICS submitted by UK HEIs (left). This plot shows the percentage of ICS in each Main Panel that had underpinning research articles in each collaboration category. The distribution for Welsh ICS is remarkably similar to the UK, with the following exceptions: in Panel A, multilateral collaboration features in fewer ICS than the UK; and in Panel B, multilateral collaboration features in more ICS than the UK. By contrast there are marked differences with the Welsh Government supported ICS with domestic collaboration being most common for Panels A, B and C but not for Panel D, where international collaboration is more important. When compared at the level of topic cluster, Welsh ICS also follow a similar pattern to the UK (Figure 17) – note that numbers in the Welsh Government data are small when presented by cluster.

Figure 16: Research collaboration – mode by panel

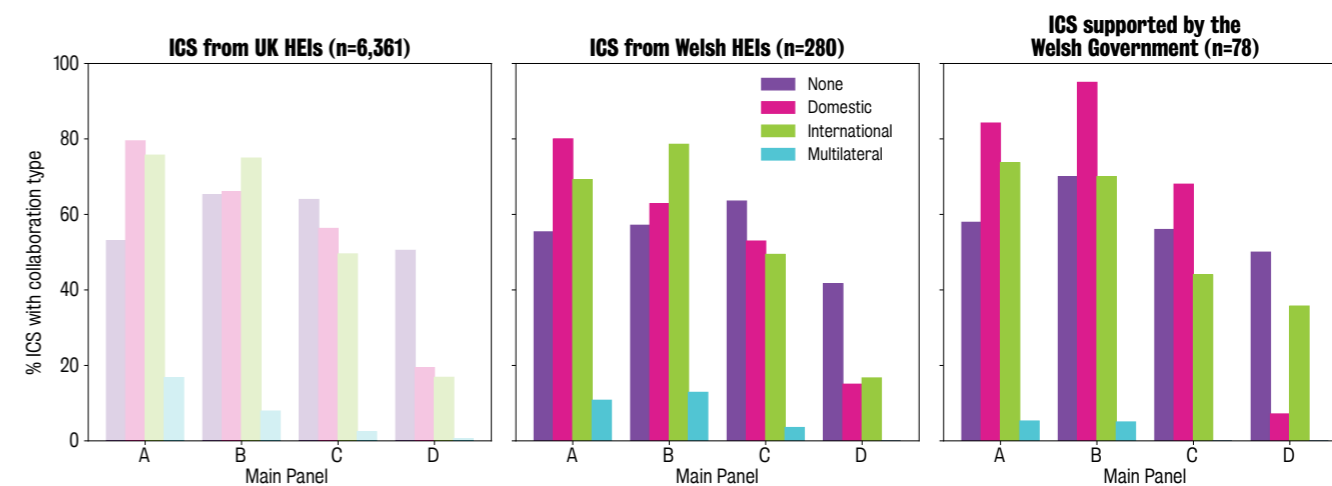


Figure 17: Research collaboration – mode by impact cluster

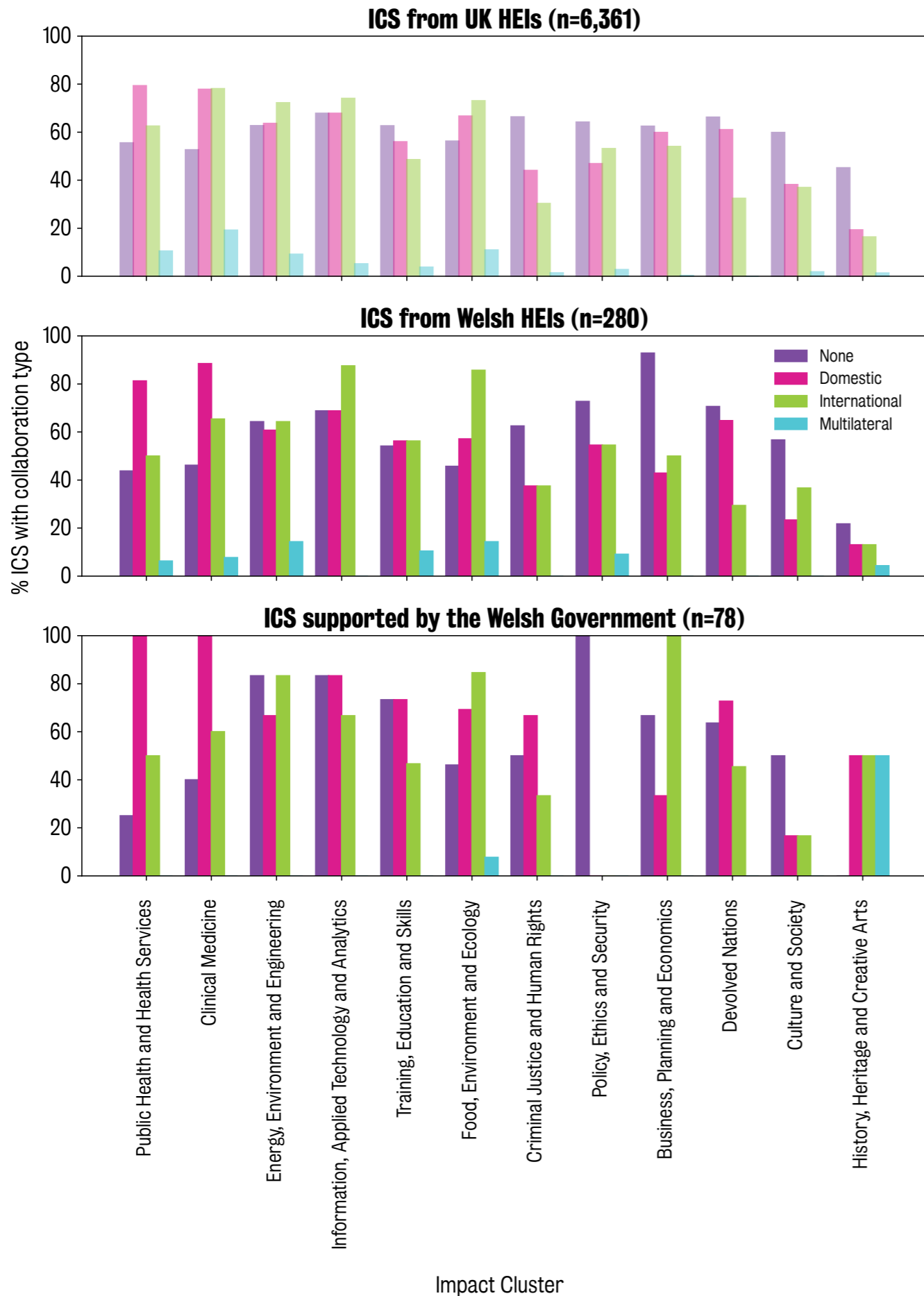


Figure 18 shows the percentage of ICS supported by the Welsh Government (right), ICS from Welsh HEIs (middle), and ICS from UK HEIs (left) that had underpinning research articles with collaborators in each sector. The distribution for Wales and Welsh Government-funded ICS is like the UK, except for corporate collaboration in Panel B which is substantially higher than in the UK. When examined by impact cluster, Figure 19 illustrates that Welsh impacts in topics under “Energy, environment and engineering” and “Information, applied technology and analytics” have more collaboration with corporate organisations than the UK.

Figure 18: Research collaboration – sector by panel

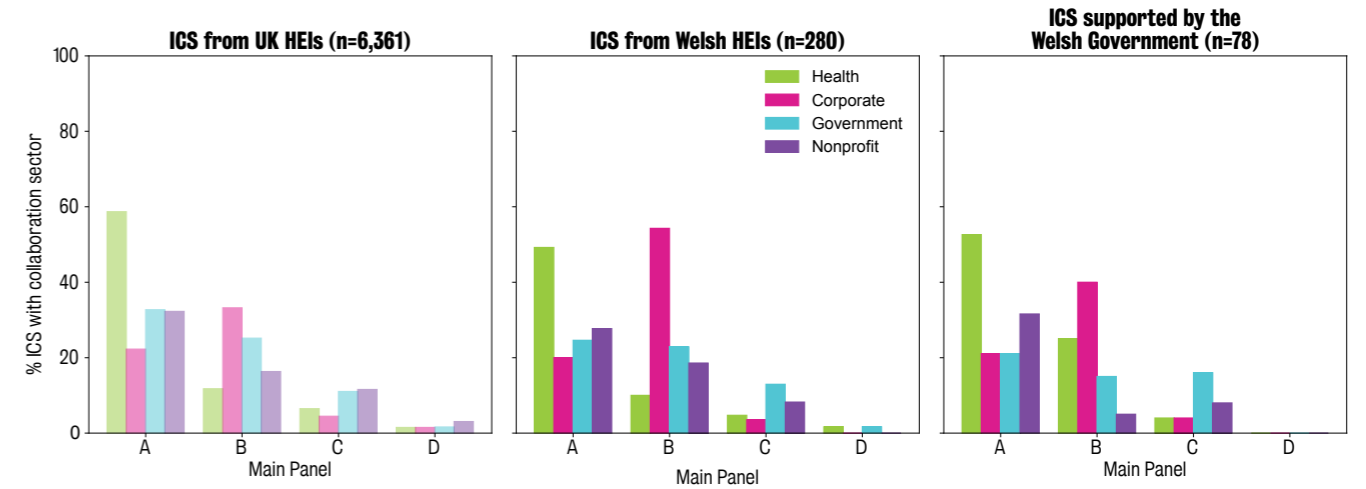
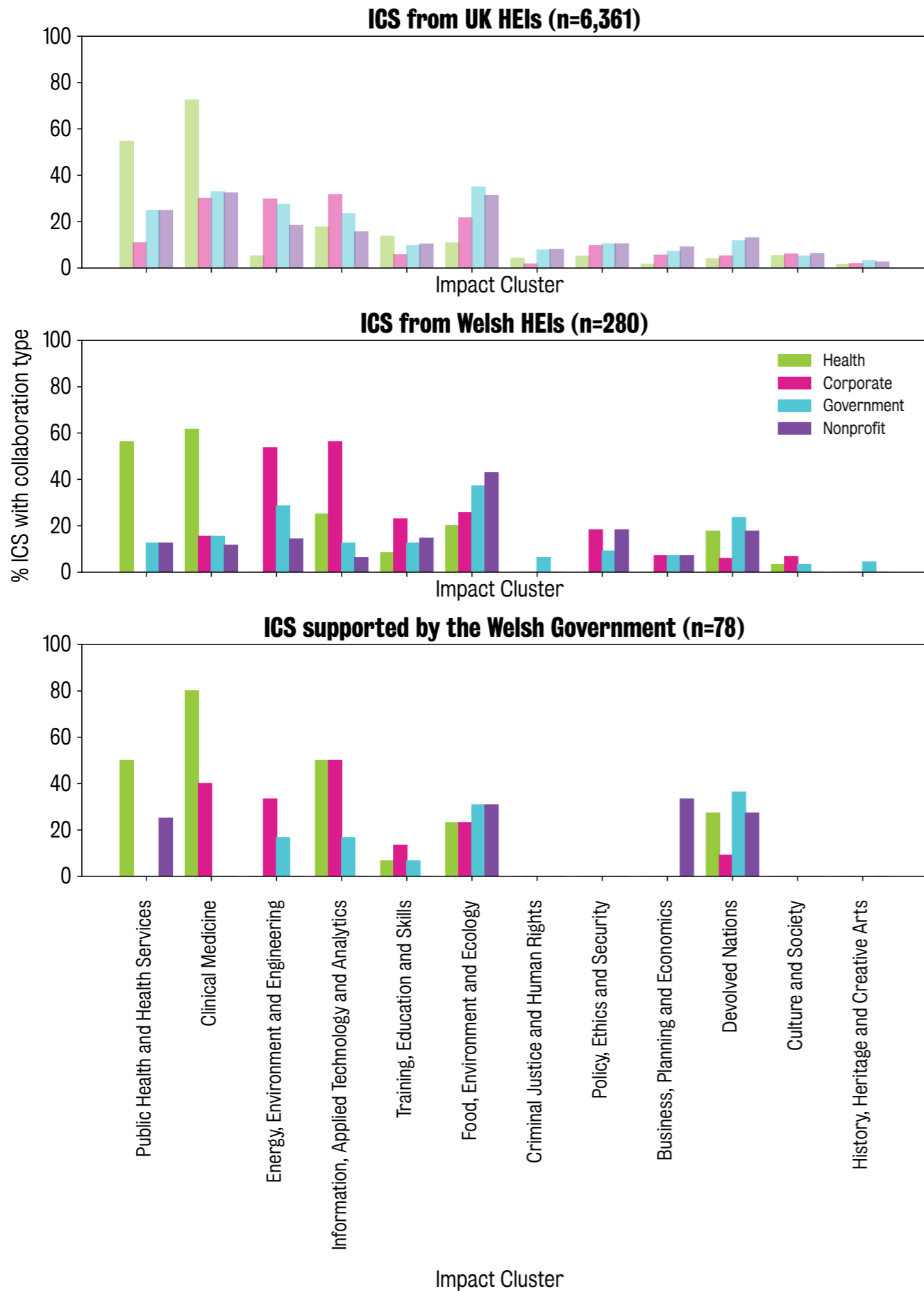


