UN SDG goals: Wales' research performance with UK and Global Comparators (2010–2019)

Executive summary

Wales committed to the UN's Sustainable Development Goals in 2015 and its share of published research dedicated to tackling global issues was among the highest of comparators. The citation impact of Welsh SDG research was the highest of all comparators, highlighting the contribution and quality of its research publications.

The purpose of this report is to assess the relative performance of Welsh research outputs related to the Sustainable Development Goals (SDGs) over the past decade (2010-19). This analysis builds on a methodology developed by Elsevier and partners (see chapter 1) that uses a bottom-up approach to identify SDG-relevant publication sets.

In 2015 Wales shared the ambition behind the United nation's SDGs and committed to contributing to them. In 2015, the same year that the United Nations adopted the SDGs, the National Assembly for Wales made the historic decision to position Wales on a more sustainable path by passing the Well-being of Future Generations (Wales) Act 2015 (WFG Act).[1]

Recognising the pivotal role that scientific research can make in helping to tackle many of the world's greatest challenges, the Welsh Government commissioned Elsevier to conduct this comparative assessment of Welsh research outputs related to the SDGs.

Although small, Wales plays a strong role in global SDG-related research. Almost one third of Welsh research relates to the SDGs and its citation impact (as measured by Filed-Weighted Citation Impact (FWCI)) is the highest of all comparators (FIGURE 0-1). This shows Wales' commitment to the global challenges the SDGs address.

A closer look at the individual SDGs reveals some interesting pattern. SDGs 1 to 16 can be grouped around three macro themes: People, Planet, and Prosperity. SDG 17 (Partnership for the Goals) targets collaboration and could not be assessed through publication analysis. Wales' activity in the SDGs is assessed through the **relative activity index** (RAI), an indicator comparing the proportion of SDG research output among the

[1] https://www.futuregenerations.wales/about-us/future-generations-act/

total output, benchmarked against the UK share for the same SDG. As can be seen in FIGURE 0-2, Wales' activity is highest in all SDGs within the Planet macro theme (comprising SDGs 6, 12, 13, 14, 15). In addition, its research impact (FWCI) for this Planet macro-theme is well above global averages— highlighting the quality of Welsh research. FIGURE 0-2 shows the relative activity index versus FWCI for Welsh research publications, with the red dotted lines being the average UK activity (x-axis) and average FWCI for Wales' overall (y-axis). An SDG's appearance in the upper-right quadrant means that much of the Welsh publication is above UK level for those SDGs for both activity and impact. Three SDGs are in a quadrant with lower activity, but higher impact (the upper-left area). It should be noted that the average FWCI for Wales' total published research (i.e including research not specifically related to SDGs) is already of high quality at 1.8, meaning that Welsh research received 80% more citations than the global average. Most of the SDGs are well above this level, showing the contribution to the SDGs and the quality of its research.

The SDGs address global issues, therefore a collaboration across borders seems relevant for research related to them. In fact, Wales' researchers collaborated on SDG research to almost the same extent internationally (FIGURE 0-3) as in its total research output, i.e half of Wales' publications were published with international partners during the study period. However, the effect of international collaboration for SDG related research seemed even more robust, with an FWCI of 3.2 for Wales' internationally collaborated publications (i.e. three times above world average)–the highest FWCI of all UK nations for this collaboration type.

FIGURE 0-3
Share (right panel) and FWCI (left panel) of internationally co-authored publications across all SDG for Wales and other UK nations, 2010–2019.
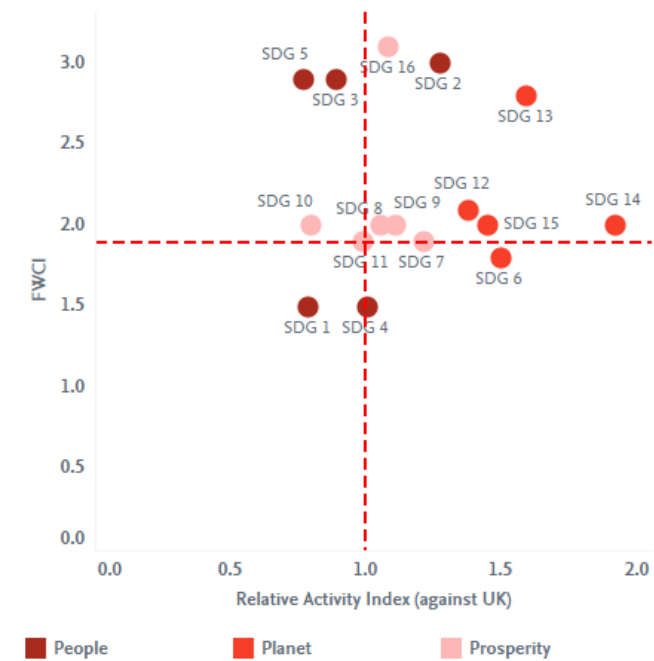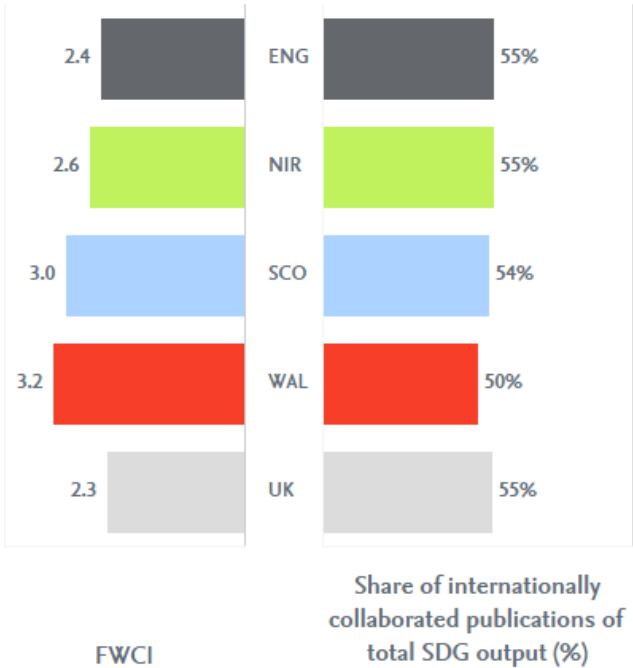*Source: Scopus*

FIGURE 0-2
Wales' relative activity index (RAI) and FWCI per SDG, 2010–2019; colour-coding indicate SDG theme. Red dotted lines indicate UK average activity and Wales average FWCI.
Source: Scopus

Foreword by Professor Peter Halligan, Chief Scientific Advisor to the Welsh Government

In 2015, the United Nations established the 2030 Agenda for Sustainable Development, as an ambitious global plan to implement the Sustainable Development Goals (SDGs), a collection of 17 interlinked global goals designed to offer a "blueprint to achieve a better and more sustainable future for all"[2].

In the same year, the National Assembly for Wales committed to the UN's Sustainable Development Goals by translating them into the seven goals of the Wales Future Generations Act[3], ensuring that 'sustainable development' would be a central organising principle for all Welsh Governments. The Act created a unique legal framework and opportunity for the development of a low carbon, resource efficient, healthy, well-educated, culturally engaged, and enterprising society, thriving within environment limits.

Although published scientific outputs are not explicitly included in the UN indicators, the UN recognized the pivotal role scientific research makes to tackling the world's greatest challenges and the critical need for these research findings to be translated into consistent government policies. Research provided by the global research community has formed the basis for society to make gains in life expectancy, poverty reduction and global health over the last century. Effective implementation of the SDGs will require access to, and the application of the best available evidence from the global academic community.

Tracking trends in scientific outputs is one way to monitor and demonstrate the levels of interest and the impact that science and research are making to help deliver the UN SDGs.

To learn more about the relative performance of Wales's science base, I commissioned Elsevier to produce a comparative metrics-based assessment of Wales's SDG research performance from 2010 to 2019.

This report shows how Welsh researchers, over the past decade, made a strong and impactful contribution to research related to the UNSDGs. The citation impact for SDG-related research for Wales was 130% above world average. While Wales overall research output performs well across all United Nations SDGs, the main focus for Welsh researchers are those SDGs relevant to the Planet (SDG 6, 12, 13, 14, 15). Research publications in this theme captured the highest share in the UK and produced a citation impact more than double the global average, placing Wales in the leading position among comparators.

A critical factor in Wales's success is the extent to which researchers collaborate extensively across borders and sectors. Welsh research showed the highest impact for those areas where Welsh researchers worked collaboratively with others, regardless of geographies and sectors, demonstrating the productive outcome of years of international networking.

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[2] Transforming our world: the 2030 Agenda for Sustainable Development, www.sdgs.un.org/2030agenda
[3] https://www.futuregenerations.wales/about-us/future-generations-act/

The quality and productivity of Wales's SDG related research is impressive, particularly when taking into account what is produced from a small country with relatively limited resources. It serves to illustrate that excellence is not the preserve of larger nations. Small countries have a lot to offer and can be ideal collaborative partners on a UK or international basis. It will be critical going forward for Wales to capitalise and exploit these research strengths to help Welsh Government deliver on the seven goals of the Wales Future Generations Act.

Prof Peter Halligan

Chief Scientific Advisor for Wales

Contents

Introduction

In 2015, Wales committed to the United Nations's Sustainable Development Goals by translating them into the seven goals of the Well-being of Future Generations (Wales) Act. This report shows how Welsh researchers have contributed to the published research related to the UN SDGs over the past decade.

In 2015, in its 2030 Agenda for Sustainable Development, the United Nations highlighted the challenges the world faced. "Billions of people continue to live in poverty and are denied a life of dignity. There are rising inequalities within and among countries. There are enormous disparities of opportunity, wealth and power. Gender inequality remains a key challenge. Unemployment, particularly youth unemployment, is a major concern. Global health threats, more frequent and intense natural disasters, spiralling conflict, violent extremism, terrorism and related humanitarian crises and forced displacement of people threaten to reverse much of the development progress made in recent decades. Natural resource depletion and adverse impacts of environmental degradation, including desertification, drought, land degradation, freshwater scarcity and loss of biodiversity, add to and exacerbate the list of challenges which humanity faces. Climate change is one of the greatest challenges of our time and its adverse impacts undermine the ability of all countries to achieve sustainable development."[4]

This UN plan for action covering the 17 Sustainable Development Goals (SDG) and their 169 targets demonstrated the scale, ambition and challenge of their agenda. Wales shared this ambition and through legislation in 2015 committed to working to deliver the SDG goals.

Sustainable Development Goals

SDG 1 (No Poverty)	SDG 10 (Reduced Inequalities)
SDG 2 (Zero Hunger)	SDG 11 (Sustainable Cities and Communities)
SDG 3 (Good Health and Well-being)	SDG 12 (Responsible Consumption)
SDG 4 (Quality Education)	SDG 13 (Climate Action)
SDG 5 (Gender Equality)	SDG 14 Life below Water)
SDG 6 (Clean Water and Sanitation)	SDG 15 (Life on Land)
SDG 7 (Affordable and Clean Energy)	SDG 16 (Peace, Justice and Strong Institutions)
SDG 8 (Decent Work and Economic Growth)	SDG 17 (Partnership for the Goals)
SDG 9 (Industry, Innovation and Infrastructure)	

TABLE 1-1
Sustainable Development Goals

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[4] Transforming our world: the 2030 Agenda for Sustainable Development, www.sdgs.un.org/2030agenda

In 2015, the same year that the United Nations adopted the SDGs, the National Assembly for Wales made the historic decision to position Wales on a more sustainable path by passing the *Well-being of Future Generations (Wales) Act* 2015 (WFG Act).[5]

This legislation reflected the collective efforts of many people from across Wales to ensure that Wales' future is shaped by a commitment to a better quality of life for both current and future generations.

With this in mind, the Welsh Government established the world's first statutory independent Future Generations Commissioner for Wales to advocate for the long term and support decision-makers in Wales.

Together with the *Environment (Wales) Act* 2016 and the *Planning (Wales) Act* 2015, Wales is on a journey to manage its natural resources in a joined-up and sustainable way.[6]

The WFG Act sets out seven interconnected goals that address:

- Climate change
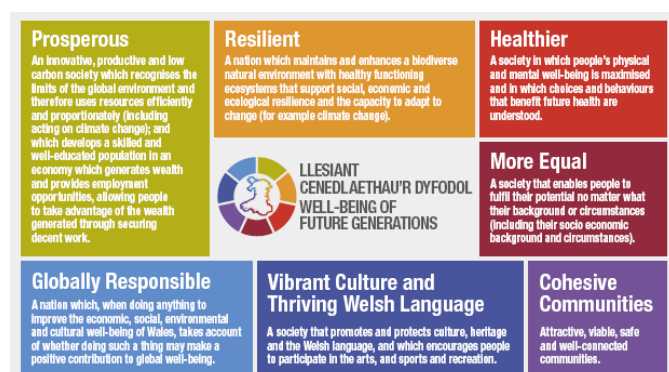- Poverty
- People with poor health and jobs

Recognising that Wales' legislative framework complemented the SDGs, the United Nations stated, '*what Wales is doing today, we hope the world will do tomorrow*'.[7]

Broadly, the challenges addressed by UN SDGs can be grouped into three overarching or interconnected macro-themes:

- **People**
- **Planet**
- **Prosperity**

Although published scientific outputs are not explicitly included in the set of targets, the UN recognized the pivotal role of scientific research in tackling many of the world's greatest challenges. Tracking trends in scientific outputs is therefore one way to monitor and demonstrate the level of interest within the research community in SDGs such as Clean Energy and Climate Action and the progress research is contributing towards achieving them. It can also help assess whether the world is on track to achieve the targets by 2030. All of this has highlighted the importance of increased international co-operation between science, policy and society and the critical need for research findings to be translated into consistent government policies.

With this in mind, the Welsh Government commissioned Elsevier to identify and evaluate Wales' scientific research contribution to the UN SDGs. Elsevier and its parent company RELX have extensive knowledge on SDG-related research and had spearheaded an initiative to develop a knowledge base of SDG-related publications[8], which has led to various publications over recent years.[9]

This report provides comparative benchmarks with the output of other UK nations and a selected number of global comparators.

For this report, SDGs 1 to 16 were grouped into three macro themes: **People, Planet, and Prosperity**. Publications related to individual SDGs were identified by using dedicated search queries and applying machine learning to enhance the quality of the resulting publication sets. Further details on the **methodology** can be found in Chapter 1 and Appendix C. As SDG 17 (Partnership for the Goals) is more a process outcome specific to increasing partnerships, no set of publications could

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be matched directly to this goal. While excluded as a search query, this goal was captured and reported under research collaboration.

The 3 macro-theme groupings of the 16 SDGs are as follows:

People

Planet

Prosperity

The first chapter of this report benchmarks the status of SDG-related research for Wales compared to other UK nations and global comparators. Chapter 2 then highlights performance on the three macro themes.

Comparators and benchmarks

Throughout the report, Wales' research performance is benchmarked against several comparators:

- UK constituent nations (Scotland, England, and Northern Ireland) as well as the United Kingdom overall

- Selected European countries (France, Germany, Italy, and Ireland)

- Selected international research nations outside Europe (United States, China)

Using relevant published research as an index of SDG related activity

Scientific research outputs take many forms, including articles in journals, books, monographs, and non-textual media such as music and art. This report focused on academic research published in journals, review articles, and conference proceedings and how often these publications are cited by other researchers in their own publications. The period covered in this report spans 2010 to 2019.

Field-Weighted Citation Impact

Field-Weighted Citation Impact (FWCI) is used throughout this report as an indicator of research impact. The FWCI divides the number of citations received by a publication by the average number of citations received by publications in the same field, of the same type and published in the same year. Calculating the score within disciplines accounts for field-dependent citation differences. The FWCI is a widely accepted normalised metric that enables comparisons across countries (Purkayastha et al., 2019; Leydesdorff et al., 2019)[10].

[10] https://snowballmetrics.com

Mapping research publications to SDGs

1.1 Approach and methods for mapping publications to SDGs

As the UN SDGs are a collection of interlinked universal goals designed to be a "blueprint to achieve a better and more sustainable future for all", mapping research publications to these goals is not straight forward or simple. The methodology used in this report employs a combination of search queries, expert input and machine learning to classify research publications to individual SDGs. This approach provides for a high level of transparency which is key for reliable and future studies.

Recognising the multiple challenges the world faces, the UN 2030 Agenda for Sustainable Development provided an ambitious plan covering actions for people, planet and prosperity. The United Nations General Assembly adopted the 17 Sustainable Development Goals (SDGs) as an integral part of the agenda. The SDGs include in total 168 specific targets designed to stimulate actions.

The UN 2030 Agenda stressed the fundamental role that science should play in implementing the Sustainable Development Goals. The connections between medical research and some targets under SDG 3 (Good Health and Well-being) or between engineering research and the development of new, efficient energy systems (SDG 7 (Clean and Affordable Energy)) are obvious. But the contribution of other disciplines and in particular the social sciences on the governance of processes or political decision is less apparent, but important.

Research and development activities are mainly captured in publications or research projects. Therefore, countries and nations have an interest in evaluating their output against the SDGs. "*Responding to these demands, data providers, consultancies, and university analysts are rapidly developing methods to map projects or publications related to specific SDGs. These 'mappings' do not analyse the actual impact of research but hope to capture instead if research is directed or related towards problems or technologies that can contribute to improving sustainability.*[11]"

Being relatively new, methods used to achieve these mappings are still in development or are being refined but most of them are based on search queries using keywords found in the UN SDG targets. As such, differences are expected depending on the choice of search terms, how they are combined, and differing interpretations of the SDGs. Prominent approaches have been developed by Bergen University (Armitage et

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[11] Rafols et al., 2021

al., 2020), the AURORA Network[12], Elsevier (Rivest et al., 2021; Jayabalasingham B., 2019), SIRIS Academic[13] or the STRINGS project[14].

Developing a search queries based on keywords from the SDG targets appears straightforward but is a complex process. Analyses from a team at Bergen University (Armitage et al., 2020) and researchers from the STRINGS project (Rafols et al., 2021) revealed that changes in methods and different databases can produce highly different results using only a small overlap in publications.

These differences can occur as the policy objectives laid out in the SDG targets need to be "translated" into scientific language and the context in which knowledge is created and used. Additionally, the use of specific bibliometric databases has effects through the coverage of scientific output, which may impact content coverage regarding some subject areas and geographical regions.

Some providers have tested approaches to eliminate this interpretational aspect by developing machine learning algorithms to identify articles relevant to the SDGs (Wastl, 2020; LaFleur, 2019). However, while these approaches eliminate the risk of a "human bias", they introduce a black box regarding the algorithms— which remains a difficult issue for transparency and reproducibility.

For these reasons, it is difficult—if not impossible—to develop a single version of truth or even a "preferred or consensus way of mapping SDGs to publications" (Rafols, 2021) or projects.

Bearing this in mind, the best way to handle the various questions and issues remains transparency. This includes providing the sets of keywords, the search queries and the way the queries were developed.

The approach used in this report is based on an Elsevier approach to mapping the SDGs and is described in more detail in the Appendix C. In short, the Elsevier approach is based on various iterations of internal and external expert consultation providing feedback to initial search queries. This feedback includes dedicated workshops and an online tool for providing feedback on a random set of publications to assess the quality of the assignment of publications to an SDG.

This transparent process resulted in search queries for each SDGs. These queries were then further complemented by a machine learning model—which helped increase the recall by approximately 10% (Rivest et al. 2021).

While no approach is perfect—as discussed earlier—this approach provides valuable insights with a high degree of recall[15] and precision, combined with a high level of transparency.

It should be noted that sufficient search queries could only be developed for SDG 1 to 16. SDG 17 (Partnership for the Goals) is more process oriented towards increasing collaboration and partnership, and therefore this goal could not be identified by using a search query.

Most importantly, for reports designed to offer a comparative performance between nations, the approach employed here is independent of the results, with all research publications treated the same.

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[12] https://aurora-network.global/project/sdg-analysis-bibliometrics-relevance/
[13] http://science4sdgs.sirisacademic.com/
[14] https://www.ucl.ac.uk/steapp/research/21st-century-decision-making/steering-research-and-innovation-global-goals
[15] A detailed description of the methodology, the search queries and the machine learning methodology with samples can be found under https://data.mendeley.com/datasets/9sxdykm8s4/2 and Rivest et al., 2021

Wales' research contribution to the UN SDGs

2.1 Wales' contribution to research on the UN SDGs

In all, 30% of Wales' research output in the study period was related to the SDGs. This was above the global average and Wales also held a leading position amongst many comparators for research impact (FWCI).

Analysis of the relative volume and citations acquired by journal articles, reviews, and conference papers provides a valuable indicator of the comparative performance of a country's research base. However, it is well established that journal articles and citation-based indicators capture research performance in some fields better than in others. Therefore, it should be noted that research outputs tend to reflect some SDG more than others. This chapter examines the scholarly output and impact of Welsh SDG-related research when benchmarked with other UK nations and global comparators.

