October 2025

Evaluation of UK Participation in H2020

Final Report - APPENDICES

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Appendix A Methodological detail

This appendix provides additional methodological detail (where needed) on key aspects of the approach to the evaluation. These sections are referenced in the main report.

A.1. Using Generative AI to classify participation per critical technology area

To identify whether a UK participation was linked to critical technologies, we used machine learning to exploit our data[1]. Using CORDA grant records with information on project abstracts, we deployed a neural network, a state-of-the-art natural language processor, to generate text classification i.e., type of critical technology for each UK project.

A neural network is a computational model inspired by how the biological neural networks process information. They consist of layers of interconnected nodes (neurons), each layer transforming the input data in some way to produce an output. Neural networks are more appropriate than traditional models for the task because they can learn complex relationships and patterns in data that simpler models might miss; they handle large amounts of data better; and as the dataset grows, they continue to improve, whereas traditional models may plateau.

There are several limitations associated with developing one's own neural network from scratch. They require large amounts of high-quality data, significant computational power for training, and are susceptible to over or underfitting based on the training data[2]. In order to avoid some of these pitfalls, a pretrained model accessed through OpenAI's API [3] was used.

Our text classification exercise is a straight-forward process involving:

- Defining the data: columns of the CORDA grants data including unique identifiers, project titles and abstracts
- Defining the query: establish the definitions of critical technologies described in the UK Science and Technology framework published in February 2024
- Defining the model: call OpenAI's GPT-4o model to read and classify the data into one or more critical technologies. This model was selected as it provides a balance of analytical capability and efficiency, compared to cheaper models such as GPT-3.5, or the newer GPT-o1, which is better suited to tasks requiring high levels of reasoning but performed similarly to 4o on classification tasks[4].
- Define the output: create a column called Classification where the model inputs the relevant critical technology(ies) for each project in the data

The model reads and identifies if the abstract falls into any critical technology category or none. It also assesses if an abstract is linked to one or more critical technologies. The definition of inputs to the model are:

- Artificial Intelligence (AI): machines that perform tasks normally performed by human intelligence, especially when the machines learn from data how to do those tasks.

[1] UK Science and Technology Framework, DSIT, February2024

[2] Overfitting refers to a machine learning model performing well on training data but struggling to correctly classify unseen data, whereas underfitting is when a model fails to capture the relevant patterns.

[3] OpenAI's API (Application Programming Interface) allows a user to access and deploy their models without the input data being used for further training of this and future models. In other words, the data remains private and can be analysed in a more parallelised process than the typical question-answer format of ChatGPT.

[4] E.g. https://www.vellum.ai/blog/analysis-openai-o1-vs-gpt-4o and own testing

- Engineering biology: the application of rigorous engineering principles to the design of biological systems.
- Future telecommunications: evolutions of the infrastructure for digitised data and communications.
- Semiconductors: a class of electronic materials with unique properties that sit at the heart of the devices and technology we use every day.
- Quantum technologies: devices and systems which rely on quantum mechanics, to provide capabilities that 'classical' machines cannot.

OpenAI's GPT-4 (Generative Pre-trained Transformer 4) is an advanced language model based on the Transformer architecture. The model can attend to different words in a sentence and understand their relationships regardless of their position in the text. GPT-4 can be fine-tuned for specific tasks (such as text classification, summarisation, etc.) by exposing it to labelled datasets for those tasks. In our case, prelabelled data was not available, so we used 'zero-shot classification', which refers to classification where the model has not been specifically trained on these categories. Although relevant training data for fine tuning is always ideal, GPT-4 has been trained on a vast range of data from various domains, and has learned to understand language structure, technical terminology, and common patterns in scientific research papers, making it well-suited for classifying texts into technology categories.

OpenAI's GPT-4 model stands out among its peers in the family of large language models, including earlier versions like GPT-3, and other models such as Google's BERT or Meta's LLaMA. While GPT-3 was already a leap forward in natural language understanding and generation, GPT-4 improves upon it with better contextual understanding, reduced biases, and enhanced accuracy in complex tasks. Moreover, GPT-4's ability to operate with few-shot (minimal examples) and zero-shot learning allows it to generalise to tasks with minimal training data, making it more adaptable than many of its counterparts.

However, because we were relying on zero-shot classification, we ensured that we used a human-in-the-loop to mitigate any errors. This involved a small random selection of classifications being verified by two individuals independently (n=30 each). This process of quality assurance suggests the model is prone more to producing false-positives than false-negatives. Therefore, we get more projects classified into a critical technology that they may not be strictly related to, however no project is classified as not associated where it indeed is. We find the occurrence of a false positive is 1 in every 15th project (7% of projects). When this bias was identified, the prompt was refined to make it clearer that 'None' was an equally valid option. While this was not 'overfitting' in the traditional sense, LLMs across the board have a tendency to choose a category label rather than not[5], so slight overrepresentation was expected. After adjustments of the prompt mitigated this error somewhat, the extent of the residual false-positives in the final output was not found to be problematic.

[5] Tam, Z. R., Wu, C.-K., Lin, C.-Y., & Chen, Y.-N. (2025). None of the Above, Less of the Right: Parallel Patterns in Human and LLM Performance on Multi-Choice Questions Answering. Findings of ACL 2025. DOI: 10.18653/v1/2025.findings-acl.1031

Xu, H., Zhang, Y., Wang, H., Li, X., & Chen, W. (2024). LLMs' Classification Performance is Overclaimed. arXiv e-prints. DOI: 10.48550/arXiv.2406.16203

A.2. Bibliometrics

A.2.1. Source

Bibliometric data was collected through the OpenAlex API. OpenAlex is a bibliographic catalogue of scientific papers, authors and institutions accessible in open access mode.

OpenAlex offers an open replacement for industry-standard scientific knowledge bases like Elsevier's Scopus and Clarivate's Web of Science. Compared to these paywalled services, OpenAlex offers significant advantages in terms of inclusivity, affordability, and availability.

Bibliometric data was retrieved for the publications emerging from H2020 projects as per CORDA data, where there was at least one UK participant, and at least one UK-based author contributing to the publication. The authors' country of residence was based on the country codes assigned by OpenAlex, which in turn is based upon their affiliated institution(s).

A total of 198,694 publications were produced as part of a H2020 project that included a UK participant. Of these, 152,933 had a valid DOI (Digital Object Identifier) that enabled them to be searched in OpenAlex. 116,093 publications (58% of the original set from CORDA) were successfully identified in the database, and after filtering for those that included at least one UK author, the final number of publications was 40,136.

Benchmarking data was collected for three groups:

1. Publications from UK researchers who had contributed to papers emerging from UK H2020 project, but excluding the publications from H2020. Each author is assigned a unique ID in OpenAlex, allowing for their associated works to be easily identified without relying on name-matching.

   Out of the 40,136 H2020 publications with UK involvement, there were a total of 57,723 unique UK authors. These authors produced a total of 991,716 publications between 2007 and 2024.
2. UK publications involving international collaboration. International collaboration was identified as instances where authors were from the UK and at least one other country, based on author's assigned country codes.
3. UK publications not involving international collaboration.

Benchmarked publications were filtered to 2007-2024 inclusive, to encompass periods before, during and after H2020. All publications were also required to be from a 'core source' as identified by the CWTS[6]. Any duplicate publications were removed, using their DOI (Digital Object Identifier) as a unique identifier.

For each publication, the following information was gathered:

- Title
- Authorships
- Publication Year
- Field Weighted Citation Impact (FWCI)[7]

[6] https://zenodo.org/records/10949671

[7] FWCI is a metric of citation impact that accounts for field, publication type and year of publication. It represents the ratio of citations received/ citations expected over a three-year period. For more information on how the FWCI is calculated in OpenAlex, see: https://help.openalex.org/hc/en-us/articles/24735753007895-Field-Weighted-Citation-Impact-FWCI

- Topics
- Associated Sustainable Development Goal(s), if relevant[8]

OpenAlex assigns each publication up to three topics. These topics are relatively granular concepts, and each is associated with a higher level sub-field, field, and domain[9]. For the purposes of this exercise, FWCI was aggregated by Field, which is based on Scopus' Subject Area Classifications[10]. There are many cases where more than one topic assigned to the publication falls within the same field, so any duplicates here were removed and only unique fields were kept.

Section A.2.3 below further discusses comparability with other proprietary data sources.

A.2.2. *Other data sources*

Data regarding citations in policy were gathered using **Overton**. Overton is the world's largest searchable database of policy documents and grey literature, encompassing over 16 million documents from more than 30,000 organisations across 190 countries. It aggregates materials such as government guidance, parliamentary transcripts, and think tank research, automatically identifying references to scholarly works within these documents. Researchers and institutions use Overton to discover policy documents, track where their work is cited in policy, and understand the broader policy landscape. Its tools for measuring research impact on government policy help develop impact case studies and enhance policy engagement.

Despite its strengths, Overton, like all databases, offers policy citations as proxies rather than definitive measures of influence. While the platform provides unparalleled access to a vast array of policy documents, interpreting its data requires consideration of several caveats. Incomplete coverage, especially for older years or regions with fewer formal policy registries, may introduce geographic and temporal biases. The lack of a standardised citation framework across policy documents can also affect the representation of scientific influence. Furthermore, not all policymakers cite scientific literature, and many policy decisions lack formalised documentation. These factors underscore the importance of complementing Overton's insights with a broader contextual understanding to ensure balanced assessments of policy engagement and influence.

Additionally, some duplicate records may occur in Overton as it classes the same document published in different sources as separate entities. This is by design, to reflect the variances in reach and visibility the same document may have when published by different organisations, however it may also inflate the count of distinct policy citations.[11]

Without a unique identifier to account for this, these duplicates could therefore not be removed without some risk of error or individual manual checks. However, any other duplication was removed, based on Overton's internal document IDs.

The **Patent Statistical Database (PATSTAT)** was used to extract data on relevant Non-Patent Literature (NPL). PATSTAT is a comprehensive global database maintained by the European Patent Office (EPO), designed for statistical research and analysis of patent data. It provides

[8] SDGs are tagged in OpenAlex using a machine learning model: https://github.com/ourresearch/openalex-sdg-classifier

[9] For more information on this hierarchy and tagging process, see: https://help.openalex.org/hc/en-us/articles/24736129405719-Topics

[10] https://service.elsevier.com/app/answers/detail/a_id/12007/supporthub/scopus/

[11] For more information on how Overton disambiguate their policy documents, see: https://help.overton.io/article/how-we-disambiguate-policy-documents

detailed bibliographic, legal status, and citation information on patents filed across multiple jurisdictions. It is an essential resource for understanding global innovation trends, technological advancements, and intellectual property landscapes.

A.2.3. Comparability with other proprietary data sources

The FWCI shown here are higher than the scores found using some other proprietary data sources[12]. It is important to note that FWCI are not comparable across scholarly databases. This is mainly because each database contains a different set of journals/publications which will inevitably lead to different indicators / values.

OpenAlex contains around 201M articles, compared to Scopus' ~71,6 M articles. (Beyond articles, Open Alex has 267.8M documents and Scopus has about 102M).

One of the main differences (and value added of OpenAlex) is that it includes a more comprehensive list of papers, including those that are open source. This should provide a better representation of scholarly production.

Many of these additional documents have zero citations, meaning that the calculated FWCI will be higher in OpenAlex and not comparable to other providers.

The higher results for the UK using OpenAlex reflect the fact that once the larger 'population' of scholarly production is taken into account, UK publications fare better than comparators.

Including more open-source publications provides a better picture in terms of knowledge flows, as these publications would then be used by a wider audience (without access to proprietary databases / journals), increasing their outreach and potential impact.

There are other discrepancies between Open Alex and other databases, including the fact that they base their analysis on main discipline / field and that the date of publication is the year in which publication first became available online[13].

Note also that outliers can play a role in the results. The main report showcases 3 examples of papers with high citations, while also showcasing why they have been so influential. One could argue that outliers should be excluded, but this is debatable. Excluding your best performers will flatten out results, which would in turn disadvantage publications that have excelled.

A.3. Survey

We administered online surveys to all identifiable UK Horizon 2020 applicants across all types of organisations (higher education, business, research organisations, and others).

One survey was designed for successful UK applicants and focused on their perceptions of the impact of receiving funding. The other, designed for unsuccessful applicants, explored their views on the implications of not receiving support. The questionnaires are presented in Appendix G.

Note that there were significant gaps in the participant contact information available and we were only able to identify ~10,000 unique named contacts across the ~100,000 UK participations in H2020 proposals (noting that the same contact may apply to multiple

[12] https://www.gov.uk/government/publications/international-comparison-of-the-uk-research-base-2025/international-comparison-of-the-uk-research-base-2025

[13] For more information on how the FWCI in OpenAlex differs from other providers, see: https://help.openalex.org/hc/en-us/articles/24735753007895-Field-Weighted-Citation-Impact-FWCI

participations, so even with a complete database we would not expect 100,000 unique contacts). Given differing GDPR rules across different areas of Horizon 2020 (e.g. differing periods for which contact information is held), there may also be a bias in the areas of the programme that contact details were available.

Email invitations were sent to each applicant group on 10 June 2025. For the successful applicant survey we approached all UK contacts (with an email address) that were identified within the e-CORDA database against one or more Horizon 2020 projects (as the contact for the coordinator or a partner organisation). These contacts were deduplicated (based on email address), such that individuals were only approached once, regardless of the number of projects they were identified against. For the unsuccessful applicant survey we approached all UK contacts (with and email address) that were identified within the e-CORDA database against one or more Horizon 2020 proposals (coordinator or partner) – and where this email address was not already identified for the successful applicant survey. Again, contacts were deduplicated (based on email address), such that individuals were only approached once, regardless of the number of proposals they were identified against.

On the day of launch, several respondents flagged that they had received the invite for the survey of unsuccessful applicants, despite having received funding under the Horizon programme. This highlighted an issue with the gaps in the contact information available from e-CORDA (whereby an individual's contact details may be present for a proposal that was unsuccessful, but missing for a proposal that they were also involved with that was successful). To ensure respondents completed the appropriate survey and to maximise response rates, we included a qualifying question at the beginning of the unsuccessful applicant survey. This identified any applicant who had received Horizon 2020 funding and automatically routed them to the survey designed for successful applicants.

Email reminders were sent to every two weeks to all contacts who hadn't started or completed a survey.

For the successful applicant survey, 486 individuals were initially contacted (based on the approach set out above), with 55 direct responses (an 11% response rate). However, an additional 516 individuals were re-routed from the unsuccessful applicant survey and completed the successful survey, bringing the total number of responses to 571. Of these, 418 completed the entirety of the survey (i.e. they reached the final page).

Table 1: Respondent summary, successful applicants

Group	Total contacted (#)	Total responded (#)	Response Rate (%)	Completed entire survey (#)
Successful applicants (at least 1 successful application)	486	55	11%	
Routed from unsuccessful survey		+ 516		
Total		**= 571**		**418**

For the unsuccessful applicant survey, 9,837 individuals were initially contacted, although 516 of these were subsequently re-routed to the successful applicant survey. A total of 575 responses were received (6% response rate), with 297 reaching the end of the survey. While the response rate was higher among successful applicants (who tend to be more willing to engage with such exercises), the larger pool of unsuccessful applicants meant that a large number of responses was obtained in both cases. The routing strategy also helped boost participation among successful applicants, ensuring a more balanced dataset.

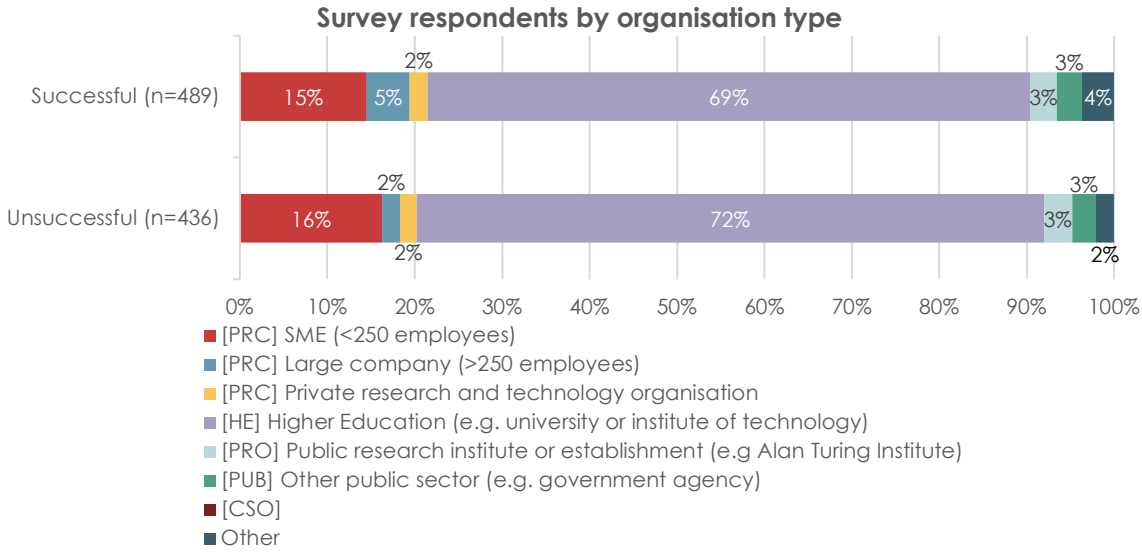
Table 2: Respondent summary, unsuccessful applicants

Group	Total contacted (#)	Total responded (#)	Response Rate (%)	Completed entire survey (#)
Unsuccessful applicants	9,837			
Unsuccessful applicants (excluding those rerouted)	9,321	**575**	6%	**297**

After cleaning the data of invalid and duplicate responses, we received 1,125 valid responses to our survey, including 570 successful applicants and 555 unsuccessful applicants. Questions within the survey were optional, resulting in a variable response rate per question. We therefore note the number of respondents for each question in the analysis.

Figure 1 shows the profile of respondents by their organisation type. Most survey respondents were from higher education sector (69% of successful respondents and 72% of unsuccessful respondents, reflecting their prominence amongst H2020 participants.

Figure 1 Share of survey respondents by organisation type for successful and unsuccessful applicants



Source: Technopolis (2025)

It is difficult to compare the distribution of responses with the population as a whole. The survey responses are based on individual contact persons (who may have participated in multiple proposals / projects), while the e-CORDA database is missing details of large numbers of individuals, while information on organisations is not standardised (and so it is challenging to deduplicate based on this). However, the table below sets out the distribution of UK participations in proposals and projects by organisation type, as an approximate benchmark.