Figure 19: Research collaboration – sector by impact cluster



While the quantitative analysis of collaboration presented here focuses on underlying research, the qualitative analysis of forms of collaboration through partnerships focused, by contrast, on connections and engagements with partners formed either during the course of the underpinning research or, later on, through emergent knowledge exchange and impact activities. However, the importance of co-production and collaboration in our qualitative analysis of partnerships – which often occur at the beginning of projects – demonstrates a connection between collaboration in underpinning research and later impact and knowledge exchange engagements.

3.4. The role of inter- and multi-disciplinary research in leading to impact

Although there are differing views on the definition and nature of inter-, multi-, and trans-disciplinary research, there is broad agreement that the disciplinarity of research varies. Whilst some takes place solely within established subject boundaries, other research may integrate knowledge from other fields, or include research teams from varying backgrounds. A commonly used bibliometric indicator for multi- and inter-disciplinarity is the Rao-Stirling (RS-IDR) metric.⁹ This metric defines interdisciplinarity using three aspects: variety (how many different subjects), balance (how skewed towards certain subjects), and disparity (how unusual the combination of subjects is). The value produced ranges from 0 (least interdisciplinary) to 1.0 (the most interdisciplinary). For the purposes of this quantitative analysis, we use the term IDR to refer generally to inter-, multi-, and trans-disciplinary research, as operationalised by Rao-Stirling, and do not attempt to differentiate them.

For each ICS, the proportion of subject categories referenced by the underpinning research articles was used to calculate interdisciplinarity. Field of Research (FoR) codes (four-digit) were assigned to the underpinning research articles based on their associated journals. Only publications that contained at least ten cited references were used, meaning the metric could not be calculated for all ICS, as summarised in Table 18 for all UK ICS. Coverage of the RS-IDR metric is good for Panels A, B and C, but is lower for Main Panel D – this gap in the coverage of publications can make metrics of this kind problematic in some Panel D areas.

Table 18: Number of ICS with RS-IDR metric by Panel, for all UK ICS

Panel	Total ICS	Number of articles linked to appropriate bibliometric items	% coverage
A	1,419	1,418	99.9
B	1,268	1,262	99.5
C	2,146	2,110	98.3
D	1,528	1,266	82.9

The distribution of the RS-IDR metric is shown in Figure 20 according to Main Panel using a box and whisker plot. It is apparent that there is some variation across panels, and we would expect this given disciplinary difference. For example, other studies using Rao-Stirling typically normalise by discipline. In this analysis, IDR is compared using a panel-normalised percentile – denoted percentile (RS-IDR). The box plot here shows the distribution of IDR scores for each ICS by Main Panel for the UK dataset (left), for the Welsh ICS (middle) and for the Welsh Government-funded ICS (right). By comparing the distribution of Welsh ICS by impact cluster (Table 19), it is possible to identify topics where Welsh research is more interdisciplinary than the UK, with such clusters including 1, 2, 7 and 10. Finally, to illustrate the type of ICS that are the most multidisciplinary, in Table 20 we have listed the top ranked Welsh ICS by the RS-IDR metric.

⁹ Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society, Interface*, 4(15), 707–719.

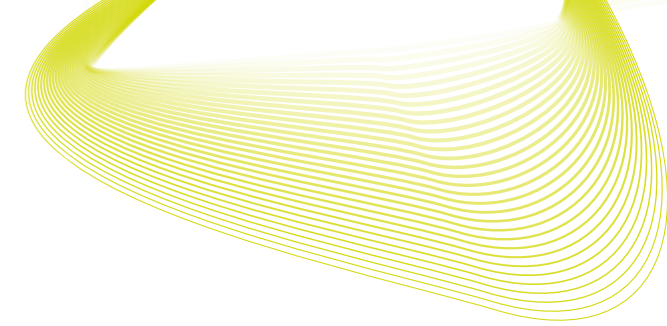


Figure 20: Distribution of RS-IDR metric, by Panel for all UK ICS compared to Welsh ICS

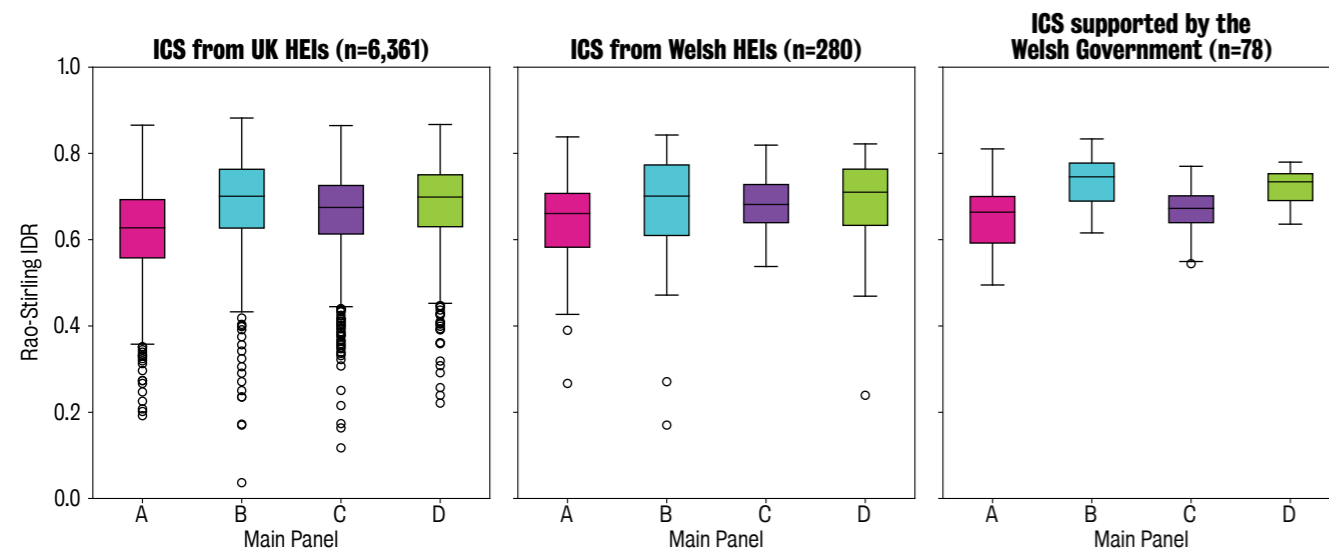


Table 19: Distribution of RS-IDR metric, by impact cluster

Cluster	Cluster label	count UK	count Wales	mean UK	mean Wales	% advantage
1	Public Health and Health Services	805	33	0.51	0.55	0.04
2	Clinical Medicine	1,256	49	0.43	0.49	0.05
3	Energy, Environment and Engineering	861	46	0.57	0.51	-0.06
4	Information, Applied Technology and Analytics	1,128	51	0.51	0.51	0.00
5	Training, Education and Skills	2,132	90	0.54	0.53	-0.01
6	Food, Environment and Ecology	966	55	0.65	0.67	0.02
7	Criminal Justice and Human Rights	578	24	0.54	0.66	0.11
8	Policy, Ethics and Security	904	35	0.53	0.56	0.03
9	Business, Planning and Economics	788	31	0.52	0.54	0.02
10	Devolved Nations	314	78	0.47	0.58	0.11
11	Culture and Society	1,378	42	0.55	0.57	0.02
12	History, Heritage and Creative Arts	823	30	0.59	0.60	0.01

Table 20: Top ranked ICS from Welsh HEIs by RS-IDR metric

ics_id	Institution name	UOA number	Title	IDR
A1992CF5-833A-4619-8161-2DCBEA025342	Cardiff University / Prifysgol Caerdydd	4	Public engagement as a vital facilitator of policy change aligned to net zero carbon emissions	0.99
B1CCCEAEA-CBF7-4648-9F84-A3D8509BD194	Aberystwyth University / Prifysgol Aberystwyth	6	Bioenergy, Land Use and Net Zero Policy	0.99
640A0FF5-AFA1-4A31-9441-B4A37E32CFAC	Wrexham Glyndwr University / Prifysgol Glyndwr Wrecsam	32	'Carbon Meets Silicon' curatorial project and collaboration	0.98
A5FF0B26-CE4D-40AD-8030-E8C3D9DE02E6	Cardiff University / Prifysgol Caerdydd	4	Changing UK legislation on consumer charges designed to reduce single-use plastic waste	0.98
04564F87-674E-4ABA-935A-3E1B5F144FEE	Cardiff University / Prifysgol Caerdydd	7	Evidence based reservoir management strategies solve taste and odour problems of drinking water supply in the UK, US and Brazil	0.98
57AFD34E-A1C1-43BC-80AC-3F2DC400D9D4	Cardiff University / Prifysgol Caerdydd	13	Reducing fuel poverty through targeted mapping of neighbourhoods	0.98
7B37468F-DBFB-4F37-BF1E-8EAFAC248CC2	Wrexham Glyndwr University / Prifysgol Glyndwr Wrecsam	32	Arts and Health Eco System of North Wales	0.97
4B540480-6708-49A4-A3B9-37F4D634AA0A	Cardiff Metropolitan University / Prifysgol Metropolitan Caerdydd	32	International design ecosystems: How Cardiff Met's research increased SME competitiveness	0.97
71EF30E1-413E-4D69-96F6-B0E39B51FA0E	Cardiff Metropolitan University / Prifysgol Metropolitan Caerdydd	32	Transforming the life quality of people with advanced dementia - and their carers - with a HUG™	0.96
A059B0BA-02C6-4D12-AA0C-DE00E59D6D5A	Swansea University / Prifysgol Abertawe	10	Mitigation of the severe impact of COVID-19 on medical provision, hospitalisations and deaths in Wales through mathematical modelling	0.96

Our qualitative analysis also coded the 280 ICS according to disciplinaryity of the underlying research. Unlike the quantitative analysis, where the RS-IDR metric does not differentiate between inter-, multi-, and trans-disciplinary research, our qualitative analysis categorised case studies according to the “depth” of their disciplinary collaboration. Using definitions from a literature review undertaken by the Public Health Agency of Canada¹⁰, we categorised levels of disciplinaryity in the following way:

- Single discipline: No engagement across disciplines of any kind
- Multidisciplinary: Multiple disciplines present in the research but not integrated
- Interdisciplinary: Multiple disciplines present, synthesising and harmonising knowledge
- Transdisciplinary: Integrating disparate disciplines and methods, transcending traditional boundaries

According to this analysis, the large majority, 77%, of Welsh ICSs were rooted in a single discipline (218 of 280), meaning 62 or 22% of ICSs employed some form of disciplinary collaboration in their underpinning research. Within this group, the most common form was multidisciplinary research, which accounted for slightly above 10% of ICS (30 out of 280) followed by interdisciplinary research at slightly below 10% (27 out of 280). The least common form was transdisciplinarity, which was present in only seven ICS overall.