Globally, the number of publications of SDG-related research almost doubled from 2010 to 2019 (FIGURE 2-1). In turn, SDG related research's share of total output rose from 24% to 30%, with an average share of 27% across the period.
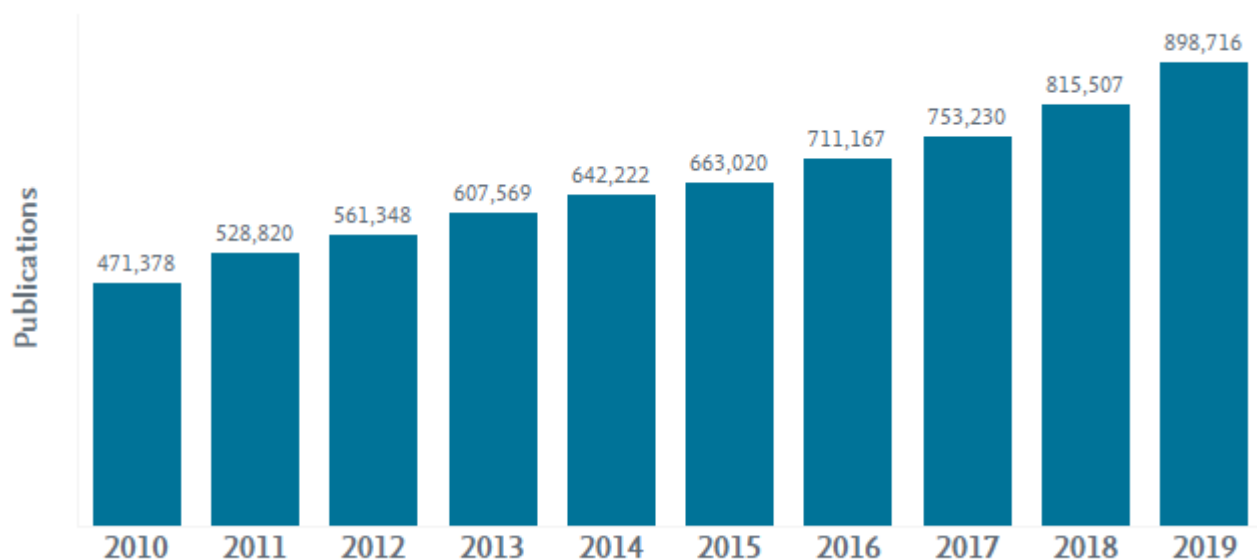

FIGURE 2-1
Global publication output for SDG-related research.
Source: Scopus

Not surprisingly, SDG 3 (Good Health and Well-being) was the most prolific globally, accounting for almost 40% of the SDG publications, followed by SDG 7 (Clean and Affordable Energy) with 13% of all SDG publications. No other SDG contributed more than a 10% share to the total SDG publications.

Wales' share of SDG research was higher than the global average

Between 2010 and 2019, Wales' researchers published more than 67,000 publications, of which more than 20,000 were related to the 16 SDGs. In other words, SDG-related research accounted for 30% of Wales's total research output. This share is slightly above the UK average (29%) and was only bettered by Northern Ireland (32%), although the differences between the UK nations are small (FIGURE 2-2).
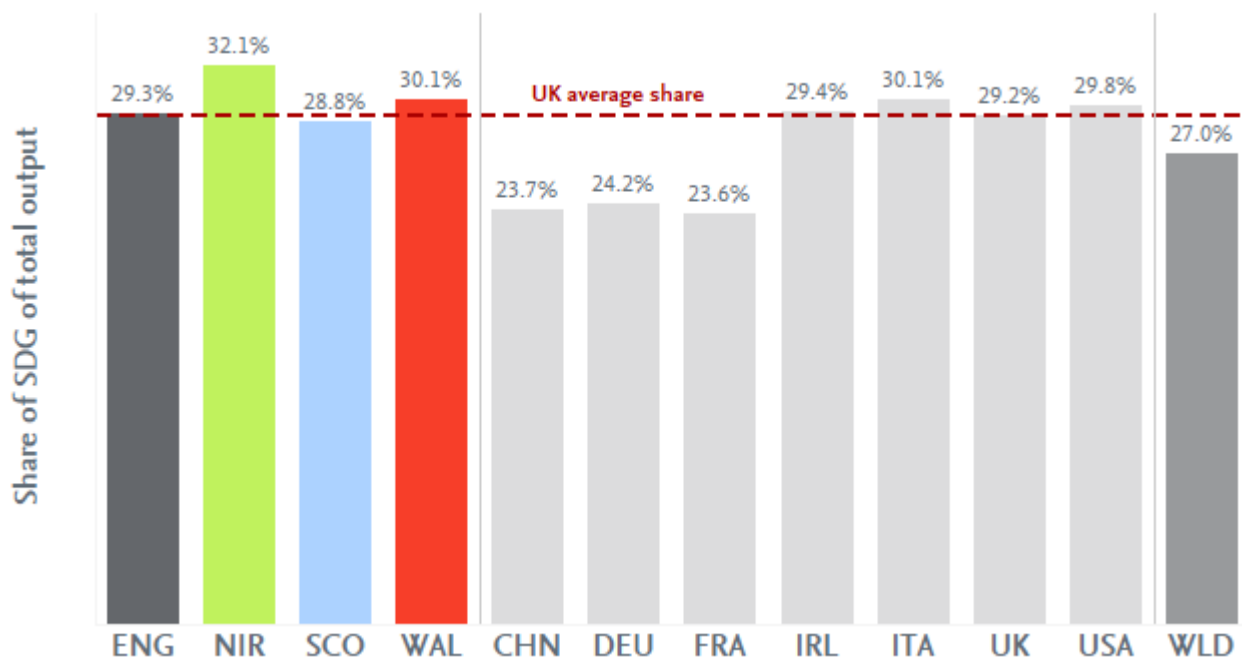

FIGURE 2-2
Share of SDG research output as a percentage of total output for Wales and comparators, 2010–2019.
Source: Scopus

Among the comparators, English-speaking countries showed the highest share of SDG-related research, except for Italy. While the global average was 27%, these countries had a share of around 30%. It is possible that the database has a language bias, since research literature is largely written in English, with China, Germany, and France having an SDG share below the global average.

Wales showed a good presence in research related to all SDGs (FIGURE 2-3). SDG 1 (No Poverty) was the only SDG whose share was less than 2%. SDG 3 (Good Health and Well-being) was the dominant SDG, in keeping with global research.
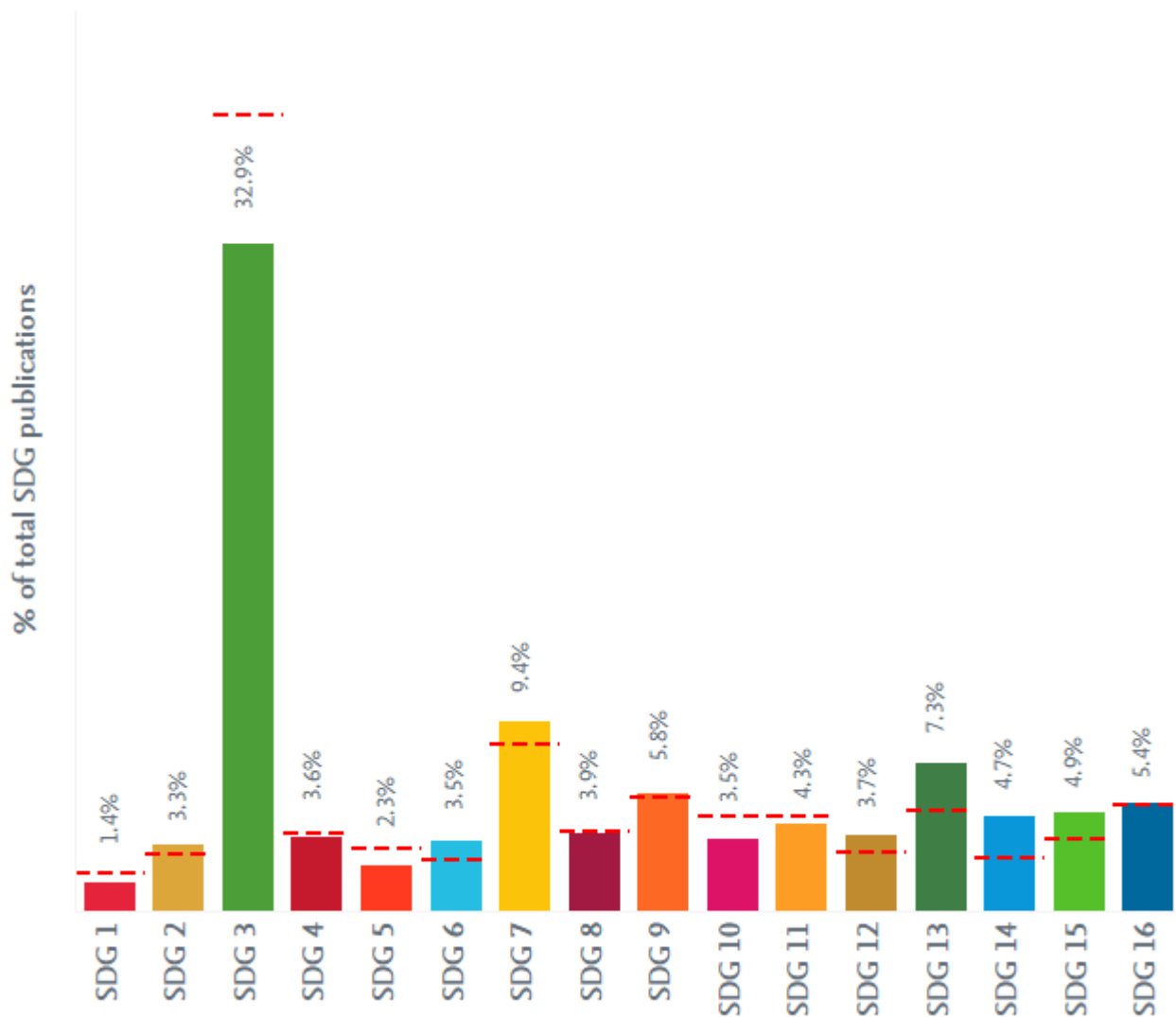
FIGURE 2-3
SDG related research output per SDG as a share of total SDG research output for Wales, 2010–2019; numbers indicate Wales' share, red dotted line indicate UK share as benchmark.
Source: Scopus

Wales' share for SDG 3 (Good Health and Well-being) was lower than those of other UK nations and global comparators (FIGURE 2-4), but its shares of research publications in SDG 13 (Climate Action), SDG 14 (Life below Water) and SDG 15 (Life on Land) were higher—underlining Wales' contribution to the Planet theme, as highlighted in the WFG Act and the Environment (Wales) Act. Chinese research appeared to focus on SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities) and showed considerably lower shares in the themes of People and Planet. Not surprisingly, German research had a large SDG footprint with strong technological aspects, such as SDG 7 (Affordable and Clean Energy) and SDG 9 (Industry, Innovation and Infrastructure).

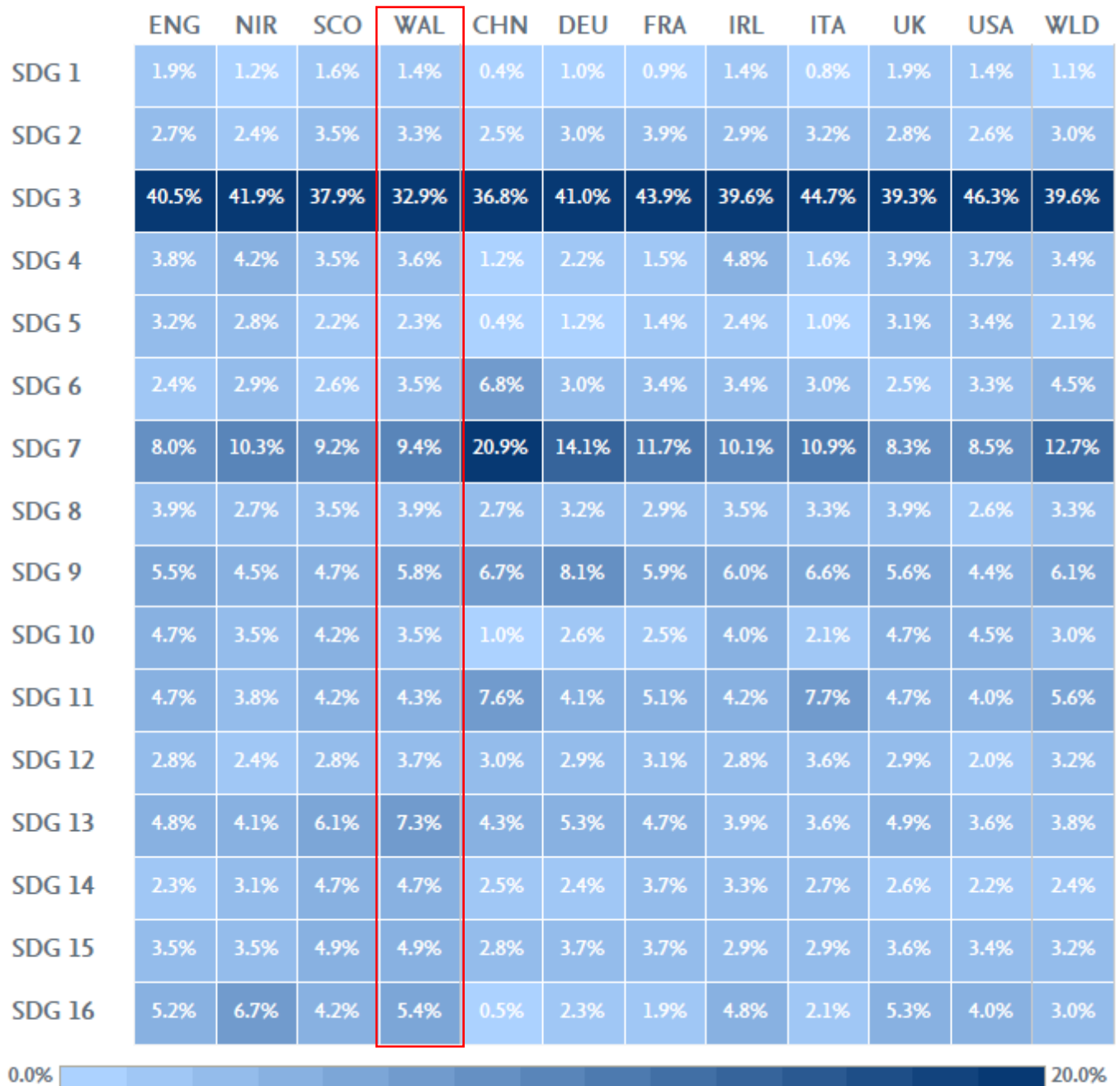|	ENG	NIR	SCO	WAL	CHN	DEU	FRA	IRL	ITA	UK	USA	WLD
SDG 1	1.9%	1.2%	1.6%	1.4%	0.4%	1.0%	0.9%	1.4%	0.8%	1.9%	1.4%	1.1%
SDG 2	2.7%	2.4%	3.5%	3.3%	2.5%	3.0%	3.9%	2.9%	3.2%	2.8%	2.6%	3.0%
SDG 3	40.5%	41.9%	37.9%	32.9%	36.8%	41.0%	43.9%	39.6%	44.7%	39.3%	46.3%	39.6%
SDG 4	3.8%	4.2%	3.5%	3.6%	1.2%	2.2%	1.5%	4.8%	1.6%	3.9%	3.7%	3.4%
SDG 5	3.2%	2.8%	2.2%	2.3%	0.4%	1.2%	1.4%	2.4%	1.0%	3.1%	3.4%	2.1%
SDG 6	2.4%	2.9%	2.6%	3.5%	6.8%	3.0%	3.4%	3.4%	3.0%	2.5%	3.3%	4.5%
SDG 7	8.0%	10.3%	9.2%	9.4%	20.9%	14.1%	11.7%	10.1%	10.9%	8.3%	8.5%	12.7%
SDG 8	3.9%	2.7%	3.5%	3.9%	2.7%	3.2%	2.9%	3.5%	3.3%	3.9%	2.6%	3.3%
SDG 9	5.5%	4.5%	4.7%	5.8%	6.7%	8.1%	5.9%	6.0%	6.6%	5.6%	4.4%	6.1%
SDG 10	4.7%	3.5%	4.2%	3.5%	1.0%	2.6%	2.5%	4.0%	2.1%	4.7%	4.5%	3.0%
SDG 11	4.7%	3.8%	4.2%	4.3%	7.6%	4.1%	5.1%	4.2%	7.7%	4.7%	4.0%	5.6%
SDG 12	2.8%	2.4%	2.8%	3.7%	3.0%	2.9%	3.1%	2.8%	3.6%	2.9%	2.0%	3.2%
SDG 13	4.8%	4.1%	6.1%	7.3%	4.3%	5.3%	4.7%	3.9%	3.6%	4.9%	3.6%	3.8%
SDG 14	2.3%	3.1%	4.7%	4.7%	2.5%	2.4%	3.7%	3.3%	2.7%	2.6%	2.2%	2.4%
SDG 15	3.5%	3.5%	4.9%	4.9%	2.8%	3.7%	3.7%	2.9%	2.9%	3.6%	3.4%	3.2%
SDG 16	5.2%	6.7%	4.2%	5.4%	0.5%	2.3%	1.9%	4.8%	2.1%	5.3%	4.0%	3.0%

0.0% ▢▢▢▢▢▢▢▢▢▢ 20.0%

FIGURE 2-4
SDG related research output per SDG as a share (%) of total SDG research output for Wales and comparators, 2010–2019; colour-coding indicates share of SDG-related research.
Source: Scopus

Citation Impact :The citation impact for published research (as measured by the FWCI) for Wales' SDG-related research (FWCI = 2.3, i.e. 130% above world average) was much higher than the total FWCI for Wales (1.8 i.e. 80% above world average) indicating the impact of SDG research. Although citation performance was

impressive across all UK nations, with SDG-related research being more cited than the overall average, Wales and Scotland held a leading position amongst the UK nations and global comparators (FIGURE 2-5).
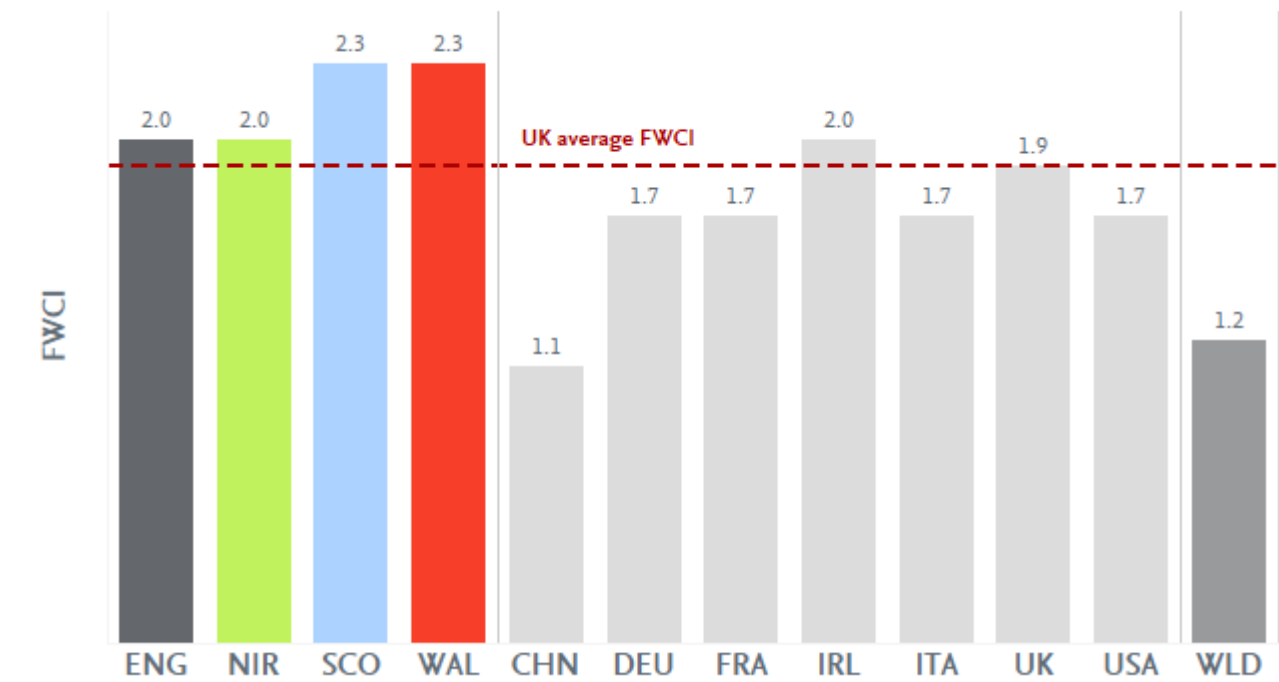

FIGURE 2-5
FWCI of total SDG-related research for Wales and comparators, 2010–2019; red dotted line indicates UK average FWCI for total SDG research.
Source: Scopus