Table 3: Number of UK applicants in proposals and number of project participants by organisation type

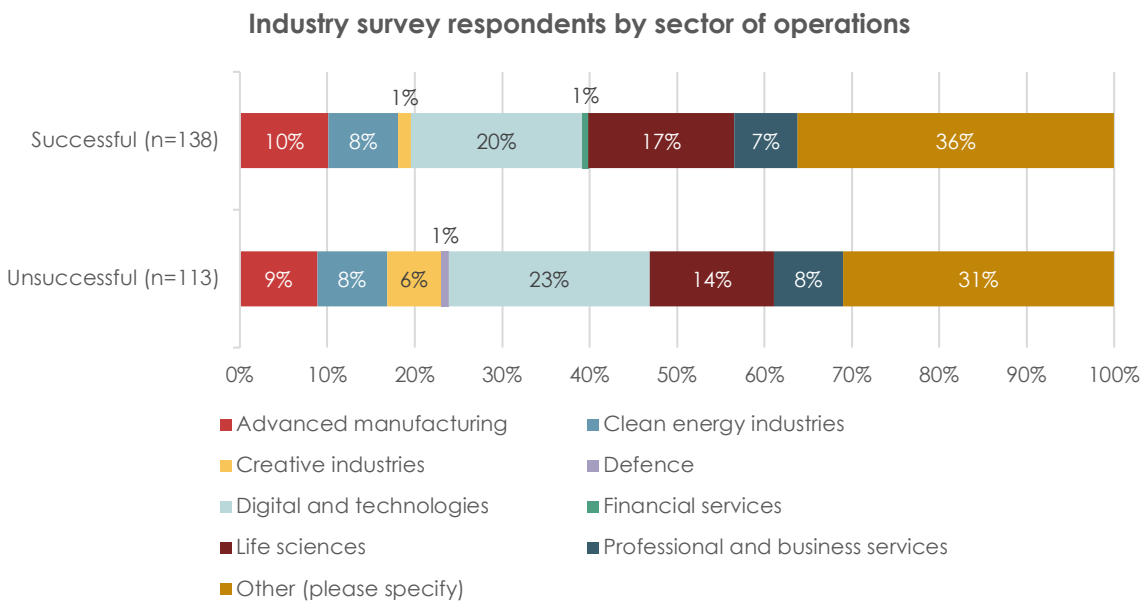
	UK Applicants	UK Participants
PRC SME	17%	14%
PRC large	15%	6%
PRC private research and technology organisation	n/a	6%
HE Higher Education	58%	59%

PRO Public research institute or establishment (REC)	5%	8%
PUB other public sector	2%	3%
CSO	n/a	n/a
Other	2%	4%
Total	**102,251**	**16,676**

Source: Technopolis (2025)

We also captured the sector of operations of the industrial survey respondents. Figure 2 shows the profile of operations for the successful and unsuccessful applicant survey respondents. Organisations in the digital and technologies sector constitute the largest share, representing 20% and 23% of successful and unsuccessful respondents respectively. This is followed by respondents within life science industries, advanced manufacturing, clean energy industries and professional/business services. Respondents who answered 'other' indicated they are part of agricultural, environmental, space, and engineering industries among others.

Figure 2 Share of industry survey respondents by sector of operations for successful and unsuccessful applicants



Source: Technopolis (2025)

Our survey of H2020 applicants contained several open text questions for respondents to express their answers without the constraints of distinct, pre-selected options. We received more than 4,000 open text responses across the 17 open text questions. Given the volume of qualitative data, an AI-assisted approach for analysis was adopted. We implemented OpenAI's GPT-4o's model (discussed in Section A.1) for its advanced natural language understanding capabilities. We used prompt engineering to describe the nature of the data, provide the open-text responses, and explain the output required. This allowed the model to extract common sentiments expressed among respondents, conduct quantitative analysis on the prevalence of key sentiments, and extract remarkable quotes. We used the default model parameters, except setting temperature=1 to produce a replicable output.

Generative AI is not error-free, so we implement specific measures to maximise transparency and identify inaccuracies. Custom prompts were designed to ensure rigour and transparency in the analysis. To ensure traceability and transparency, the model was required to include full phrases from original responses in quotation marks. To prevent any hallucinations, all quotes that were output by the model were identified in the raw open text. The output from OpenAI was used solely as a summary of each question and all analyses were developed from this, strengthened by human insights.

The model was accessed securely through Microsoft's Azure OpenAI platform, and does not use user input for training. No data ever leaves our Microsoft-protected servers under any circumstance. In addition, no personally identifiable information was included in the data submitted to the model.

A.4. Stakeholder Interviews

A programme of semi-structured stakeholder interviews was undertaken with senior representatives from the UK research and innovation sector. The intention was to capture higher level / strategic views on UK participation, benefits and the role and added value of Horizon 2020 (and FP) funding from across key stakeholder bodies.

A topic guide was developed to frame these interviews, which covered the following topics:

- Horizon 2020 in the context of wider activities
  - Rationale for pursuing / investing in international R&I collaboration. Why / when is it important.
  - Scale and importance of international R&I collaboration. Role / place of H2020 / FP within this.
  - Advantages / disadvantages of UK participation in H2020 / FPs vs other international efforts. Unique role played by H2020 / FP. Added value of H2020 / FP.
- Counterfactual
  - What does H2020 / FP funding enable, that wouldn't be possible otherwise (scale, access, scope, timing, resources, expertise, infrastructure, outcomes, impact, etc.)
  - Without H2020 / FP, could similar objectives be achieved. To what extent / how.
- EU-referendum
  - Implications for collaboration and partnerships
  - Lessons for the value of international R&I programmes
- The future
  - Role of FP participation in international strategies.
  - Importance / value of UK participation in FPs
  - Barriers / challenges to FP application, participation and benefits.

Nine individuals were suggested to DSIT by the study team, based on desk research and our knowledge of the sector. DSIT complemented this list with a further nine individuals, meaning 18 stakeholders were approached in total. This included representatives from government (DSIT, DESNZ, DEFRA, Scottish Government, Northern Ireland Executive) and its agencies (UKRI, UKSA), plus other relevant bodies (British Academy, Royal Academy of Engineering, Academy of Medical Sciences, Universities UK, Confederation of British Industries).

Potential interviewees were approached by email, with at least one reminder sent. A total of 14 individuals agreed to be interviewed and were consulted. The role / department and organisation of these individuals is summarised in the table below.

Table 4 Stakeholder interviewees

European Programmes, DSIT	International, UKRI
UK-EU Research Policy, DSIT	Horizon Europe NCP, IUK UKRI
International and Economic Security Analysis, DSIT	Global Strategy, Policy and Engagement, British Academy
Research Infrastructure, DSIT	International Partnerships, Royal Academy of Engineering
Research, Economy and EU programmes, NI Exec	Science Policy, Academy of Medical Sciences
H2020 NCP, UKRI	Global R&I Policy, Universities UK
UK Research Office, UKRI	Europe, Confederation of British Industry

A.5. Economic benefits (quasi-experimental approach)

The section presents the detailed methodology for estimating the impact of UK participation in Horizon 2020 on the turnover and employment of industry participants. The analysis is grounded in a staggered difference in difference design. Below, we describe the processes for data preparation, and the matching of treated units to appropriate counterfactuals, before visualising various outputs, including plotted results and tables for relevant sub-groups from descriptive and inferential analysis.

A.5.1. Introduction

We linked e-CORDA data (based on organisation names) to the FAME database[14] to retrieve information on company characteristics and revenue and employment figures for both successful and unsuccessful Horizon grant holders. In total, 1,875 successful (80% i.e., =1875/2341) and 6,939 (52% i.e., = 6939/13392) unsuccessful companies were matched to FAME records. The matched dataset was then reviewed for completeness, duplication and outliers to ensure data quality and reliability.

Turnover and employment data per company runs from 2006 to 2025. We retained companies that had at least 3 years of non-missing turnover and employment data before and after the treatment event. For companies that did not participate, we retained those with at least 9 years of records. The historical data points are essential for establishing a comparable baseline between the two groups, which is critical for robust counterfactual analysis.

Our compilation and analysis of data was structured to support sensitivity analysis. We performed two layers of sensitivity checks – different timing of intervention and different types of companies.

To assess sensitivity to timing of intervention we estimated separate impacts– first, where treatment is assumed to occur in the year in which company joins the programme (project start date), and second, in the year in which company leaves the programme (project end date). The impacts are not expected to manifest in the immediate term; therefore, we hypothesised positive impacts to become observable post leaving the programme. However, we also hypothesised that joining the programme could initiate changes that influence company financials over the successive years. These potential early effects were therefore worth exploring in parallel.

[14] FAME is a comprehensive database focusing on UK and Irish companies, offering rich company data, detailed financials, global ownership structures, risk insights and relevant news.

To assess the sensitivity of impacts to the underlying sample we computed impacts for both SMEs and non-SMEs separately. We hypothesised that the impact of funding and support from the Horizon 2020 programme is more pronounced for the SMEs.

We present results across two scenarios and three sub-groups, yielding a total of six sets of average treatment effect on the treated (ATT) estimates:

Scenario 1: Treatment time = Project Start Year

- All companies: Treated group vs. counterfactual
- SMEs only: Treated group vs. counterfactual
- Non-SMEs only: Treated group vs. counterfactual

Scenario 2: Treatment time = Project End Year

- All companies: Treated group vs. counterfactual
- SMEs only: Treated group vs. counterfactual
- Non-SMEs only: Treated group vs. counterfactual

A note on our Matching and Difference-in-Difference design

To create a counterfactual of successful companies, i.e., a similar company that did not receive the funding, we applied Propensity score matching (PSM). PSM is a statistical technique used to estimate treatment effects by pairing treated and untreated units with similar characteristics. It reduces selection bias by balancing observed covariates between groups, mimicking random assignment. PSM is considered credible because it improves causal inference in observational studies, ensuring that comparisons are made between comparable units, thereby isolating the effect of the intervention more reliably than simple group comparisons.

Our difference-in-difference estimator was based on Sant'anna and Callaway (2021) design. Traditional difference-in-differences (DiD) methods often assume uniform treatment effects and rely on strong assumptions like parallel trends, which can lead to biased results when treatment timing varies. This approach improves credibility by allowing treatment effects to differ across groups and over time, and by comparing treated units only to appropriate control groups. It produces group-time average treatment effects, which are then aggregated, offering a more flexible and accurate framework for policy evaluation in staggered adoption contexts.

In practice, group-time average treatment effects refer to the estimated impact of a treatment for a specific group (defined by the time they first receive the treatment) at a specific point in time. For example, if firms joined a programme in 2020, the method estimates the effect on those firms in 2021, 2022, etc., comparing them only to firms that have not yet been treated by that time. This approach avoids inappropriate comparisons—such as comparing early-treated units to later-treated ones—by ensuring that each group is only compared to valid control units. It allows for dynamic treatment effects (effects that evolve over time) and heterogeneity (effects that differ across groups).

For clarity, we present the stepwise processing and analysis of data split by two scenarios. In the first we present the descriptives of data, matching results and estimation tables for intervention assumed as per project start date. In the second we present the details for intervention assumed as per project end date. Successful applicants are referred to as treated companies / group / unit and unsuccessful applicants as counterfactuals or counterfactual units.

A.5.2. Overview of full data

We have 1,875 treated companies of which 81% are SMEs and 19% are non-SMEs (see Table 5). Assuming treatment occurs in the year when the project started, our usable sample consists of 498 companies with higher representation of non-SMEs to SMEs. Likewise, assuming treatment occurs in the year when the project ended, our usable sample reduces to 321 companies, again with more non-SMEs to SMEs. The share of SMEs reduces due to the lack of statutory requirement for publishing their financial statements.

Table 5: Breakdown of sample, successful companies (treated group)

	All records	**Complete records 1**	**Complete records 2**
All companies	1875	498	321
SMEs-only	1536	209	146
Non-SMEs only	339	289	175

Note: Complete records 1 are total number of companies with at least 3 years of data before and after joining the programme and minus outliers. Complete records 2 consists of total number of companies with at least 3 years of data before and after leaving the programme. Source: Technopolis (2025)

Table 6 compares variable means between the full dataset ("All Records") and two subsets of complete records. Across all variables—Age, Sector, Region, Log Turnover, and Log Employment—complete records show slightly higher averages, particularly for Age and Log Employment, suggesting that companies with complete data tend to be older and larger. The differences are modest for categorical variables like Sector and Region, indicating minimal bias in representation. Overall, the comparison highlights that while complete records may skew toward more established firms, the sample remains broadly representative across key dimensions.

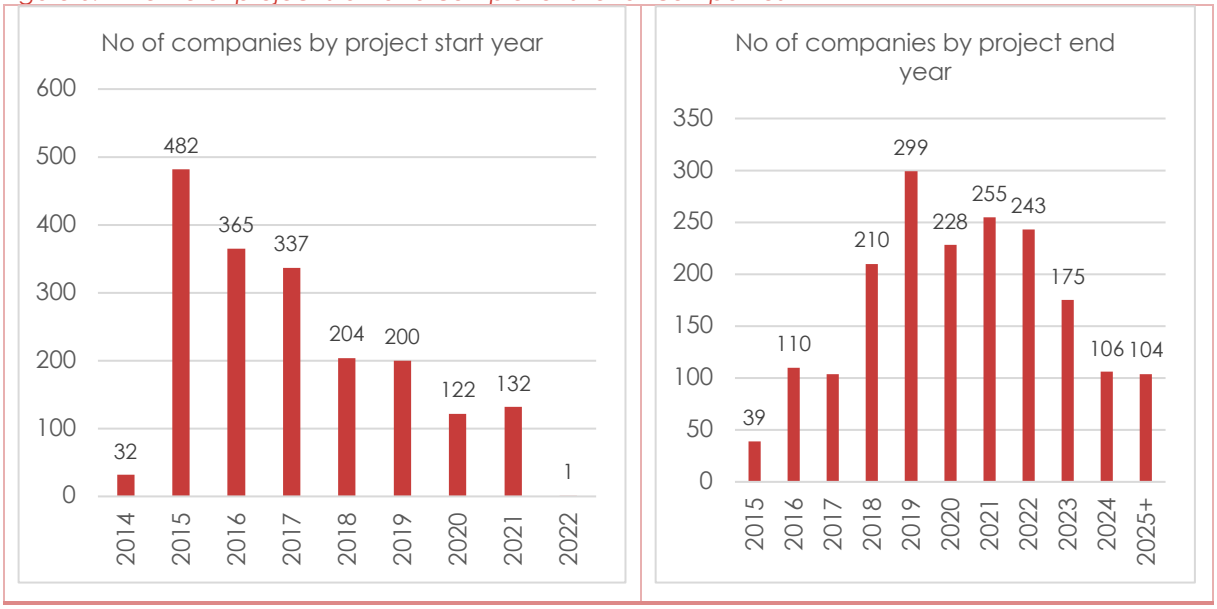
Table 6: Variable means, Population and Sample

Mean	**All records**	**Complete records (1)**	**Absolute Difference**	**Complete records (2)**	**Absolute Difference**
Age	21.8	25.9	4.1	26.6	4.8
Sector	10.7	10.6	0.1	10.6	0.1
Region	5.7	5.6	0.1	5.6	0.1
Log Turnover	9.3	9.5	0.2	9.6	0.3
Log Employment	3.4	4.3	0.9	4.4	1

Source: Technopolis (2025)

In Figure 3, the chart on the left illustrates the distribution of companies across project start dates from 2014 to 2021, with a pronounced peak in 2015 (482 companies), followed by a steady decline through 2021. This suggests a surge in program uptake in 2015, tapering off in subsequent years. The second chart tracks project end dates from 2015 to 2024. Majority project completions occur in 2019 (299 companies) with a sustained mass until 2022 followed by a steady decline. For regressions assuming treatment occurs as per year of project completion we expect low samples of companies that are treated post 2019 and have sufficient post intervention data.

Figure 3: Timeline of project start and completions for all companies



Source: Technopolis (2025)

Due to the paucity of sample in case of late project starts (2020 onwards) and early project end dates (2015-2017), we present results for four periods (years) before and after treatment in both scenarios. We present significance at 1% confidence level.

A.5.3. Scenario 1 – Matching and Regression results

Matching Results

We match a treated company to a control company (counterfactual) using Propensity Score Matching. Probit regression is used to predict propensity of treatment based on age, sector, region, lagged revenue, lagged employment. The process involves dynamic matching; therefore, a company treated in 2016 is matched to a never treated company based on their pre-treated characteristics. We allow treated units to match to any nearest 3 neighbours and with a caliper of 0.05 (difference between propensity scores). We use matched pairs within the common support region (complete overlap of propensity scores). Balance tests show that good matches are achieved.

About 130 treated companies find a counterfactual translating to a sample of matched treated and counterfactual units of 260 companies. As for SME-only companies, the total sample is 72 companies with 36 treated units matched to counterfactual. As for non-SMEs, the total sample is 140 with 70 treated units matched to counterfactual. The non-SME group achieves higher number of matches than SMEs due to a larger underlying sample of complete records.

Table 7: Number of treated companies that were matched to a counterfactual.

Treated units	# found a match
All companies	130
SMEs only	36
Non-SMEs only	70

Source: Technopolis (2025)

Table 8 to Table 10 present post-matching balance tests for all companies, SMEs, and non-SMEs, respectively, to evaluate the effectiveness of propensity score matching in achieving covariate balance between treated and control groups. Across all samples, the matching procedure appears highly successful, with negligible bias in most covariates.

In Table 8 (all companies), mean values for age, region, sector, and lagged performance indicators are nearly identical between groups. Bias percentages are close to zero, and all t-tests yield non-significant results ($p > 0.05$), indicating no systematic differences post-matching. Variance ratios are within acceptable bounds, except for lagged turnover (1.43), which slightly exceeds the threshold.

Table 8: Post-matching balance tests, All companies

	Mean			**t-test**		**V(T)/**
Variable	Treated	Control	%bias	t	p>t	V(C)
Age	36.57	36.57	0.0	0.0	1.0	1
2.region	0.12	0.12	0.0	0.0	1.0	.
3.region	0.22	0.22	0.0	0.0	1.0	.
4.region	0.02	0.02	0.0	0.0	1.0	.
5.region	0.07	0.07	0.0	0.0	1.0	.
6.region	0.04	0.04	0.0	0.0	1.0	.
7.region	0.02	0.02	0.0	0.0	1.0	.
8.region	0.23	0.23	0.0	0.0	1.0	.
9.region	0.09	0.09	0.0	0.0	1.0	.
10.region	0.02	0.02	0.0	0.0	1.0	.
11.region	0.09	0.09	0.0	0.0	1.0	.
12.region	0.06	0.06	0.0	0.0	1.0	.
Sector (SIC 2007)	11.24	11.24	0.0	0.0	1.0	1
Lagged Employment	5.30	5.22	4.3	1.7	0.089	0.94
Lagged turnover	10.45	10.37	3.5	1.45	0.147	0.99
* if variance ratio outside [0.93; 1.08]						

Source: Technopolis (2025)

Table 9 (SMEs only) shows similarly strong balance, with zero bias across most variables. Lagged employment and turnover show minor bias (4.6% and 5%), but t-tests remain non-significant. The variance ratio for lagged turnover (1.43) exceeds the acceptable range, suggesting slight imbalance.

Table 9: Post-matching balancing test, SMEs only

	Mean	**t-test**	**V(T)/**			
Variable	Treated	Control	%bias	t	p>t	V(C)
Age	30.77	30.77	0	0	1	1
2.region	0.2	0.2	0	0	1	.
3.region	0.28	0.28	0	0	1	.
4.region	0.02	0.02	0	0	1	.
5.region	0.14	0.142	0	0	1	.
6.region	0	0	0	.	.	.
7.region	0	0	0	.	.	.
8.region	0.14	0.14	0	0	1	.
9.region	0	0	0	.	.	.
10.region	0.028	0.02	0	0	1	.
11.region	0.11	0.11	0	0	1	.
12.region	0.05	0.05	0	0	1	.
Sector (SIC 2007)	11.08	11.08	0	0	1	1
Lagged employment	3.71	3.66	4.6	0.81	0.41	1.04
Lagged turnover	8.62	8.54	5	1.06	0.28	1.43*
*	if	variance	ratio	outside	[0.86;	1.16]

Source: Technopolis (2025)

Table 10 (non-SMEs) confirms excellent balance, with all variables showing 0% bias and non-significant t-tests. Variance ratios are within bounds, except for lagged employment (0.82), which falls slightly below the threshold.

Overall, the matching procedure effectively balances covariates, supporting the validity of subsequent treatment effect estimation.