¹⁰ Choi, B. C. K., & Pak, A. W. P. (2006). Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness. *Clinical and Investigative Medicine. Medecine Clinique Et Experimentale*, 29(6), 351–364.

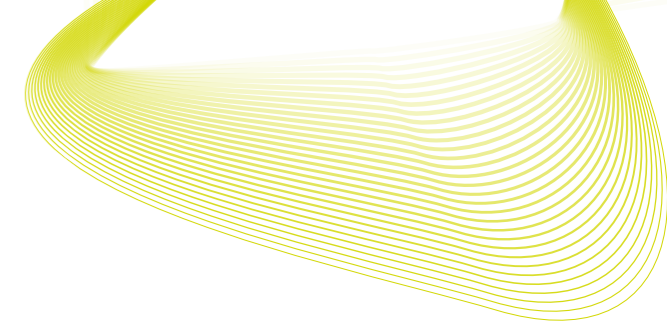


Table 21 maps the spread of different forms of disciplinarity in relation to the four Main Panels. This shows that, as might be expected, single discipline research was consistently present across all Main Panels, representing between 70% (Panel D) and 89% (Panel A) of ICS. Main Panel D contained the greatest proportion of interdisciplinary ICS (10 ICS; 17%), and Main Panel B the highest number of multidisciplinary (11 ICS or 16%). Transdisciplinary research occurred only in small numbers of cases in each panel.

Table 21: Disciplinarity and the four Main Panels

Panel	Interdisciplinary	Multidisciplinary	Single discipline	Transdisciplinary
Main Panel A	3	3	58	1
Main Panel B	5	11	53	3
Main Panel C	9	10	65	1
Main Panel D	10	6	42	2

Because of the relatively small numbers involved here, it is difficult to make robust connections with the quantitative analysis. However, mirroring the quantitative data presented above, our qualitative analysis shows that in Panel D, multi-, inter-, and trans-disciplinary research represented a slightly larger proportion of the research overall, compared to the other panels (in particular, Panel A).

3.5. The impacts of Welsh Government-funded research

In addition to partnerships, different forms of dissemination, levels of collaboration, and interdisciplinary engagement, the funding source of underlying research is a key variable in understanding the characteristics of impactful research. While this report has already touched on aspects of the 78 Welsh Government-funded case studies submitted by Welsh HEIs in 2021, including analyses of sectoral impact and the forms that impact has taken, this section offers a focused analysis of this sub-group, in the wider context of research funding for Welsh ICSs.

Funding of underlying research

Our qualitative analysis coded each of the 280 ICS to identify the funding sources of the underlying research described, where that information was available (in 20% of ICS, no funder was reported or the funding source was not clear). We found that three quarters of ICS (211 out of 280) reported a funder from the UK – including funders specific to Wales – while 29% (82 out of 280) mentioned an international funder (from outside the UK).

Of the UK-wide funders, the single most prominent source was UK Research and Innovation (UKRI) which was identified as a funder in 40% of the 280 ICS overall. Within this grouping of UKRI-funded case studies, the Engineering and Physical Sciences Research Council (EPSRC) (11% of ICS), the Arts and Humanities Research Council (AHRC) (11%), and the Economic and Social Research Council (ESRC) (9%) were the most prominent UKRI funders, while the remaining research councils (the Natural Environment Research Council (NERC), Biotechnology and Biological Sciences Research Council (BBSRC), Medical Research Council (MRC), Science and Technology Facilities Council (STFC), and other UKRI-wide funding schemes) are reported as funders by 34 (12%) of ICS in total. The second most prominent source of funding from UK funders was the charitable sector, including organisations such as Cancer Research UK and the Joseph Rowntree Foundation, which was cited in 11% of ICS, while industry or commercial funding sources for

underlying research (as opposed to sources of commercial revenue gained subsequent to the underpinning research, which is reported on later) were reported by the same proportion of case studies.

82 case studies reported research funding from international sources, which represents 29% of our ICS sample. European Union funding sources – such as EU Structural Funding or the Welsh European Funding Office – represented more than two-thirds of international funding sources (68%) and was noted by a fifth of ICS overall, underlining the importance of this funding source for Welsh research and impact.

Welsh Government funding

Welsh Government funding supported 78 case studies, which represents 28% of the overall sample of ICSs submitted to REF in 2021 and a large majority (88%) of the ICS that reported a specifically Welsh funding source, whether governmental or otherwise.

As has already been outlined in Section 2.5, the sectoral impacts made by Welsh Government-funded research in REF 2021 mirrors that of the wider trends in all 280 of the Welsh ICSs – irrespective of their final impact location. “Human health and social work activities” is the most-commonly cited sector of impact, while “education” and “public administration” also feature prominently as the second and third most commonly reported sectors of impact. Similarly, the nature of these impacts is also consistent: “changing processes and practices” is also the most reported type of impact, followed by impacts on “policy and governance”, “economic impacts”, and a “change in public attitudes or perceptions”.

Data on the sectoral impact of the 78 Welsh Government-funded case studies cross-referenced with the nature of these impacts demonstrates that the ultimate impacts made by this subgroup are comparable to those of our wider sample, with some small differences. Amongst Welsh Government-funded case studies that changed processes and practices (the most prominent type of impact), the most impacted sectors were “human health and social work activities” (28 of 78, or 36% of the whole set of Welsh Government-funded ICS), “education” (23 of 78, or 29%) and “public administration and defence” (17 of 78, or 22%). Smaller numbers of ICS changed processes and practices in other sectors, such as “biodiversity, ecology and environmentalism” (12), “arts, entertainment and recreation” (6), “information and communications” (6), “justice” (6) and “manufacturing” (6).

Among Welsh Government-funded ICS that cited an impact on policy and/or governance, the most prominent sectors of impact were very similar to those impacting processes and practices: “human health and social work activities” (19 of 78), followed by “education” (17), “public administration and defence” (17), “biodiversity, ecology and environmentalism” (7) and “justice” (5). While overall numbers making an economic impact or having an impact on public attitudes or perceptions were smaller, the distribution across sectors was again similar.

4. Beneficiaries

4.1. The beneficiaries of research from HEIs in Wales

Research from Wales impacted on a wide array of beneficiaries. These ranged from adopters of research findings to those who have benefited indirectly from the resulting products or services, from those who have directly collaborated with or commissioned researchers to those who have been exposed to research through dissemination of findings. Despite various attempts, it has proven very difficult to use quantitative methods to identify beneficiary groups, so this section is of particular interest in developing a greater understanding of who benefits from research undertaken in Welsh HEIs.

25 different beneficiary types appear in the ICS submitted to REF 2021 from Welsh HEIs. These can be grouped into two broad categories, ‘decision makers and influencers’, which includes policymakers, officials, and other influential stakeholders in policy processes – whether in government or in other areas of decision-making – and different “socio-demographic groups” among the public.

The former beneficiaries, reported in 186 ICS (66%) were more common than the latter, reported in 135 (48%). Additionally, as has been reported in Section 2.5, impact occurred across 30 separate sectors of the economy, from the arts to justice and policing to veterinary sciences. Approximately one ICS in every three (35%) reported impact in “human health and social work”, with 25% reporting impact in “education”, and 22% in “public administration and defence”. Impact in the arts was reported by 43 ICS (15%) and “heritage and tourism” in 33 (11%).

Decision makers and influencers

The “decision makers and influencers” who benefited from research originating in Wales were spread across Wales, the rest of the UK, and internationally (EU and non-EU). Of the 186 ICS which reported impact on these stakeholders, 105 (or 56%) were based in Wales (broken down in Table 22). Within this total figure, 55 ICS (52%) reported impact on government departments, 14 on health boards (13%), 16 on local government (15%), and 18 on Welsh Government-sponsored agencies (17%) such as Natural Resources Wales. Direct impact on politicians (22) and elected police and crime commissioners (6) occurred in around 25% of ICS in aggregate.

Table 22: Breakdown of ICSs reporting impact on “decision makers and influencers” in Wales (n=105)

Decision maker, policy, and influencer beneficiaries	No. ICS
Government departments	55
Politicians	22
Government-sponsored agencies (Welsh)	18
Local government	16
Health Boards	14
Professional associations & trade bodies	9
Police and Crime Commissioners	6
Regulators	5
Think tanks	2

The spread of impact on decision makers and influencers outside of Wales was at a similar level internationally and in the rest of the UK, with 79 of the 280 ICS reporting international impact in this way (33 EU, 60 non-EU) and 82 describing impact on politicians and policymakers in the rest of the UK. Within the EU, for example, beneficiaries included both those based within the transnational institutions of the European Union itself (including the European Commission) and at the national level amongst member states such as Belgium, France, Germany, Portugal, and, most notably, Ireland. This spread of transnational and national is also apparent globally, with beneficiaries ranging from the United Nations, UNESCO and the World Health Organisation to international sporting associations, from the governments of Uganda and Madagascar to the High Courts of India and Jamaica.

The use of research by decision makers and influencers within the rest of the UK mirrored use in Wales and internationally, with impact on UK-wide government departments such as the Ministry of Defence, devolved government in Scotland, the National Health Service, the Met Office, local public health departments, the London Ambulance Service, and the BBC.

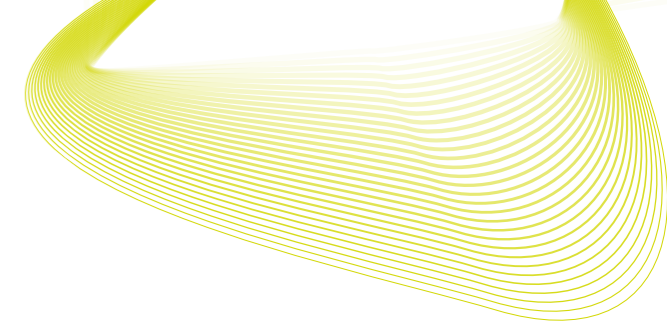
Socio-demographic groups

The broad range of public beneficiaries of research from Wales can be broken down into 14 socio-demographic categories, from children and young people (ie those under the age of 18) to women and gender-based groups (see Table 23). Of these, by far the most common public beneficiaries from research were children and young people, occurring in 69 of the 280 case studies (or 25%). In several cases, this is as a direct result of researchers engaging with schools via workshops and learning activities, or with Welsh Government to change the curriculum as delivered in the classroom, or by providing educational materials. The majority of ICS in which children and young people are reported beneficiaries of research are Wales-based.

Table 23: Breakdown of ICS reporting impact on demographic and public groups

Beneficiary Group	No. ICS
Children (under 18)	69
Communities	48
Women and gender-based groups	30
Marginalised & minority communities	21
Families (nuclear)	18
Other	17
Citizens	16
Disabled people	14
Elderly	13
Carers	8
Parents	5
Refugees	4
Cancer patients	1
Creative industries professionals	1

The international examples of impact reveal continued efforts by Wales-based researchers to engage with communities on issues such as representation (in Myanmar and Namibia), gender-based violence and justice (in Afghanistan), and fertility treatment (in Japan). These efforts are indicative of Wellbeing of Future Generations legislation which was introduced in Wales in 2015 and aspires to global responsibility. In Wales,



too, there is emphasis on representation, healthcare, and violence, aspects which point to two more of the legislation’s aims, namely community cohesion and a more equal Wales. One example was “Making Ethnic Minority Women Visible” (2014-2019), a submission by Swansea University. This case study built on previous work on memory, commemoration, and recuperation, particularly of Welsh-Jewish women in the Swansea Valley, and used creative writing together with broadcasting to contribute to public debates about the necessity of memorials to named Welsh women and to kickstart the process which led to the erection of a statue to Betty Campbell in central Cardiff in 2021.