Wales's leading position becomes more apparent, however, when one plots FWCI against the share of SDG-related research. FIGURE 2-6 highlights two clusters of comparators, one with comparators above the global SDG share of publications and one with shares below the global average. During the study period, Wales was amongst the leading countries by share of research activity as well as citation impact.
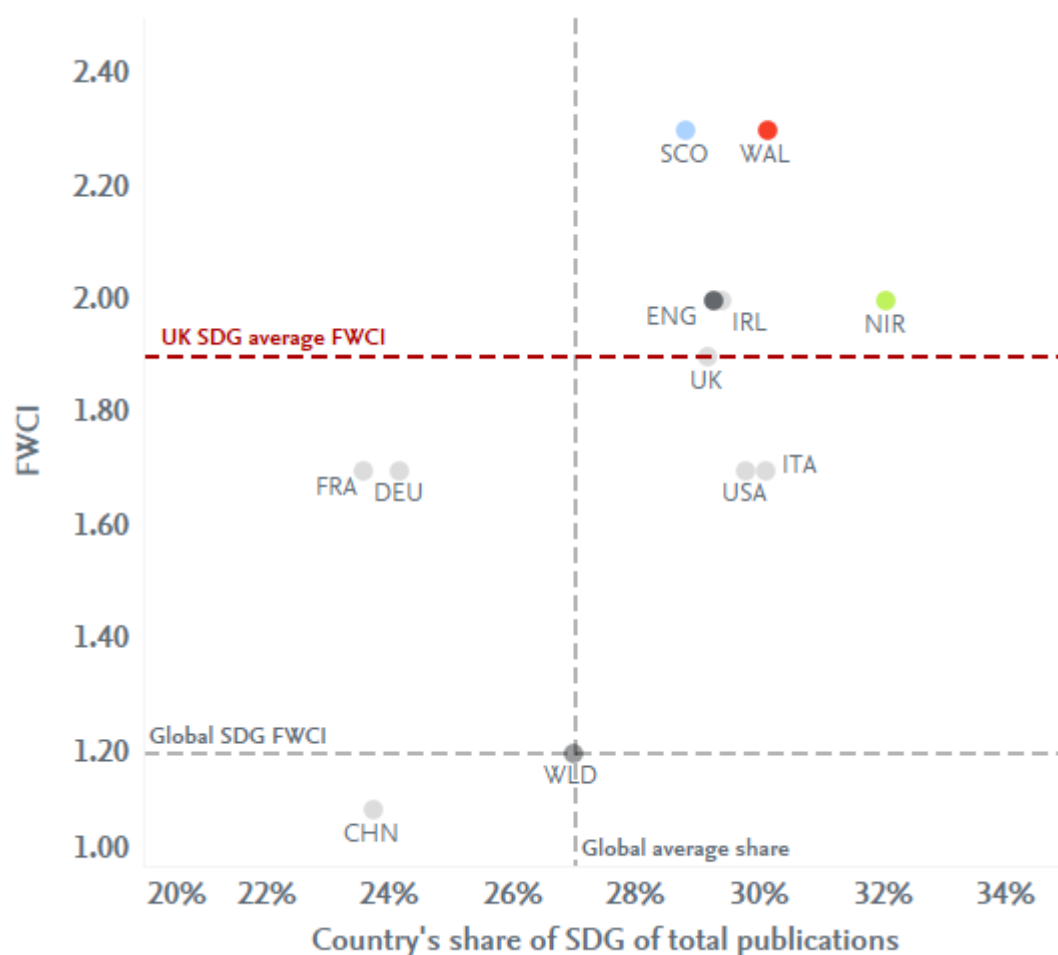
FIGURE 2-6
Country's share of SDG-related research plotted against corresponding FWCI, 2010–2019.
Source: Scopus

Collaboration remains key

Previous landcape reports[16] have highlighted the importance of collaboration, whether international or cross-sectoral, between the academic and corporate sectors[17]. Wales, as a small research nation, benefits from collaboration with international partners. *The performance-based assessment of the Welsh Research Base (2021)* has shown that international collaboration for Wales grew from 42% of its total research output in 2010 to 58% in 2018, with an average of 50%. Internationally collaborated publications showed a high FWCI (2.4), placing Wales in a leading position amongst all UK nations.

As the SDGs address global issues, collaboration across borders was required. In fact, Wales' researchers collaborated on SDG research to almost the same extent internationally (Figure 2-7) as in its total research output, i.e half of Wales' publications were published with international partners during the study period.

[16] A performance-based assessment of the Welsh Research base, (2010–2018), Elsevier, 2021 and International Comparative Performance of the Welsh Research Base 2010–2014, update 2016, Elsevier, 2018

[17] International collaboration refers to a publication with at least one author from Wales and one author from a country outside the UK. Cross-sector collaboration refers to a publication with at least one author from the academic sector and one author from the corporate sector.

However, the effect of international collaboration for SDG related research seems even more robust, with an FWCI of 3.2 for Wales' internationally collaborated publications (i.e. three times above world average)–the highest FWCI of all UK nations for this collaboration type.
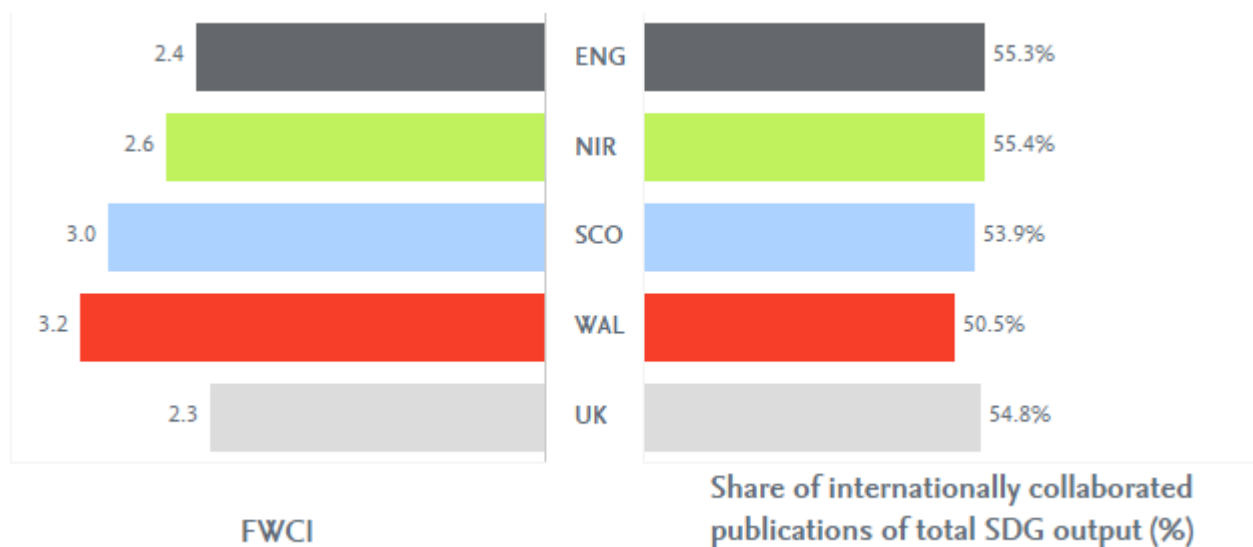

Figure 2-7
Share (right panel) and FWCI (left panel) of internationally co-authored publications across all SDG for Wales and other UK nations, 2010–2019.
Source: Scopus

The share of academic-corporate collaborations for SDG publications was at the same level as those revealed by the landscape reports: around 7%. The impact was however much higher than those in the previous reports, showing an FWCI of 7.0 (Figure 2-8). This needs a note of caution, as the total number of academic-corporate collaborations was relatively low, at less than 1,400 publications in total. Almost 50% of these publications were within SDG 3 (Good Health and Well-being), and the impact score might be affected by the scores of some publications with more than 100 authors.
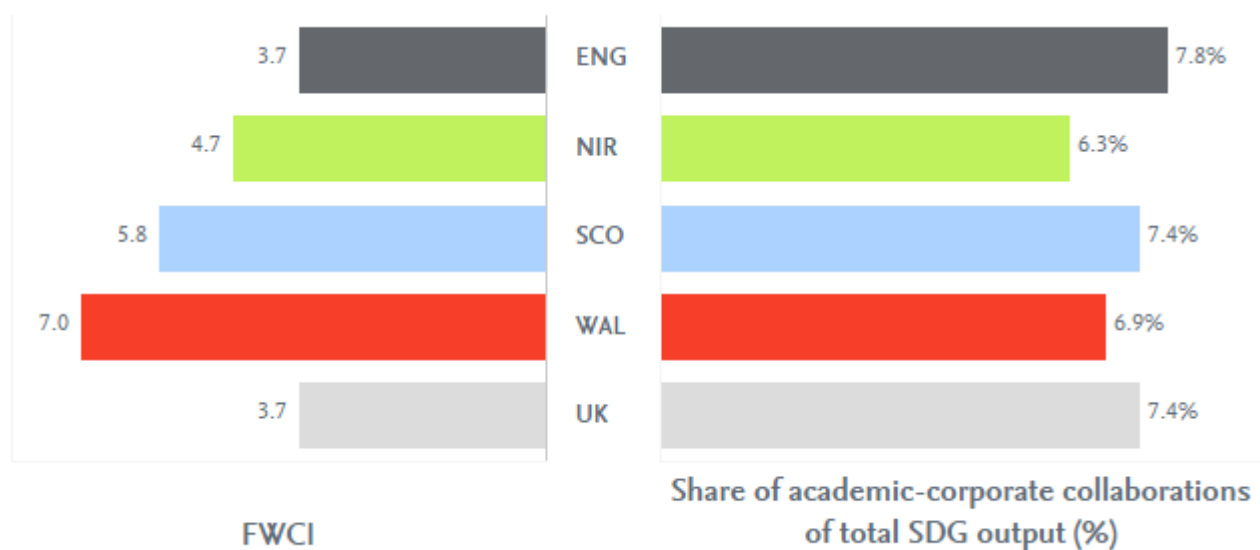
Figure 2-8
Share (right panel) and FWCI (left panel) of academic-corporate co-authored publications across all SDG for Wales and other UK nations, 2010–2019.
Source: Scopus

2.2 Wales' research activity and impact across SDG themes

Wales' research activity on the Planet-themed SDGs was above the other two macro themes, and well above the UK and global level. Welsh research also demonstrated high citation impact, above the UK average in almost all SDGs.

While the previous chapter provides a summary of the different levels of research participation across all SDG, this chapter delves deeper into individual SDGs. This report employs the relative activity index (RAI)[18] and also the FWCI for the UK and global comparators to benchmark Wales's research participation and research impact with UK nations.

Given the different sizes of the UK nations, it does not make sense to simply quantify the total number of publications; for comparison purposes it is better to calculate the relative share of SDG-related research divided by the share of SDG-related research for comparator benchmarks (United Kingdom or world). An RAI above 1 for an SDG suggests a particular area of focus, whereas a value below 1 indicates less focus.

FIGURE 2-9 confirms the findings of the previous chapter (FIGURE 2-4) and demonstrates that Wales had a strong presence within the Planet macro-theme during the study period (2010-2019). While Wales' publication shares in the People- and Prosperity-related SDG macro themes were both similar to the UK level, its publication shares in all Planet-related SDGs were strikingly well above the UK level, and were almost double the activity level of the UK in SDG 14 (Life below Water).

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[18] The relative activity index (RAI) is defined as the share of a country's article output on an SDG topic relative to the global (or UK share) of articles for the same topic. For example, Wales published 3.6% of its articles in SDG 7, while for the UK 3.0% of all articles were published in SDG 7. The RAI for Wales in SDG 7 is calculated as 3.6%/3.0% = 1.2. A value of 1.0 indicates that a country's research activity in a field corresponds exactly with the global activity in that field; a value higher than 1.0 implies a greater emphasis; and a value lower than 1.0 suggests a lesser focus.
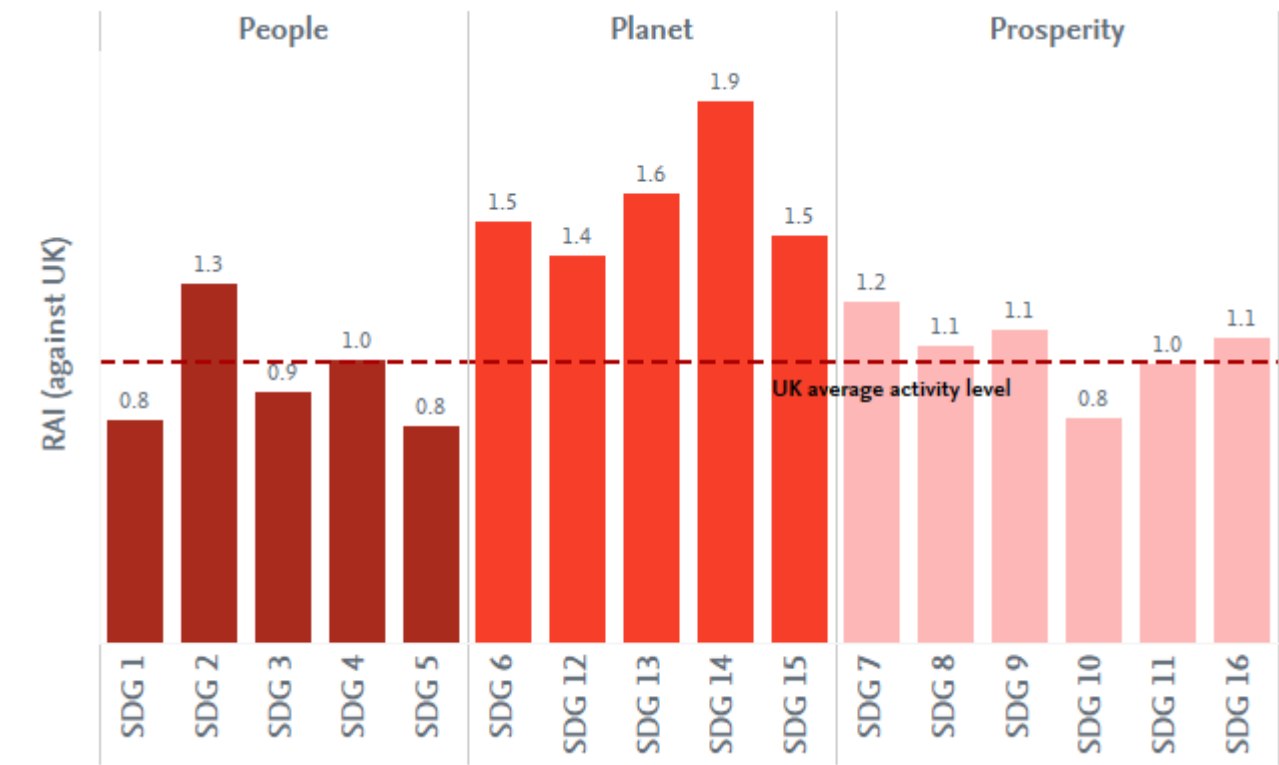
FIGURE 2-9
Wales' relative activity index (RAI) compared to the UK's activity level for SDG-related research per SDG, 2010–2019;
red dotted line indicates UK average activity level (=1.0).
Source: Scopus

FIGURE 2-10 (left panel) highlights the RAIs of all four UK nations against the UK average level for all SDGs over the study period. Wales was the leading UK nation for RAI in the Planet-themed SDGs. Scotland almost reached the same level as Wales for SDG 14 (Life below Water) and SDG 15 (Life on Land). For the other SDGs—SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action)—Wales was well ahead of other comparators. When benchmarked against global activity, a similar performance is confirmed. Wales and Scotland seem to be more specialised in the Planet-themed SDGs compared to the global average and the comparators (FIGURE 2-10, right panel).

It should be noted, however, that all UK nations for most SDGs were well above global activity levels. UK nations only dipped below global activity in SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities). This finding may be related to the strong footprint of China in both these SDGs: China, with its high output numbers in these SDG's, may well influence global averages.
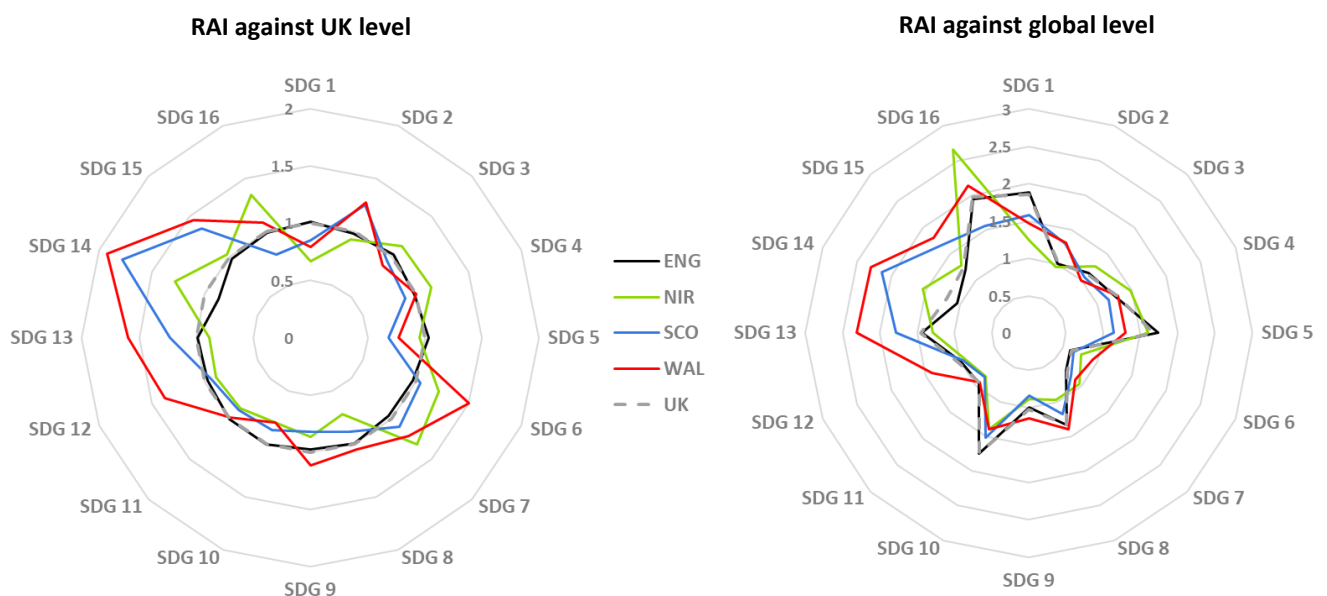
RAI against UK level

RAI against global level

Relative activity index (RAI) against the UK (left panel) and global (right panel) activity level for UK nations' SDG-related research per SDG, 2010–2019.
Source: Scopus

Research impact (citation)

FIGURE 2-11 displays differences between the UK's and Welsh FWCIs per SDG. In the case of Wales, its research outputs only dropped below the UK average for SDG 1 (Zero Poverty) and SDG 7(Affordable and Clean Energy), while for half of the SDGs, Wales' FWCI is more than 0.3 points (i.e. more than 30%) higher than the UK average.