Table 10: Post-matching balancing test, non-SME only

	Mean		**t-test**	**V(T)/**		
Variable	Treated	Control	%bias	t	p>|t|	V(C)
Age (sq.)	2334.20	2334.20	0	0	1	1
2.region	0.13	0.13	0	0	1	.
3.region	0.17	0.17	0	0	1	.
4.region	0.01	0.01	0	0	1	.
5.region	0.04	0.04	0	0	1	.
6.region	0.06	0.06	0	0	1	.
7.region	0.04	0.04	0	0	1	.
8.region	0.26	0.26	0	0	1	.
9.region	0.10	0.10	0	0	1	.
10.region	0.01	0.01	0	0	1	.
11.region	0.09	0.09	0	0	1	.
12.region	0.06	0.06	0	0	1	.
Sector (SIC 2007)	11.77	11.77	0	0	1	1
Lagged employment	6.35	6.38	-1.6	-0.48	0.629	0.82*
Lagged turnover	11.67	11.68	-0.6	-0.16	0.87	0.92
*	if	variance	ratio	outside	[0.90;	1.11]

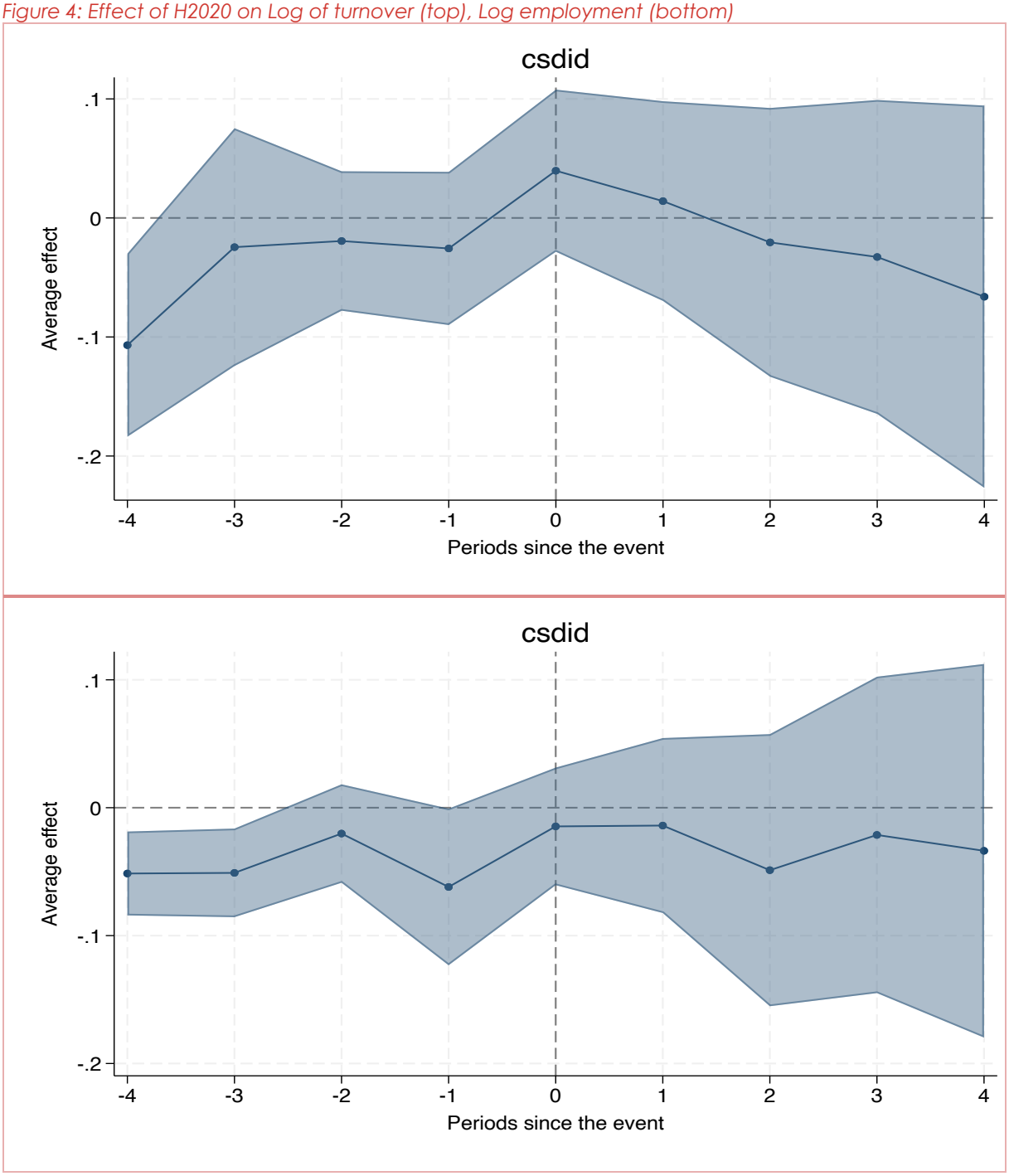
Source: Technopolis (2025)

DiD Results

ATTs – All companies

Table 11, Table 12 and Table 13 present dynamic treatment effects on log turnover and log employment, respectively, using event-time analysis. For both outcomes, average treatment effects before and after treatment (the pointe marked 'csdid' are statistically insignificant, suggesting no strong evidence of impact. Across individual time periods (years), most coefficients are small and non-significant, with wide confidence intervals. Overall, the results indicate limited dynamic effects of the intervention on firm turnover or employment over time.

Figure 4: Effect of H2020 on Log of turnover (top), Log employment (bottom)



Source: Technopolis (2025)

Table 11: Log turnover, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.01	0.02	-0.62	0.54	-0.05	0.03
Post_avg	-0.02	0.07	-0.23	0.82	-0.15	0.11
Tm4	-0.02	0.04	-0.68	0.50	-0.09	0.05
Tm3	0.01	0.03	0.39	0.70	-0.05	0.07
Tm2	-0.02	0.02	-0.98	0.33	-0.07	0.02
Tm1	-0.01	0.03	-0.43	0.67	-0.07	0.04
Tp0	0.02	0.03	0.87	0.38	-0.03	0.08
Tp1	0.00	0.04	0.11	0.92	-0.07	0.08
Tp2	-0.05	0.05	-0.96	0.34	-0.16	0.05
Tp3	-0.05	0.06	-0.85	0.40	-0.17	0.07
Tp4	-0.06	0.07	-0.77	0.44	-0.20	0.09

Source: Technopolis (2025)

Table 12: Log employment, dynamic effects

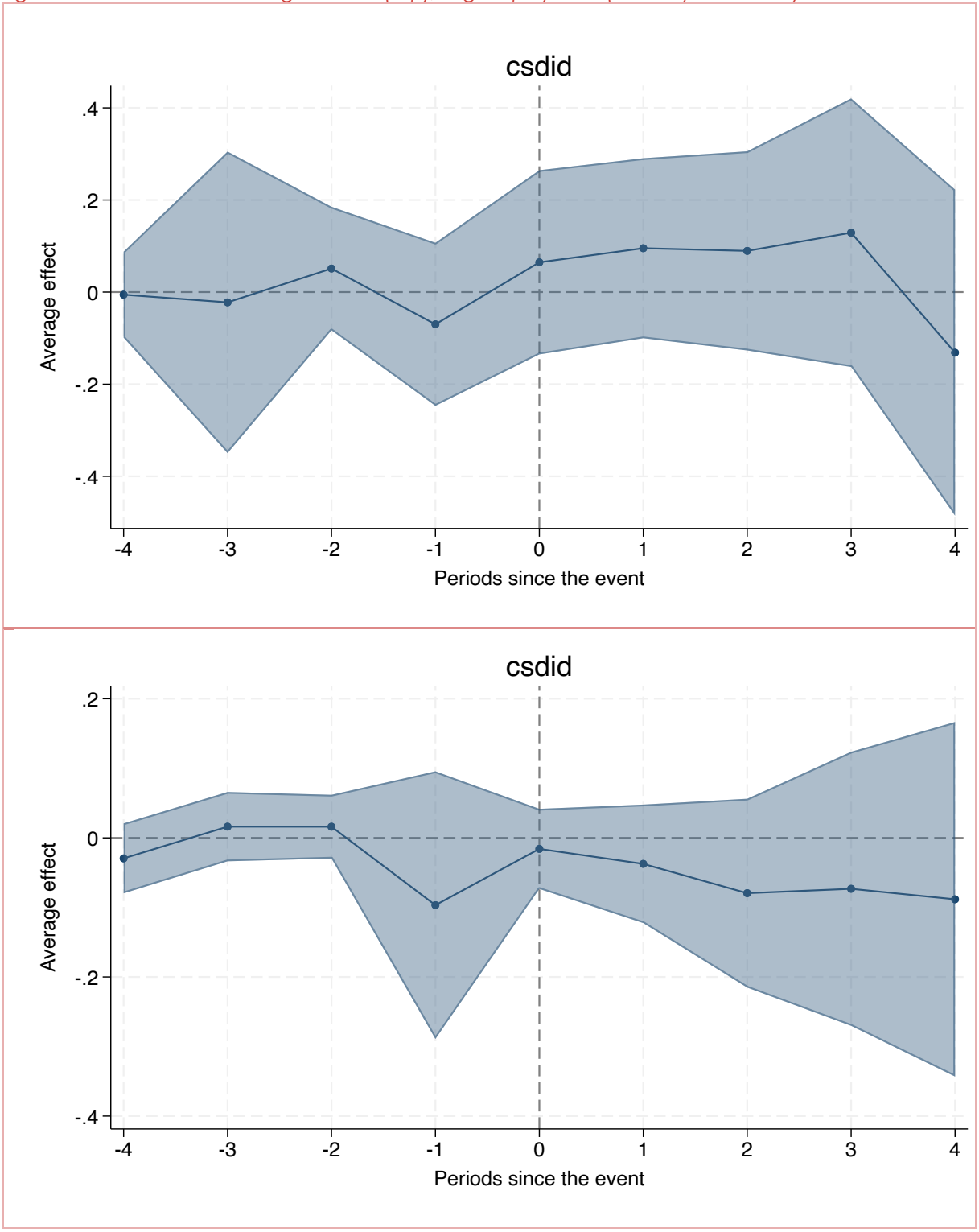
	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.02	0.01	-1.24	0.22	-0.04	0.01
Post_avg	0.00	0.06	-0.03	0.98	-0.12	0.12
Tm4	-0.02	0.02	-0.84	0.40	-0.06	0.02
Tm3	-0.02	0.02	-1.22	0.22	-0.05	0.01
Tm2	0.01	0.02	0.59	0.56	-0.02	0.04
Tm1	-0.02	0.02	-0.86	0.39	-0.05	0.02
Tp0	0.00	0.02	-0.19	0.85	-0.04	0.03
Tp1	0.00	0.03	0.02	0.99	-0.06	0.06
Tp2	-0.01	0.05	-0.31	0.76	-0.10	0.08
Tp3	0.03	0.05	0.56	0.57	-0.08	0.14
Tp4	0.03	0.06	0.47	0.64	-0.09	0.15

Source: Technopolis (2025)

ATTs - SMEs

Table 13 and Table 14 present dynamic treatment effects on log turnover and employment using start-year alignment. The average treatment effect post-treatment is positive for turnover and negative for employment but statistically insignificant for both outcomes.

Figure 5: Effect of H2020 on Log Turnover (top), Log employment (bottom) = SMEs only



Source: Technopolis (2025)

Table 13: Log turnover, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	0.02	0.04	0.60	0.55	-0.05	0.09
Post_avg	-0.20	0.14	-1.41	0.16	-0.48	0.08
Tm4	0.02	0.08	0.21	0.84	-0.13	0.17
Tm3	0.06	0.05	1.13	0.26	-0.05	0.17
Tm2	-0.02	0.05	-0.35	0.73	-0.11	0.07
Tm1	-0.15	0.08	-1.88	0.06	-0.31	0.01
Tp0	0.03	0.07	0.50	0.62	-0.10	0.17
Tp1	-0.01	0.09	-0.06	0.95	-0.18	0.17
Tp2	-0.12	0.11	-1.08	0.28	-0.33	0.10
Tp3	-0.04	0.13	-0.35	0.72	-0.29	0.20
Tp4	-0.13	0.16	-0.83	0.41	-0.45	0.18

Source: Technopolis (2025)

Table 14: Log employment, dynamic effects

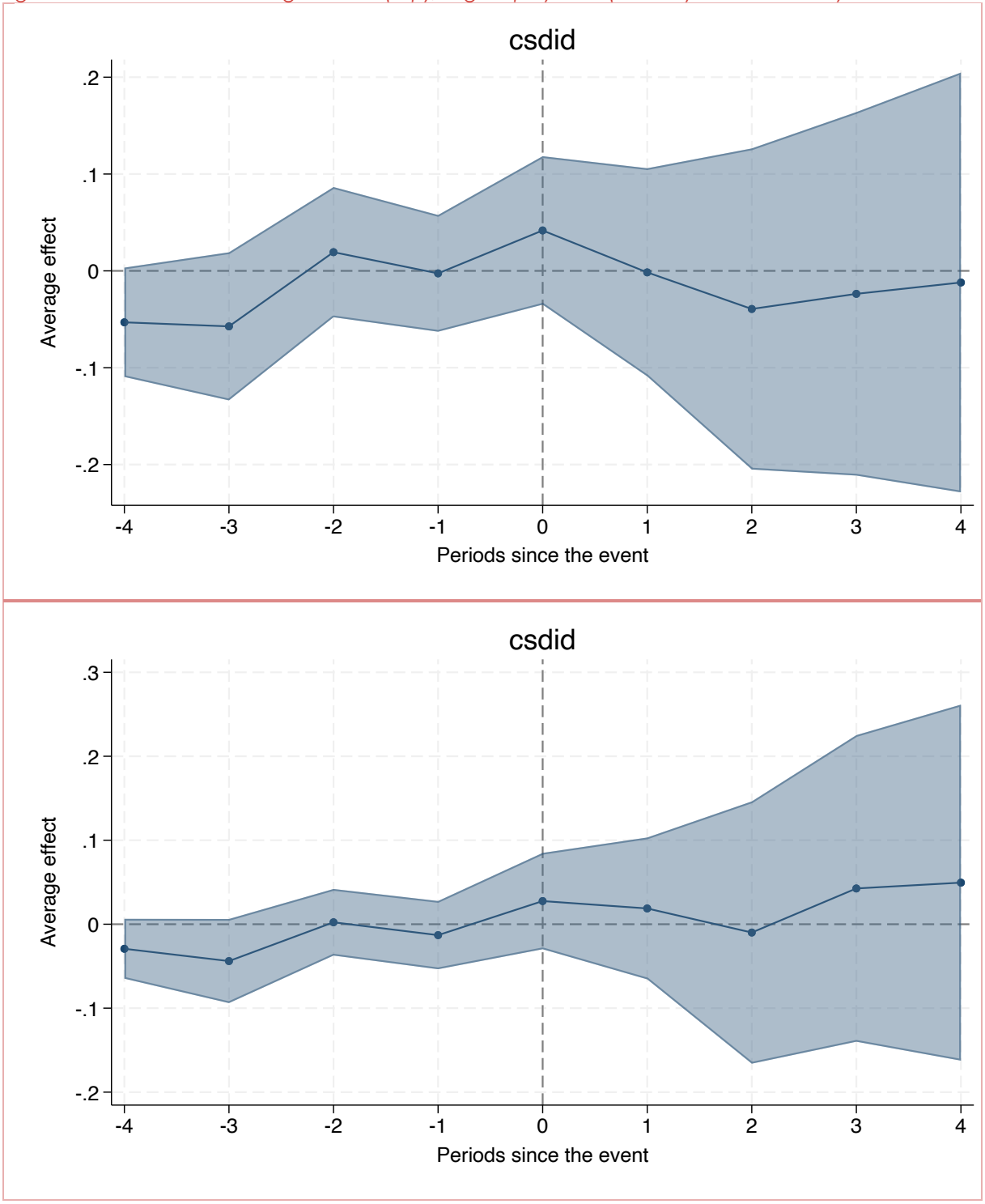
	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.02	0.03	-0.78	0.44	-0.07	0.03
Post_avg	-0.09	0.10	-0.94	0.35	-0.29	0.10
Tm4	-0.03	0.03	-0.98	0.33	-0.10	0.03
Tm3	0.01	0.03	0.24	0.81	-0.05	0.07
Tm2	-0.01	0.04	-0.21	0.83	-0.09	0.07
Tm1	-0.10	0.07	-1.35	0.18	-0.25	0.05
Tp0	-0.06	0.04	-1.59	0.11	-0.13	0.01
Tp1	-0.09	0.06	-1.48	0.14	-0.21	0.03
Tp2	-0.10	0.08	-1.16	0.25	-0.26	0.07
Tp3	-0.06	0.11	-0.53	0.59	-0.28	0.16
Tp4	-0.06	0.12	-0.47	0.64	-0.29	0.18

Source: Technopolis (2025)

ATTs - non-SMEs

Table 15 and Table 16 present dynamic treatment effects on log turnover and employment using start-year alignment with extended pre- and post-treatment periods. The average treatment effects before and after treatment are statistically insignificant for both outcomes.

Figure 6: Effect of H2020 on Log turnover (top), Log employment (bottom) – non-SMEs only



Source: Technopolis (2025)

Table 15: Log turnover, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	0.00	0.02	-0.23	0.82	-0.04	0.03
Post_avg	0.02	0.08	0.19	0.85	-0.15	0.18
Tm4	-0.01	0.03	-0.22	0.83	-0.06	0.05
Tm3	-0.03	0.03	-0.95	0.34	-0.09	0.03
Tm2	0.01	0.03	0.48	0.63	-0.04	0.06
Tm1	0.00	0.03	0.17	0.87	-0.05	0.06
Tp0	0.04	0.03	1.30	0.19	-0.02	0.11
Tp1	0.02	0.05	0.40	0.69	-0.07	0.11
Tp2	-0.02	0.07	-0.30	0.76	-0.15	0.11
Tp3	-0.04	0.08	-0.47	0.64	-0.20	0.12
Tp4	-0.03	0.09	-0.34	0.73	-0.22	0.15

Source: Technopolis (2025)

Table 16: Log employment, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.01	0.01	-1.02	0.31	-0.04	0.01
Post_avg	0.09	0.08	1.05	0.29	-0.07	0.24
Tm4	-0.01	0.02	-0.23	0.82	-0.05	0.04
Tm3	-0.04	0.02	-1.50	0.13	-0.08	0.01
Tm2	0.00	0.02	0.19	0.85	-0.03	0.04
Tm1	-0.02	0.02	-0.93	0.35	-0.05	0.02
Tp0	0.05	0.02	2.01	0.04	0.00	0.10
Tp1	0.06	0.04	1.76	0.08	-0.01	0.13
Tp2	0.03	0.06	0.56	0.58	-0.09	0.16
Tp3	0.09	0.08	1.19	0.23	-0.06	0.24
Tp4	0.06	0.09	0.69	0.49	-0.11	0.24

Source: Technopolis (2025)

A.5.4. Scenario 2 – Matching and Regression results

Matching Result

The matching algorithm used to find a counterfactual for all companies is slightly different to the one used to find counterfactuals for subsets of SMEs and non-SMEs. This is to ensure that all groups achieve largest matched pairs without compromising on comparability.

For all companies, the probit regression uses age, region, sector, and average of two lagged turnovers pre-treatment, and average of two lagged employment pre-treatment. It allows up to 2 neighbours per treated company and a caliper of 0.02.

For SMEs and non-SMEs, we apply squared of age, region, sector, and lagged turnover and employment to derive propensity scores from probit regression. We allow treated units to match to any nearest 3 neighbours and with a caliper of 0.05 (difference between propensity scores). We use matched pairs within the common support region (complete overlap of propensity scores). The process involves dynamic matching; therefore, a company treated in 2016 is matched to a never treated company based on their pre-treated characteristics. Balance tests show that good matches are achieved.

Approximately 70 treated companies were successfully matched to counterfactuals, resulting in a total sample of 140 matched units. For SMEs, the matched sample includes 23 treated companies and 23 counterfactuals, totalling 46. In contrast, the non-SME group comprises 53 treated companies matched to 53 counterfactuals, forming a sample of 106. The higher number of matches among non-SMEs reflects the larger pool of complete records available, enabling more robust matching. The overall low number of total matches compared to Scenario 1 is due to smaller underlying sample of complete records explained in Section A.5.2.