4.2. The nature of beneficiary engagement

How researchers engaged with beneficiaries (and vice-versa) varied in nature from the adoption of research in practice to active collaboration with the research team. Overall, there are six categories of involvement which occur in the case studies:

- Adopted research in practice (occurring in 127 ICS, or 45%)
- Benefited from research as third party (131 ICS, or 47%)
- Commissioned or engaged researcher (80 ICS, or 29%)
- External collaborator of research team (39 ICS, or 14%)
- Partner of research team (44 ICS, or 16%)
- Provided innovation (22 ICS, or 8%)

Typically, beneficiaries engaged with researchers either by adopting research in practice or by a more indirect influence, for example through research influencing policy which impacts upon provision and funding of Welsh language centres, or the creation of third-party apps using historical collections collated and published by researchers.

These connections may be nuanced further by considering the nature of engagement alongside the beneficiary type. This analysis reveals, for example, that Welsh policymakers were the most likely adopters of research in practice and the most likely to commission or engage researchers, followed by policymakers from the rest of the UK and internationally. Amongst socio-demographic groups, involvement was typically as third-party beneficiaries with children and young people the most commonly reported group.

Beneficiaries of Welsh Government-funded research

As outlined in Section 2.5, the 78 ICS supported by Welsh Government funding made impacts across a range of sectors, the most prominent of which were “human health and social work activities”, “education” and “public administration and defence” – as well as a diverse range of other sectors, from the justice sector to agriculture and fisheries.

Beyond this high-level picture of sectoral impact, we see that the primary beneficiary groups of these ICS were “decision makers and influencers”, on whom 54 of these 78 case studies had an impact.

Significantly, 48 of these (62%) are ICS that report an impact on a Welsh decision-maker, policymaker, or related stakeholder. As might be expected, this is a higher proportion than the overall sample, in which 38% of

ICS impacted Welsh policy stakeholders. Specific beneficiaries included government departments, agencies, or legislation (29 ICS), such as the Welsh Government’s Tobacco Control Delivery Plan 2017-2020, the Wales Environment Act and the national Curriculum for Wales (2022). Other key Welsh policy stakeholders included local government and health boards, cited by nine and four ICS respectively, as well as individual politicians or officials named in the case studies (in 10 ICS).

Impacts on the rest of the UK were reported in 17 ICS, while international impacts were identified in 13. In the former group, many impacts are cited across the nations of the UK, in England, Scotland, and Northern Ireland, as well as across the UK as a whole.

Half of Welsh Government-funded ICS (39 of 78) had an impact on wider public and specific sociodemographic groups within that. A further breakdown of the most prominent demographic groups referenced in these Welsh government-funded ICSs can be found in Table 24.

Table 24: Breakdown of Welsh Government-funded ICS reporting impact on demographic and public groups

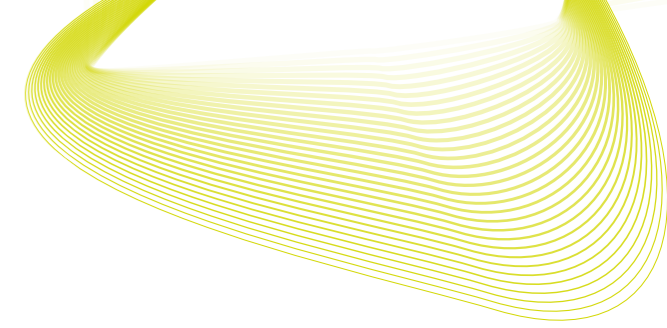
Demographic groups	Number of Welsh Government-funded ICS reporting impacts
Children (under 18)	20
Communities	16
Marginalised & minority communities	9
Women and gender-based groups	7
Families (nuclear)	6
Citizens	4
Carers	3
Elderly	3
Refugees	3

Echoing our analysis of the importance of education at a sectoral level, the largest demographic group within these beneficiaries was children under the age of 18, on which 20 of these 78 ICS made an impact. One example of such an impact was a case study describing how research-led mentoring programmes had increased the uptake of modern languages at GCSE level in participating schools. Communities – such as local and regional populations or groups in Wales and in other contexts – also represented a significant group, with 16 ICS citing an impact on communities. This included, for example, research on storytelling that led to successful bids from Welsh valley towns for extensive funding for post-coal mining community regeneration, and on rural crime that improved trust and communication between communities and the police.

Other important groups benefiting from this Welsh Government-funded research include marginalised communities (9 ICS), including forced migrants in Wales, as well as women or other gender-based groups (7 ICS).

4.3. Welsh Government priorities

This section examines the impact of Welsh HEI research in relation to a series of key Welsh Government priorities: climate change and net zero, Cymraeg 2050, children and young people, Welsh national wellbeing indicators, and productivity. To do so, each ICS was read and coded depending on whether it had an impact that was relevant to each of these areas. Overall, we found that 102 of the 280 ICS reported an impact that was relevant to the Welsh Government priorities noted. Such impact may also be taken as a measure of the Well-



being of Future Generations (Wales) Act, which has complimentary priorities and overlapping wellbeing goals including vibrant culture and a thriving Welsh language, more cohesive communities, a more equal Wales, and a healthier Wales, although this aspect was not separately coded.

The most prominent of the priorities was children and young people, an impact related to which was reported by 56 ICS (one fifth of the overall sample). Impacts related to climate change and net zero were found in just under 10% of ICS (27 of 280). 14 ICS had impacts relevant to the Welsh Government's Cymraeg 2050 priorities for Welsh language and culture, while 13 case studies reported impacts that are connected to improving economic productivity.

Wales's national wellbeing indicators comprise 50 separate metrics and indexes of wider physical, mental, social, and economic wellbeing. This makes creating a single category for analysis difficult, due to the diversity of indicators – from pay gap data to birth weight statistics. In this section, therefore, we highlight key areas within the other Welsh Government priority areas where specific indicators are particularly relevant.

Children and young people

The Welsh Government's Children and young people's plan outlines its four-year strategy to provide children in Wales with the "best start in life", from the provision of early years education and equality in education, to training and skills for employment, emotional and mental wellbeing, and support for homelessness prevention, family connection, and economic equity.

We found that the 56 ICS that reported an impact on this priority area could be divided into three further categories. As might be expected, given the prominence of education in the sectoral impacts of Welsh research, education and skills for young people (37 ICS) is the largest of these, followed by physical or mental well-being (11), and social and economic interventions (8). Among this first and largest group, education and skills, we found that just under two-thirds of ICS (24 out of 37) made an impact on young people's learning, education or skills via outreach methods, including talks or workshops for young people or schools, online resources, or public exhibitions. For example, one research team developed their research on the optimal mathematical arrangements of soap bubbles and energy minimisation to be communicated with young people at festivals and in schools. Another project, on sex and relationships education in Wales, used creative and co-productive outreach methods with school students, in combination with structural changes to policy and curriculum, to transform young people's understanding of sexuality and gender in Wales.

Other projects (12 ICS) had impacts on young people's learning via influencing wider structures within the education system, such as curriculum design or the practice and processes used by teachers in schools. This included, for example, research in collaboration with the National Library of Wales on the history and literature of travel in Wales being adapted for new open-access teaching resources for schools, as well as influencing a wider review of the Wales national curriculum.

11 ICS reported impacts related to the physical and mental wellbeing of young people, such as a project on the psychological factors that led to successful or failed adoption placements which influenced the establishment of a new Adoption Together Service and led to improved mental health and wellbeing outcomes for adopted children. Other ICS, eight in total, were more closely related to social and economic interventions and/or conditions for young people, such as research on the Senedd Cymru that has informed the new Senedd and Elections (Wales) Act 2020 that plans to extend the right to vote to people aged 16 and 17.

Predictably, children are the primary beneficiaries in these ICS, with 50 of 56 reporting impacts on research users under the age of 18. Similarly, the most common form of research user involvement is benefiting from

research as a third party, with a quarter of ICS relating to the children and young people priority reporting this kind of involvement. This includes projects where research into gravitational wave data was translated into workshops for GCSE and A-level students that improved their applied understanding of maths and physics, as well as the benefits to infants of research that improved mothers' confidence in breastfeeding.

The geographical reach of these ICS was both national and international, with 54 of the 56 relevant case studies reporting an impact in the UK (including Wales) and 49 of 56 citing an impact specific to Wales. 29 ICS in this group were categorised as having international impact.

The impacts created by this group of ICS can be linked to key Welsh national wellbeing indicators such as "Percentage of children with two or more healthy lifestyle behaviours" and "Measurement of development of young children", which capture the wider social, developmental wellbeing of young people.

Climate change and net zero

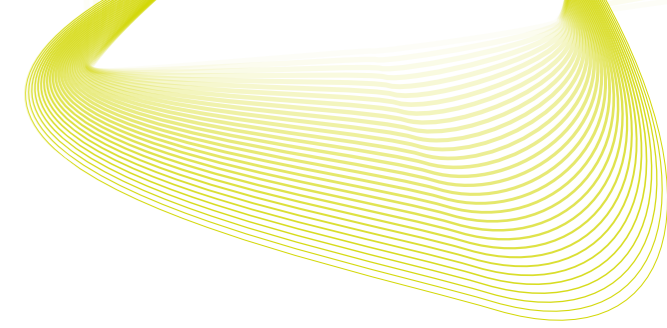
The Welsh Government's Net Zero Wales: Carbon Budget 2021-25 document acknowledges the need for urgent action on climate change and sets out 123 policies and proposals, alongside commitments and action from every corner of Wales to achieve a range of related objectives, including the wider objective to reduce greenhouse gas emissions to net zero by 2050.

A number of Welsh national wellbeing indicators with specific environmental metrics are also relevant to this area of impact, as is the Future Generations aim of a "resilient Wales" which "maintains and enhances a biodiverse environment". Importantly, the metric of "Emissions of greenhouse gases within Wales" is directly relevant to the wider net-zero goals, as is "The global footprint of Wales", which concerns the "area of land needed to provide raw materials, energy and food" and to absorb the pollution and waste generated by Wales. Another, indicator the "Amount of waste generated that is not recycled, per person", is also relevant here to concerns around climate change.

We coded the ICS in our sample according to whether they produced impacts that were relevant to these wider objectives. In doing so, we found 27 case studies (just under 10% overall) had an impact that could be understood to contribute to these objectives. Of this group of 27 ICS, 14 were directly related to either reducing emissions or the energy sector, relevant to the wellbeing indicator regarding Welsh global ecological footprint described above. These included a major industrial engineering project on the use of hydrogen in achieving zero-carbon industrial development, and economic research on renewable energy investment informing new energy policies and helping to secure investment for marine energy projects. Other projects (8 ICS) were more directly focused on policy influence, for example, a project on the socio-cultural values of "nature" for the EU influenced a wide range of international policy initiatives, including the Metz Charter on Biodiversity, agreed at a meeting of the G7 in 2019.

Other projects (4 ICS) in this group were more relevant to ecological, natural or environment sciences, or created impact on environmental objectives through education or outreach (2 ICS).

The 27 ICS that reported impacts relevant to climate change and net zero targets were spread across a number of sectors. The most prominent of these, as might be expected, is the "biodiversity, ecology and environmentalism" sector, in which 11 ICS reported an impact. However, other sectors too were relevant here, including the energy sector (4 ICS), "agriculture, forestry, and fishing" (4 ICS) and the wider policy sector (3 ICS). Other impacts were divided across a diverse range of sectors, from manufacturing to heritage and tourism, as well as transport.



Of this group of ICS, 19 of 27 had a specific impact in Wales, 24 in the UK as a whole and 16 internationally. Of this group, 11 ICS were Welsh Government-funded.

Cymraeg 2050

The Welsh Government's Cymraeg 2050 vision envisages a million Welsh speakers by 2050 and sets out its plans to realise this by a) increasing the number of Welsh speakers, b) increasing the use of Welsh and c) engendering favourable infrastructural and contextual conditions for these developments to take hold.