Amongst UK nations, Wales was the leading nation for research citation impact. The previous chapter showed that Wales and Scotland perform similarly , but FIGURE 2-12 reveals that the main drivers for Scotland's high citation impact were SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being), whereas Wales' contribution to research remained highly cited across the board with peaks for SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 5 (Gender Equality), SDG 13 (Climate Action), and SDG 16 (Peace, Justice and Strong Institutions).
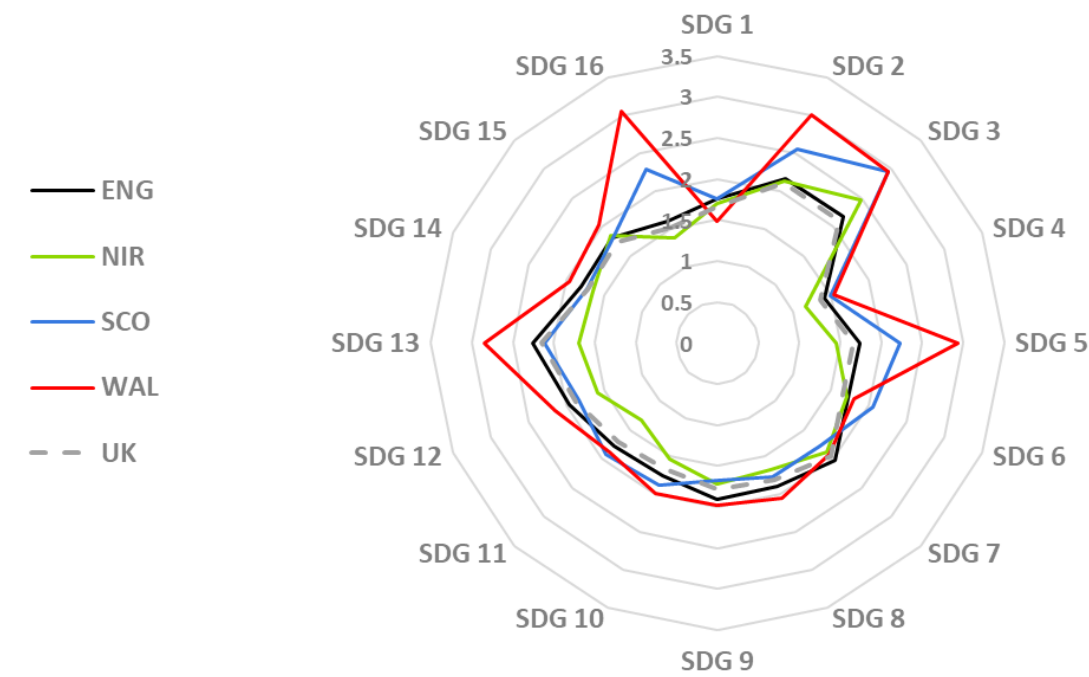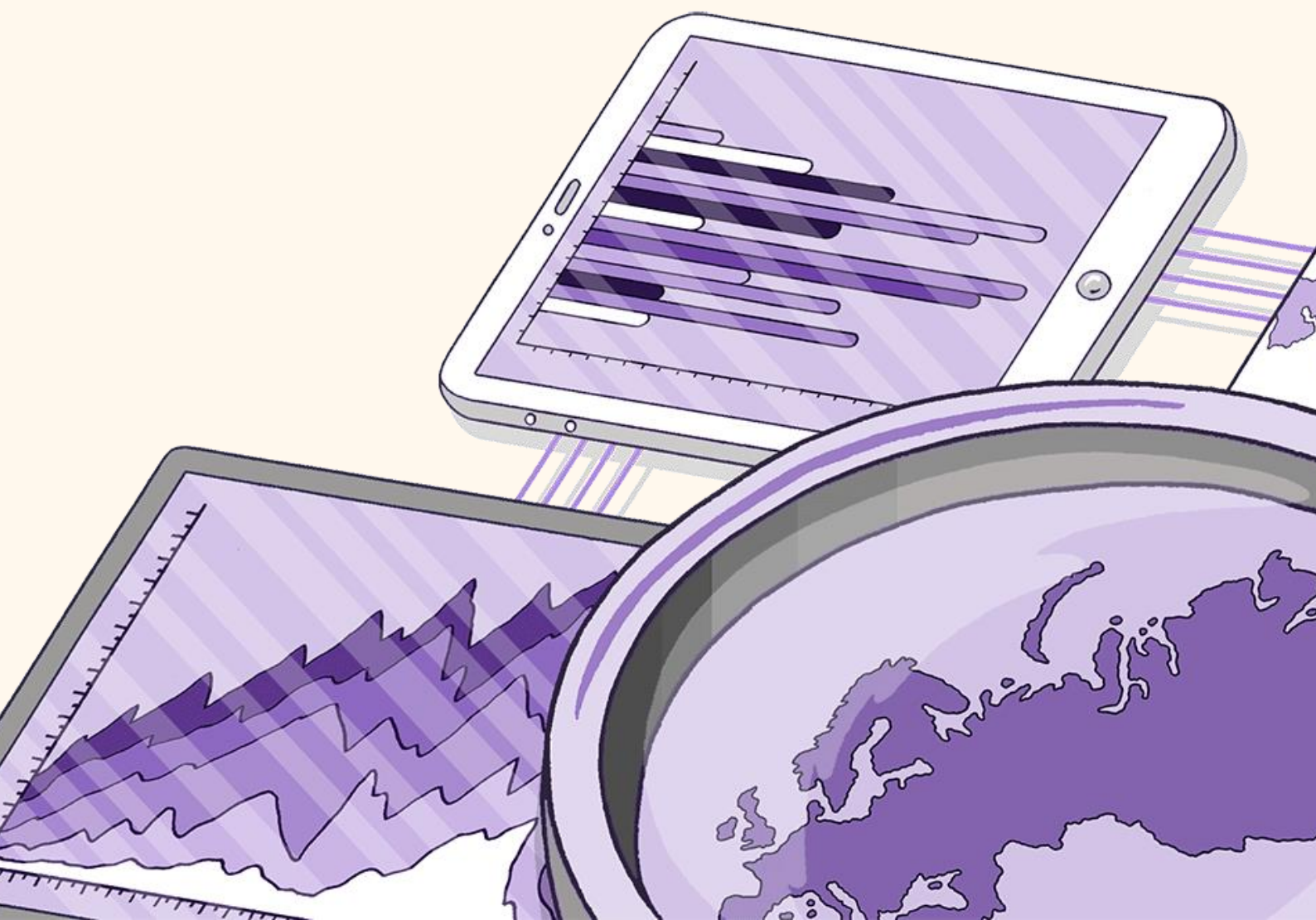
SDG Macro-themes

3.1 Macro-theme 1: People

Under the People theme, Wales had a higher FWCI than the UK average for most SDGs, but only showed an activity level above the UK for SDG 2 (Zero Hunger).

People SDGs
SDG 1 (No Poverty)
SDG 2 (Zero Hunger)
SDG 3 (Good Health and Well-being)
SDG 4 (Quality Education)
SDG 5 (Gender Equality)

Table 3-1
SDGs included in the People macro-theme

Over the study period, Wales' activity for the People related SDGs was only above the UK level for SDG 2 (Zero Hunger) (FIGURE 3-1). Wales and Scotland displayed an RAI of 1.3 for publications related to these SDGs, highlighting both nations' research contribution to the global challenge of combatting hunger. Wales was most prolific in SDG3 (Good Health and Well-being), as was the case around the globe, but its relative activity for this SDG was lower than the UK average.

FIGURE 3-1
Relative activity index (RAI) against UK level for Wales and other UK nations in selected SDGs, 2010–2019; red dotted line indicates UK activity as benchmark.
Source: Scopus

Despite Wales having a relatively lower specialisation in most of the SDGs within this theme, its average citation impact was ahead of the other UK nations for SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), and SDG 5 (Gender Equality) (FIGURE 3-2).

FIGURE 3-2
Citation impact: FWCI for Wales and other UK nations in selected SDGs, 2010–2019; red dotted line indicates the UK FWCI per SDG as benchmark.
Source: Scopus

SDG 2 (Zero Hunger) addressed global questions

Wales published 813 publications in SDG 2 (Zero Hunger) between 2010 and 2019. Research output from Wales in this SDG returned the highest FWCI of all UK nations, accruing three times the global average number of citations (FWCI = 3.0).

International collaborations were responsible for Wales' high FWCI with these publications achieving an FWCI of 3.5 (250% above global average) and accounting for 67% of Wales' publications in SDG 2. This is interesting as the share of internationally co-authored publications was similar across all UK nations, but Wales showed the highest FWCI from these publications. The high impact does not relate to hypercollaborated publications[19], but there is a high number of highly cited publications with only a few collaborating authors. Researchers from Swansea University accrued the highest numbers of citations.

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[19] The terms 'hypercollaborative co-authorship' and 'hypercollaboration' have been coined to classify the growing phenomenon of articles that have hundreds or even thousands of co-authors. The rise of so-called 'Big Science' – a term used to describe research that requires major capital investment and is often, but not always, international in nature – may be one of the causes of this phenomenon. Often these publications accrue a very high number of citations.
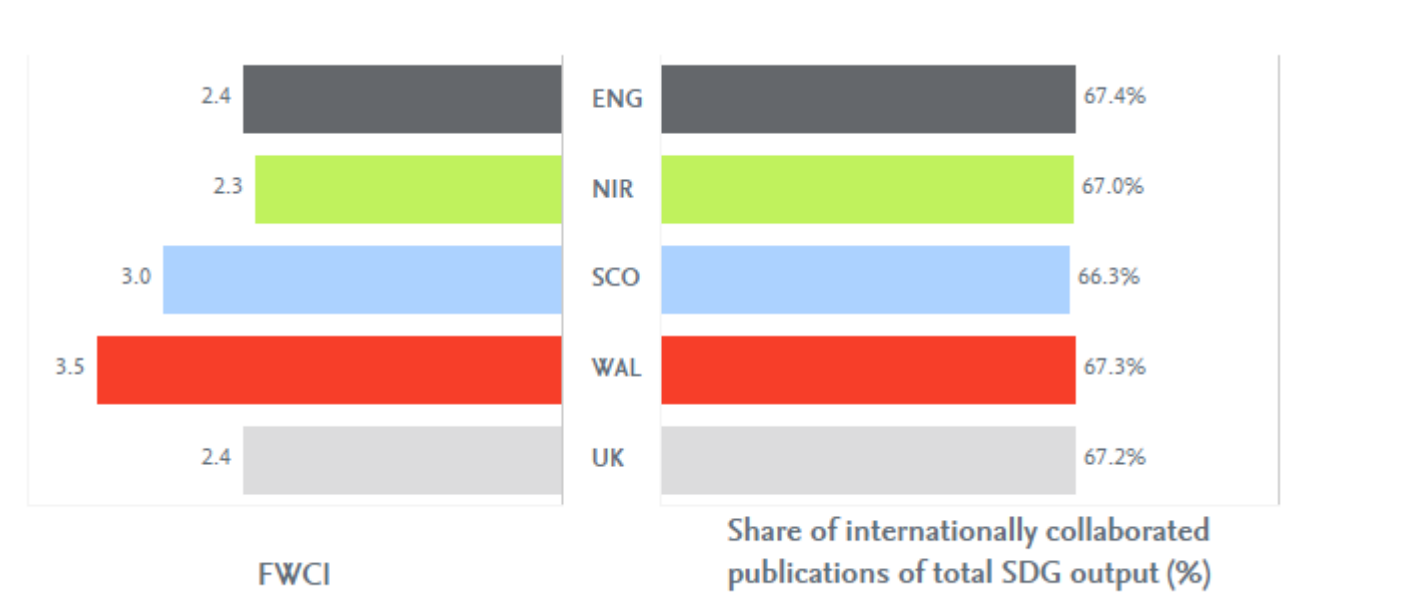
The impact of research partnership becomes apparent when looking at collaboration across sectors. Although the overall number of academic–corporate collaborations was relatively low for Wales (59), it accounted for 7% of SDG 2 publications and displayed an FWCI of 8.9 (almost 8 times the global average). Researchers at Bangor University and Aberystwyth University appear to be driving this kind of collaboration.
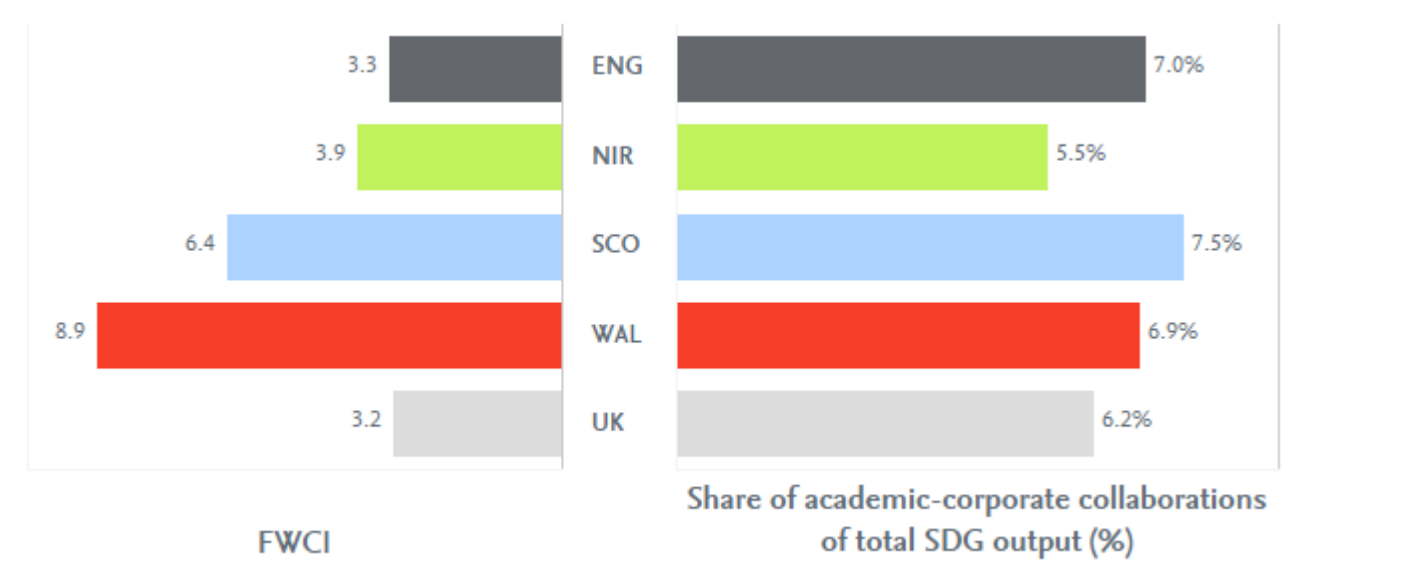
Bangor University and Aberystwyth University remained the most prolific institutions in Wales, addressing global issues in this topic (FIGURE 3-5). Bangor University research focused on 'Agroforestry' and Aberystwyth University on 'Crop' while global research focused on 'Food Security', Malnutrition', and 'Agriculture', followed by individual plants such as 'Rice', 'Triticum' and 'Zea Mays'.

FIGURE 3-5

Word cloud for Wales' main research keyphrases in SDG 2, 2010–2019; size here indicates relevance, colour-coding indicates trend with green = growing and blue = declining from 2010 to 2019.
Source: Scopus and SciVal

SDG 3 (Good Health and Well-being) was the most productive SDG for the global research community, the UK and Wales, but Wales' RAI was below the UK average

Globally SDG 3 (Good Health and Well-being) was the most prolific research area related to the UN SDG. This is not surprising and can be explained by the considerable overlap with publications in Medicine and related productive subjects. For Wales, it remained the most productive SDG, although Wales' RAI for this SDG was below the UK average. In total, Wales produced more than 8,500 publications and accrued an FWCI of 2.9 for this SDG, highlighting the strong position of Wales' research in this subject.

International (FIGURE 3-6) and cross-sector (FIGURE 3-7) collaboration remained the main drivers for this performance, although Wales showed the lowest share of international collaborations of all UK nations. A few of these publications were hypercollaborated publications—that is, publications with more than 1,000 authors—, which usually attract very high citation counts. Cardiff University was the Welsh institution most engaged with this SDG, sucessfully collaborating with many global partners.
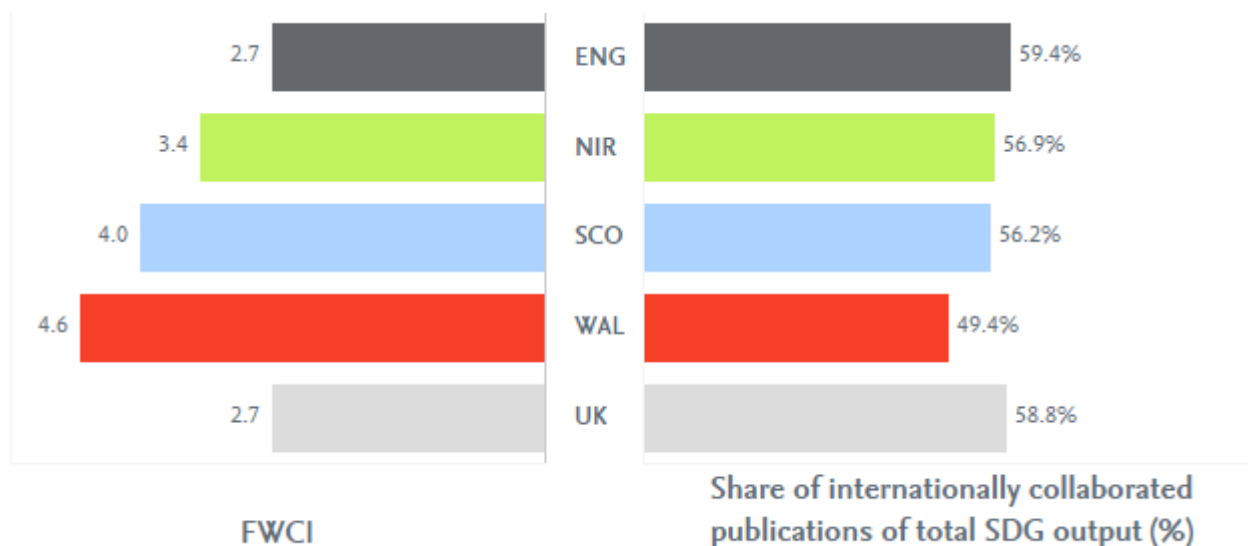
Share (right panel) and FWCI (left panel) of internationally co-authored publications in SDG 3 for Wales and other UK nations, 2010–2019.
Source: Scopus

Many of the academic–corporate collaborations related to hypercollaborated publications stemming from the Global Burden of Disease Study. Cardiff University and Swansea University were the most active institutions in these cross-sector collaborations.
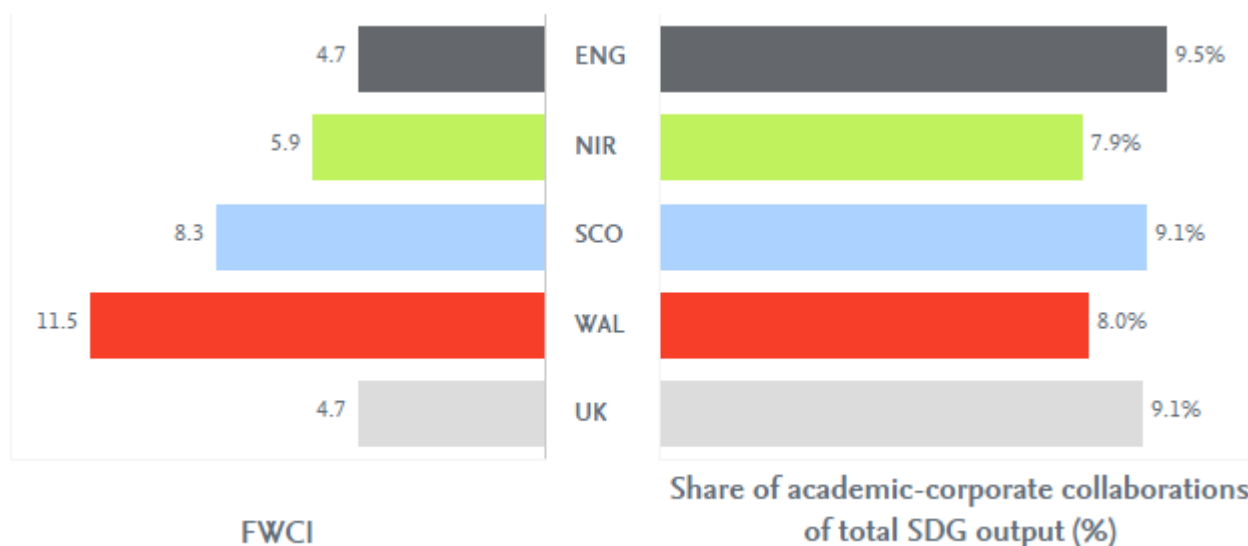
Share (right panel) and FWCI (left panel) of academic-corporate co-authored publications in SDG 3 for Wales and other UK nations, 2010–2019.
Source: Scopus

The most relevant set of keyphrases for research, as shown in FIGURE 3-8 involved cancer-related research and diabetes. While globally cancer-related research questions were most relevant as well, diabetes was not as prominent as it was for Welsh research. Cardiff University was driving Welsh research on this SDG
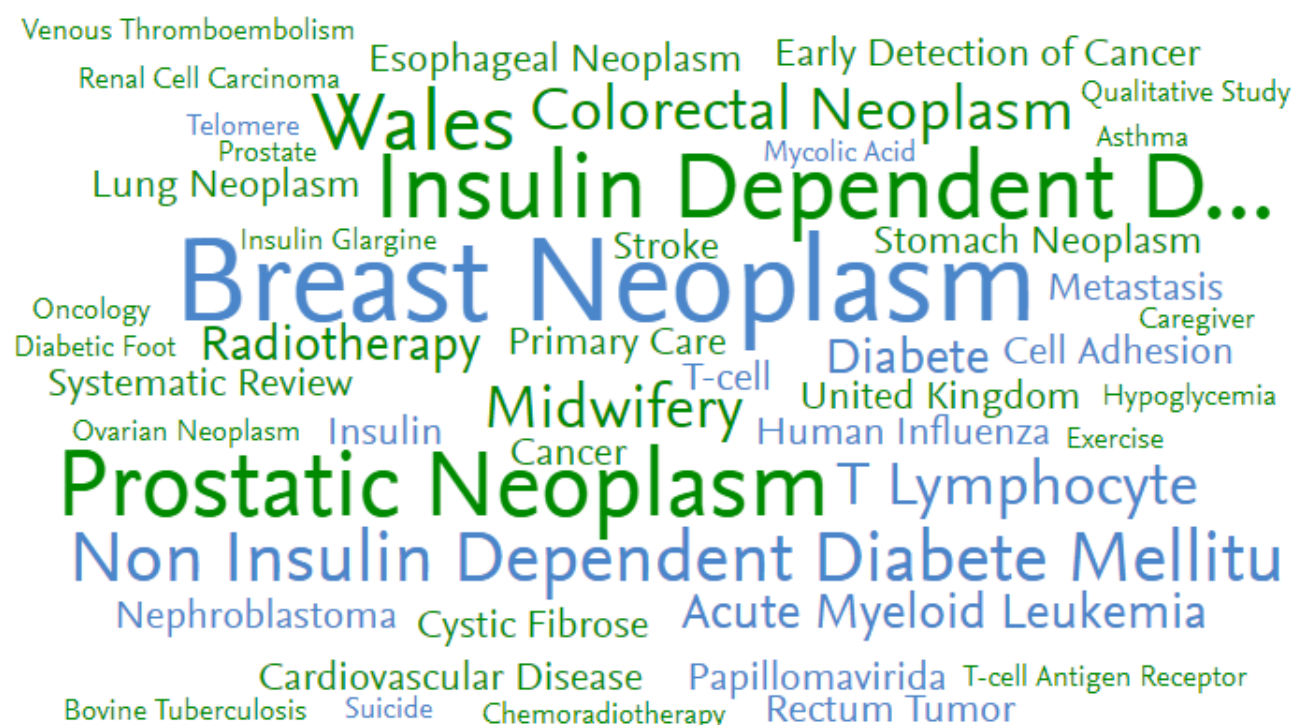
FIGURE 3-8
Word cloud of Wales' main keyphrases in SDG 3, 2010–2019; size indicates relevance, colour coding indicates trend with green = growing and blue = declining from 2010–2019.
Source: Scopus and SciVal

SDG 5 (Gender Equality): low research output but high citation impact

Another SDG with a similar pattern is SDG 5 (Gender Equality). While Wales had an RAI below the UK average (RAI = 0.8, FIGURE 3-1) for this SDG, the citation impact for published research was 2.9 (i.e. almost three times above world average).