Table 17: Number of treated companies that were matched to a counterfactual

Treated companies	**# Found a match**
All companies	70
SMEs only	23
Non-SMEs only	53

Source: Technopolis (2025)

Table 18 to Table 20 present post-matching balancing tests for all companies, SMEs, and non-SMEs, respectively. Across all groups, the matching process achieves excellent covariate balance, with negligible bias between treated and control units. For categorical variables like region and sector, the mean values are identical across groups, and t-tests confirm no statistically significant differences. Continuous variables such as age, lagged employment, and lagged turnover also show minimal bias, with most variance ratios falling within acceptable thresholds. The SME group shows slightly higher bias in lagged turnover (7.1%) and a variance ratio outside the preferred range, but this is not statistically significant. Non-SMEs exhibit slightly higher bias in lagged employment and turnover yet remain within acceptable limits. Overall, the results confirm that the matched samples are well-balanced, supporting the credibility of subsequent treatment effect estimates. This strengthens the validity of the PS matching.

Table 18: Post-matching balancing test, All companies

	Mean			**t-test**		**V(T)/**
Variable	Treated	Control	%bias	t p>t		V(C)
Age	39.63	39.63	0	0	1	1
2.region	0.13	0.13	0	0	1	.
3.region	0.18	0.18	0	0	1	.
4.region	0.01	0.01	0	0	1	.
5.region	0.01	0.01	0	0	1	.
6.region	0.07	0.07	0	0	1	.
7.region	0.02	0.02	0	0	1	.
8.region	0.23	0.23	0	0	1	.
9.region	0.11	0.11	0	0	1	.
10.region	0	0	0	.	.	.
11.region	0.10	0.10	0	0	1	.
12.region	0.08	0.08	0	0	1	.
Sector (	11.63	11.63	0	0	1	1
Lagged employment	5.57	5.52	2.9	0.96	0.335	0.83*
Lagged turnover	10.78	10.70	3.4	1.15	0.248	0.93
* if variance	outside [0.90; 1.11]					

Source: Technopolis (2025)

Table 19: Post-matching balancing test, SMEs

	Mean	**t-test**	**V(T)/**			
Variable	Treated	Control	%bias	t	p>t	V(C)
Age sq.	1291.30	1291.30	0.00	0.00	1.00	1.00
2.region	0.23	0.23	0.00	0.00	1.00	.
3.region	0.32	0.32	0.00	0.00	1.00	.
4.region	0.00	0.00	0.00	.	.	.
5.region	0.09	0.09	0.00	0.00	1.00	.
6.region	0.00	0.00	.	.	.	.
7.region	0.05	0.05	0.00	0.00	1.00	.
8.region	0.09	0.09	0.00	0.00	1.00	.
9.region	0.00	0.00	0.00	.	.	.
10.region	0.00	0.00	0.00	.	.	.
11.region	0.14	0.14	0.00	0.00	1.00	.
12.region	0.09	0.09	0.00	0.00	1.00	.
Sector (SIC 2007)	11.68	11.68	0.00	0.00	1.00	1.00
Lagged turnover	3.86	3.78	7.10	1.08	0.28	0.76*
Lagged employment	8.54	8.52	0.80	0.13	0.90	1.04
*	if	variance	ratio	outside	[0.83;	1.21]

Source: Technopolis (2025)

Table 20: Post-matching balancing test, non-SMEs

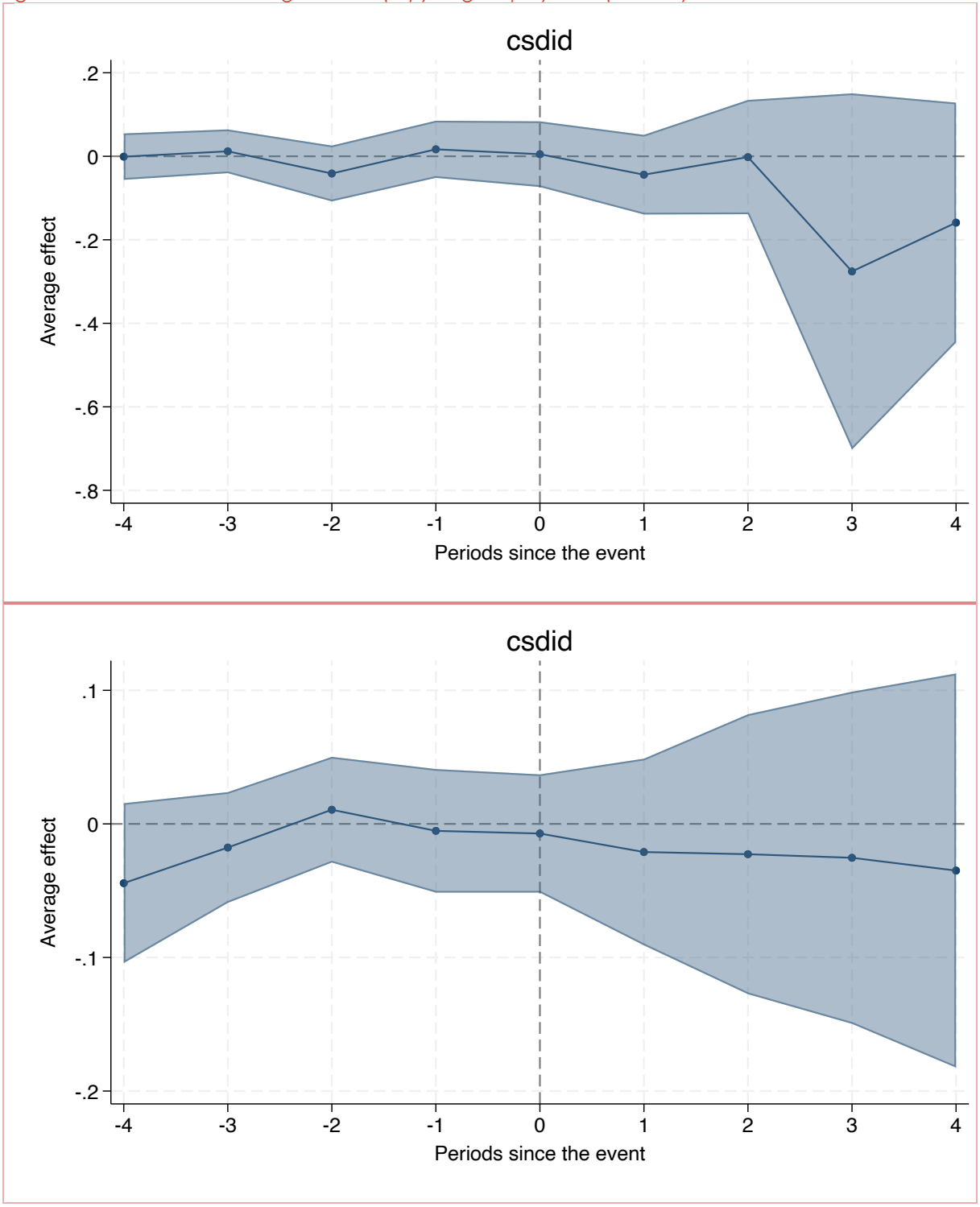
	Mean	**t-test**	**V(T)/**			
Variable	Treated	Control	%bias	t	p>t	V(C)
Age sq.	2133.10	2133.10	0.00	0.00	1.00	1.00
2.region	0.12	0.12	0.00	0.00	1.00	.
3.region	0.19	0.19	0.00	0.00	1.00	.
4.region	0.02	0.02	0.00	0.00	1.00	.
5.region	0.02	0.02	0.00	0.00	1.00	.
6.region	0.08	0.08	0.00	0.00	1.00	.
7.region	0.04	0.04	0.00	0.00	1.00	.
8.region	0.25	0.25	0.00	0.00	1.00	.
9.region	0.13	0.13	0.00	0.00	1.00	.
10.region	0.00	0.00	0.00	.	.	.
11.region	0.06	0.06	0.00	0.00	1.00	.
12.region	0.06	0.06	0.00	0.00	1.00	.
Sector (SIC 2007)	11.67	11.67	0.00	0.00	1.00	1.00
Lagged employment	6.26	6.20	3.70	1.07	0.29	0.86*
Lagged turnover	11.58	11.51	4.50	1.21	0.23	1.02
*	if	variance	ratio	outside	[0.89;	1.13]

Source: Technopolis (2025)

ATTs – All companies

Table 21 to Table 22 present dynamic treatment effects on log turnover and log employment over time. For both outcomes, all coefficients before and after treatment are statistically insignificant, suggesting no strong immediate or sustained impact of the programme on the treated companies.

Figure 7:Effect of H2020 on Log turnover (top), Log employment (bottom)



Source: Technopolis (2025)

Table 21: Log turnover, dynamic effects

	Coefficient	Std.err	z.	P>z	[95%	CI]
Pre_avg	0.00	0.02	-0.25	0.80	-0.04	0.03
Post_avg	-0.08	0.11	-0.78	0.44	-0.29	0.13
Tm4	0.03	0.03	0.92	0.36	-0.03	0.08
Tm3	-0.01	0.02	-0.37	0.71	-0.06	0.04
Tm2	-0.02	0.03	-0.57	0.57	-0.09	0.05
Tm1	-0.02	0.03	-0.52	0.60	-0.09	0.05
Tp0	0.01	0.05	0.29	0.77	-0.08	0.11
Tp1	0.01	0.06	0.09	0.93	-0.11	0.12
Tp2	0.06	0.07	0.84	0.40	-0.08	0.20
Tp3	0.04	0.09	0.41	0.68	-0.14	0.22
Tp4	-0.13	0.15	-0.87	0.39	-0.42	0.16

Source: Technopolis (2025)

Table 22: Log employment, dynamic effects

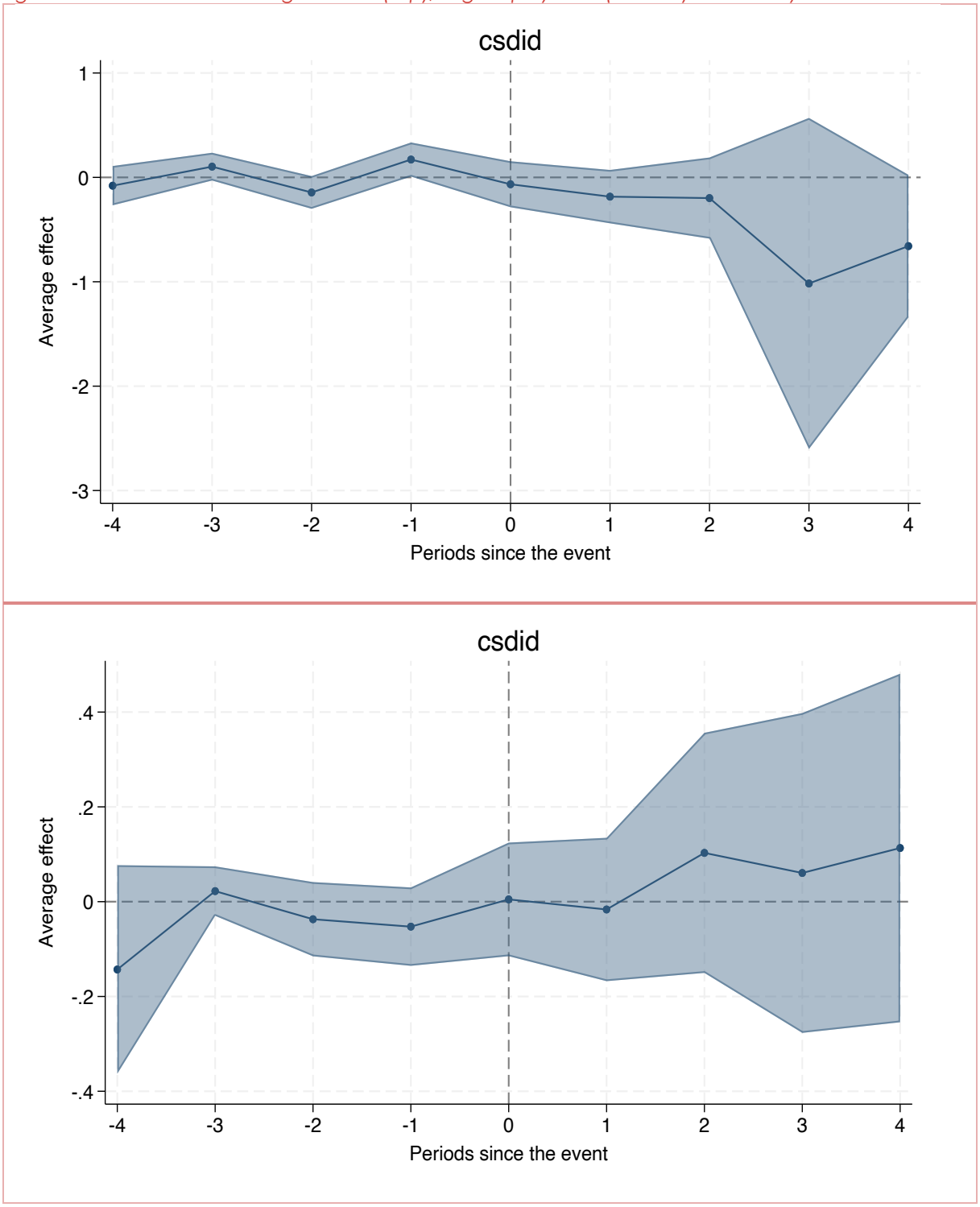
	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	0.00	0.01	0.16	0.87	-0.03	0.03
Post_avg	-0.01	0.07	-0.18	0.86	-0.16	0.13
Tm4	0.00	0.02	-0.17	0.86	-0.04	0.04
Tm3	0.02	0.02	0.77	0.44	-0.03	0.06
Tm2	0.01	0.02	0.50	0.61	-0.03	0.06
Tm1	0.01	0.03	0.31	0.76	-0.05	0.06
Tp0	0.00	0.03	-0.12	0.91	-0.06	0.05
Tp1	0.00	0.04	0.02	0.98	-0.08	0.08
Tp2	-0.05	0.07	-0.65	0.51	-0.19	0.09
Tp3	-0.04	0.07	-0.49	0.62	-0.18	0.11
Tp4	-0.08	0.08	-1.03	0.30	-0.24	0.07

Source: Technopolis (2025)

ATTs – SMEs

Table 23 and Table 24 present dynamic treatment effects on log turnover and log employment. For both outcomes, all coefficients are statistically insignificant. There are no trends in the pre-treatment period between the two groups, proving that the parallel trends assumption hold. The model however also does not find any statistically significant difference between the treatment and counterfactual groups in the post-treatment period attributable to Horizon 2020.

Figure 8:Effect of H2020 on Log turnover (top), Log employment (bottom) – SMEs only



Source: Technopolis (2025)

Table 23: Log turnover, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	0.01	0.03	0.31	0.76	-0.04	0.06
Post_avg	-0.26	0.20	-1.31	0.19	-0.66	0.13
Tm4	-0.08	0.10	-0.83	0.41	-0.27	0.11
Tm3	0.10	0.07	1.52	0.13	-0.03	0.24
Tm2	-0.14	0.08	-1.80	0.07	-0.30	0.01
Tm1	0.17	0.08	2.05	0.04	0.01	0.33
Tp0	-0.07	0.11	-0.59	0.56	-0.29	0.15
Tp1	-0.18	0.13	-1.41	0.16	-0.44	0.07
Tp2	-0.20	0.20	-1.00	0.32	-0.59	0.19
Tp3	-1.02	0.81	-1.26	0.21	-2.60	0.57
Tp4	-0.66	0.35	-1.89	0.06	-1.34	0.02

Source: Technopolis (2025)

Table 24: Log employment, dynamic effects

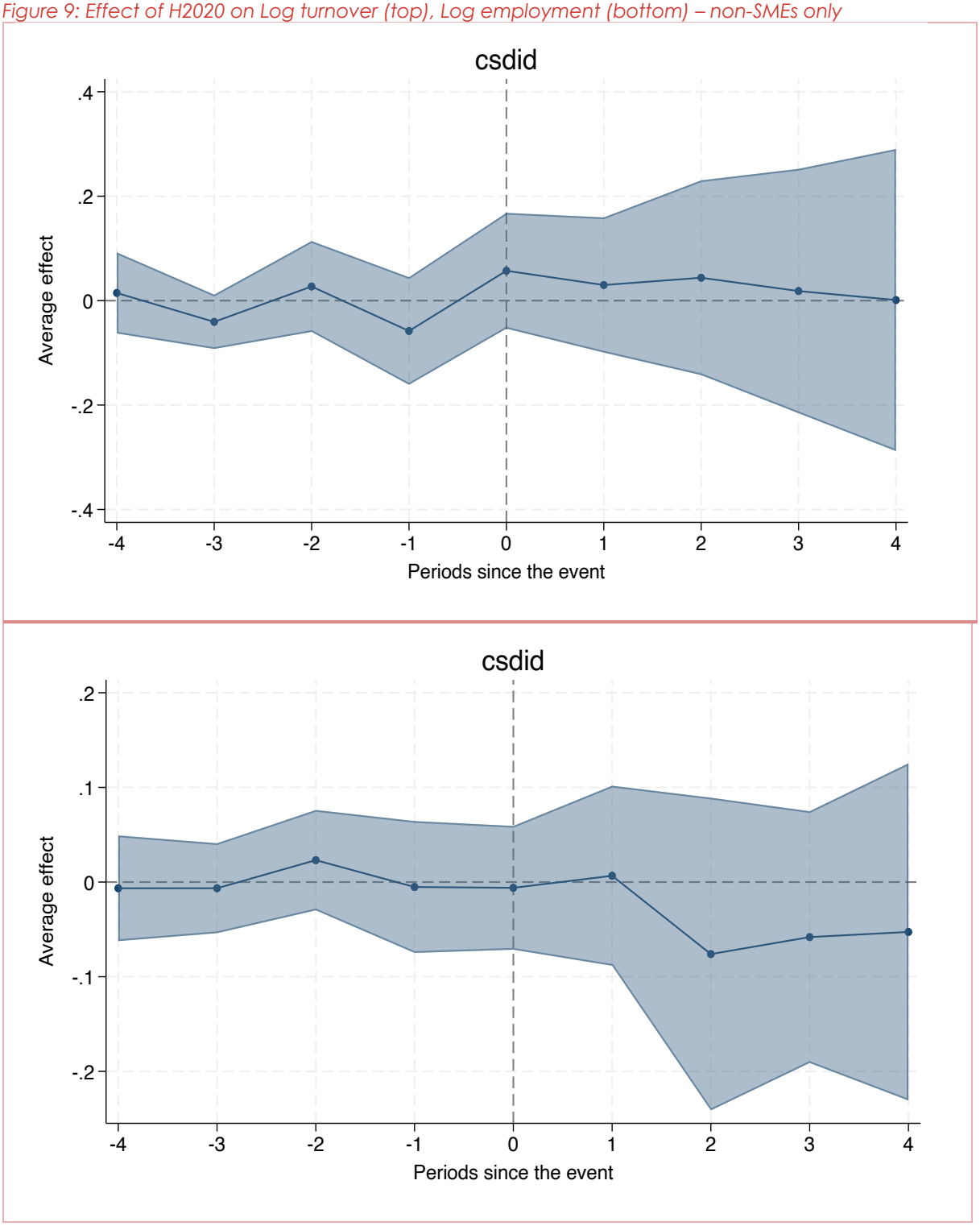
	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.01	0.02	-0.60	0.55	-0.06	0.03
Post_avg	0.17	0.14	1.23	0.22	-0.10	0.43
Tm4	-0.14	0.11	-1.27	0.20	-0.36	0.08
Tm3	0.02	0.03	0.84	0.40	-0.03	0.07
Tm2	-0.04	0.04	-0.93	0.35	-0.12	0.04
Tm1	-0.05	0.04	-1.25	0.21	-0.14	0.03
Tp0	0.00	0.06	0.08	0.94	-0.12	0.12
Tp1	-0.02	0.08	-0.21	0.83	-0.17	0.13
Tp2	0.10	0.13	0.80	0.43	-0.15	0.36
Tp3	0.06	0.17	0.35	0.73	-0.28	0.40
Tp4	0.11	0.19	0.60	0.55	-0.25	0.48

Source: Technopolis (2025)

ATTs – non-SMEs

Table 25 and Table 26 present dynamic treatment effects on log turnover and log employment. For both outcomes, all coefficients are statistically insignificant, indicating no statistically significant impact of the programme on the treated companies over time.