This vision can also be related to Future Generations legislation and the overriding milestone entitled "a Wales of vibrant culture and thriving Welsh language", under the purview of which come a number of national wellbeing indicators. These include two that are directly relevant here: "Percentage of people who speak Welsh daily and can speak more than just a few words of Welsh" and "Number of people who can speak Welsh".

We coded the ICS in our sample according to whether their impacts contributed in a direct way to these plans and the wider vision, and found that 14, or 5% of the total sample, did so. These ICS were predominantly from Main Panel D with, perhaps unsurprisingly, the largest representation – six ICS – coming from Modern Languages and Linguistics. A further four ICS belonged to other Panel D UOAs, two to Panel C and one each to Panels A and B.

ICS that had an impact related to Cymraeg 2050 focused particularly on "changing practice or processes" (9 ICS), such as making resources on advanced mathematical research available in Welsh, or research on innovation in screen media production helping to accelerate digital media strategy and investment for Welsh language broadcasters and production companies. Six ICS had a more indirect influence on Welsh language development via policy impact. This included a case study on research into the legal and policy context of "Language Commissioners" in Ireland and Wales leading to a range of policy outcomes, including clear recommendations on the role of the Welsh Language Commissioner in relation to that of the Welsh Government and a streamlining of Welsh language standards. Two ICS were coded as having impacts relevant to both policy and practice, including one reporting research on how to encourage the use of Welsh in everyday life, which influenced key Welsh Government policy as well as the way in which Welsh language education is practiced through the creation of a toolkit in community settings.

While these ICS were, as might be expected, primarily focused on impacts in Wales, they also had international impacts – for example, one influenced Irish language policy, while another developed resources for diagnosing literacy skills in Czech and Slovak contexts.

Overall, eight of the 14 ICS we identified as relevant to Cymraeg 2050 were funded by the Welsh Government.

Productivity

The Welsh Government's Regional Investment in Wales after Brexit plan outlines the objective to close a "productivity gap" between Wales and the other UK nation and defines productivity as "a measure of how well an economy combines resources to produce goods and services". Productivity, therefore, can be understood as a measure of efficiency in relation to production and development. It also serves as a wellbeing goal, per the Well-being of Future Generations (Wales) Act 2015.

While any economic impact could be thought to contribute in some way to productivity by, for example, creating commercial revenue that can be re-invested in production, we sought to use the narrow definition

outlined in the Welsh Government's plan to identify ICS that directly contributed to this objective of supporting improvements in the efficiency with which goods and services are produced in Wales. As such, we identified 13 ICS where such a contribution was clearly present and divided these into two thematic categories: "people" and "processes".

The former category (which accounted for eight ICS) collected examples where the impact focused on improving productivity by empowering or supporting individuals or communities to be productive in work, whether, for example, through research on real time data analytics in energy management services being used to upskill employees in areas of deprivation, or improving business performance in Wales through leadership training informed by business and management research.

The second category, "processes", referred to impacts on technical structures, particularly supply chains, that contribute to improved efficiency. A paradigmatic example of this is a project using cutting-edge research on "Contemporary Operations Management Paradigms" leading to efficiencies in supply chains across a variety of industries in Wales and the UK, including "the productive performance of food businesses in Wales".

Of this group of ICS, five reported having funding from the Welsh Government.

5. Other characteristics

5.1. The volume and distribution of disciplines and impact types for continued ICS

Of the 280 ICS that were submitted by Welsh HEIs to REF 2021, 16 (or 3.6%),¹¹ were marked as being continued from a REF 2014 submission, as listed in Table 25. Given the small numbers and differences in guidance by panel it is hard to provide any commentary on their distribution. However, for the UK, and as reported in the UK-wide study, there was evidence that submitting units to REF 2021 found this guidance on continuation difficult to interpret as there were ICS that were submitted as being continued that were not (at least to criteria we tested) and, similarly, some that did appear to meet our criteria but were not submitted as being continued.¹²

Table 25: List of continued ICS submitted by Welsh HEIs

Institution name	Main panel	Unit of assessment name	Title	Primary topic label
Cardiff University / Prifysgol Caerdydd	A	Clinical Medicine	Global adoption of the Dermatology Life Quality Index into clinical practice	Clinical trials
Cardiff University / Prifysgol Caerdydd	A	Psychology, Psychiatry and Neuroscience	Improving the health of adults and young people with learning disabilities through the Cardiff Health Check	Disability, inclusion and care
Cardiff Metropolitan University / Prifysgol Metropolitan Caerdydd	A	Allied Health Professions, Dentistry, Nursing and Pharmacy	Innovation and improved food safety in the Welsh food sector	Food systems
Cardiff University / Prifysgol Caerdydd	A	Allied Health Professions, Dentistry, Nursing and Pharmacy	Shaping UK and international strategies to reduce violent crime through policy and legislation	Domestic abuse and sexual violence
Cardiff University / Prifysgol Caerdydd	B	Chemistry	Scaling-up the environmentally friendly production of Perspex®	Environmental sustainability
Cardiff University / Prifysgol Caerdydd	B	Chemistry	Novel gold-based catalyst methods for PVC production	Environmental sustainability
Cardiff University / Prifysgol Caerdydd	B	Physics	The commercialisation of Terahertz technology: from astronomy to the international market	Intelligence, Artificial Intelligence and computing
Cardiff University / Prifysgol Caerdydd	B	Engineering	Improving international flood risk management and hydro-epidemiological modelling strategies	Water and environmental monitoring
Cardiff University / Prifysgol Caerdydd	B	Physics	Universe in the classroom: Transforming perceptions, teaching practice and public awareness of astronomy	Teaching and schools
Cardiff University / Prifysgol Caerdydd	C	Architecture, Built Environment and Planning	Changing EU directives to improve the energy efficiency of non-residential buildings across Europe	Energy and energy efficiency
Swansea University / Prifysgol Abertawe	C	Business and Management Studies	Influencing UK and Welsh Government policies in the areas of employment and public sector pay	Employment and wages
Cardiff University / Prifysgol Caerdydd	C	Business and Management Studies	Shaping peer-led approaches to improve local government performance in England and Wales	Wales
Cardiff University / Prifysgol Caerdydd	D	English Language and Literature	Transforming understanding of, and engagement with, historical illustrations through digital archives	Digital environments
Swansea University / Prifysgol Abertawe	D	History	Copperopolis Reborn: A historic global industry, place-making and heritage-led regeneration	History and cultural heritage
Cardiff University / Prifysgol Caerdydd	D	Communication, Cultural and Media Studies, Library and Information Management	Improving decision-making for patients in vegetative and minimally conscious states	Clinical trials
Cardiff University / Prifysgol Caerdydd	D	Communication, Cultural and Media Studies, Library and Information Management	Enhancing the accuracy and impartiality of journalism: reshaping broadcasters' editorial guidelines and practices	Media and communication

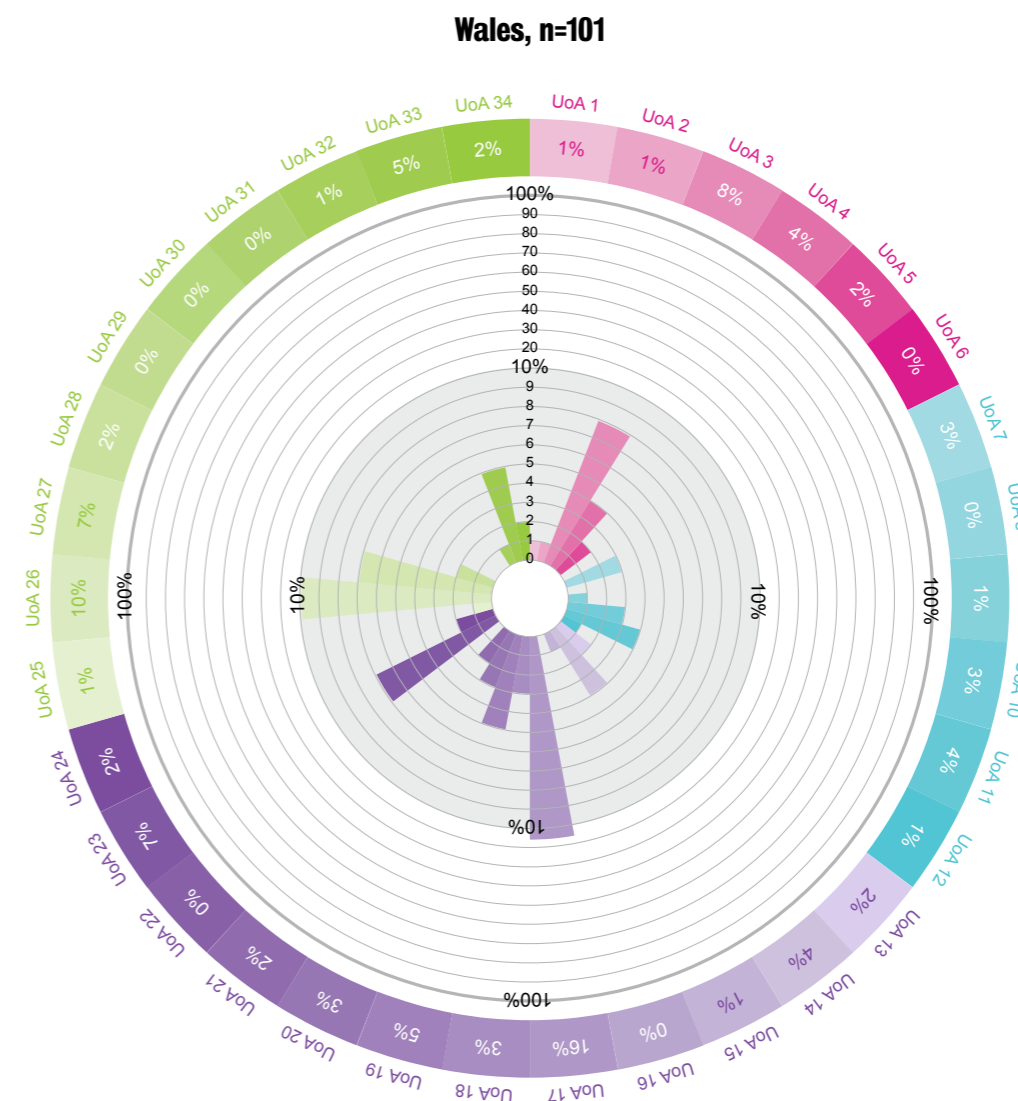
¹¹ slightly lower than for the UK as a whole which was 5.1%, or n=322.

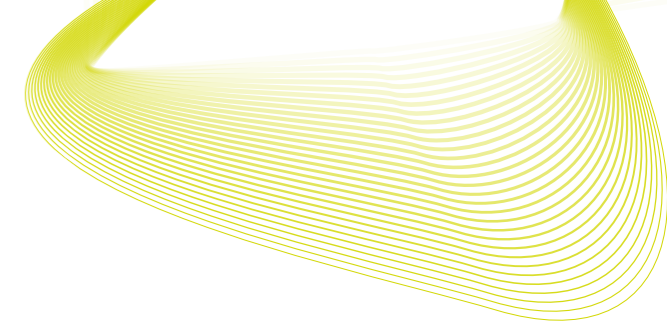
¹² Stevenson, C., Grant, J., Szomszor, M., Ang, C., Kapoor, D., Gunashekar, S., & Guthrie, S. (2023). Data enhancement and analysis of the REF 2021 Impact Case Studies. Santa Monica, Calif.: RAND Corporation. RR-A2162-01. www.rand.org/t/RR-A2162-1

5.2. The characteristics of other ICS that focus on Wales and their relationship to the discipline of “Wales Studies”

As noted above, one of the 79 impact topics identified for the UK was “Wales”, sitting in an impact cluster (10) for the “Devolved nations”. The impact wheel for “Wales” was originally presented in Figure 6, but only based on the case studies submitted by Welsh HEIs (n=86). In Figure 21, the impact wheel for the full set of case studies (n=101) is presented showing the full extent of UOAs contributing to impact on this topic. Although the two Figures are similar, there is a noticeable increase in the proportion of case studies submitted to UOA23 (Education) – from 3.5% to 7% – indicating that impact on this topic is exported to Wales from other regions in the UK. Of the total 101 ICS, five UOAs account for nearly half of the ICS: UOA17 (Business and Management Studies) 17%, UOA26 (Modern Languages and Linguistics) 10%, UOA3 (Allied Health Professions, Dentistry, Nursing and Pharmacy) 8%, UOA23 (Education) 7% and UOA27 (English Language and Literature) 7%.