The total number of research publications was low (594), and only 33% of these were published with international collaborators. Nevertheless, these internationally collaborated publications accounted for an FWCI of 6.4 (more than six times the global average), driving the citation impact of Welsh research (FIGURE 3-9). Eleven publications stemmed from academic–corporate collaborations, with six of them being part of the Global Burden of Disease Study and showing exceptionally high citation rates.
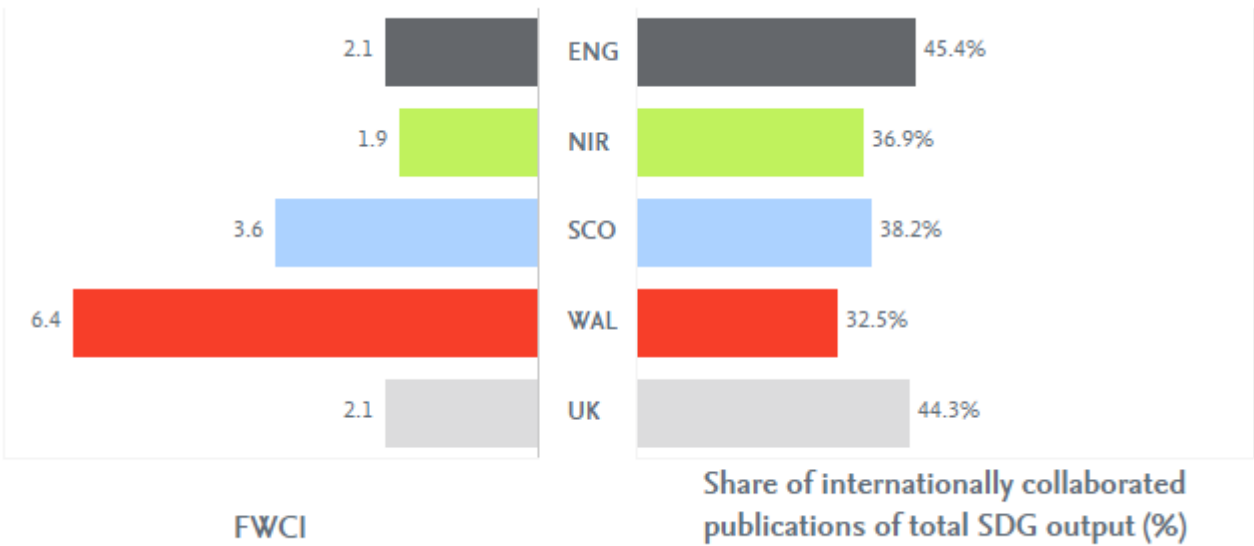
The main drivers for research related to gender equality came from Cardiff University, with researchers here accounting for more than half of the total output from Wales. Below, FIGURE 3-10 highlights key research topics for Wales' research within SDG 5 (Gender Equality). There is a high overlap with global gender research, although HIV—prominently featured in global research—is not visible within Wales' research.
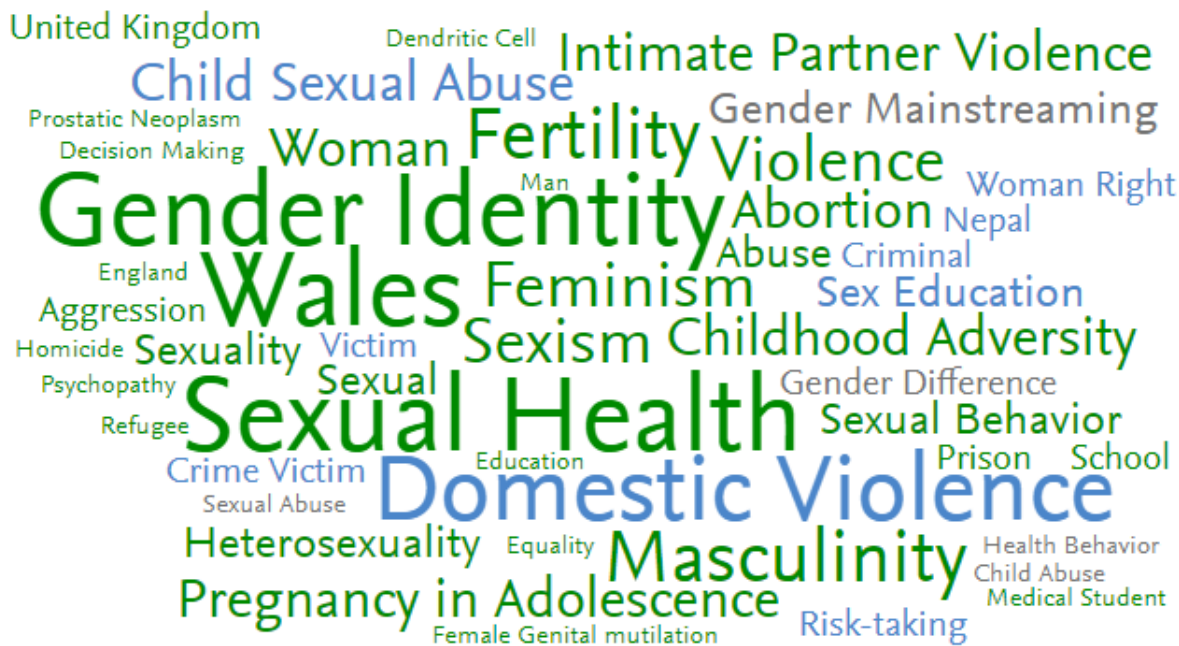
3.2 Macro-theme 2: Planet

Research from Wales made significant contributions to the Planet SDGs, displaying a high share of research activity and the highest citation impact when benchmarked against UK and global comparators.

Planet SDG
SDG 6 (Clean Water and Sanitation)
SDG 12 (Responsible Consumption)
SDG 13 (Climate Action)
SDG 14 Life below Water)
SDG 15 (Life on Land)

Table 3-2
SDGs included in the Planet macro-theme.

As can be seen from Figure 2-11, during the study period Welsh research was both the most concentrated and impactful for the Planet macro themed SDGs.

In chapter 2.1, FIGURE 2-4 shows a solid presence for China in SDG 6 (Clean Water and Sanitation), but Wales also displays high shares in all SDGs within this theme. The same holds for the FWCI, with Wales leading in almost all SDGs.

A closer look into relative activity and FWCI—compared with the other UK nations—for the Planet macro-theme reveals that Wales demonstrated the highest relative activity against the UK average for all these five SDGs (FIGURE 3-11).
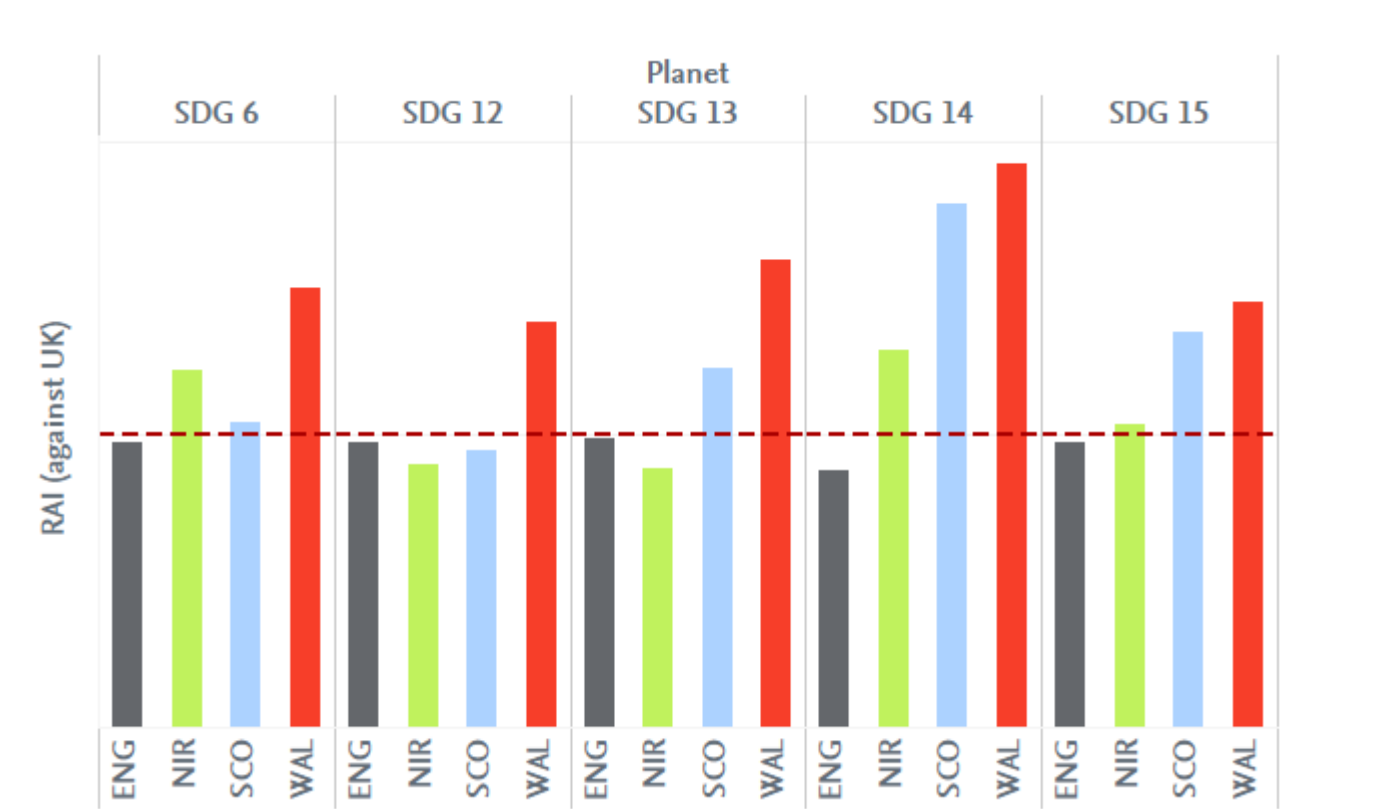
FIGURE 3-11
Relative activity index (RAI) against the UK level for Wales and other UK nations for selected Planet SDGs, 2010–2019;
red dotted line indicates UK activity as benchmark.
Source: Scopus

In four of the five SDGs, Wales led the UK in terms of FWCI; Scotland had the highest FWCI for SDG 6 (Clean Water and Sanitation) (FIGURE 3-12). Wales' FWCI was always above the UK average.
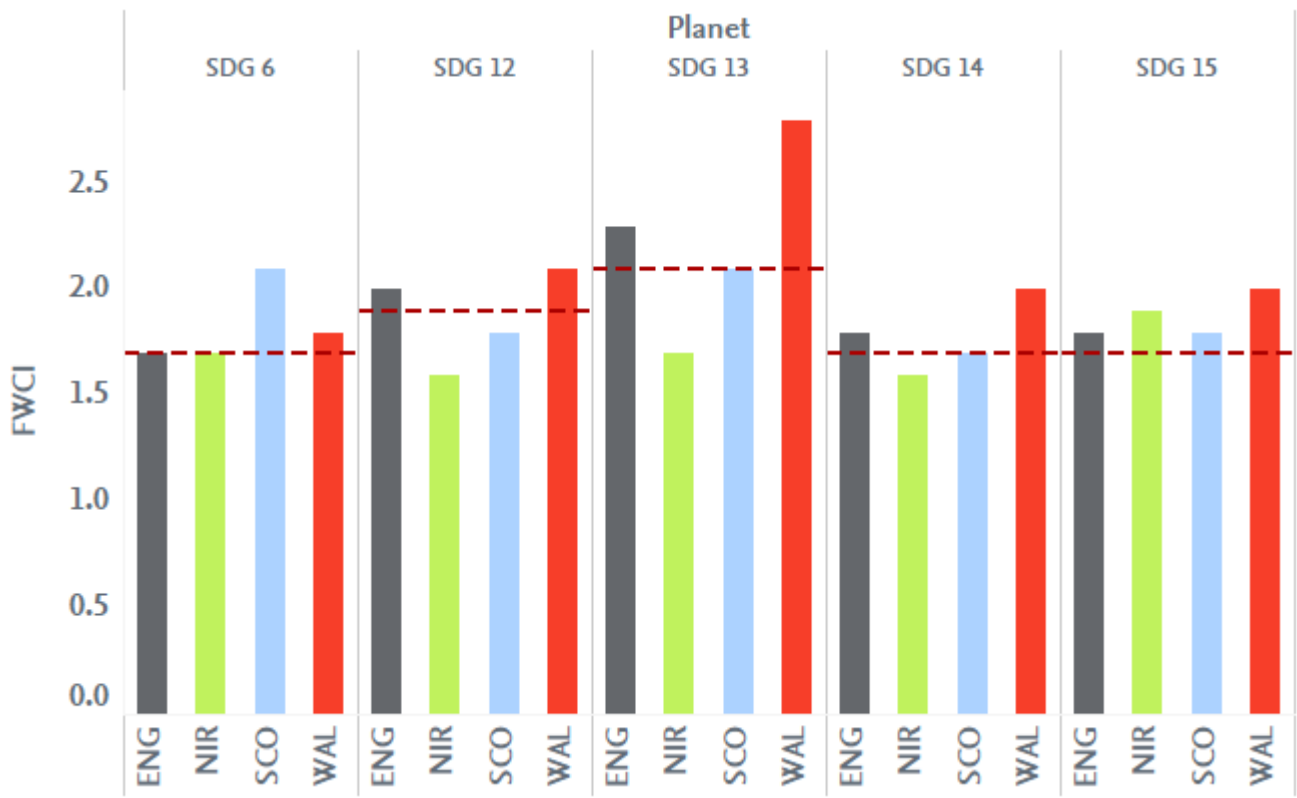
SDG 6 (Clean Water and Sanitation) and SDG 12 (Responsible Consumption) had an activity well above and an FWCI around the UK average

For both these SDGs, Wales' shares of international (60% for SDG 6 and 50% for SDG 12) and of academic–corporate collaboration (6% for SDG 6 and 5% for SDG 12) were at or below its average on overall SDG research. These publications returned a high FWCI between 1.9 and 4.1. It should be noted that although the impact for these SDGs was around UK average, this was much higher than the world average. For SDG 6, the research topics are driven by water treatment, with researchers from Swansea University's Centre Water Advanced Technologies and Environmental Research (CWATER) being highly active.

Figure 3-13
Word cloud for Wales' main key phrases in SDG 6, 2010–2019; size indicates relevance, colour-coding indicates trend with green = growing and blue = declining from 2010 to 2019.
Source: Scopus and SciVal

In SDG 12 (Responsible Consumption), researchers from Cardiff University accounted for almost half of Wales' publications. It is interesting, however, that these researchers were from different research groups like the Understanding Risk Research Group, the Center for Business Relationships, Accountability, Sustainability and Society, and the Logistics and Operations Management Section. Many research topics were covered in the SDG, spanning from Tourism to Waste Disposal and Corporate Responsibility (Figure 3-14).

Wales' FWCI in SDG 13 (Climate Action) was the highest of all global comparators

Wales' research in SDG 13 (Climate Action) had an average FWCI of 2.8, which was 0.7 points above the UK average (FIGURE 3-15). This is impressive because the UK average FWCI was already 2.1—more than twice the global average. The high impact for all UK nations' research here correlated with a high share of research activity—highest of all global comparators. The main drivers behind the Welsh research performance in this SDG were Cardiff University, Bangor University and Aberystwyth University, with publications from Aberystwyth University producing the highest FWCI.
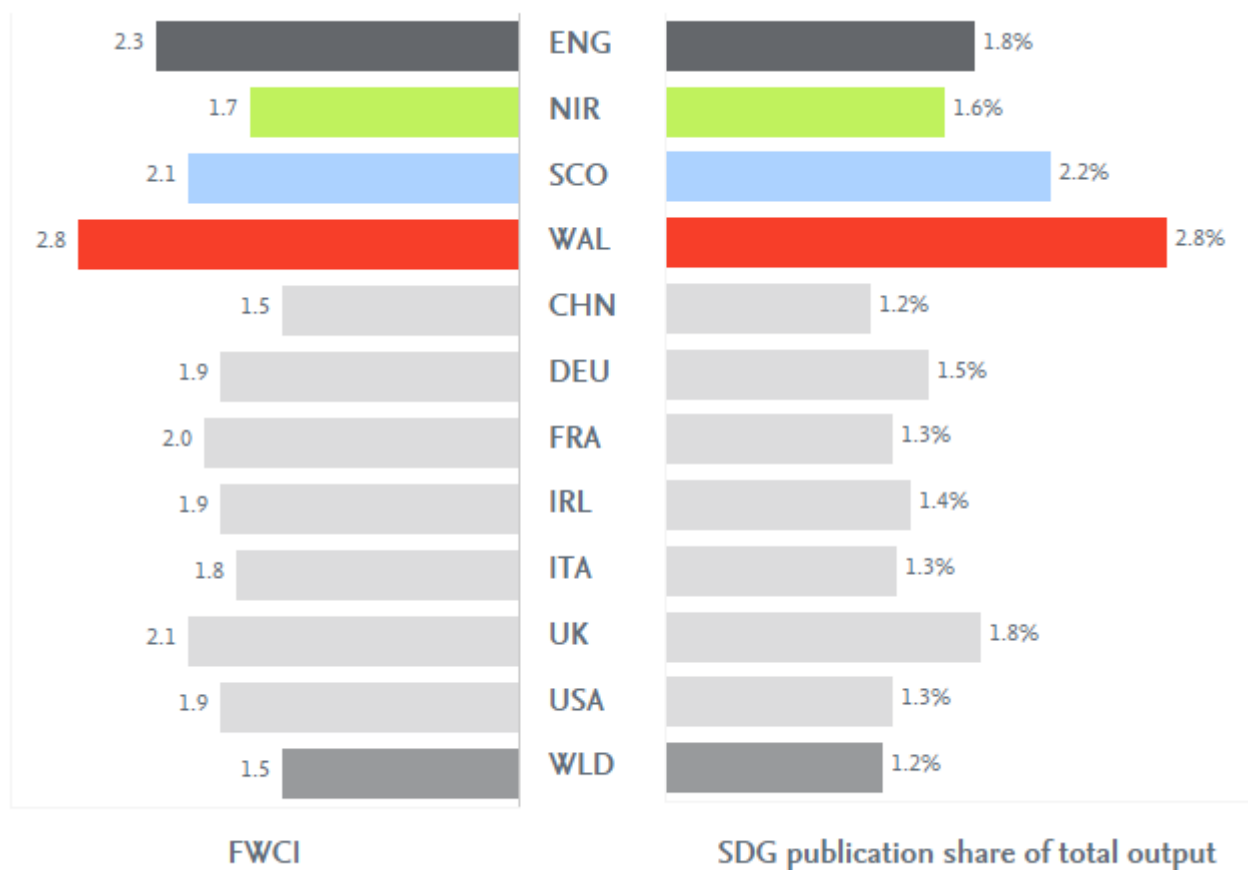
FWCI		SDG publication share of total output
2.3	ENG	1.8%
1.7	NIR	1.6%
2.1	SCO	2.2%
2.8	WAL	2.8%
1.5	CHN	1.2%
1.9	DEU	1.5%
2.0	FRA	1.3%
1.9	IRL	1.4%
1.8	ITA	1.3%
2.1	UK	1.8%
1.9	USA	1.3%
1.5	WLD	1.2%

FIGURE 3-15
Share (right panel) and FWCI (left panel) of publications in SDG 13 for Wales and global comparators, 2010–2019.
Source: Scopus