Figure 9: Effect of H2020 on Log turnover (top), Log employment (bottom) – non-SMEs only



Source: Technopolis (2025)

Table 25: Log turnover, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.01	0.02	-0.51	0.61	-0.04	0.03
Post_avg	-0.04	0.15	-0.26	0.80	-0.34	0.26
Tm4	0.01	0.04	0.37	0.71	-0.06	0.09
Tm3	-0.04	0.03	-1.53	0.13	-0.09	0.01
Tm2	0.03	0.04	0.61	0.54	-0.06	0.11
Tm1	-0.06	0.05	-1.11	0.27	-0.16	0.04
Tp0	0.06	0.06	1.01	0.31	-0.05	0.17
Tp1	0.03	0.07	0.45	0.65	-0.10	0.16
Tp2	0.04	0.10	0.46	0.65	-0.14	0.23
Tp3	0.02	0.12	0.15	0.88	-0.22	0.25
Tp4	0.00	0.15	0.01	0.99	-0.29	0.29

Source: Technopolis (2025)

Table 26: Log employment, dynamic effects

	Coefficient	Std. err.	z	P>z	[95%	CI]
Pre_avg	-0.01	0.02	-0.33	0.74	-0.04	0.03
Post_avg	0.06	0.07	0.84	0.40	-0.08	0.19
Tm4	-0.01	0.03	-0.23	0.82	-0.06	0.05
Tm3	-0.01	0.02	-0.27	0.79	-0.05	0.04
Tm2	0.02	0.03	0.86	0.39	-0.03	0.08
Tm1	-0.01	0.04	-0.15	0.88	-0.07	0.06
Tp0	-0.01	0.03	-0.18	0.86	-0.07	0.06
Tp1	0.01	0.05	0.14	0.89	-0.09	0.10
Tp2	-0.08	0.08	-0.90	0.37	-0.24	0.09
Tp3	-0.06	0.07	-0.86	0.39	-0.19	0.07
Tp4	-0.05	0.09	-0.58	0.56	-0.23	0.13

Source: Technopolis (2025)

Appendix B Rapid Evidence Assessment

At the start of the study a Rapid Evidence Assessment (REA) was undertaken to identify, compile and analyse recently published reports and impact evaluations of the European RTD framework programmes. This informed the development of a Theory of Change of UK participation in H2020, and helped further develop the key research questions and approach to the next phase of the study.

We focused our search on evaluations relating to Horizon 2020 or recent iterations of the Framework Programme, and the following criteria:

- The evaluation is mid-term or ex-post (rather than ex-ante)
- It includes participation of any country, or multiple countries
- It attempts to measure effects (beyond perception or purely qualitative)
- It sets up benchmarks or counterfactuals (both qualitative and quantitative)

Our search begun with our own extensive repository of past evaluation reports and was then expanded using Google and Google scholar (noting that most examples were expected from grey rather than academic literature). The REA was not intended to be exhaustive.

A total of 19 reports and evaluations were identified. These were categorised as (i) general impact assessments of the EU FPs, (ii) Country-specific or national-level impact assessments and (iii) thematic impact assessments, for example with a specific focus on partnerships.

From each paper, we extracted key findings (where available) on:

- The evaluation approach
- The strengths and limitations of the evaluation approach
- Whether a Theory of Change is presented
- Where a framework for key benefits / impacts / outcomes has been developed
- Examples of key benefits reported and
- Motivations and barriers to participation

A summary of the reports is presented in Table 27, followed by summary analysis of key findings from the review.

Table 27 Headline findings from EU framework programme evaluation record

Evaluation / Study	Theory of Change	Framework for Benefits	Benefits to FP participation reported	Motivations / barriers to participation
Impact Assessments of the EU Framework Programme				
Understanding the Long-Term Impact of the Framework Programme (Technopolis, 2024)	•••	•	•••	
Evaluation of the Sixth Framework Programme for Research and Technological Development, 2002-2006 (EC, 2009)		••	••	•••
Ex-post evaluation of the 7th EU Framework Programme, 2007-2013 (EC, 2015)		••	•••	••
Evidence framework on monitoring and evaluation of Horizon Europe (EC, 2023)	•••	•	•••	
The benefits of associating to EU research and innovation programmes (Russel Group, 2024)			••	
Ex-post evaluation of Horizon 2020, the EU framework programme for research and innovation (EC, 2024)		••	•••	
Country-specific Impact Evaluations				
Evaluation of UK involvement with the Research Framework Programme and other European Research and Innovation Programmes (BEIS/ICF, 2017)	•••	•	•••	•••
Evaluation of Austrian Participation in the 4th EU Framework Programme for Research, Technological Development and Demonstration (Technopolis, 2001)		•	•••	•••
Norwegian participation in Horizon 2020 in health, ICT and industry (Technopolis, 2017)			•	•••
Impacts of the Framework Programme in Sweden (Technopolis, 2008)			•••	•
Evaluation of Chinese participation in the EU Framework Programme (Technopolis, 2008)		•	•••	•••
An Evaluation of the Operation and Impacts in Ireland of the EU's Fourth Framework Programme for Research and Development (Technopolis, 2001)		•	•••	•••
Evaluation of Framework Programme 6 in Ireland (Technopolis, 2009)		•	•••	••
Thematic Impact Evaluations of Framework Programmes				
An analysis of the role and impact of Research Performing Organisations' participation in the Framework Programmes (Technopolis, 2012)		••	•••	•••
Ex-post evaluation of the activities carried out by DG Enterprise and Industry under FP6, Innovation and Space Research Activities (GHK/Technopolis, 2008)	•		•••	•
Biennial Monitoring Report (BMR) 2022 on partnerships in Horizon Europe (EC, 2022)	•••	••	••	••
The Horizon Europe Programme: A strategic assessment of selected items (EP, 2024)			••	••
Assessment of the Impact of Actions completed under the 5th Community Research Framework Programme – Survey (EC, 2005)		•	•••	•••
Ex-post evaluation of NMP (FP6) – Strategic Level		•	•••	•••

Technopolis, 2024 (• some information presented in report, •• in-depth information presented, with a dedicated section, ••• a significant focus, with detailed information and examples cited throughout report)

B.1. Approaches to evaluating the impact of Framework Programmes

Most FP evaluations used mixed methods approaches, but only five were grounded in a comprehensive ToC. This is likely to be because developing a ToC for the FPs is a complex task and many studies simply assume the impact pathways emerging from investments. Where ToCs have been developed, their scope and complexity vary significantly. Some evaluations apply simple intervention logics focused on immediate outcomes, such as the number of applications to the FPs and jobs created or sustained. Others take a more comprehensive approach, integrating advanced methodologies to capture a broader range of impacts - although encapsulating the full scope of FPs within a single model remains a challenge.

Survey questionnaires are widely used to gather feedback from project participants and are typically complemented by other methods, such as network analysis and bibliometrics, to allow for triangulation. However, control groups are rarely utilised to assess additionality, and baseline data is often absent, making it difficult to compare the "before and after" impacts. Limited data availability is a recurring issue, with gaps in CORDA data frequently cited as a barrier to the effective use of methodologies like bibliometrics and patent analysis.

A further challenge lies in the significant time lags associated with research and innovation benefits, which often take years—or even decades—to materialize. This is particularly true for basic or fundamental research, where the eventual applications are often unknown at the project's outset or completion. Such projects can yield unexpected long-term benefits, often realised with the support of additional funding from other sources. However, the alignment of FP evaluations with programming cycles limits their ability to capture these long-term impacts. Evaluations typically focus on immediate outcomes and rely on surveys and interviews to gather insights into participants' goals and programme administration. This short-term focus restricts evaluations to static analyses, such as network structures and publication performance, without fully capturing dynamic changes or establishing causal relationships.

Attempts to investigate long-term benefits have highlighted the difficulty of attributing these outcomes to the original FP investments. These challenges align with recent findings from Technopolis, which emphasize the limitations of existing methods for evaluating the long-term impacts of public investments in research, development, and innovation (RD&I).[15]

B.2. Key benefits reported

We have identified five high-level categories under which outcomes and impacts have been reported in FP evaluations. These categories have then informed the outputs, outcomes and impacts presented in our Theory of Change.

The benefits of FPs at the national level are varied and context-dependent. In Ireland, for example, the effects of participating in FPs have been large because national R&D funding was small. Similarly, previous evaluations have noted that some impacts for the UK have been large because of the limited national R&D funding available for companies. For countries with a well-established national R&D funding system, the impacts are less clear. Each of the five high-level categories we have identified is discussed in-depth below.

[15] What methods work for evaluating the impact of public investments in Research, Development and Innovation, Technopolis Group for DSIT, 2024

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Research

Research impacts and benefits are the most frequently cited outcomes in evaluation reports. Indicators to assess research benefits include publications in high-ranking journals, knowledge dissemination (conferences, exchanges and visits), and the emergence of new technologies or scientific fields. Bibliometric analysis often highlights that lead scientists involved in FP projects tend to outperform peers in publications and citations, underscoring the quality and influence of research funded via this route. Beyond academic outputs, some evaluations also emphasise non-academic contributions, such as policy papers, new datasets, software and models.

Additional research benefits include the ability to leverage further funding from diverse sources, which is particularly important for basic/fundamental research, as technologies mature along the innovation pathway. Several evaluation reports highlight that these lead indicators, such as publications and early-stage technological advancements, serve as early signals of future impacts. These include the potential for new products, services, and economic returns, all stemming from progress achieved through short- and medium-term outcomes.

Several evaluations also note that the European FPs have helped to modernise participating countries' research and innovation systems. For example, the *Ex-Post Evaluation of the 7th EU Framework Programme* highlighted the structuring effects of FP7, serving as a role model for research funding organisations and universities in other countries. In addition, the introduction of 'Responsive Research and Innovation (RRI)' as a guiding orientation by the Commission was cited as another example of structuring effects. The report noted that a growing number of RRI-related initiatives have been launched in several R&I systems of participating countries.

Collaboration and partnerships

Benefits that relate to collaboration and partnerships are also frequently cited and investigated in the identified evaluation reports. Reports note that the FP provides a range of opportunities for researchers and innovators to engage in international collaboration that would otherwise not occur. Examples cited are activities such as visits, workshops, conferences and joint working that support partnership building, scoping and the preparation of future research proposals (both in future FP programmes and in other international collaboration programmes). Providing access to a global talent pool and facilities which, when combined with the infrastructure of national systems, are inherently stronger and deeper, are also highlighted.

Skills and Knowledge

The FP evaluation record also reveals that research and innovation activities lead to the development of new knowledge and skills. This includes new and improved understanding among researchers and innovators (including SMEs) of new research methods.

In addition, some evaluation reports note that the mobility of researchers allows them to access new international networks. For example, the recent evaluation of the Horizon 2020 programme revealed that most respondents (85%) agreed or strongly agreed that Horizon 2020 had improved the skills of researchers and facilitated the emergence of new researchers. In doing so, FP participants have a new and improved understanding of available research capacity, capabilities and infrastructure, which can support career progression and employability.

Although long-term outcomes are less frequently investigated and their attribution to the FP investments are less clear, some reports do also note that in the long-term, new skills and knowledge are expected to lead to strengthened R&I capabilities for researchers.

Innovation and the Economy

Benefits related to innovation and the economy are less frequently investigated in the evaluation reports identified, and where they are discussed, this largely relates to the innovation activities of participating SMEs. Translational research activities carried out by participating SMEs lead to new and improved products, services and processes, as well as new and improved technologies and the development or improvement of new technical standards. Additionally, in the short-term, such activities lead to traditional innovation outputs such as Intellectual Property and patents, as well as new spin-offs and start-ups.

The evaluation record also notes that participating innovators (including SMEs) often emphasise that participating in the FP is expected to enhance industrial competitiveness by:

- Expanding the pool of research and technology that could lead to future innovations
- Actively influencing industrial standards and best practice to gain a strategic edge, and
- Exploring new markets, to diversify opportunities and access untapped revenue streams

In the long-term, these should lead to increased income from commercialisation of research and technology, although these benefits are rarely investigated in evaluation reports.

Wider Societal Benefits

Wider societal benefits of R&I programmes are less frequently investigated and discussed as compared to other key outcomes. This is because such benefits depend on the uptake and application of scientific outputs and innovative solutions, often over a much longer timeframe. As a result, many evaluations note that these are significantly more challenging to capture.

Where societal benefits are identified, they are often linked to addressing larger, global challenges, such as climate change, sustainable development and health, and advancing our scientific understanding in these areas. Additionally, evaluations highlight that funding for R&I can help tackle societal challenges by leveraging additional resources for sustainable developing and fostering a coordinated approach across national R&I systems.

B.3. Motivations and barriers to participation

Of the 19 relevant papers identified through the rapid evidence assessment, 15 address motivations and barriers to participating in the Framework Programmes.

Many of these evaluations highlight that participants often seek additional research funding—supplementary or complementary to national R&I funding—as well as opportunities to address specific scientific or technical questions alongside experts in their fields. This is particularly true for participants from countries where there is limited national R&I funding. By accessing complementary expertise, including infrastructure and data, participants seek to maintain and enhance their own capabilities in specific research areas. For those involved in innovation activities (SMEs included), evaluations show that applicants are motivated to participate in Framework Programmes to influence the development of markets and standards relevant to their products, processes, or services. In doing so, innovators seek to build competitive and strategic advantage, as well as develop new streams of revenue for products in the long-term.

Some reports indicate that the nature of the challenges addressed through R&I are a significant motivator for participation in the FPs. Applicants recognise that issues such as carbon emissions, extreme weather, health and wellness, and emerging technologies are best tackled via international partnerships, which enable systematic rather than fragmented approaches.

The administrative complexity of the FP frequently emerges as a barrier or deterrent, for both academic and business participants. Participants often note that the time and resources

required for activities such as project management and coordination across international partners detracted from the resources and time for scientific tasks. This is particularly true for smaller actors and less R&D intensive countries, that often do not have the resources to participate on equal terms, favouring incumbent networks from a limited number of countries.

SMEs face unique challenges. Under the first three years of Horizon Europe, SMEs received EUR 6.6 billion in EU contributions, representing about 20% of programme funding. This is a large increase compared to H2020, but there is not a commensurate increase in the number of SMEs participating.[16] Five evaluation reports identified that the administrative burden of preparing proposals, limited understanding of program details, eligibility criteria, and difficulties in meeting match-funding requirements or securing private investment limited the participation of SMEs.

Additionally, some evaluations identify broader barriers to international scientific collaboration. These include cultural and language challenges, as well as limited experience in cross-country cooperation, which can discourage participation. This aligns with existing research on international collaboration; a 2018 Technopolis study on the main drivers and barriers to international collaboration identified that there was demand to do more collaboration with strategic partner countries, but that individual research organisations and UK businesses do less than they would wish to because multiple barriers exist to international SRTI.[17]

[16] EC DG for Research and Innovation, *SME participation in Horizon Europe – Key figures (and key issues) in the first three years*, Publications Office of the European Union, 2024, **https://data.europa.eu/doi/10.2777/576670**

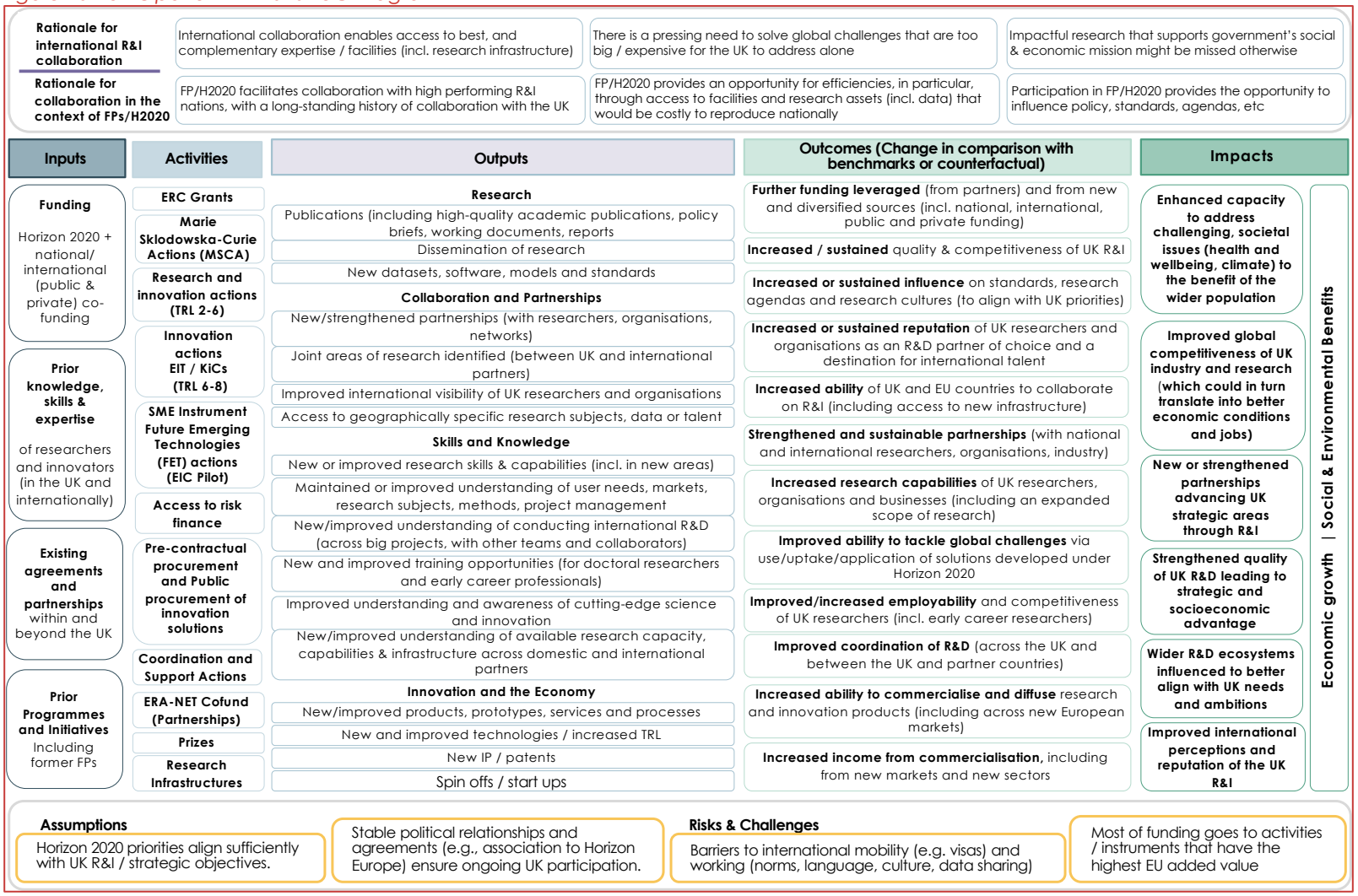
[17] Technopolis (2018) Drivers and Barriers for Collaboration, prepared for BEIS (not published yet).