Figure 21: Impact wheel for “Wales” topic





As discussed in the methodological Annex A, each of the ICS could be “tagged” to up to three topics. As a result, it is possible to see the impact areas that overlap with the “Wales” impact topic, as summarised in Table 26. Perhaps not surprisingly, given the analysis so far, topics such as “Training and skills”, “Digital environments” and “Teaching and education” lead this “top 10” list.

Table 26: Leading impact topics overlapping with the “Wales” impact topic

Topic number	Topic Label	Number of ICS	%
72	Training and skills	13	12.87
73	Digital environments	11	10.89
4	Teaching and education	10	9.90
31	Language and linguistics	8	7.92
49	Students and education	8	7.92
54	Housing and homelessness	7	6.93
60	Social services and primary care	7	6.93
62	Media and communication	7	6.93
37	Business and entrepreneurship	6	5.94
47	Young people and youth support	6	5.94

The prominence of the “Wales” topic is worth noting here. Given no comparable topic exists for “England”, “London”, or “The UK”, it suggests – based on the specific topic model derived from the UK-wide REF ICS data set – that research undertaken in Welsh HEIs has an explicit local or national concern with impact in “Wales”.

Further comparative analyses of the topics “Northern Ireland” and “Scotland” with respect to the ICS from the relevant nations might help reveal whether the preoccupation with “Wales” in Welsh ICS is numerically disproportionate. However, this putative analysis would only reveal relative prevalence of these topics. Further qualitative and discursive analysis of the ICS in which the “Wales”, “Scotland”, and “Northern Ireland” impact topics are present would help us compare how ICS from these nations refer to these topics. The absence of topics such as “England” or “London” should also not be taken as an indication that local impact is any less important or prevalent in ICS from these areas, but merely that the language used in case studies does not foreground these topics in the same way as from other nations.

It also does not straightforwardly follow that all 86 of the ICS categorised within the “Wales” impact topic can be considered as “Wales Studies” – that is, “the intellectual exploration, explanation and understanding of all things relating to Wales and its relations with the wider world.” (LSW, 2020). The “Wales” impact topic is derived from the section of the ICS which is specifically focused on impact, whereas “Wales Studies” can more readily be associated with “underpinning research”. As our analysis has shown, underpinning research can have multiple pathways to impact and research on the Welsh language, for example, might have impact in non-Welsh contexts such as in Ireland. Moreover, both of these – the underpinning research and the impact of the research – have a relation to but are distinct from the geographical location of the impact, which is presented in this report as a separate category of analysis.

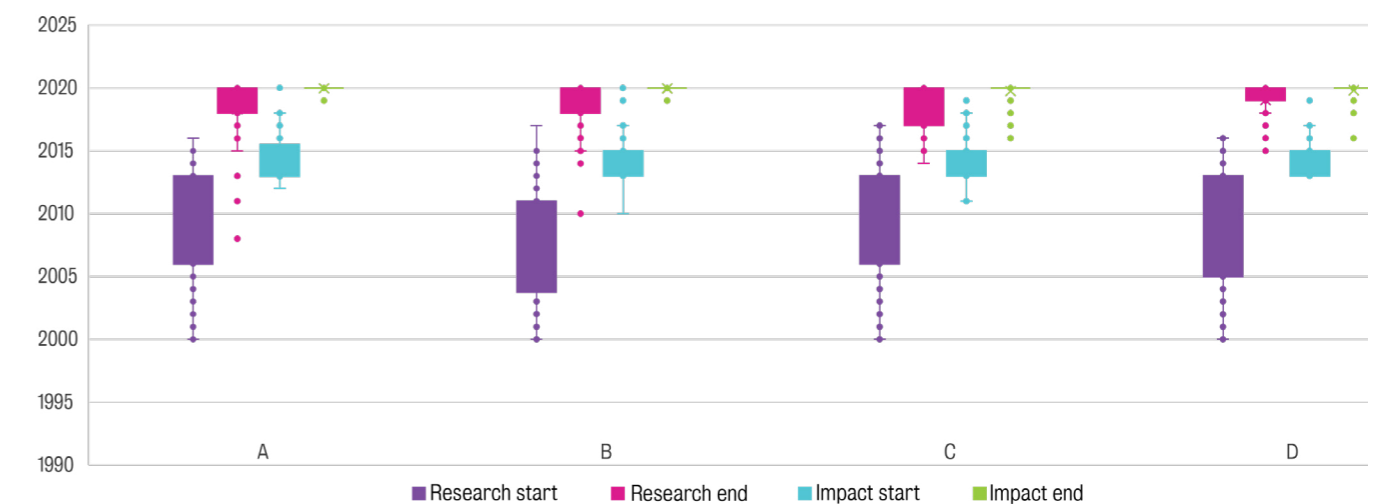
As previous sections in this report have shown, however, Wales as a nation is a key feature of ICS from Welsh HEIs – both in the proportion of ICS that report an impact specifically in Wales, as well as in terms of the

profile of the beneficiaries of Welsh research. We would welcome any further research into the “Wales” topic that would further reveal how this theme operates in this collection of ICS.

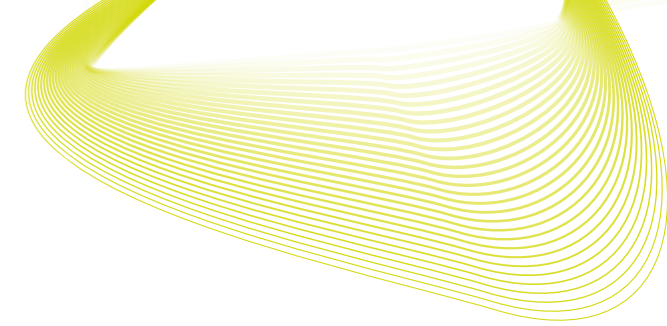
5.3. Time lags between underpinning research and impact outcomes

Based on the contextual information provided within the ICS we can examine when the research started and ended (by taking the dates associated with the grants referenced in the ICS) and when the impact started and ended (through the dates listed in the sources to corroborate impact in the ICS). While this does not capture the length of time prior to a funded project that may have been spent on research, it does provide a useful indicator of how long it takes for funded research to create impact. We find that the average time lag from the start of research to the end of impact (2020) across the set of ICS is 11 years (Figure 22). This boxplot shows the time-lags between research and impact across the Panels. Boxes represent the median and interquartile range (IQR) with the whiskers extending to 1.5 multiplied by the IQR. Colours represent the variables (purple: start date of research, pink: end date of research, turquoise: start date of impact, green: end date of impact). Dots represent the outliers and therefore the full range of values within the data. This is comparable with previous estimates from the literature for the time lag associated with research translation, noting that these estimates typically start from the funding of research rather than first publication.¹³ Looking by panel we also see some differences. On average it takes about three years longer for research in Panels A and B to translate into impact than for Panels C and D. It should however be noted that within an ICS, HEIs often list more recent grants and therefore the true time lags are likely to be longer.

Figure 22: Time lag between research and impact, by Main Panel



¹³ Eg Morris, Z.S., Wooding, S., Grant, J. (2011). The answer is 17 years, what is the question: understanding time lags in translational research. *J R Soc Med*, 104:510–520. 10.1258/jrsm.2011.110180



5.4. Connections between the social and economic impact of research and related citation data

For the UK dataset, 20,548 unique Document Object Identifiers (DOIs) were extracted from Section 3 (underpinning research) of the ICS and matched to records in OpenAlex. OpenAlex is an open-source database that tracks citations to articles and provides a range of citation indicators that are widely used by bibliometricians to report on citation impact. Best practice is to use a normalised metric that accounts for relative differences in citation behaviour across disciplines, publication type (article, reviews, books, etc), and year of publication. Citations are expressed as Mean Cites – ie average citation percentile (field normalised) – for DOIs associated with ICS and Mean HCP Count – average number of highly cited papers (>0.99 percentile, top 1%). The proportion of ICS with more than one linked DOI is relatively high for Main Panels A, B and C (A:99.9%, B:99.5%, C:98.3%) but significantly lower in Panel D (83%). As with any bibliometric analysis, it is important to consider how representative findings are, given gaps in coverage, and whether they are an indicator of impact for the research discipline in mind.

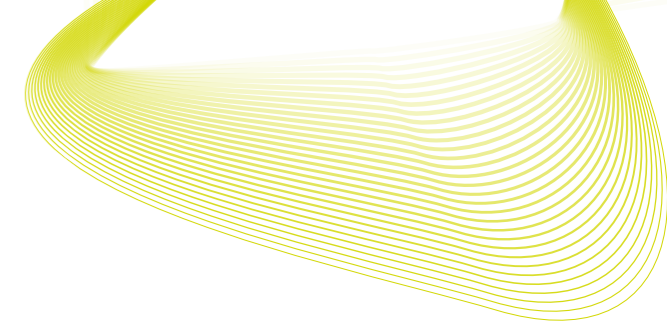
The citation impact of underpinning research is summarised in Tables 27-29 for the UK data and for Wales by Panel (Table 27), Unit of Assessment (Table 28) and impact clusters (Table 29). Overall, on these indicators, Wales performs worse than the UK average with some exceptions, for example, UOA32 (Art and Design: History, Practice and Theory), UOA34 (Communication, Cultural and Media Studies, Library and Information Management) and UOA18 (Law).

Table 27: Citation data for underpinning research linked to OpenAlex, by Panel

Main panel	Number of UK ICS	Mean Cites (UK)	Mean HCP Count (UK)	Number of Welsh ICS	Mean Cites (Wales)	Mean HCP Count (Wales)
A	1419	0.92	1.47	65	0.89	0.95
B	1268	0.89	0.89	70	0.88	0.86
C	2146	0.88	0.46	85	0.87	0.48
D	1528	0.70	0.10	60	0.64	0.05

Table 28: Citation data for underpinning research linked to OpenAlex, by Unit of Assessment

UOA number	UOA name	Number of UK ICS	Mean Cites (UK)	Mean HCP Count (UK)	Number of Welsh ICS	Mean Cites (Wales)	Mean HCP Count (Wales)
1	Clinical Medicine	254	0.95	2.58	7	0.96	3.29
2	Public Health, Health Services and Primary Care	151	0.94	1.99	2	0.88	0.50
3	Allied Health Professions, Dentistry, Nursing and Pharmacy	393	0.89	0.80	23	0.88	0.74
4	Psychology, Psychiatry and Neuroscience	326	0.92	1.28	19	0.89	0.47
5	Biological Sciences	192	0.91	1.59	7	0.85	0.86
6	Agriculture, Food and Veterinary Sciences	103	0.89	0.85	7	0.86	0.86
7	Earth Systems and Environmental Sciences	148	0.92	1.27	14	0.89	0.50
8	Chemistry	113	0.89	1.09	5	0.84	1.20
9	Physics	169	0.90	1.46	10	0.94	2.70
10	Mathematical Sciences	176	0.88	0.85	9	0.81	0.11
11	Computer Science and Informatics	271	0.90	0.80	13	0.91	0.92
12	Engineering	391	0.87	0.53	19	0.85	0.37
13	Architecture, Built Environment and Planning	127	0.88	0.52	3	0.88	0.00
14	Geography and Environmental Studies	180	0.91	0.87	11	0.85	1.09
15	Archaeology	59	0.88	0.51	2	0.88	1.50
16	Economics and Econometrics	88	0.90	0.67			
17	Business and Management Studies	504	0.90	0.59	23	0.91	0.57
18	Law	226	0.80	0.13	8	0.90	0.13
19	Politics and International Studies	166	0.87	0.36	9	0.77	0.00
20	Social Work and Social Policy	222	0.85	0.35	8	0.72	0.25
21	Sociology	107	0.89	0.53	5	0.91	0.80
22	Anthropology and Development Studies	77	0.86	0.30			
23	Education	230	0.87	0.23	7	0.90	0.29
24	Sport and Exercise Sciences, Leisure and Tourism	160	0.89	0.50	9	0.90	0.44
25	Area Studies	57	0.81	0.14			
26	Modern Languages and Linguistics	154	0.76	0.16	12	0.65	0.08
27	English Language and Literature	273	0.68	0.08	14	0.61	0.00
28	History	240	0.76	0.06	11	0.70	0.00
29	Classics	48	0.81	0.10			
30	Philosophy	85	0.86	0.35			
31	Theology and Religious Studies	68	0.75	0.06	2	0.74	0.00
32	Art and Design: History, Practice and Theory	262	0.52	0.03	9	0.66	0.00
33	Music, Drama, Dance, Performing Arts, Film and Screen Studies	196	0.64	0.06	9	0.49	0.11
34	Communication, Cultural and Media Studies, Library and Information Management	145	0.81	0.18	3	0.95	0.33