In this SDG, Welsh researchers showed strong international collaboration over the study period, with a share of publications of almost 70%. These collaborations accrued an average FWCI of 3.3 (FIGURE 3-16). Wales led within UK nations in both share and FWCI.
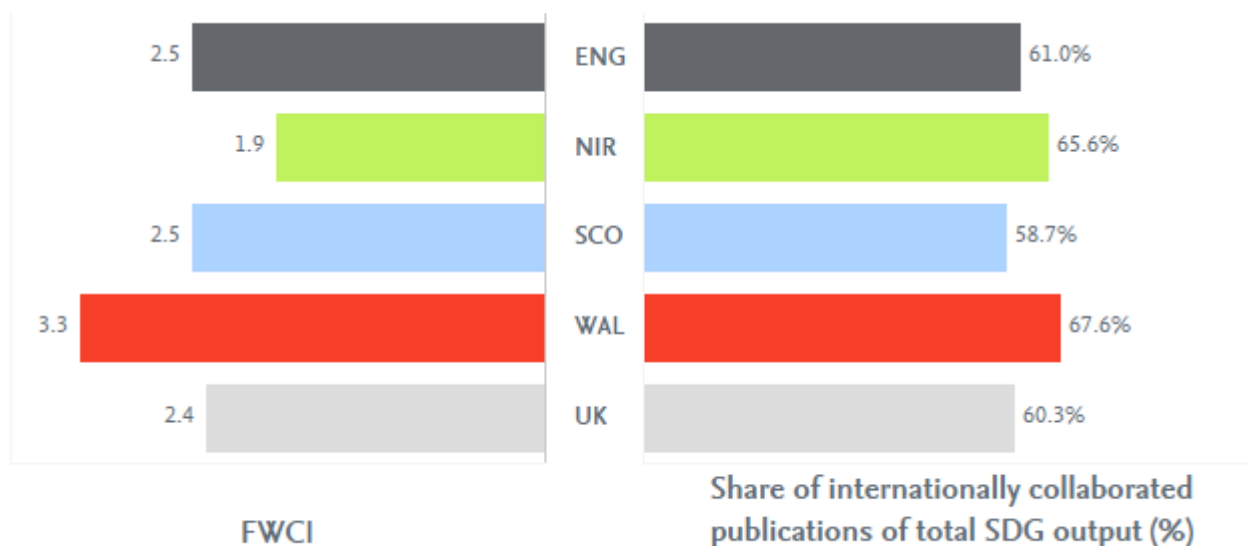
Share (right panel) and FWCI (left panel) of internationally co-authored publications in SDG 13 for Wales and other UK nations, 2010–2019.
Source: Scopus

Academic–corporate collaboration accounted for 7% of all Welsh publications in SDG 13. The associated average FWCI was 3.1, which was higher than the average of Wales for this SDG. Northern Ireland's average FWCI for academic–corporate collaboration was the highest amongst the UK nations at 4.0, despite Northern Ireland having the lowest share (FIGURE 3-17).
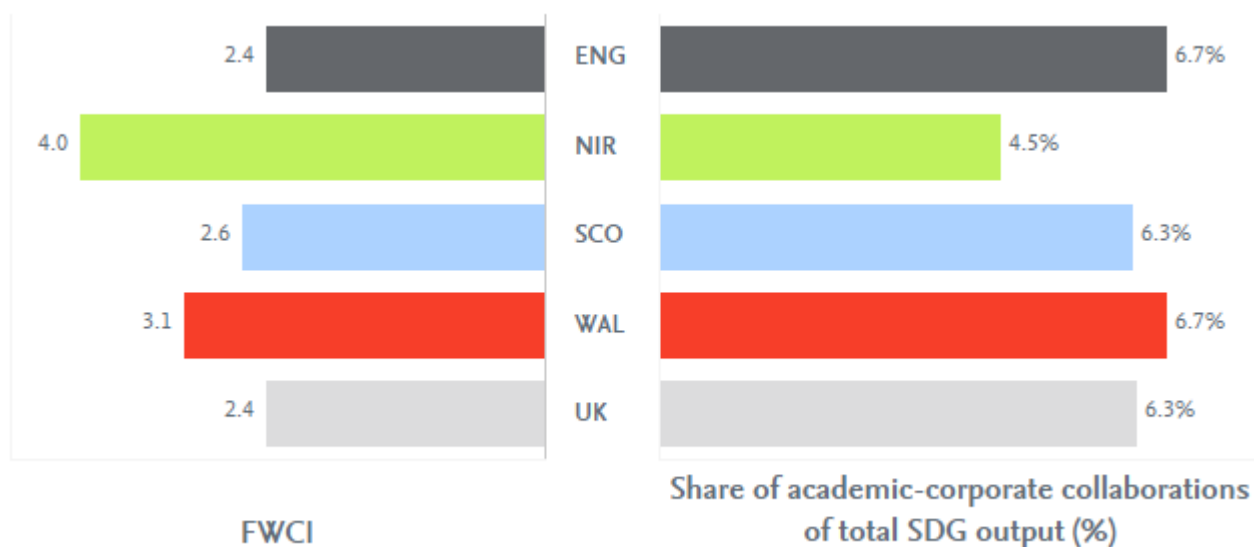

FIGURE 3-17
Share (right panel) and FWCI (left panel) of academic–corporate co-authored publications in SDG 13 for Wales and other UK nations, 2010–2019.
Source: Scopus

Research on SDG 13 (Climate Action) tend to group around global questions and therefore the high share of international collaboration is understandable. Researchers from Aberystwyth University again led by FWCI with a broad range of topics around 'Climate Change', 'Glacial Lake', and 'Ice Cover.'
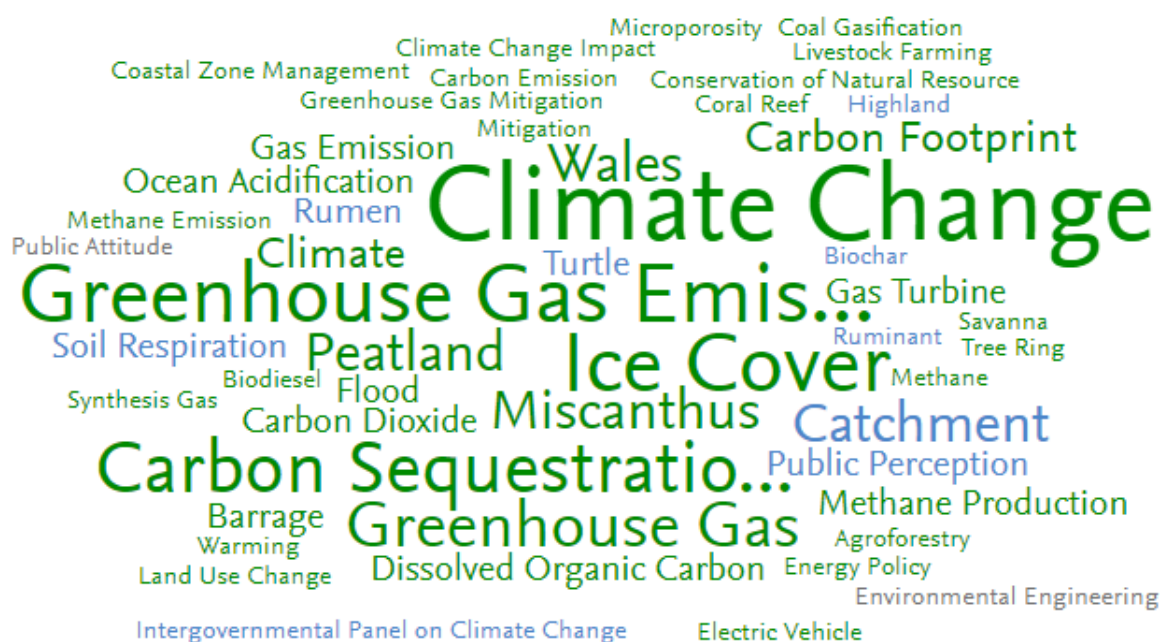

FIGURE 3-18
Word cloud of Wales' main key phrases in SDG 13 (2010–2019); size indicates relevance, colour-coding indicates trend with green = growing and blue = declining from 2010 to 2019.
Source: Scopus and SciVal

High activity level for SDG 14 (Life below Water) for Wales translates into high FWCI

Research on SDG 14 (Life below Water) was the SDG with the highest relative activity (RAI = 1.9) for Wales, with almost double the share of publications than the UK average (FIGURE 3-11). Moreover, this high research activity translated into a high FWCI, although not to the same level as SDG 13. All UK nations were among the leading global comparators by FWCI.

Cross-sector collaboration was strong in all UK nations for this SDG, although Wales and Northern Ireland secured a share below the UK average (FIGURE 3-19). Nevertheless, Wales' FWCI for cross-sector collaboration was the highest of all UK nations—although the total number publications render this score susceptible to outlier effects.
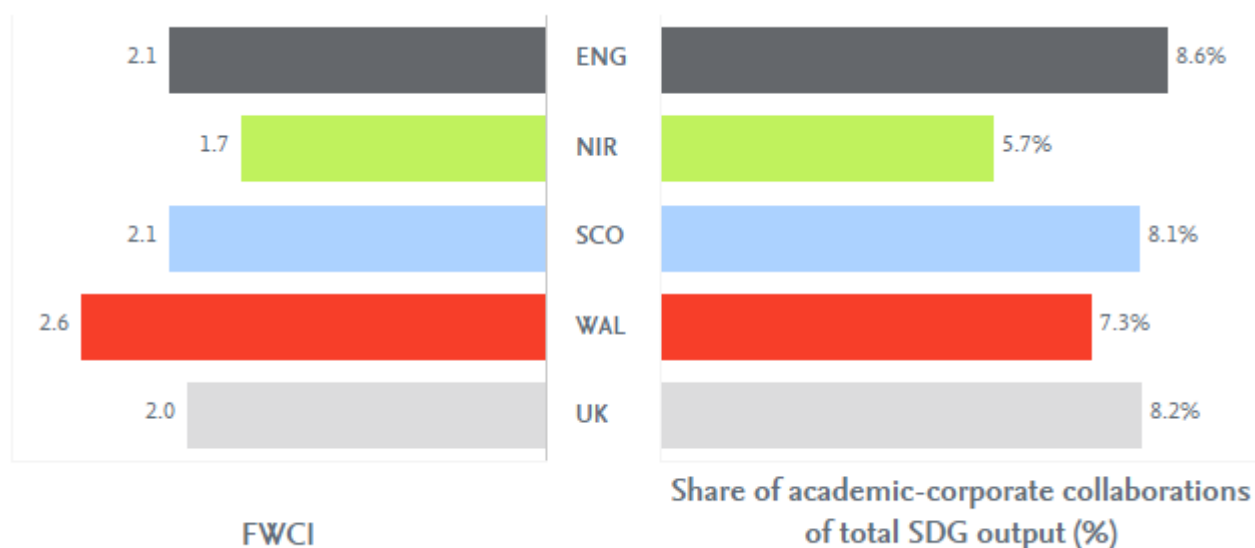
FIGURE 3-19
Share (right panel) and FWCI (left panel) of academic–corporate co-authored publications in SDG 14 for Wales and other UK nations, 2010–2019.
Source: Scopus

Researchers from Bangor University published most among the Welsh institutions for this SDG. The keyphrases covered global questions (FIGURE 3-20), although this SDG addressed many topics that were also relevant for the Welsh community like 'Irish Sea', 'Salmo Salar', or 'Coastal Zone Management', the latter being mentioned in publications from the University of Wales Trinity St. David.
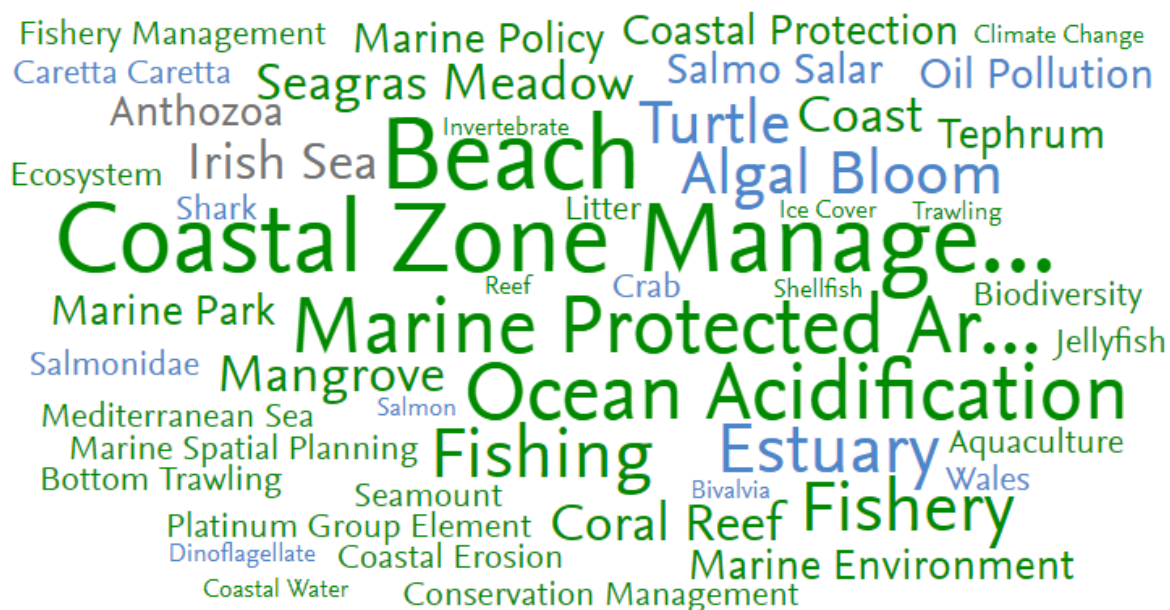

FIGURE 3-20
Word cloud of Wales' main keyphrases in SDG 14 (2010–2019); size indicates relevance, colour-coding indicates trend with green = growing and blue = declining from 2010 to 2019.
Source: Scopus and SciVal

Wales led in SDG 15 (Life on Land) by share and by impact, addressing global questions

SDG 15 (Life on Land) showed a similar picture to that of SDG 13 (Climate Action) and SDG 14 (Life below Water). The UK nations, especially Wales and Scotland, displayed the highest relative share of the total output of all global comparators and led by FWCI (FIGURE 3-21).
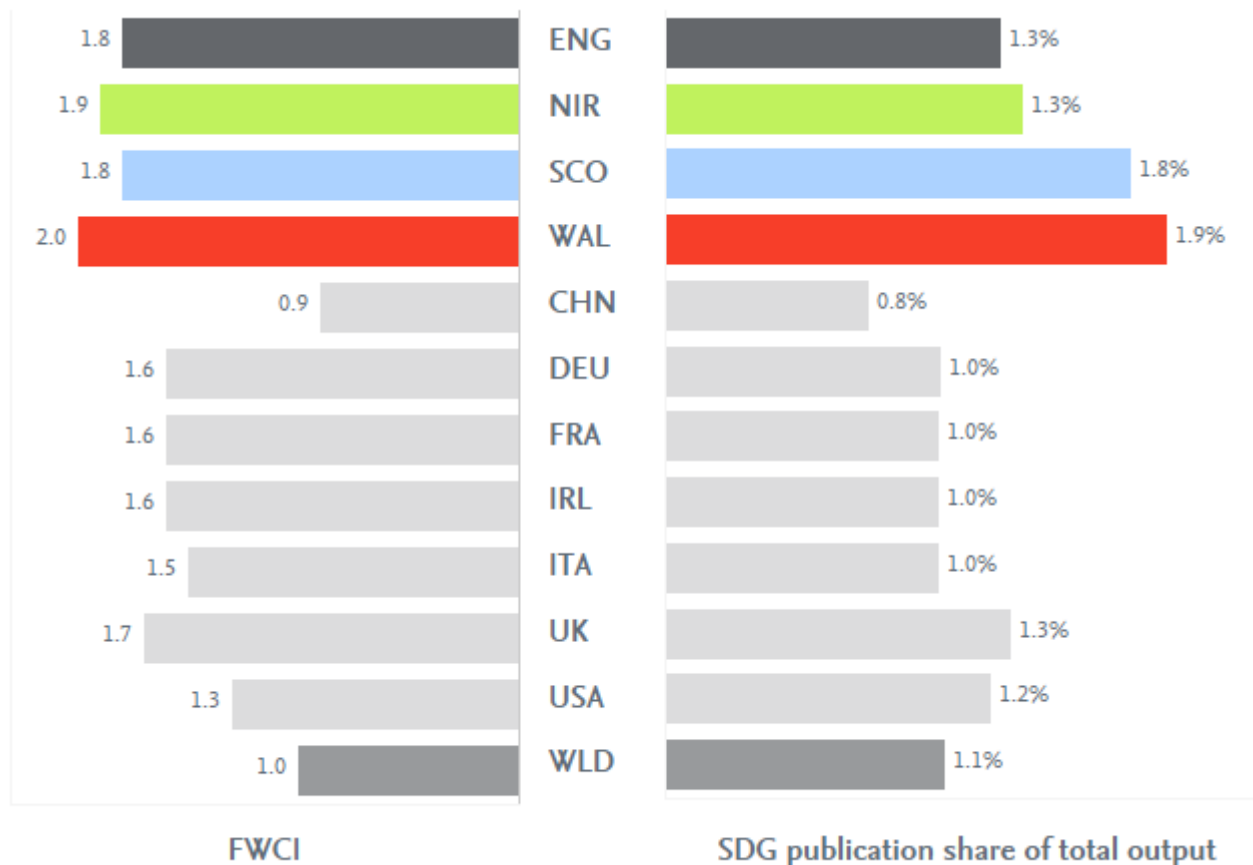

FIGURE 3-21
Share (right panel) and FWCI (left panel) of publications in SDG 15 for Wales and global comparators, 2010–2019.
Source: Scopus

Almost three quarters of all publications for this SDG stemmed from international collaboration with highly renowned international partners, which helps drive the excellence of Welsh research (FIGURE 3-22). Academic–corporate collaborations again played a minor role with 5% of all SDG publications in this SDG, although here again they displayed a high FWCI (4.0) (FIGURE 3-23).
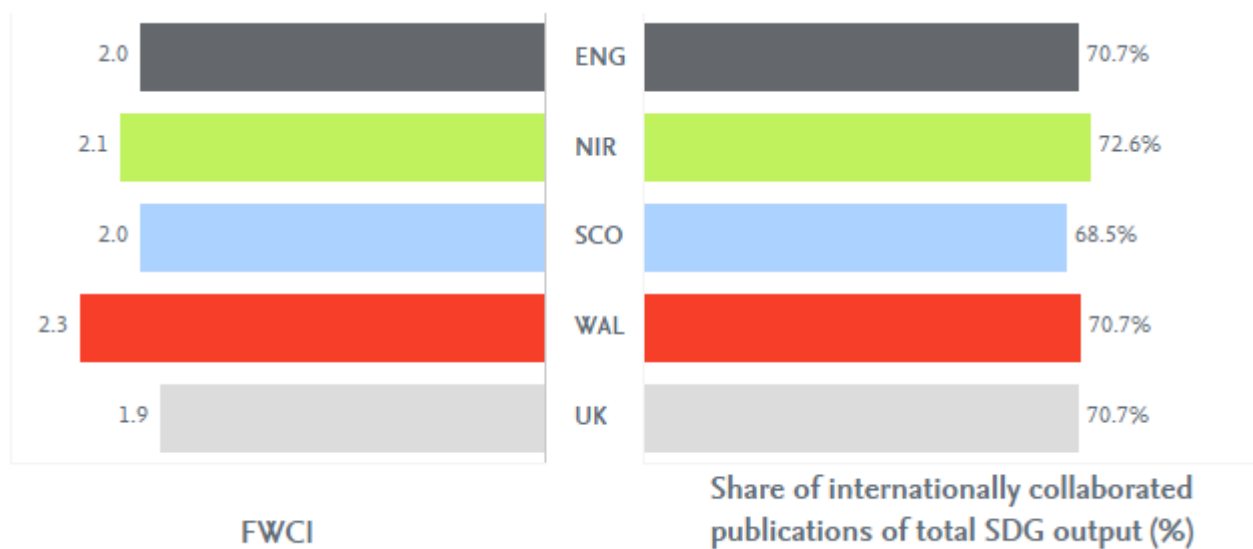
FIGURE 3-22
Share (right panel) and FWCI (left panel) of internationally co-authored publications in SDG 15 for Wales and other UK nations, 2010–2019.
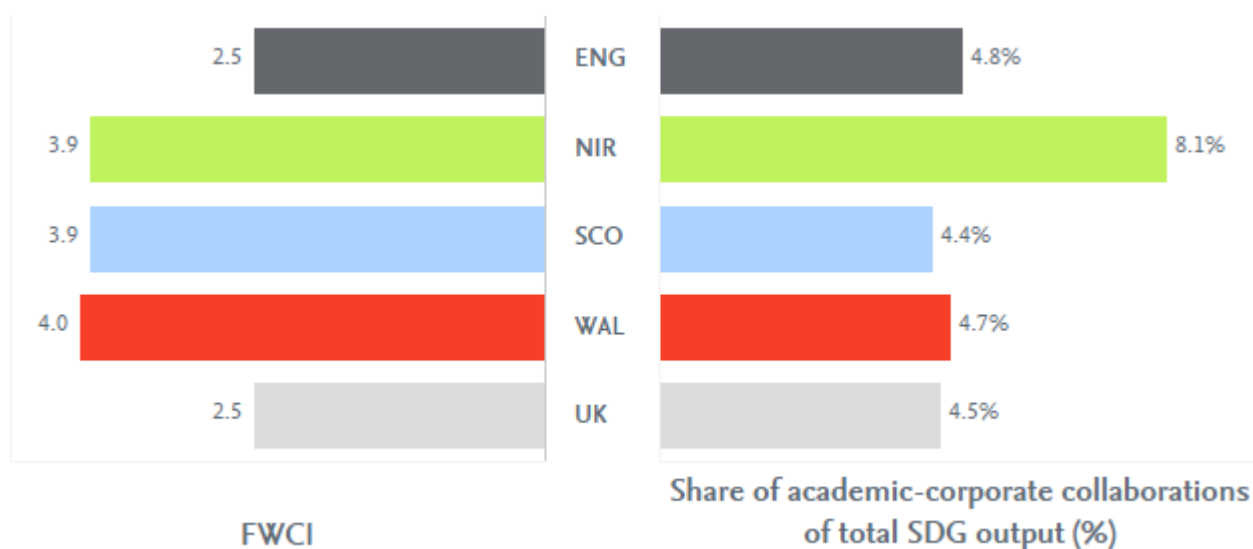*Source: Scopus*