Appendix C H2020 Theory of Change Narrative

A Theory of Change (ToC) is a programme theory that explains how an intervention (in this case Horizon 2020 participation) is intended to produce results. These expectations, and the extent to which they are actually realised, are then tested (where possible) through the evaluation.

Figure 10 presents a high-level summary, capturing the main intentions and expectations for participation, in a structured way within a single diagram. Section 3 of the main report sets out the overall rationale for intervention. In this appendix, we present the narrative for all the other elements of the ToC, starting with inputs and activities, then outputs and outcomes, and finally impacts.

Figure 10 Participation in H2020 ToC Diagram



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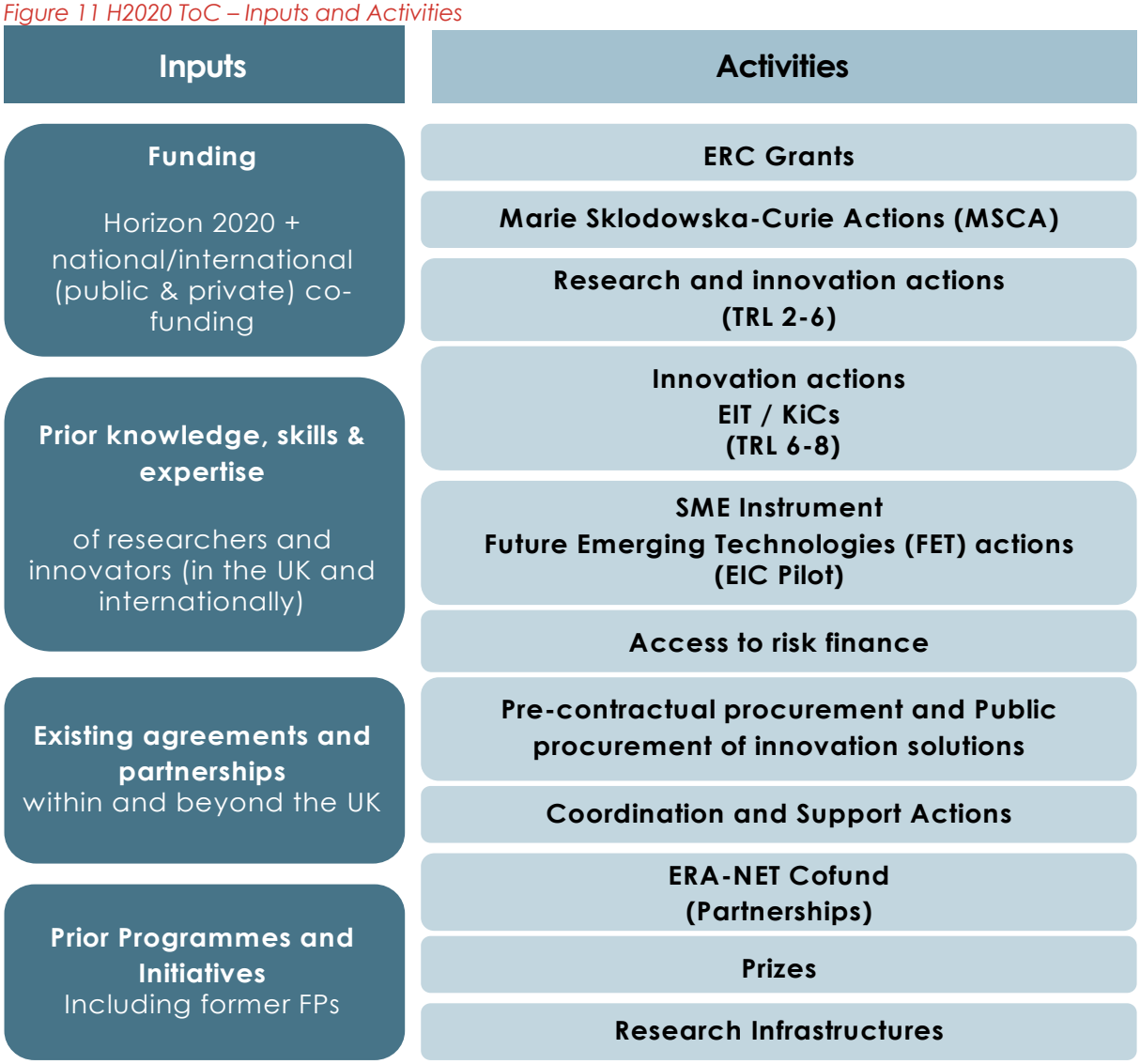
C.1. Inputs and activities

Figure 11 shows the inputs and activities section of the UK participation in H2020 ToC diagram. These elements are then described in more detail.

Figure 11 H2020 ToC – Inputs and Activities



One of the main inputs to UK participation in H2020 is **funding** to support international SRTI collaboration. Overall, Horizon 2020 had a budget of nearly EUR 80 billion, which includes UK government funding (€2.4bn a year on average), plus **co-funding** (in cash and in-kind) from partners and collaborators.

UK researchers and innovators write and submit proposals, often in consortia consisting of **existing agreements and partnerships**, within and beyond the UK. Both UK and international applications bring with them **prior knowledge, skills and expertise** to support proposal writing and the research activities that follow. This includes lessons learned from **past programmes and initiatives,** including participation in **former FPs.**

Horizon 2020 supports all stages of research and innovation, from early stage, foundational research through to applied research and commercialisation, as well as skills, talent and

capacity development. There are 11 **main types of activities** (or funding instruments under which activities can take place):

- European Research Council (ERC) Grants offering 4 core grant schemes: Starting, Consolidator, Advanced and Synergy Grants (and an additional Proof of Concept Grant scheme), to support the innovation potential of research ideas and results.
- Marie Sklodowska-Curie Actions (MSCA) are the EU's flagship programme for doctoral and postdoctoral training. They are intended to equip researchers with
- Research and innovation actions: that establishes new knowledge and/or explores a new or improved technology, product, process, service or solution
- Innovation actions EIT/KiCs (TRL 6-8): that produces plans or designs for new or improved products, processes or services including prototyping, testing, demonstrating, piloting, large-scale product validation and market replication (i.e. closer to market activities)
- SME Instrument Future Emerging Technologies (FET) actions (EIC Pilot): offers three complementary lines of action (FET Open, FET Proactive, and FET Flagships) to foster new technologies with the potential to open new fields for scientific knowledge and technologies (i.e. novel and high risk)
- Access to risk finance: via InnovFin (EU Finance for Innovators) where applicants can access a range of debt and equity products and advisory service to support the availability of finance for R&I activities across Europe (and associated countries)
- Pre-contractual procurement and Public procurement of innovation solutions: which challenges industry from the demand side to develop innovative solutions for public sector needs and provides a first customer reference that enables companies to create competitive advantage on the market.
- Coordination and Support Actions: which aim to improve cooperation between legal entities from the EU and associated countries, for example on issues related to standardisation, dissemination, policy and mutual learning.
- ERA-NET Cofund (Partnerships: which provide multi-annual co-funding to bring together private and/or public partners together to address shared research priorities, including the green and digital transitions.
- Prizes: a pilot instrument under H2020, which awarded Horizon Prizes to the most innovative solutions to grand societal challenges, including in areas related to the green transition and global health.
- Research Infrastructure: which provides funding to access a range of infrastructure required to conducting R&I including laboratories, scientific instrumentation and technologies, data resources, computational tools, and communication networks.

Assumptions

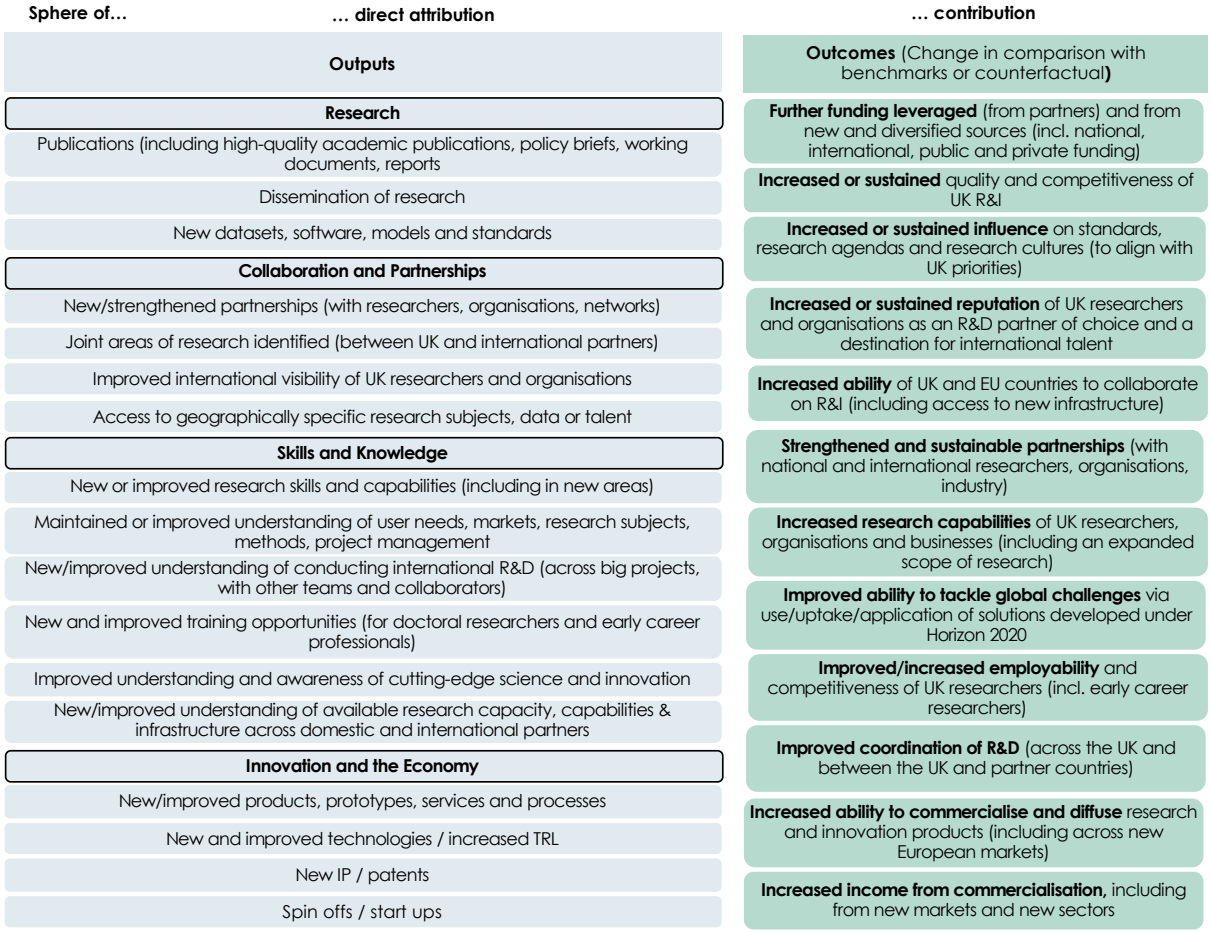
There are a number of assumptions (and associated risks and challenges) that apply to the realisation of the ToC (including the outputs, outcomes and impacts). The include:

- H2020 priorities align sufficiently with UK R&I / strategic objectives: This primarily relates to UK Government / DSIT support and funding, but also applies to the EU, whose ongoing interest and commitment to H2020 (and future framework programmes) is important.
- Barriers to international mobility (e.g. visas) and working (norms, language, culture, data sharing): these practical challenges in terms of mobility and international working are minimal and can be overcome.
- Most of the funding goes to activities / instruments that have the highest EU added value: opportunities, funding available and accessible to the UK through H2020 are (mainly) in areas that offer added value compared to what it could achieve otherwise.

C.2. Outputs and outcomes

Figure 12 shows the **outputs and outcomes section of the ToC diagram,** which are the spheres of direct attribution and contribution, respectively. Outputs are expected to materialise as the H2020 projects (in which the UK is involved) and programmes progress, while outcomes are expected to emerge between 1-3 years after H2020 projects and programmes have ended.

Figure 12 H2020 ToC – Outputs and outcomes



Outputs and outcomes have been grouped into 4 broad areas (although there are cross-overs and interlinkages between these different areas, with multiple pathways from individual outputs to outcomes). These outputs and outcomes are presented in more detail below.

Research

Many activities under H2020 – particularly collaborative R&D and activities relating to access to and investment in research infrastructure, are expected to lead to (typical) R&I outputs. This includes **high quality peer reviewed publications** co-authored between UK and international researchers, but also **other types of publications,** including working documents, summary reports and policy briefs. Some of these other types of publications are expected to be tailored and **disseminated** to audiences beyond academia, to include policymakers and industry. **Other research outputs are also expected**, including new datasets, software, models and standards, depending on the nature of the specific activity participants are involved with.

Dissemination of these various research outputs will be achieved through a variety of means, including conferences and presentations, social media, teaching and training activities.

By conducting these collaborative R&D activities (and the associated outputs that emerge from these activities), UK participation in H2020 is expected to support participants to **leverage further funding**. This includes both further funding from partners for H2020 projects and activities (i.e. extra funding beyond the initial inputs, capacity, and other resources) and to leverage funding for future projects. Sources for additional funding are expected to be from new and diversified sources, including national, international, public and private funding and may take the form of further grants, or investments, or the use of internal resources. Additional funding is also expected to have positive feedback loops to other output and outcome areas described in the ToC, including the identification of joint areas of research and the increased ability for the UK and EU to collaborate (discussed in the next section).

Research outputs are also expected to **increase or sustain the quality and competitiveness of UK R&I,** including, through contributions to the development of standards, policies, research agendas and the strengthening of research cultures to better align with UK needs and priorities (with the latter also influenced by collaboration and partnerships outputs, described below).

Assumptions

- H2020-funded research tackles global and socioeconomic challenges, and this is widely disseminated among (and accessible to) relevant end users

Collaboration and Partnerships

UK participation in H2020 will support the **creation of new strengthened partnerships**, or the **further strengthening of existing partnerships**, between individuals, institutions and organisations, across borders and across sectors (academia, industry, third sector, policy). In addition, it is anticipated that these partnerships will continue over time (e.g. through Horizon Europe) and that there will be an **increased ability for the UK and EU countries to collaborate,** as a result of new knowledge and understanding generated through project activities, as well as increased access (including access to research infrastructure) and enhanced ways of working. Through these partnerships, UK participants and international partners are expected to increasingly **identify joint areas of research** and increase **access to geographically specific research subjects, data or talent** that would otherwise not be available in the UK.

More generally, it is anticipated that H2020 partnerships and interactions will help increase or sustain the **international visibility of UK researchers and organisations**, as an 'R&I partner of choice' or as a destination of choice for talent and investment.

Assumptions

- Partnerships and interactions have developed positively, with mutual benefits for those involved in the UK and the EU.
- Partnerships have been institutionalised, such that they can continue on over time and into future programmes, regardless of whether individuals change positions or organisations.
- H2020 funded activities have enabled new partnerships between industry and academia (as well as other sectors) and EU partners that did not exist before, improving connectivity.
- International partners hold geographically specific research subjects, data or talent that is not available in the UK and aligns with UK needs and priorities and that these are shared through project activities.

Skills and Knowledge

All project activities (particularly those that have a focus on capacity building) are expected to lead to the development of **new or improved research skills and capabilities** (including and expanded scope of research and geographic reach), amongst researchers, innovators and industry. Throughout the project lifetime, it is also expected that project activities lead to **new and improved training opportunities** (for doctoral researchers and early career professionals), although this is likely to emerge more under certain activities where this is a particular focus (e.g. Marie Sklowdowska-Curie Actions (MSCA)). Over time and as these new skills are applied in more research projects, this is expected to **improve or increase the employability** and competitiveness of UK researchers (particularly for young and early career researchers).

Where projects focus on innovation (e.g. pre-commercialisation, market engagement activities), this is also expected to lead to the **maintained or improved understanding of user needs, markets, research subjects, methods and project management** both in the EU and in the UK. This is expected, in turn, to contribute to the **increased ability to commercialise and diffuse R&I products**, discussed in detail in the Innovation and Economy outputs and outcomes.

Through collaboration, UK participants (and EU partners) H2020 activities are also expected to lead to an **improved understanding and awareness of cutting-edge science and innovation** (through work that EU partners have already conducted and through joint activities undertaken in the project). Additionally, activities are anticipated to lead to **new and improved understanding of available research capacity, capabilities and infrastructure among UK and EU partners.** This is particularly relevant for organisations in the UK where it is expected this may lead to an increased demand for those facilities and future joint ventures. This improved understanding, in turn, is expected to lead to an **improved coordination of R&D** (across the UK and between the UK and EU countries), where partners can better identify research efficiencies (e.g. via shared infrastructure) and shared research priorities (that align with UK needs).

Assumption

- H2020 training opportunities are sufficient to support upskilling / increased employability

Innovation and the Economy

Translational research and business-led innovation, in particular, are expected to lead to (typical) innovation outputs, including **new and improved products, services and processes**, as well as **new and improved technologies** (with an increase in the technology readiness level (TRL)), plus **Intellectual Property or patents** and **new spin-offs or start-ups.**

These outputs are expected to increase the **ability to commercialise and diffuse** research and innovation products (including across new European markets), including access to new supply chains, trade opportunities, key infrastructure and skills. In the long-term, this should also lead to **increased income from commercialisation** of research and technology (in particular for UK and EU beneficiaries), including from new EU markets explored through H2020 project activities. Innovation outputs, and the uptake and application of these outputs and solutions developed under H2020, may also lead to an **improved ability to tackle global challenges**.

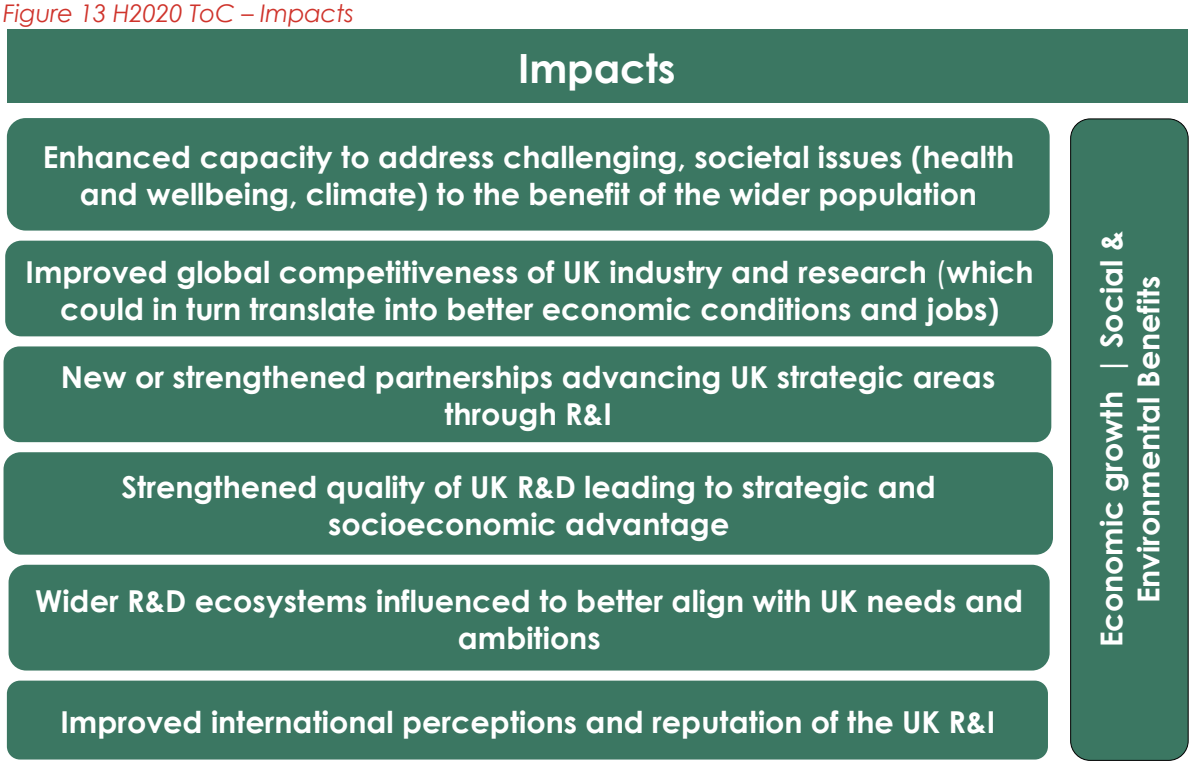
Assumptions

- Support provided by H2020, and progress made is sufficient to support commercialisation or to unlock further resources for developments towards commercialisation (de-risking).
- There is also an assumption that successful innovation outcomes would outweigh the (inevitable) failures. Related to this, the extent and breadth of innovation outputs and outcomes will in part be dependent upon the share of the H2020 portfolio (and which is allocated to UK participants) that is dedicated to translational and business-led research (where these outputs and outcomes are much more likely, at least in the shorter-term).