6. Concluding reflections

Table 29: Citation data for underpinning research linked to OpenAlex, by Impact Cluster

Cluster	Cluster label	Number of UK ICS	Mean Cites (UK)	Mean HCP Count (UK)	Number of Welsh ICS	Mean Cites (Wales)	Mean HCP Count (Wales)
1	Public Health and Health Services	315	0.89	0.85	16	0.87	0.88
2	Clinical Medicine	786	0.92	1.74	26	0.89	0.88
3	Energy, Environment and Engineering	501	0.88	0.84	28	0.86	1.04
4	Information, Applied Technology and Analytics	386	0.89	0.87	16	0.88	0.81
5	Training, Education and Skills	1116	0.86	0.49	48	0.82	0.60
6	Food, Environment and Ecology	613	0.88	0.83	35	0.89	0.66
7	Criminal Justice and Human Rights	363	0.85	0.24	16	0.83	0.56
8	Policy, Ethics and Security	397	0.88	0.55	11	0.89	0.82
9	Business, Planning and Economics	309	0.88	0.61	14	0.83	0.36
10	Devolved Nations	77	0.87	0.23	17	0.83	0.47
11	Culture and Society	663	0.82	0.45	30	0.79	0.13
12	History, Heritage and Creative Arts	835	0.66	0.11	23	0.54	0.00

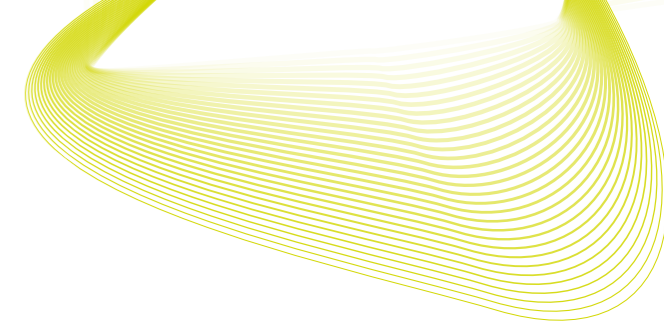
This analysis of the 280 publicly-available ICS submitted by Welsh HEIs as part of the REF 2021 exercise has given us the rare opportunity to explore comprehensively the impacts reported in an entire geographic region. While it is important to bear in mind that these impacts represent only a portion of the benefits to wider society created by research in Wales, they nevertheless paint a rich picture of the nature of the impacts produced, the mechanisms supporting this and the groups of people that benefit. Building on a similar analysis of REF 2014,¹⁴ this report once again demonstrates the diversity of the contributions made by Welsh HEIs to Wales, the wider UK and internationally.

As was the case in REF 2014, the impacts created by research in Welsh HEIs largely reflected trends in the UK more widely, with impacts across the 79 impact topics emerging from multiple disciplines and drawing on underpinning research from a wide range of research fields. The observation that the creation of impact is a bespoke activity – as demonstrated by the many possible pathways described in the ICS – highlights the value of taking a detailed, qualitative approach to its reporting and assessment. The in-depth narratives provide a detailed picture of the mechanisms leading to impact and the wide range of stakeholders involved and/or benefiting – for example, in illustrating the substantial contribution of research in Welsh HEIs to benefiting children and young people in Wales.

More generally, this analysis demonstrates that impact is a collective process, which involves different partners collaborating on a range of different activities, often over an extended period of time. It demonstrates the commitment of researchers in Welsh HEIs – and others they work with – to maximising benefits outside academia and, in doing so, the value of research to wider society.

¹⁴ Hinrichs-Krapels, S. & Hewlett, K. (2017) Impacts of academic research from Welsh universities: A comprehensive review of the REF 2014 impact case studies. The Policy Institute at King's.

Annex A: Methodological approach



This report is based on an analysis of 280 ICS submitted by Welsh HEIs as part of REF 2021. The full corpus of the 6,361 non-redacted ICS submitted by all UK HEIs can be found in the REF 2021 Impact Case Study database (<https://results2021.ref.ac.uk/>).

The analysis focuses on the information provided within the ICS submitted for REF 2021. Each case study has a common format which is shown in Box 2. In addition, metadata (also referred to as contextual data) is submitted alongside each case study, not used as part of the assessment, which includes:

- name(s) of funder(s)
- Global Research Identifier of funder(s): <https://www.grid.ac/>
- name(s) of funding programme(s)
- grant number(s)
- amount of grant (in GBP (Sterling))
- ORCID for each named researcher, where held
- name(s) of formal partner(s)
- country/countries where the impact occurred.

This information, along with any additional data sets that can be linked to the case studies (eg via the publications referenced in the “references to the research” section), forms the basis for our analysis.

Box 2. ICS structure

The template for ICS submissions is as follows. This information forms the basis of our analysis.

Institution:		
Unit of Assessment:		
Title of case study:		
Period when the underpinning research was undertaken:		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Period when the claimed impact occurred:		
Is this case study continued from a case study submitted in 2014? Y/N		
1. Summary of the impact (indicative maximum 100 words)		
2. Underpinning research (indicative maximum 500 words)		
3. References to the research (indicative maximum of six references)		
4. Details of the impact (indicative maximum 750 words)		
5. Sources to corroborate the impact (indicative maximum of 10 references)		

To conduct the analysis required for this study, we developed a bespoke, mixed-methods approach consisting of a range of quantitative and qualitative analytical tools. We detail these analytical tools and approaches below.

Topic modelling

To explore the types of impacts described in the REF ICS we used a topic modelling approach. Topic modelling is a natural language processing technique that determines how certain clusters of related words (topics) can be used to categorise underlying data. Because it is data-driven, results are derived from the data itself and thus not dependent on subjective notions of structure or conceptual categorisations of impact. We conducted the topic modelling based on the text provided in Section 4 of the ICS – “Details of the impact”. This means the analysis is focused on the impact itself rather than other aspects of the case study. Based on this empirically driven topic modelling approach, we identify 79 impact “topics” for the whole UK set of ICS (n=6,361) and apply that model for the subset of Welsh ICS (n=280).

Topic modelling was implemented using Python and the open-source libraries Scikit-learn¹⁵ and nltk.¹⁶ Raw text from Section 4 was normalised using the following steps: lowercasing; the replacement of diacritic characters with ascii equivalents; the removal of punctuation characters; and normalisation of urls (ie full urls replaced with the domain name linked). Lemmatization was not used. Trigrams were extracted (ie up to three word sequences) for each ICS after which common stop-words, short words, and digits with only 1 or 2 characters were removed. In addition, words appearing in more than 50% of documents, or in fewer than five ICS were removed. The final list of words included 136,147 unique tokens which are weighted using TF-IDF.

Following text-processing, nonnegative matrix factorization (NMF) was used to create the topic model. Topic models were created for a range of target topics between 65 and 85. The topic coherence metric was used to measure each model which revealed a local maximum for 79 topics – the final number used in the analysis. For each ICS, up to three topics were chosen – the primary topic being that with the largest weight, and optionally a secondary and tertiary topic, if and only if their weight exceeded a minimum threshold (higher than 95% of all weights).

Indicative labels were created using the top 20 most highly weighted words that were used to inform the creation of short topic labels. In addition, related topics were grouped together into 12 clusters based on Ward’s method (an algorithm for solving hierarchical clustering problems) using the word-weight for each topic as the feature vector.

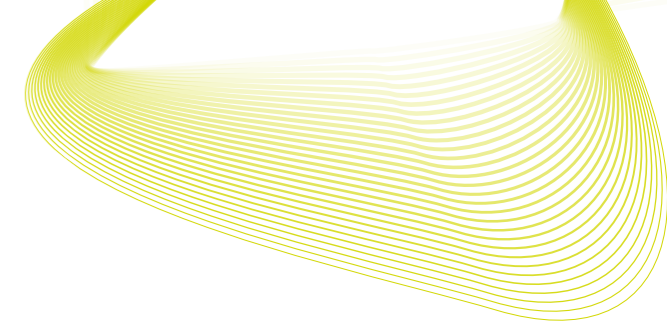
It is worth noting that topic labels were assigned based on an assessment of the words found in that topic. While this process comprised a number of iterations of labelling based on internal review and further reading of the content of the case studies tagged by a particular topic, it was nevertheless subjective.

Analysis of the underpinning research

As part of the study, the ICS were associated with additional metadata to support the analysis. ICS contained a description of the underpinning research that led to the reported impact (Section 2) and a list of research artefacts (such as publications, patents, grant awards) that exemplify the research (Section 3). Text mining was used to identify and extract fragments from the ICS documents that matched patterns typically seen in bibliographic referencing. By searching for mentions or hyperlinks to DOIs in these text fragments, or by using

¹⁵ <https://scikit-learn.org/>

¹⁶ <https://www.nltk.org/>



the CrossRef Simple Text Query Service¹⁷ to match them with CrossRef records, each ICS was associated with a list of underpinning research DOIs. Across the whole UK dataset, a total of 25,433 unique DOIs were discovered. Each DOI was cross-referenced with corresponding bibliographic records in the Web of Science, of which 20,548 (81%) could be matched with a unique Accession Number (aka UT).

Data from OpenAlex (see Box 3) were used to analyse the publications listed in Section 3 of the ICS, exploring aspects of collaboration modes, interdisciplinarity and complimentary classification systems (Fields of Research).

Box 3. OpenAlex

OpenAlex is completely free, open source, and CC0 (<https://docs.openalex.org/license>). Using OpenAlex, we retrieved the list of cited references for each linked DOI and associated them with FoR codes by following the mappings in the ERA journal list. FoR codes were assigned to ICS based on the most frequently referenced fields of research.

Field of Research (FoR)

This approach involved using the Australian and New Zealand Standard Research Classification (ANZSRC) 2008 Fields of Research (FoR) to capture subject categories, based on a publicly available journal mapping, with cited reference lists extracted from the OpenAlex database. The classification system has three levels of detail: (i) Divisions (2-digit codes), (ii) Groups (4-digit codes) and (iii) Subjects (6-digit codes). 4-Digit Fields of Research (Groups), the second level in a three-tier hierarchy of research subjects, were used for this analysis.

To determine these subject categories, we utilised the public ERA Journal mapping file from 2018.¹⁸ This file contains mappings for 25,017 journals to Fields of Research (up to three per journal). Not all journals listed have mappings to a 4-digit FoR code – for example, the Lancet just maps to Division 11 – Medical and Health Sciences. However, 21,570 journals are mapped to at least one 4-digit FoR code. Using OpenAlex data, we calculated a weighting for each DOI to every 4-digit FoR code. If at least ten referenced works for the DOI were indexed in OpenAlex, this weighting was used as the proportion of references made to journals that map to the FoR code. If referenced works for the DOI are not indexed, the average weight for the journal is used. This average weighting is based on a sample of 200 recent works, following the same methodology as above (ie looking at the proportion of cited references to journals in the ERA mapping list). For each ICS, the average weighting for each FoR code is calculated based on all the DOIs mentioned (ie under Section 3 – References to the Research). For each DOI in the dataset, a weight is calculated to each 4-digit FoR code based on the proportion of references made to journals that are assigned those categories in the ERA mapping.