Figure 3-23
Share (right panel) and FWCI (left panel) of academic–corporate co-authored publications in SDG 15 for Wales and other UK nations, 2010–2019.
Source: Scopus

For this SDG, researchers from Bangor University and Cardiff University were the most productive accounting together for two thirds of Wales' publications. Swansea University and Aberystwyth University were also highly impactful. Bangor University's focus was on 'Biodiversity' and 'Invasive Species' in 'Madagascar,' while researchers from Cardiff University published research about 'Elephants' and 'Borneo'.
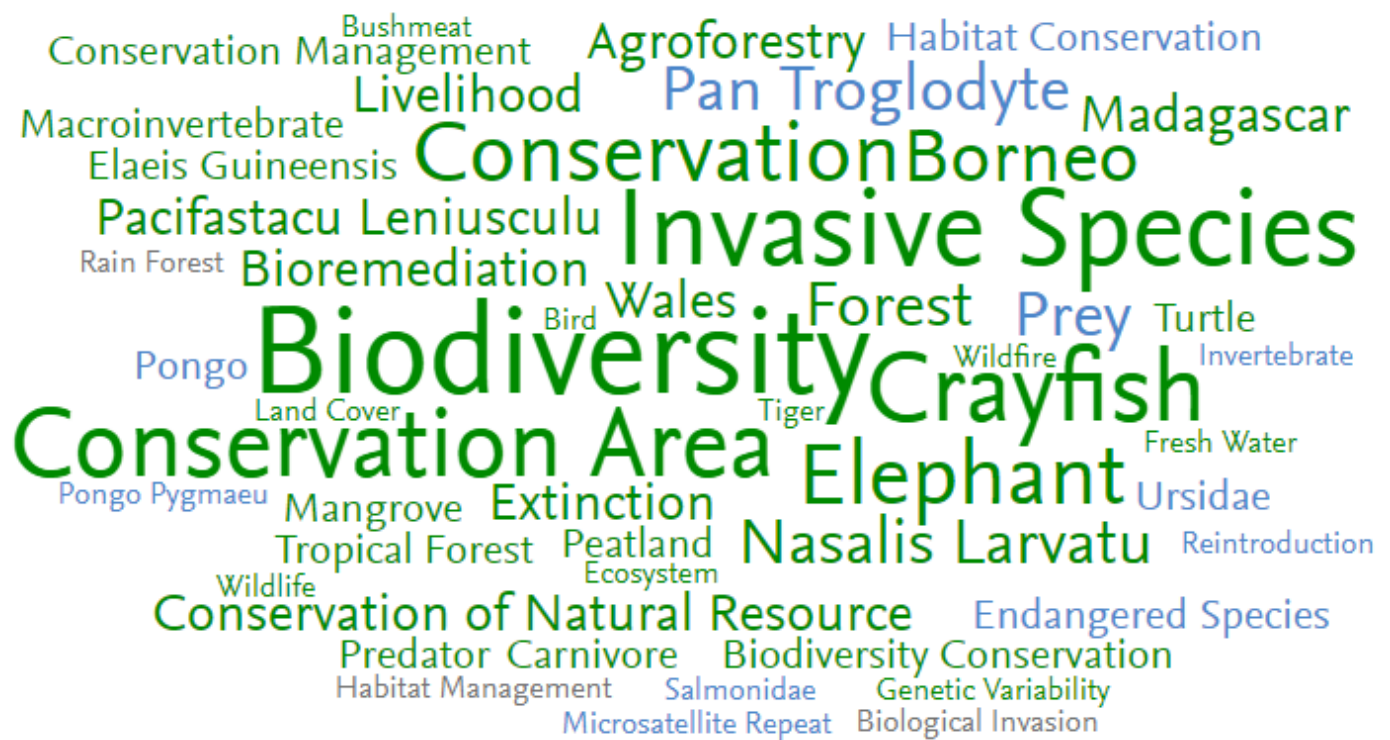
Word cloud of Wales' main key phrases in SDG 15, 2010–2019; size indicates relevance, colour-coding indicates trend with green = growing and blue = declining from 2010 to 2019.
Source: Scopus and SciVal

3.3 Macro-theme 3: Prosperity

All UK nations showed a strong presence under the Prosperity theme. Wales' performance was at UK activity levels except for SDG 16 (Peace, Justice and Strong Institutions), where its FWCI was twice the UK average.

Prosperity SDG
SDG 7 (Affordable and Clean Energy)
SDG 8 (Decent Work and Economic Growth)
SDG 9 (Industry, Innovation and Infrastructure)
SDG 10 (Reduced Inequalities)
SDG 11 (Sustainable Cities and Communities)
SDG 16 (Peace, Justice and Strong Institutions)

Table 3-3
SDGs included in the Prosperity macro-theme.

For most SDGs related to the Prosperity theme, Wales' relative research activity was at or slightly above the UK level. Research related to SDG 7 (Clean and Affordable Energy) showed a strong focus for Wales and Northern Ireland (FIGURE 3-25), whereas research related to SDG 10 (Reduced Inequalities) was 20% below the UK average.

Research citations for Welsh publications showed a similar picture, with the FWCI for most of these SDGs around the UK average, except SDG 16 (Peace, Justice and Strong Institutions), for which Wales showed a remarkably high FWCI. SDG 7 (Clean and Affordable Energy) was the only SDG with an FWCI below the UK average (FIGURE 3-26).
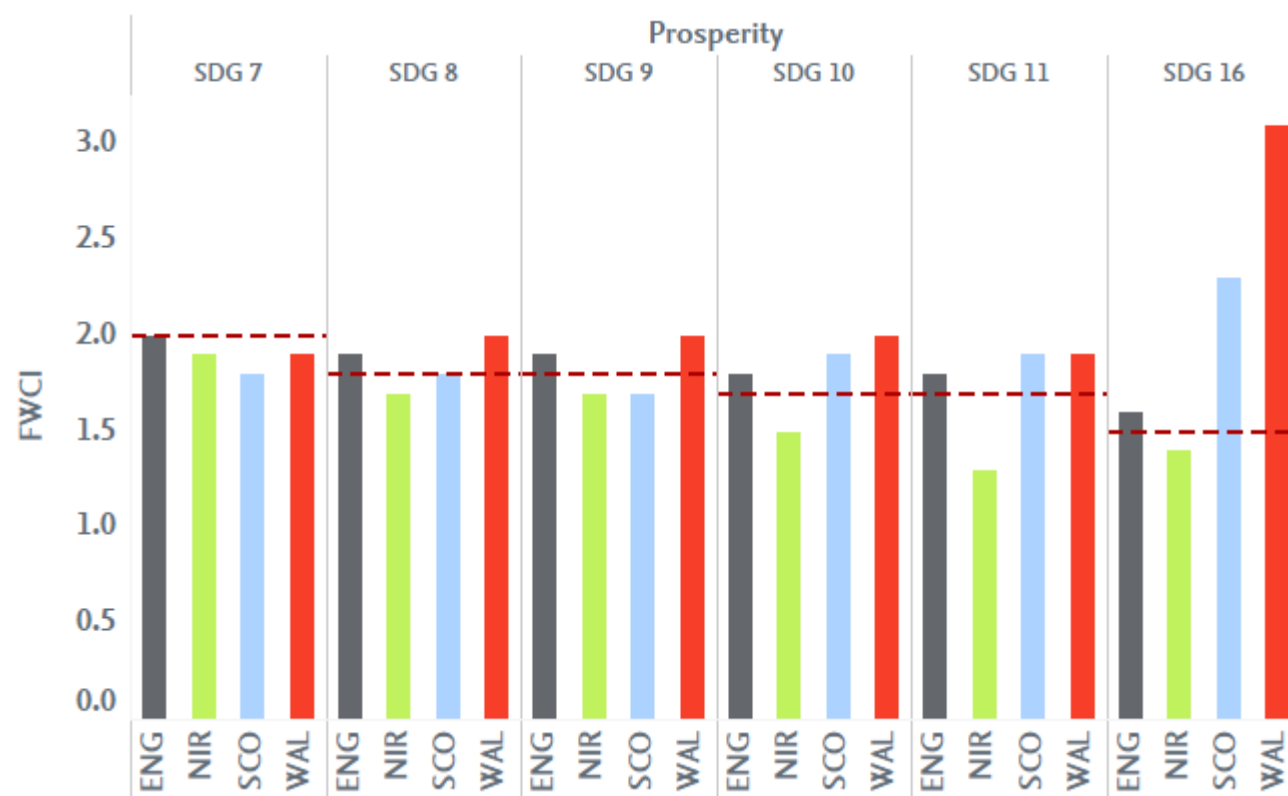
Wales showed an FWCI of 1.9 for SDG 7 (Clean and Affordable Energy)

The relative research shares for SDG 7 (Clean and Affordable Energy) publications for each of the UK nations either equaled (Northern Ireland) or were (Wales, Scotland and England) below the global average of 4% (FIGURE 3-27). This may be explained by China's strong footprint in this theme, which influenced the global average due to its large number of publications. Although the relative publication shares were below the world average, the citation impact of the UK nations' publications were well above it. The UK had an FWCI of 2.0, with Wales only slightly below it.

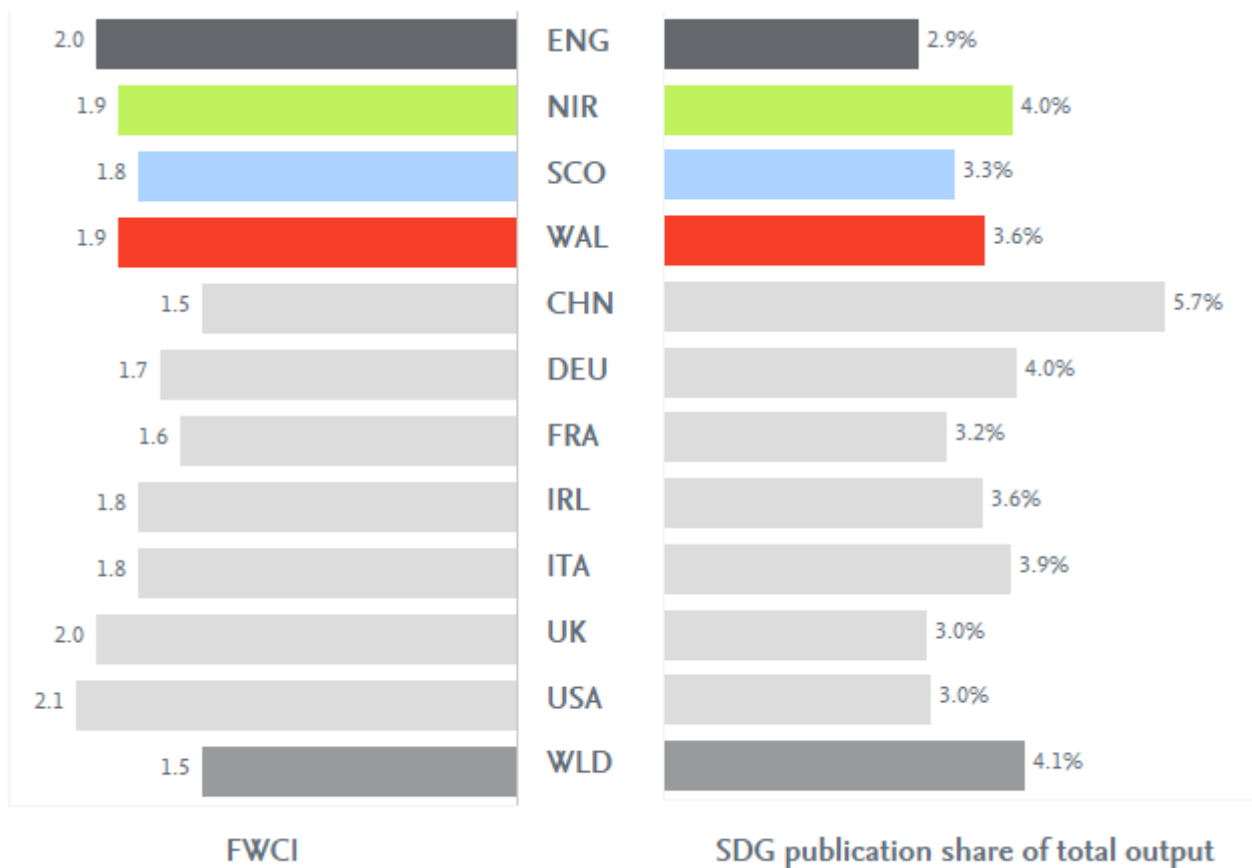| FWCI		SDG publication share of total output
2.0	ENG	2.9%
1.9	NIR	4.0%
1.8	SCO	3.3%
1.9	WAL	3.6%
1.5	CHN	5.7%
1.7	DEU	4.0%
1.6	FRA	3.2%
1.8	IRL	3.6%
1.8	ITA	3.9%
2.0	UK	3.0%
2.1	USA	3.0%
1.5	WLD	4.1%

FIGURE 3-27
Share (right panel) and FWCI (left panel) of publications in SDG 7 for Wales and global comparators, 2010–2019.
Source: Scopus

Wales' research publications were highly collaborative, with more than 50% of publications internationally collaborated and 11% cross-sectoral. The main collaborators for these publications were local corporations such as Motor Design Ltd and IQE plc.
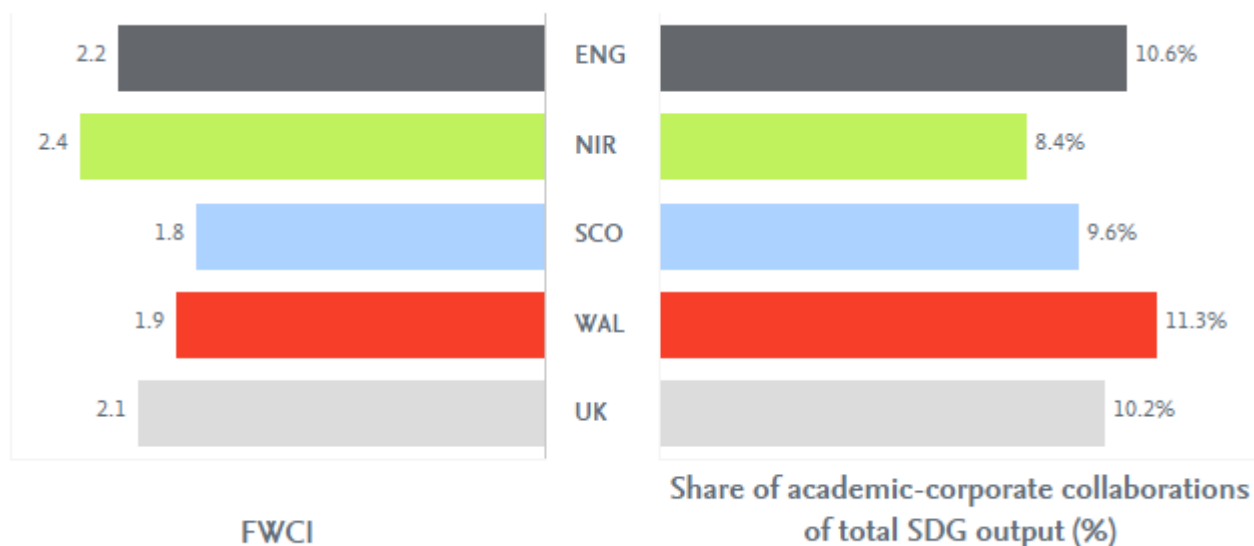
FIGURE 3-28
Share (right panel) and FWCI (left panel) of academic-corporate co-authored publications in SDG 7 for Wales and other UK nations, 2010–2019.
Source: Scopus

All Welsh universities had research publications in SDG 7 (Clean and Affordable Energy), with Cardiff University and Swansea University being most active, but with Bangor University, Aberystwyth University and Wrexham Glyndwr University also showing considerable output. Focus areas within this SDG were 'Solar Cells', 'Wind Turbine', and 'Smart Grids' and 'Electric Vehicles' (FIGURE 3-29). This differed only slighty from global research topics: similar keywords appeared globally, although 'Biodiesel' also featured prominently.
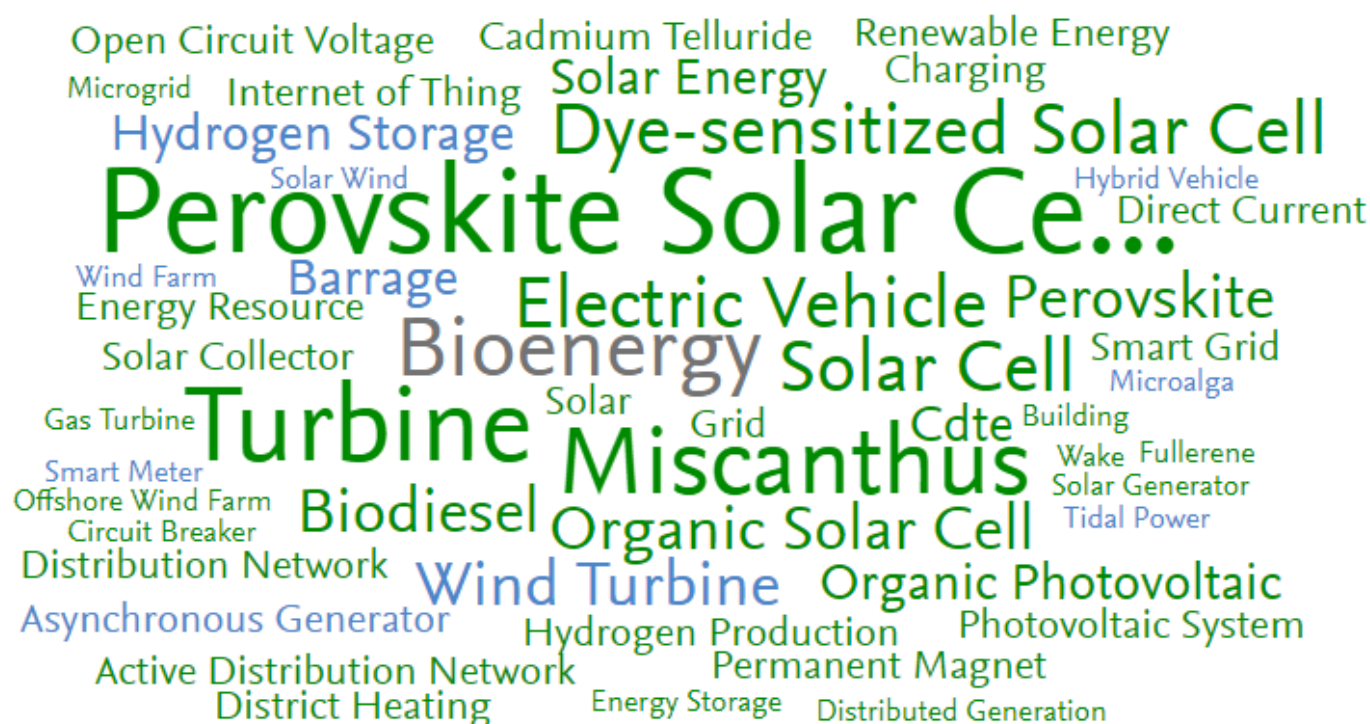
SDG 8, SDG 9, and SDG 9 for Wales were at UK level in impact and relative activity—above the global average

SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure) and SDG 10 (Reduced Inequalities) showed a Welsh activity level around the UK average, with a citation impact also around the UK average. It should be noted that the United Kingdom was one of the main global contributors to these three SDGs over the study period. Therefore, showing activity and impact at UK level means scoring well above the global averages.

In the case of SDG 16 (Peace, Justice and Strong Institutions), Welsh research publications produced the highest FWCI of all global comparators

For SDG 16 all UK nations produced a share of SDG publications well above the global average. This performance may have benefited from a language bias, as SDG 16 (Peace, Justice and Strong Institutions) was dominated by English language literature. The main contributors to this SDG were the United States, the United Kingdom, Australia and Canada.