C.3. Impacts

Figure 13 shows the impacts section of the ToC diagram. UK participation in H2020 is expected to contribute to (influence) the attainment of impacts that should materialise in the medium to longer term, between 4-10 years after H2020 projects and programmes have ended.

Figure 13 H2020 ToC – Impacts



The impacts include:

- An **enhanced capacity to address challenging, societal issues (health and wellbeing, climate)** through the uptake of products, processes and solutions developed through H2020 activities **to the benefit of the wider population** (in the UK and the EU)
- The **improved global competitiveness of UK industry and research, which in turn could lead translate into better economic conditions and jobs** in the UK
- The **strengthened quality of UK R&I leading to strategic and socioeconomic advantage** in the UK (e.g. through trade agreements).

Finally, there is also the expectation that innovation (and a strong R&I sector) can deliver **economic growth**, by supporting increases in productivity and competitiveness.

These new partnerships and increases in R&I capabilities are expected, over time, to support progress towards other areas of impact, including an **enhanced capacity to address challenging, societal issues (e.g. health & wellbeing, climate)** through the uptake of products, processes and solutions developed through H2020 activities **to the benefit of the wider population** (in the UK and the EU). This connects back to the original rationale for international R&I collaboration, and that such challenges (carbon emissions, extreme weather, global pandemics) are best addressed internationally, through shared ideas, expertise and facilities.

Additional expected impacts from UK participation in H2020 relate to supporting the global strategic position of the UK, and the opportunities and advantage that this enables. This includes through:

- **New or strengthened partnerships** at the researcher and institutional level that could support wider diplomatic efforts and enhance the UK's soft power and influence, which in turn could also **advance UK strategic areas through R&I**, that are expected to continue long-term
- **Wider R&D ecosystems influenced** to better align with UK needs and ambitions (for example through norms, standards, culture, policies, and regulations)
- Improved **international perceptions and reputation of UK R&I** as a trusted R&I partner for future joint activities and investment and as a leader in cutting-edge R&I

These impacts will also have positive feedback loops to other impact areas described above, including in particular the advancing of common strategic areas and addressing of shared challenges.

Assumptions

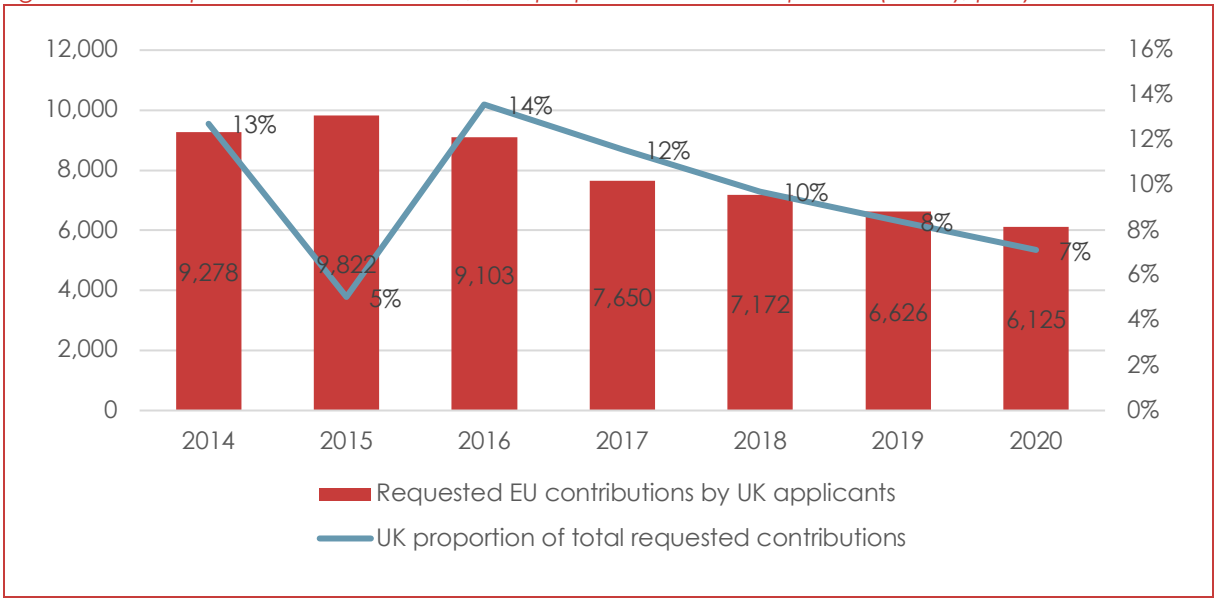
- The scale of UK participation in H2020 and the programme overall (resources and duration including continued association to future framework programmes, including Horizon Europe) is sufficient to contribute to strengthen R&I capabilities and quality
- Research and innovation-based solutions provide sufficient input to deliver economic growth, and social and environmental benefits

Appendix D Additional analysis of H2020 participation

This appendix provides additional analysis of the UK's H2020 participation. These results are referenced, but not shown in full within the main body of the report.

D.1. UK participation in proposals

Figure 14 UK Requested EU contributions, as a proportion of total requested (EURm), per year



Source: Technopolis (2025) based on EU CORDA Applicants data.

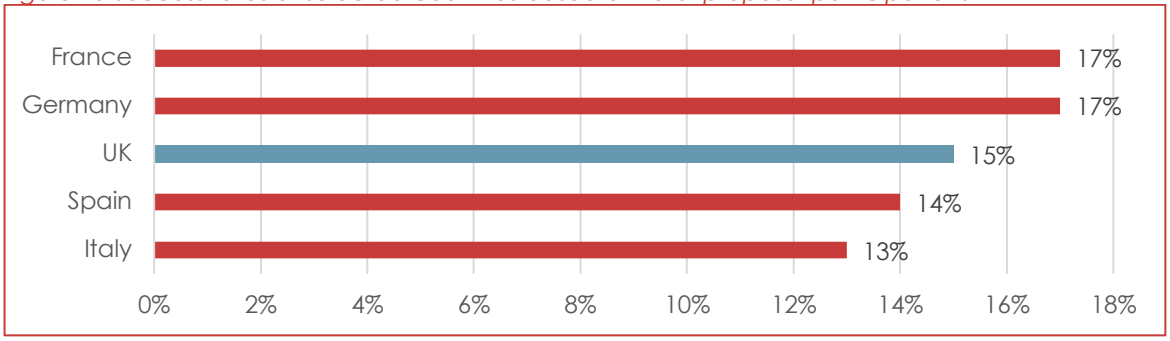
Table 28 Country rankings –Proportion of all proposal coordinators / hosts

2014			2020			Final rank (2014-2020)	
1	**UK**	**15%**	1	ES	12%	**1**	**UK**
2	ES	13%	2	IT	12%	2	ES
3	IT	13%	**3**	**UK**	**10%**	3	IT
4	DE	10%	4	DE	9%	4	DE
5	FR	8%	5	FR	8%	5	FR
6	NL	6%	6	NL	5%	6	NL
7	SE	3%	7	CH	4%	7	SE
8	EL	3%	8	IL	4%	8	BE
9	BE	3%	9	SE	3%	9	DK
10	FI	2%	10	BE	3%	10	CH

Source: Technopolis (2025) based on EU CORDA Applicants data.

D.2. UK success rate in H2020

Figure 15 Success rates of selected countries based on total proposal participations



Source: Technopolis (2025) based on EU CORDA data.

Table 29 Average success rates, pillar/ programmes

Pillar	Programme	UK Participations in proposals	UK Success Rate (based on participations in proposals)	vs	H2020 success rate (based on participations in proposals)
Excellent Science	European Research Council (ERC)	10,599	16%	>	13%
	Future and Emerging Technologies (FET)	4,868	7%	>	5%
	Marie Skłodowska-Curie Actions (MSCA)	34,134	14%	>	13%
	Research Infrastructures	1,243	16%	<	17%
Industrial Leadership	Access to risk finance	27	11%	=	11%
	Innovation in SMEs	2,821	18%	>	15%
	Leadership in Enabling and Industrial Technologies (LEIT)	13,866	16%	>	13%
	Other (IL)*	7	52%	>	47%
Societal Challenges	Climate action	3,893	14%	<	16%
	Energy	4,620	15%	>	14%
	Europe in a changing world	3,277	14%	>	9%
	Food and the bioeconomy	3,987	2%	<	4%
	Health and wellbeing	8,568	45%	=	45%
	Other (SC)*	83	12%	<	13%
	Secure societies	2,605	14%	>	13%
	Transport	4,035	14%	<	15%
Spreading excellence and widening participation		687	24%	=	24%
Science with and for Society		1,110	9%	<	10%
European Innovation Council		1,583	11%	>	9%
Indirect actions		238	9%	=	9%
Total		**102,251**	**15%**		**15%**

Source: Technopolis (2025) based on EU CORDA data. Note: the "Other" category corresponds to proposals where a pillar is indicated but not a programme. The 'vs' column compares UK and overall success rates in a programme, and indicates whether the UK rate is higher than (>), equal to (=) or less than (<) the overall rate.

Table 30 UK success rates (based on participations in proposals), by action type

Type of action	UK Participations in proposals	UK success rate	Vs	H2020 success rate
Research and Innovation Actions (RIA)	34,385	16%	>	14%
Marie Skłodowska-Curie Actions (MSCA)	34,025	15%	>	14%
Innovation Actions (IA)	11,566	16%	>	15%
European Research Council (ERC)	10,591	14%	>	13%
SME instrument	6,741	7%	>	6%
Coordination and Support Actions (CSA)	4,747	26%	=	26%
Framework Partnership Agreement (FPA)	69	38%	=	38%
ERA-NET-Cofund	65	94%	<	96%
Pre-Commercial-Procurement (PCP)	44	50%	>	47%
Joint Programme (COFUND-EJP)	15	100%	=	100%
Public Procurement of Innovative Solutions (PPI)	2	100%	>	29%
Total	**102,250**	**15%**	**=**	**15%**

Source: Technopolis (2025) based on EU CORDA data. The 'vs' column compares UK and overall success rates per type of action, and indicates whether the UK rate is higher than (>), equal to (=) or less than (<) the overall rate.

D.3. UK participation in H2020 projects

Table 31 to Table 34 show **the top ten organisations in each group of stakeholder**, ranked by the total value of their participation (EUR m) [18].

Table 31 Top 10 UK organisations – Research organisations (REC) (based on value of their participation)

Name	Total number of projects	Total value of their participation (EUR m) (based on EC contribution)	Location
United Kingdom Atomic Energy Authority	16	82	UKJ14
The Francis Crick Institute Limited	79	61	UKI31
European Centre For Medium-Range Weather Forecasts	45	27	UKJ11
John Innes Centre	34	23	UKH15
The James Hutton Institute	44	20	UK
Department Of Health	41	20	UKE42
National Oceanography Centre	31	16	UKJ32
Centre For Process Innovation Limited Lbg	18	14	UKC12
The Babraham Institute	23	11.2	UKH12
European Social Survey European Research Infrastructure Consortium	10	10.4	UKI43

Source: *Technopolis (2025) based on CORDA data.*

Table 32 Top 10 UK organisations – Public organisations (PUB) (based on value of their participation)

Name	Total number of projects	Total value of their participation (EUR m)	Location
United Kingdom Research And Innovation	259	117	UKK14
Met Office	31	15	UKK43
The Secretary Of State For Environment, Food And Rural Affairs	42	14	UKI31
Natural History Museum	41	12	UKI31
Welsh Government	4	9	UKL22
Uk Space Agency	9	9	UKK14
Birmingham City Council	13	7	UKG31
Department For Business Energy And Industrial Strategy	4	7	UKI31
Aberdeen City Council	4	6	UKM50
British Broadcasting Corporation	11	5	UK
National Institute For Health And Care Excellence	13	4	UKD33

Source: *Technopolis (2025) based on CORDA data.*

[18] Note that tagging of organisations in CORDA can be inconsistent, and we have manually placed some organisations in the relevant tables

Table 33 Top 10 UK organisations – Private organisations (PRC, Non-SMEs) (based on value of their participation)

Name	Total number of projects	Total value of their participation (EUR m)	Location
Rolls-Royce Plc	23	41	UKI31
Twi Limited	42	31	UKH12
Johnson Matthey Plc	54	18	UKI31
Samsung Electronics (Uk) Limited	13	11	UKJ25
Leonardo Mw Ltd	5	10	UKH37
Ricardo Consulting Engineers Limited	13	7	UKJ27
Marine Current Turbines Limited	1	7	UKK11
Arm Limited	20	6	UKH12
National Nuclear Laboratory Limited	19	6	UKD61
Johnson Matthey Fuel Cells Limited	8	5	UKI31

Source: Technopolis (2025) based on CORDA data.

Table 34 Top 10 UK organisations – SME Private organisations (based on value of their participation)

Name	Total number of projects	Total value of their participation (EUR m)	Location
Itm Power (Trading) Limited	15	29	UKE32
Nats (En Route) Public Limited Company	35	21	UKJ35
Orbital Marine Power Limited	3	17	UKM65
Nova Innovation Ltd	6	17	UK
Trilateral Research Ltd	37	11	UKI32
Trust-It Services Limited	37	11	UKI54
Npl Management Limited	31	9	UKI74
Aircraft Research Association Limited	5	9	UKH24
Information Catalyst For Enterprise Ltd	15	9	UKD63
British Telecommunications Public Limited Company	19	8	UKI31

Source: Technopolis (2025) based on CORDA data.

In terms of **collaborators,** Germany, France, Spain, Italy and the Netherlands were the top 5 collaborating countries on UK H2020 projects based on total number of participants**.** This ranking is the same for projects where the UK is the lead / host (Table 36). This reflects the long-standing history of collaboration, and the fact that these countries were major participants in H2020.

There was also relatively strong collaboration between the UK and Belgium, Greece, Sweden, Switzerland and Austria.

Analysis of changes to the UK's collaborations over time show a couple of significant shifts. Most notably, Germany was the UK's top collaborator country in the first half of H2020 (2014-17) but ranked 10th in latter period (2018-2020). In contrast, Malta went from 30th to 15th across the same period. There are no significant rises and falls spotted among the other top 30 collaborators group.

Table 35 Top 10 collaborating countries on UK projects

Country	Number of participations from those countries (in projects that include UK participation)	Percent of all participations/ collaborations
Germany	7,262	14%
France	6,127	11%
Spain	5,700	11%
Italy	5,456	10%
Netherlands	3,941	7%
Belgium	2,916	5%
Greece	1,908	4%
Sweden	1,897	4%
Switzerland	1,677	3%
Austria	1,411	3%

Source: Technopolis (2025) based on CORDA data.

Table 36 Top 10 collaborating countries on UK projects – UK lead

Country	Number of participations from those countries (in projects that include UK participation)	Percent of all participations/ collaborations
Germany	714	14%
France	575	11%
Italy	468	9%
Spain	421	8%
Netherlands	397	8%
Belgium	252	5%
Switzerland	184	4%
Sweden	169	3%
United States	153	3%
Greece	141	3%

Source: *Technopolis (2025) based on CORDA data.*

Appendix E Additional analysis – bibliometrics

E.1. Effect of decline in UK H2020 participation – synthetic control group approach

We can exploit the UK's EU exit as a 'natural shock' that led to lower UK participation in H2020 using a synthetic control (SC) group approach. SC is an innovative statistical method used in quasi-experimental research designs, particularly when experimental control groups are not feasible. It provides a way to create a counterfactual for a single treated unit using data from multiple controls. In this case, the treatment is the UK, and the SC a composite of a basket of comparable (in terms of research and industrial development) countries.

The EU referendum offers a natural experiment (external shock), with a before and after (2016) period, where there was a marked changed in levels of UK H2020 participation. This allows us to explore the extent to which this changed level of participation (a decline) has also led to a visible (and statistically significant) decline in the *overall volume of publications*. This analysis is not intended to show the effect of the EU referendum, but uses it as a 'device' to showcase the extent to which a decreased involvement in the FP/H2020 affected UK research outcomes.

Outcome of interest. The analysis focuses on *volume* of publications, mainly because research *impact* (as measured by Field Weight Citation Impact) has decreased among European countries (in relative terms) over time due to a considerable increase in citations from countries such as China and India, making analysis (which explores trends over time) difficult to interpret.

Note that there is a lag in *volume* of publications. However, since we have trend data and 8 years had passed since the EU referendum, we expect the effect to be minimal.

Unit of analysis. The unit of analysis are publications for each Field of Research (FoR). Publications are classified under 20 FoR and classification is based on OpenAlex.

Comparator countries. A synthetic control group (SCG) has been established, based on volume of publications, from a combination of five countries: Germany, France, Italy, the Netherlands and Spain. They have similar H2020 participation levels to the UK, and a comparable research base. We formed an SCG for each FoR to account for different degrees of specialisation across different countries. In many instances Germany received a weight of 1 as the closest comparator (and a better fit than a weighted average of the 5 countries).

Results. We found three distinct groups in terms of effect (note that the distribution of publications across those areas is presented in the main report).

- There seems to be a negative effect on the UK's overall research volume (publications) emerging from the decline in UK H2020 participation in only three FoR: Biochemistry (FoR 13), Chemistry (16) and Earth & Planetary Sciences (19). However, this apparent decline (relative to the comparator) is not statistically significant (there is high probability the effect has been produced by chance rather that by the decline in H2020 participation after 2016) (see Figure 16). Note that there is a sharp decline in the number of Chemistry publications in the UK, which would warrant further investigation (and it is outside the scope of the study).

  A prior study conducted by Technopolis showed that 'Chemistry' was among the top 15 disciplines in the UK with the highest EU funding (as a proportion of their research income) in 2014/15 (23%) (10th position).[19] 'Biosciences' and 'Earth, marine & environmental sciences' were also among the top 15 disciplines when looking at absolute value of EU funding (2nd and 8th positions respectively). The figures that were used on EU funding go beyond the FP but provide an indication of dependency on these type of programmes.

[19] The role of EU funding in UK R&I. https://technopolis-group.com/wp-content/uploads/2020/02/The-role-of-EU-funding-in-UK-research-and-innovation.pdf. Disciplines defined using HESA cost centres

These results indicate that some of the disciplines that are more dependent on funding may have indeed experienced a negative effect from a decline in participation (but not all).

- Conversely, there are four FoRs where the UK has developed a substantial advantage against comparator countries despite (because of) the decline in H2020 participation. This includes: Computer Science (FoR 17), Engineering (22), Material Science (25). Furthermore, the difference is statistically significant. Note that in all cases the UK advantage started before 2016, and this lead has increased or been maintained. (Figure 17).