For each ICS, the average weight across all linked DOIs is used to determine the final subject categories. Up to three of the most highly weighted FoR codes above a threshold of 0.05 (ie on average, 5% of references) were assigned.

When no FoR groups could be suggested (either because no DOIs were linked or none of the linked DOIs had sufficient data in OpenAlex), FoR groups were manually assigned (n=448). Manual assignment was based on reading of the ICS, looking for mentions of specific fields or subjects in Section 2 (Underpinning Research), and the journal names / conference venues / book titles listed in Section 3 (References to the research). Appropriate FoR groups were selected from the full list that best matched the field(s) of underpinning research, although it should be noted that this is a somewhat subjective assessment on the nature of underpinning

¹⁷ <https://apps.crossref.org/SimpleTextQuery>

¹⁸ <https://webarchive.nla.gov.au/awa/20220309020544/> <https://www.arc.gov.au/excellence-research-australia/era-2018-journal-list>

research. When only one DOI was linked to an ICS, additional manual review was undertaken to verify suggested categories (n=561).

Inter- and multi-disciplinary analyses

Bibliometric indicators have been developed to measure various aspects of disciplinarity, utilising information from the underlying publication records such as cited references, citing papers, author affiliations, or text processing of the article abstracts. Each of these indicators provides a measurement that aligns with different interpretations of what disciplinarity is. For example, the variety of subjects referenced in a paper can be used to measure the disciplinarity of the underlying research. Similarly, the variety of subjects citing the research can be used to measure how it was utilised. By examining the affiliations of authors on papers, or by clustering authors according to co-author networks, it is possible to measure variety in the disciplinary makeup of the research team. Although prior research¹⁹ highlights challenges with the interpretation of such indicators, largely because different methodologies produce conflicting results, they are still widely used to report on the relative disciplinarity of research collections.

One of the most commonly used bibliometric disciplinarity indicators is based on the Rao-Stirling metric²⁰ which defines interdisciplinarity using three aspects: variety (how many different subjects), balance (how skewed towards certain subjects), and disparity (how unusual the combination of subjects is). The value produced ranges from 0 (least interdisciplinary) to 1.0 (the most interdisciplinary). This was one of several interdisciplinarity metrics that was recently investigated in another commissioned report.²¹ Hence, for the purposes of this analysis, we use the term IDR to refer generally to inter-, multi-, and trans-disciplinary research, as operationalised by Rao-Stirling, and do not attempt to differentiate them.

For each ICS, the proportion of subject categories referenced by underpinning research articles is used as the feature vector. As discussed above, FoR were used to capture subject categories, based on a publicly available journal mapping, with cited reference lists extracted from the OpenAlex database. 4-Digit Fields of Research (Groups), the second level in a three-tier hierarchy of research subjects, were used. Only publications that contained at least ten cited references were used, meaning the metric could not be calculated for all ICS. Coverage of the RS-IDR metric is good for Main Panels A, B and C, but is lower for Main Panel D because some ICS are not linked to any bibliographic items.

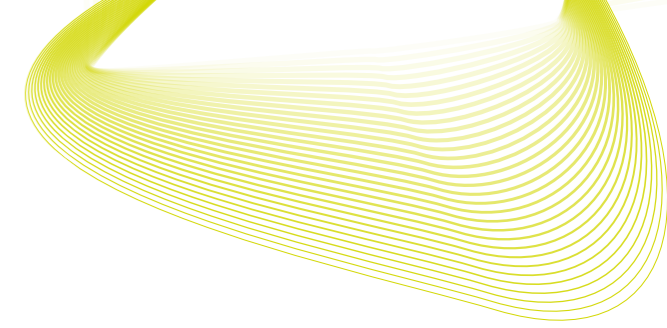
Bibliometric impact

20,548 DOIs were matched to records in OpenAlex. OpenAlex is an open source database that tracks citations to articles and provides a range of citation indicators that are widely used by bibliometricians to report on citation impact. Best practice is to use a normalised metric that accounts for relative differences in citation behaviour across disciplines, publication type (article, reviews, books, etc), and year of publication. Citations were expressed as Mean Cites – ie average citation percentile (field normalised) – for DOIs associated with ICSs and Mean HCP Count - average number of highly cited papers (>0.99 percentile, top 1%).

¹⁹ Adams, J., Loach, T. and Szomszor, M. (2016). Interdisciplinary research: methodologies for identification and assessment. Do we know what we are measuring? Digital Science. (Online – open access): https://digitalscience.figshare.com/articles/report/Digital_Research_Report_Interdisciplinary_Research_-_Methodologies_for_Identification_and_Assessment/4270289

²⁰ Stirling, A. (2007). A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society, Interface*, 4(15), 707–719

²¹ Rosemberg, C., Nielsen, K., Campbell, D., and Khayat, P. (2022) REF outputs analysis: Maximising the use of REF data. A report by Technopolis and Science-Metrix. <https://repository.jisc.ac.uk/8982/1/ref-outputs-maximising-the-use-of-ref-data-main-report.pdf>



Geotagging

Using geotagging, we have identified all mentions of geographic locations in Section 4 of the ICS – “Details of the impact” by using the open-source Edinburgh Geoparser. The Edinburgh Geoparser is a system to automatically recognise place names in text and disambiguate them with respect to a gazetteer. For the purposes of this analysis, the open-source Geonames²² gazetteer was used as it provides global coverage and contains an extensive list of place names. We also made use of the limiting geographical area feature that allows users to provide a rectangular locality box. The geoparser will prefer places in the area specified but will still choose locations outside it if other factors give them higher weighting. For this analysis, a bounding box surrounding the UK was used, helping to properly disambiguate common place names that appear in multiple geographies.

Following the automatic tagging process, a series of manual curation steps were used to ensure high-quality, accurate data. Custom spreadsheets showing the matched tokens, their context (a text fragment including 10 tokens before and after the match), and basic gazetteer information (eg country name, region, population) were created for manual review. In particular, tokens containing location names that are part of a longer proper noun were reviewed. For example, the text “research conducted at the University of X” was often incorrectly matched to the location X by the geoparser. Other examples of this filtering include project names, strategies, report titles, television station names, charity names, governmental departments, prisons, military facilities, hospitals, and NHS trusts.

Qualitative analysis

In addition to the quantitative, automated methods of analysis described above, a manual qualitative analysis of the 280 ICS was conducted in order to develop a richer, more detailed, and nuanced picture of these case studies and their key pathways, beneficiaries, and the nature of the impact they describe.

This was carried out by manually reading and coding each case study using the NVivo qualitative data analysis software.²³ A codeframe was initially developed using a combination of inductive and deductive approaches. We used an initial codeframe derived from previous comparable analyses of ICS to sort material according to the key areas of our analysis – sectors of impact, types of impact, and beneficiaries – which was reviewed and revised as a team and then applied to an initial sample of case studies, during which the initial codeframe was revised, nuanced, and added to as the data required.

In the case of our sectoral analysis of impact, we used a purely deductive approach, employing the pre-existing categories of the UK’s condensed Standard Industrial Classification to map in what areas of economic and social activity ICS had an impact. In all other cases, the codeframe was iterated on an ongoing basis as we worked through the data.

The qualitative analysis draws primarily from information presented under the “details of the impact” section of the ICS. The exception is in Chapter 3, where we draw also on the section on “underpinning research” to establish the nature of the work that led to impacts.

As with previous reports, this study makes no judgements about whether the information presented was accurate or authoritative, but instead seeks to capture objectively the information supplied by HEIs and researchers. Individual case studies are not linked to how they were ranked by the expert panels, as the ranking

²² <http://www.geonames.org/>

²³ NVivo is a qualitative data analysis software that allows for the coding of text-based information. For more information about this software, see: <https://lumivero.com/products/nvivo/>

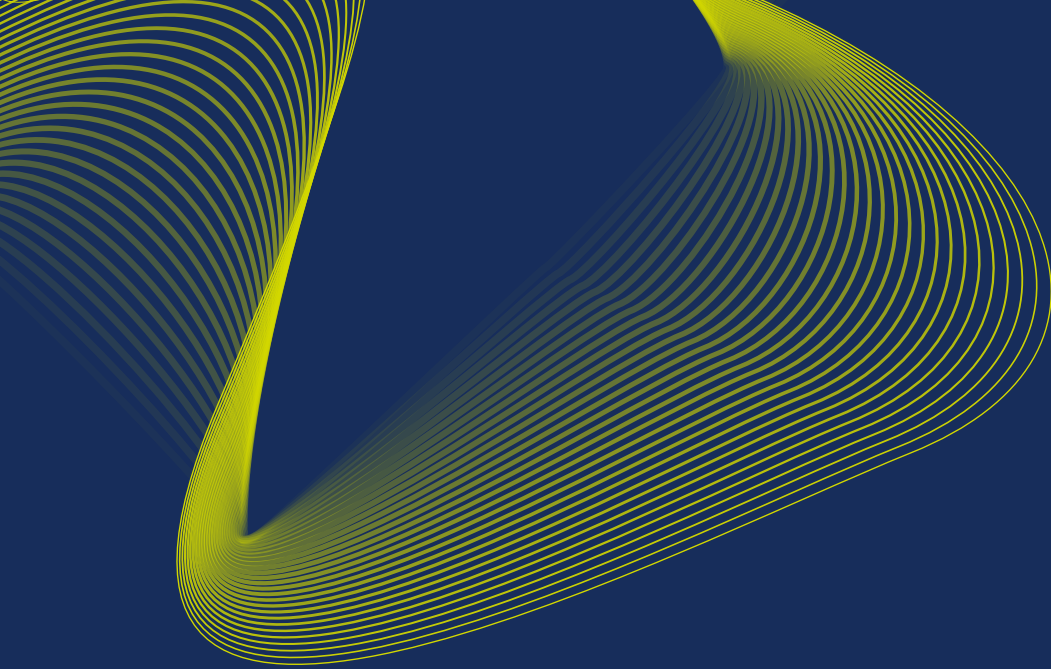
of individual ICS is not in the public domain. The criteria for showcasing individual case studies are therefore based on those that are well evidenced or that embody trends in reporting.

Caveats and limitations

Using the database of ICS submitted to REF 2021 as source material for analysis comes with at least three important caveats, which should help to frame the context for its interpretation.

1. The ICS submitted to REF 2021 were written for assessment, not analysis. The impacts reported were therefore selective and compiled according to requirements and guidelines published by the REF team to assist in preparing impact case studies. It should not, therefore, be assumed that they provide a comprehensive account of how all research in Wales has had impact beyond academia.
2. Impact was reported in a free-text format. As a result, much of the information captured is freely described, resulting in variable levels of quantitative and geographic information that when measured using metrics can differ substantially from one case study to the next. Case study authors may also omit certain types of information, such as the level of income from commercialisation activities.
3. The design of the ICS template may have influenced how impact was reported, as suggested by other analyses of these case studies,²⁴ encouraging authors to trace a direct and causal pathway from originating research to activity beyond academia. However, it is likely that such a focus on forward trajectories within a prescribed timeframe does not fully represent the nuances of how academic research actually had an impact beyond academia. There may be numerous engagement, collaborative and co-design activities that take place during the research process that had already enabled some impact to occur.

²⁴ Eg Greenhalgh, T. and Fahy, N., 2015. Research impact in the community-based health sciences: an analysis of 162 case studies from the 2014 UK Research Excellence Framework. *BMC medicine*, 13(1), pp.1-12.



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