Ireland was at a similar level to Wales, showing a high FWCI as well. Although Wales had an RAI of 1.1 against the UK level, its FWCI was twice as high as the UK average. The main drivers of impact in this SDG were publications from the Global Burden of Disease Study, although this would not explain the difference between Wales and other UK nations, as all of them participated in this study.

| FWCI		SDG publication share of total output
1.6	ENG	1.9%
1.4	NIR	2.6%
2.3	SCO	1.5%
3.1	WAL	2.1%
1.3	CHN	0.1%
1.5	DEU	0.7%
1.4	FRA	0.5%
2.6	IRL	1.7%
1.5	ITA	0.8%
1.5	UK	1.9%
1.4	USA	1.4%
1.1	WLD	1.0%
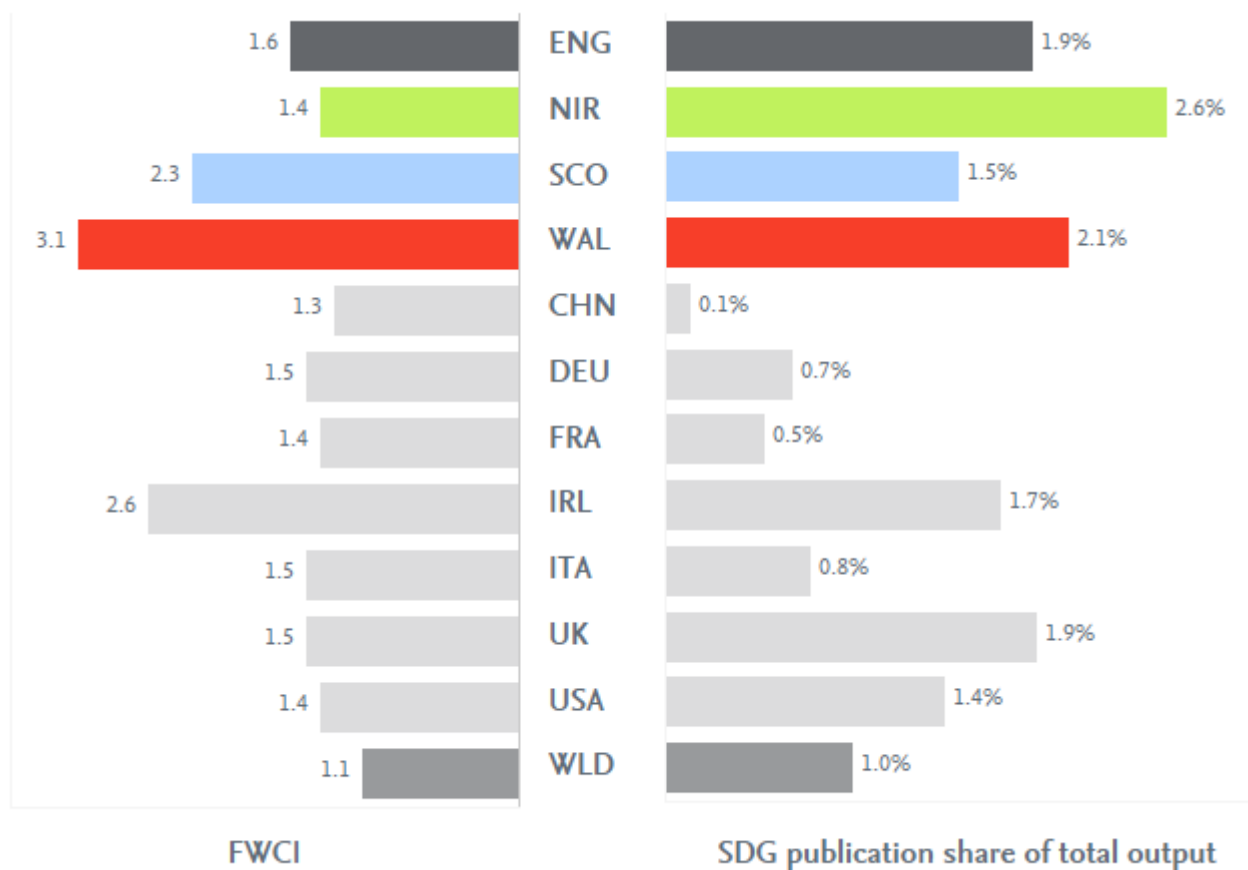
FIGURE 3-30
Share (right panel) and FWCI (left panel) of publications in SDG 16 for Wales and global comparators, 2010–2019.
Source: Scopus

The keyphrases for Welsh research publications in this SDG reflect both local and global research questions (FIGURE 3-31). Wales' research in SDG 16 accrued an FWCI of 3.1 and is mainly driven by participation in the Global Burden of Disease Study (some of its publications included in this SDG). Given the relatively small number of publications, however, these heavily cited publications may have skewed the FWCI. This holds especially for Swansea University.

The effect of hypercollaborative publications was visible in the FWCI for collaborated publications; only 30%
of publications in SDG 16 were published in international collaboration, and this FWCI was driving Wales'
average FWCI in this SDG towards three times the global average. As mentioned already, this may be related
to participation in the Global Burden of Disease Study where some of the publications from SDG 16 are
included within this study. However, this does not explain the difference between the UK nations.
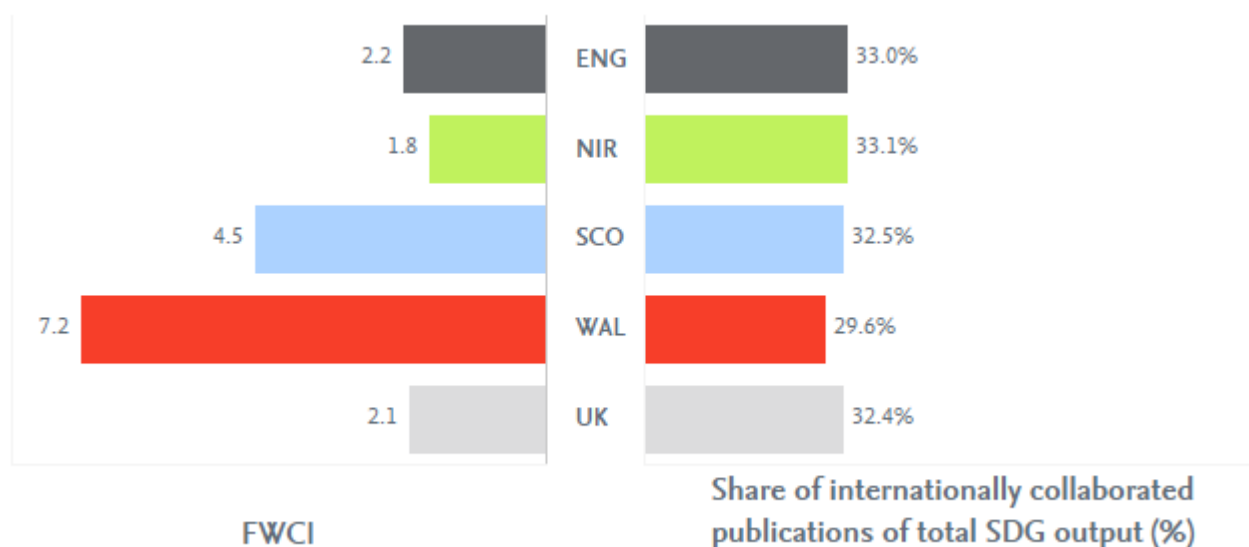
Conclusion

Wales' research output over the past decade demonstrated a strong contribution to the UN's SDGs. Research publications under the Planet themed SDGs, in particular, showed research activity well above UK level. The FWCI of Wales' research publications for this theme was more than double the global average, placing Wales in the leading position for all comparators.

The purpose of this report was to assess and benchmark the performance of Welsh research outputs related to SDG goals over the past decade (2010–2019). This analysis builds on a methodology developed by Elsevier and partners (see chapter 1) that provides a bottom-up approach to identify SDG-relevant publication sets.

The results confirm the contribution that researchers in Wales have made to the United Nations' SDGs, with more than 30% of Wales' total research output related to SDGs. This level of activity was slightly higher than the United Kingdom's share across all SDGs. Despite its limited resources as a small nation, Wales' researchers remained key contributors to the global research on SDGs with high citation impacts.

Wales was among the leading global comparators

Globally, the relative share of SDG-related research for Wales was among global leaders for comparators used and in many cases above the global average. While the research output was well balanced, the main focus for Welsh researchers was on those SDGs related to the Planet theme (SDGs 6, 12, 13, 14, 15) capturing the highest share and the highest FWCI of all UK nations here. Wales' relative activity against the UK average was the highest across all UK nations for all SDGs in the Planet theme. All research institutions in Wales contributed to research dedicated to tackling these challenges for humankind.

The quality of Wales research was very high

In general, Wales' research was highly cited, with an average FWCI of 2.3 across all SDGs. The main drivers of this excellence were SDGs within the Planet theme, such as SDG 13 (Climate Action) and SDG 14 (Life below Water), which attained the highest FWCI. But Wales' research was also highly cited in other themes as well. In particular, SDG 2 (Zero Hunger), SDG 5 (Gender Equality) and SDG 16 (Peace, Justice and Strong Institutions) displayed a very high FWCI. With this high impact, Wales was setting a leading position in global SDG research.

Collaboration remained key

One of the key results of this report is that Wales' researchers collaborated effectively across borders and sectors. Welsh research on the UN SDGs showed the highest FWCIs in areas in which Welsh researchers worked collaboratively with others, regardless of geographies and sectors. This was not limited to what are known as hypercollaborated publications—those including hundreds or even thousands of researchers—but included targeted collaborations with highly renowned international research institutions, whether they were academic or corporate entities.

Appendix A

Glossary of terms

Academic–corporate collaboration is defined as a publication where at least one author is affiliated with a corporation and at least one author is affiliated with an academic institution.

Author refers to any individual listed in the author by-line of a Scopus-indexed publication.

Citation is a formal reference to earlier work in a research journal publication. Citations are used to credit the published source of an idea or finding. The number of citations received by a publication from subsequently published articles are used as a proxy for the influence or impact of the publication in the general available literature. In this report, 'citations' refer to citations by any Scopus-indexed publications, whereas citations made by other types of documents (e.g., patents, clinical guidelines) specifically reference the type of document that the citation was made in (e.g., as 'patent citations' or citations in clinical guidelines).

Collaboration (i.e., research collaboration) is defined as publications resulting from the efforts of two or more authors. Collaboration can be further categorised into the following types:

- International collaboration—affiliations listed by authors include institutions from two or more countries

- National collaboration—affiliations listed by authors include least two different institutions and all institutions are from the same country

- Institutional collaboration—all authors are affiliated with the same institution

Field-Weighted Citation Impact (FWCI) is a recognised indicator of the citation impact of a publication. It is calculated by comparing the number of citations actually received by a publication with the number of citations expected for a publication of the same document type, publication year, and subject. An FWCI of more than 1.00 indicates that the entity's publications have been cited more than would be expected based on the global average for similar publications; for example, 2.11 means 111% more than the world average. An FWCI of less than 1.00 indicates that the entity's publications have been cited less than would be expected based on the global average for similar publications; for example, 0.87 means 13% less than the world average.

In general, the FWCI is defined as:

$$FWCI = \frac{C_i}{E_i}$$

with

C_i = citations received by publication i

E_i = expected number of citations received by all similar publications in the publication year plus following 3 years

When a similar publication is allocated to more than one subject, the harmonic mean is used to calculate E_i.

To calculate mean FWCI for the publication set, we used the following formula:

$$\overline{FWCI} = \frac{1}{N} \sum_{i=1}^{N} \frac{C_i}{E_i}$$

Where N = the number of Scopus-indexed publications in the publication set.

The FWCI is always defined with reference to a global baseline of 1.0 and intrinsically accounts for differences in citation accrual over time, differences in citation rates for different document ages (e.g., older documents are expected to have accrued more citations than more recently published documents), document types (e.g., reviews typically attract more citations than research articles), as well as subjects (e.g., publications in Medicine accrue citations more quickly than publications in Mathematics. The FWCI is one of the most sophisticated indicators in the modern bibliometric toolkit.[20]

The FWCI uses an un-weighted variable 5-year window. The mean FWCI value for 2012 publications, for example, is calculated for documents published in 2012 using their citations in 2012–2017. For recent output with less than five years since publication, all citations available at the date of data extraction are used in the calculation. For instance, if an article was published in 2016, and the data were extracted in 2018, the article's FWCI is calculated using the article's 2016–2018 citations.

Publication (unless otherwise indicated) denotes the main type of peer-reviewed documents published in journals: articles, reviews, and conference papers.

Relative activity index (RAI) is defined as the share of a country's article output on an SDG topic relative to the global (or UK share) of articles for the same topic. For example, Wales published 3.6% of its articles in SDG 7, while for the UK 3.0% of all articles were published in SDG 7. The RAI for Wales in SDG 7 is calculated as 3.6%/3.0% = 1.2. A value of 1.0 indicates that a country's research activity in a field corresponds exactly with the global activity in that field; a value higher than 1.0 implies a greater emphasis; and a value lower than 1.0 suggests a lesser focus.

[20] Purkayastha, A., Palmaro, E., Falk-Krzesinski, H.J., and Baas, J. (2019). Comparison of two article-level, field-independent citation metrics: Field-Weighted Citation Impact (FWCI) and Relative Citation Ratio (RCR). *Journal of Informetrics, 13*(2), 635–642, https://doi.org/10.1016/j.joi.2019.03.012.

Appendix B
Methodology

Our methodology is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. The Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems[21] gives a good overview of this field. It is based on the pioneering work of Derek de Solla Price (1978),[22] Eugene Garfield (1979),[23] and Francis Narin (1976)[24] in the USA; Christopher Freeman, Ben Martin, and John Irvine in the United Kingdom (1981, 1987);[25] and researchers in several European institutions including the Centre for Science and Technology Studies at Leiden University, the Netherlands, and the Library of the Academy of Sciences in Budapest, Hungary.

The analyses of bibliometric data in this report are based upon recognised advanced indicators (e.g., the concept of relative citation impact rates). The base assumption is that such indicators are useful and valid, though imperfect and partial measures, in the sense that their numerical values are determined by research performance and related concepts, but also by other, influencing factors that may cause systematic biases. In the past decade, the field of indicator research has developed best practices that state how indicator results should be interpreted and which influencing factors should be considered. Our methodology builds on these practices.

Counting

All analyses make use of **whole counting** of research publications rather than **fractional counting**. For example, where a paper has been co-authored by an author from Cardiff University and one author from Swansea University, then that paper counts as **one publication** towards the publication count of both institutions. Total counts for each institution or country are the unique count of publications. Hyper-authored publications, defined as publications with more than 100 authors were included in the analysis.

Measuring collaboration

Publications with two or more authors are viewed as collaborations. Collaboration resulting in research publications are a useful measure to understand which researchers are working to generate publications. Collaboration is assessed by analysing the author affiliations associated with each publication and categorising publications based on who has contributed as an author and what each author's affiliation is. Collaboration was assessed based on geography and sector. Geographic collaborations categorise publications into groups based on the location of author affiliations. For example, **institutional collaboration** is ascribed to publications where all authors are affiliated with the same institution; **national collaboration** is ascribed to publications where authors are affiliated with at least two different institutions but where all affiliations are within the same country; **international collaboration** is ascribed to publications where authors are affiliated with at least two different countries. Cross-sector collaborations categorise publications into

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[21] Moed H., Glänzel W., & Schmoch U. (2004). *Handbook of quantitative science and technology research*. Kluwer.

[22] de Solla Price, D.J. (1977–1978). Foreword. In *Essays of an Information Scientist* (Vol. 3, pp. v–ix).

[23] Garfield, E. (1979). Is citation analysis a legitimate evaluation tool? *Scientometrics, 1*(4), 359–375.

[24] Pinski, G., & Narin, F. (1976). Citation influence for journal aggregates of scientific publications: Theory with application to literature of physics. *Information Processing & Management, 12*(5), 297–312.

[25] Irvine, J., Martin, B. R., Abraham, J. & Peacock, T. (1987). Assessing basic research: Reappraisal and update of an evaluation of fourradio astronomy observatories. *Research Policy, 16*(2-4), 213–227.

groups based on the sector of author affiliations and categorises publications according to which sectors are represented among the author affiliations.

Appendix C

Data set creation

Data source

The data sets for each SDG were built using Elsevier's Scopus database of scientific literature, which contains roughly 44 million peer-reviewed documents published in over 50,000 journals since 1996. The document types included in the data sets are **journal articles, reviews, and conference papers covering 2010–2019.** These documents are collectively referred to as 'publications' or 'papers' in this report.

Since 2018, Elsevier has generated SDG search queries to help researchers and institutions track and demonstrate progress towards the targets of the United Nations Sustainable Development Goals (SDGs). At the end of 2018, Elsevier developed two versions of the SDG queries. One version was created by the Elsevier Analytical Services group and another by the Science-Metrix group, who had recently become part of Elsevier. At that time, Science-Metrix was creating queries for 5 of the 16 SDGs, as part of pro-bono work for UNESCO, with the approach outlined below.

SDG topical data sets

A bibliometric study of research related to the SDGs presents challenges, the main ones relates to the creation of "relevant publication data sets". For example, the scope of each SDG is broad, rendering the task of reliably covering all relevant literature problematic; as the search terms used cover a diversity of target topics within each SDG to ensure coverage in these areas. For this report, Elsevier employed a bottom-up approach for the construction of SDG-relevant publication data sets, whereby data sets were first constructed by SDG target and then aggregated at the SDG level. Details of this approach are presented below.

Data set construction

Building the foundation or core data set for each set of target topics within an SDG: First, a brainstorming session took place for each UN SDG. Each session served to challenge the views of three analysts on the definition of each target within an SDG, to reach a consensus on their interpretation in bibliometric terms. To ensure the highest standards of quality, the subsequent work of harvesting the literature of relevance to the agreed definitions was performed manually by analysts skilled in balancing both the recall and precision of bibliometric data sets. The first step in building a topical data set was to define a set of core terms and specialist journals whose specificity to the target at hand was very high. These terms and journals were then used to retrieve matching publications from the Scopus database to obtain a seed data set. This is often the most sensitive part of the process, as the core terms/specialist journals must be very precise and cover all pertinent aspects of the target. Where possible, this was achieved by an analyst familiar with the target at hand. Otherwise, the process was informed by a literature review, which was conducted as a complement to the above brainstorming sessions, thereby offering an elementary understanding of the target. The fact that at this stage, targets were more specific than the overarching SDGs made this an easily approachable task. The papers returned by each query were then inspected to ensure high precision of the seed data set. Queries that returned proportionally too much noise were removed or limited by combination with supplementary terms. At this stage, precision was prioritised (aiming for at least 95 %) at the expense of recall, which remained low (< 60 %) in some cases. Precision is the percentage of relevant papers in a random sample of

publications in the seed data set. Recall is the percentage of publications from the specialist journals that are captured by the selected search terms.

Expanding the seed data set for each target within an SDG: The seed data set was then expanded by broadening the keyword-based query. To simplify this step and all subsequent ones, a data set helper tool was developed. The tool first computed the term frequency–inverse document frequency (TF–IDF) of all noun phrases (extracted using a natural language processing algorithm) appearing in the papers of the seed data set to ease the identification of additional relevant terms. It also computed the number of additional publications each of these terms would add, to help prioritise the selection of additional terms towards increasing recall from the seed. The tool enabled tracking the precision of each search expression before its inclusion in the query. This was achieved by enabling analysts to rate the pertinence of individual papers within random samples of matching publications. The recall figure was continuously updated as the query was expanded. Recall sets other than the seed were also specified to test the recall. During the process, the tool computed the share of each journal's output appearing in the expanding data set. Using this information, analysts looked for journals that had a high share of papers included in the data set and analysed their scope to decide whether it would be worth adding them in full. Work continued until no more relevant terms or journals were worth adding, at which point recall was good (> 70 %) and precision was high (> 90 %).

Final verifications for the expanded data set for each target and merging into a final SDG data set: At this stage, further verifications were performed with the tool's help. The first involved looking for queries with a low contribution to recall yet a very high number of returned papers, as this is often the signature of a search expression that is off-topic or an indication that the seed or other reference data set is missing a portion of relevant research. Another verification was to look at the subfields of science in which the papers were classified to identify those that could be related to off-topic papers. Finally, the recall was also measured for each journal appearing in the data set to search for potential biases across the subject matters of relevance to a given topic (i.e. some specialist journals having lower recall than others).

Updates to the approach

In 2020 inspired by the earlier queries, Elsevier, through its Science-Metrix group, used a new approach to mapping publications to the SDGs. Taking stakeholder feedback into account, they significantly increased the number of search terms used to define each SDG. Those queries were then complemented by a machine learning model, which helped increase the recall by approximately 10%.[26]

As a result, Elsevier's 2021 SDG mapping captures on average twice as many articles as the 2020 version, while keeping precision above 80%. The mapping also has a better overlap with SDG queries from other independent projects. Times Higher Education (THE) are using the Elsevier 2021 SDG mapping as part of their 2021 Impact Rankings.

[26] Rivest, Maxime et al. (2021), 'Improving the Scopus and Aurora queries to identify research that supports the United Nations Sustainable Development Goals (SDGs) 2021', Mendeley Data, V2, doi: 10.17632/9sxdykm8s4.2

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Authors

This study was conducted and written by Dr. Jörg Hellwig, and data extraction was done by Jan-Maarten van Schalkwijk.

Dr. Jörg Hellwig is an Analytical Product Manager at Elsevier's Research Management division. He focuses on analysing the research performance and trends for public agencies and academic institutes. Prior to this role, he worked as a Customer Consultant for Elsevier's Research Intelligence in Germany, the Netherlands, South Africa and the United Kingdom, responsible for supporting the adoption and use of SciVal, Scopus and various analytical tools and solutions for research performance and planning. This role implied a thorough knowledge of the higher education sector in various countries. Dr. Hellwig holds a PhD in Chemistry from Georg August University of Göttingen in Germany, with a subsidiary subject of Communication Theory and Publicism. After receiving his PhD, he worked in pharmaceutical companies for almost 10 years before joining Elsevier in 2008.

Jan-Maarten van Schalkwijk is a data scientist at Elsevier. He is an expert on the extraction of bibliometric and scientometric indicators, which provide quantitative measures in support of research assessment. Prior to his current role, he was the senior pricing analyst for the Research Product portfolio, specialising in value-based pricing models. Within RELX he has won multiple awards, including for innovation.

Notes

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