  This is despite the fact that 'IT, systems sciences & computer software engineering' was found in our prior study to have a high proportion of research income from EU funding (30%). Similarly, five fields of engineering (apart from IT) also appeared amongst the top 15th disciplines when looking at absolute value of EU funding. This may mean that in the case of Computer Science and Engineering it was possible to pivot to other sources of funding.
- There is also a substantial advantage against comparator countries in the area of Physics & Astronomy (FoR 31), even if there has been a decline in total volume of publications over the past years. As shown above a substantial number of publications in this field have emerged from H2020 projects. This indicates that H2020 may have contributed to sustaining a leadership position (even with a decline in the volume of publications).

For the remaining 13 FoRs, there is no substantial increase or decrease after 2016 (in comparison with the synthetic control group), and observed differences are not statistically significant. (See appendix E for full results across these FoRs).

Overall, this analysis indicates that only three disciplines may have been significantly affected (in terms of the volume of research output) by the decline in UK participation in H2020.

Further testing. To test the robustness of results we conducted additional analysis and included a further variable in the construction of the synthetic control group. This variable is Higher Education Expenditure on R&D (HERD), taken from the OECD Main Science & Technology Indicators[20]. The rationale for including HERD was to seek to account for previously unobserved characteristics between the UK and the control group. In this case, it is reasonable to believe that UK research funding previously provided by the EU Framework Programmes was replaced by domestic funding sources at or around the time of the UK's departure from the EU (a substitution effect). The idea is that adding additional controls will lead to a synthetic control that better mimics the behaviour of the UK time series for the pre-treatment period (2008-2015).

We tested this for one FoR (Chemistry). Comparison with prior results shows that the inclusion of further controls had little impact on the similarity of the two time series in the pre-EU referendum period. This is also shown by the weights placed on yearly observations of HERD being small in magnitude relative to publication count. As a further experiment, we also included Government allocation for R&D (GBARD). Again, this had little impact on results.

Limitations and caveats. Further explanatory variables could help to improve the analysis. As stated above, the introduction of R&D expenditure did not alter the results, however future studies could consider other variables such as value of research income by sources over time, which could help to improve the analysis. However, it is important to note that adding this or other explanatory variables would require sourcing and including data on the same indicators for each of the 6 countries, for each of the 10 years under analysis, which could be challenging.

Additionally, as shown in the graphs below even in the cases where the difference in results after the EU referendum were statistically significant, in most cases the parallel trend assumption is not fully met (close similarity between the UK and synthetic control before 2016) and the synthetic control does not fully mimic the trend of the UK across all fields.

[20] https://www.oecd.org/en/publications/serials/main-science-and-technology-indicators_g1g1e97b.html

Figure 16 Change in volume of publications (synthetic control group analysis) - I

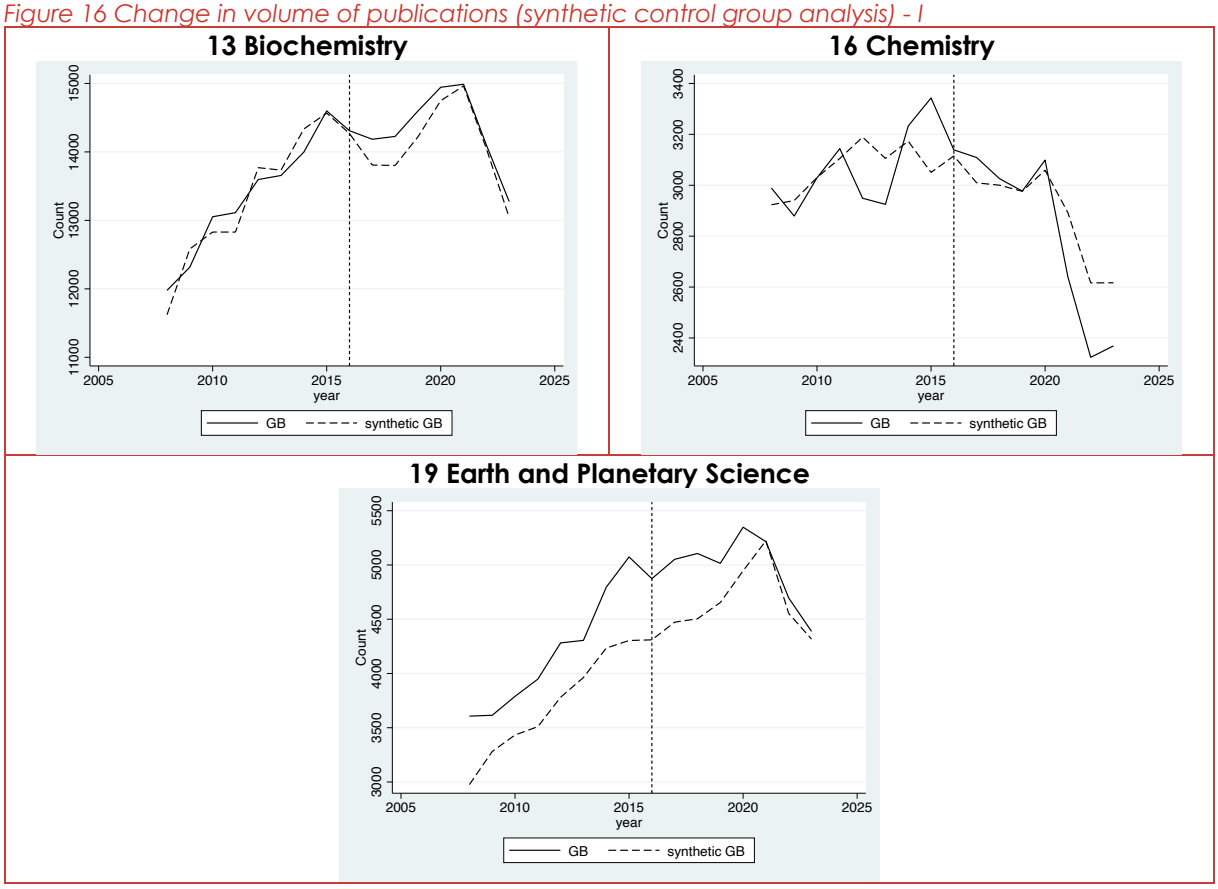
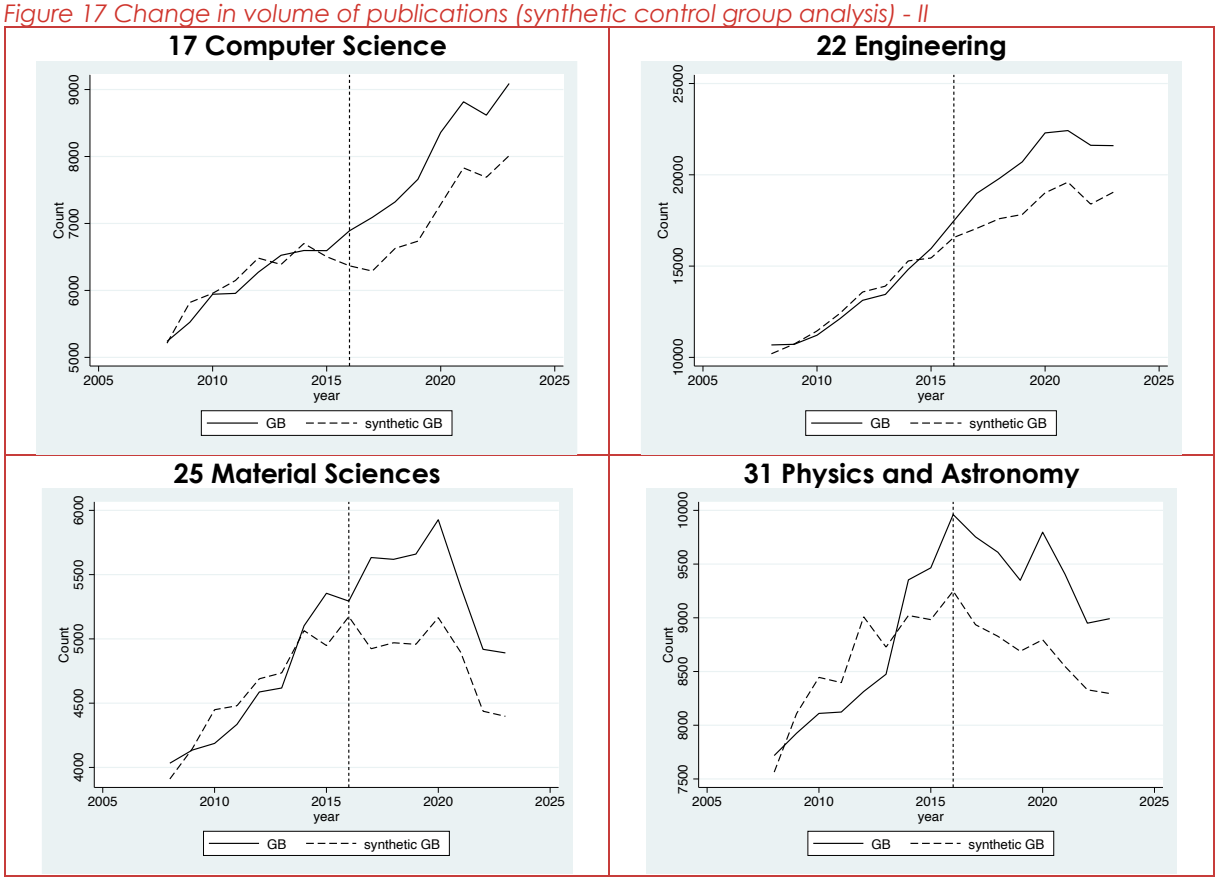
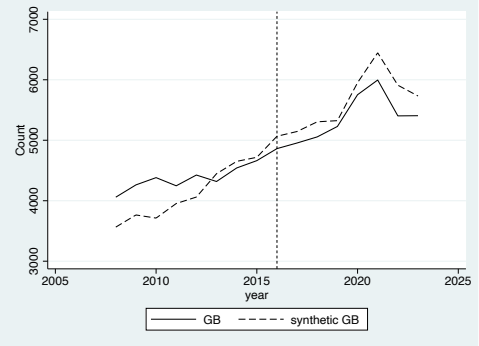


Figure 17 Change in volume of publications (synthetic control group analysis) - II

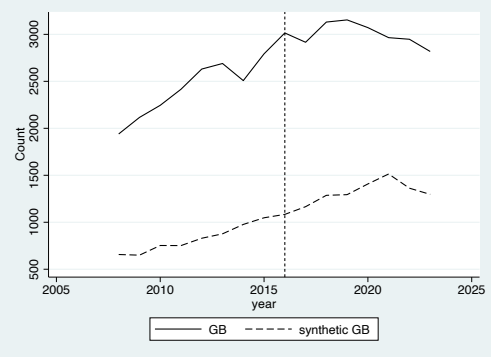


For completeness, the following graphs present the results from the Synthetic Control estimation across all Fields of Research. Only the results shown above were statistically significant; the graphs below are only presented to provide additional information on UK's trends across FoRs)

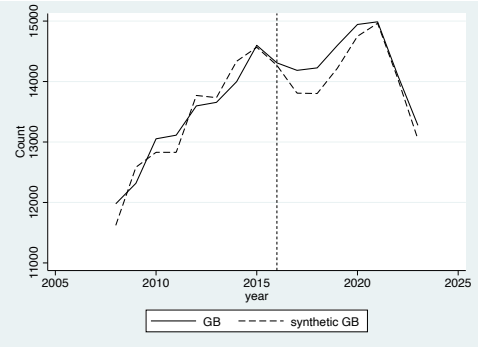
Field 11Agricultural and Biological Sciences



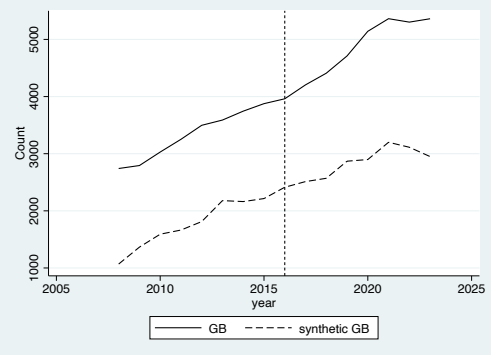
Field 12 Arts and Humanities



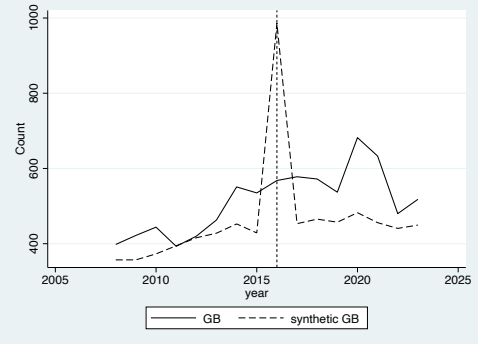
Field 13 Biochemistry, Genetics and Molecular Biology



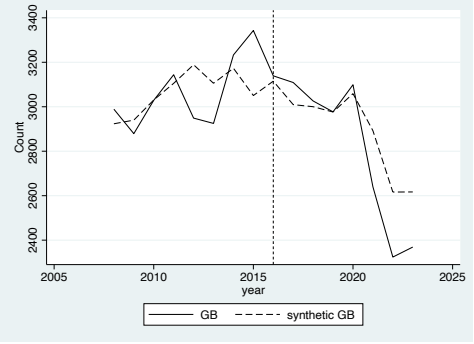
Field 14 Business, Management and Accounting



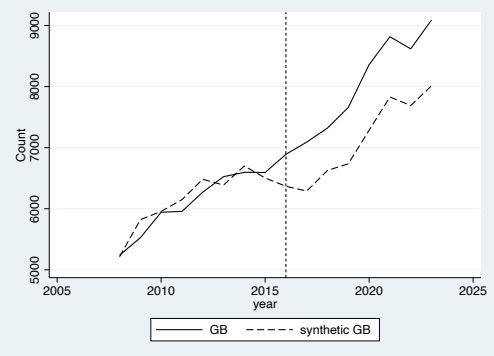
Field 15 Chemical Engineering



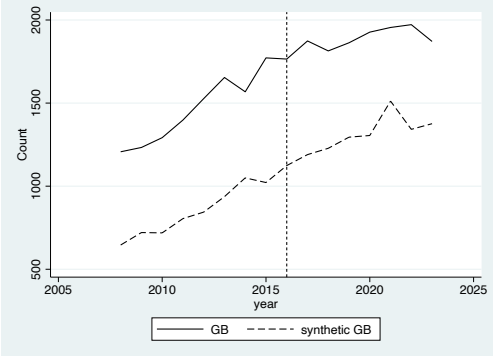
Field 16 Chemistry



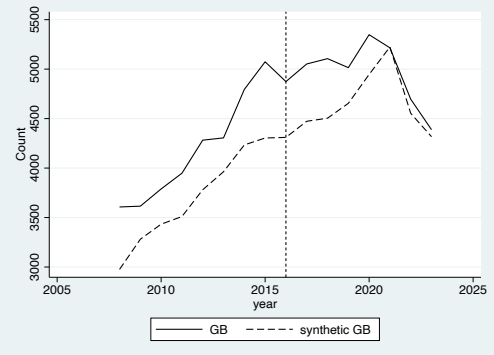
Field 17 Computer Science



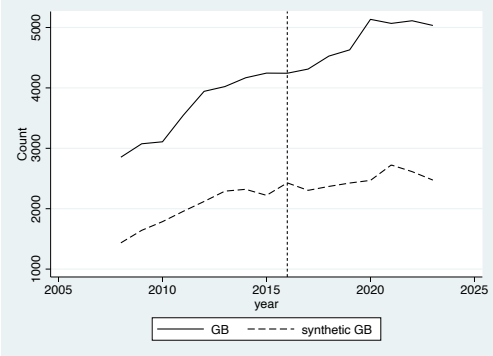
Field 18 Decision Sciences



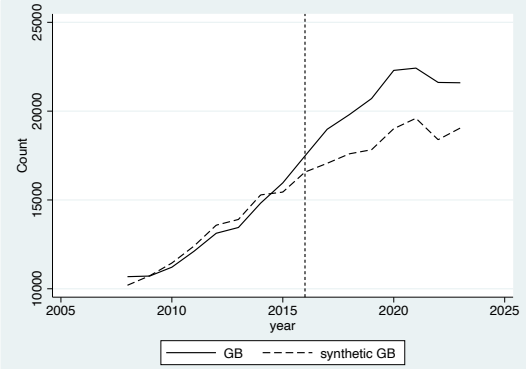
Field 19 Earth and Planetary Sciences



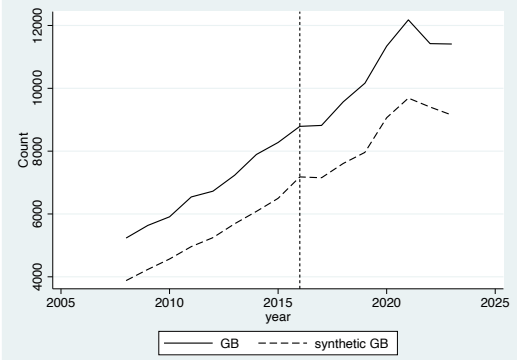
Field 20 Economics, Econometrics and Finance



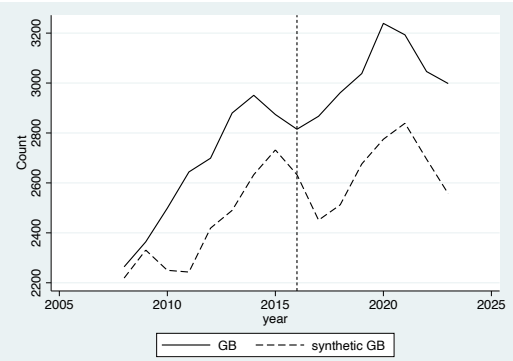
Field 22 Engineering



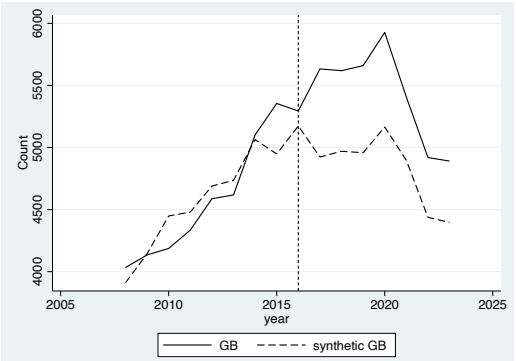
Field 23 Environmental Science



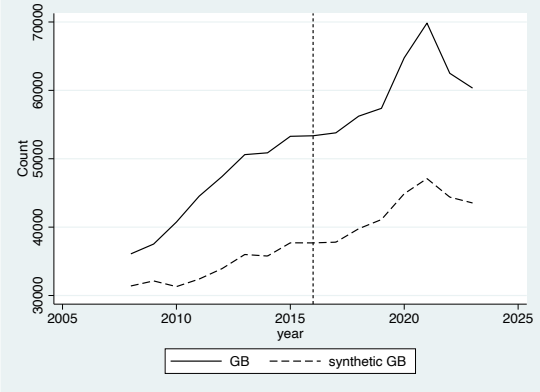
Field 24 Immunology and Microbiology



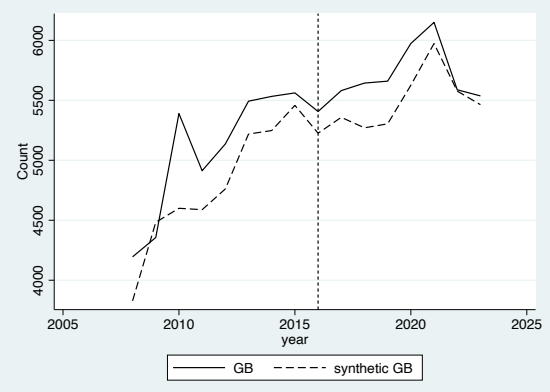
Field 25 Materials Science



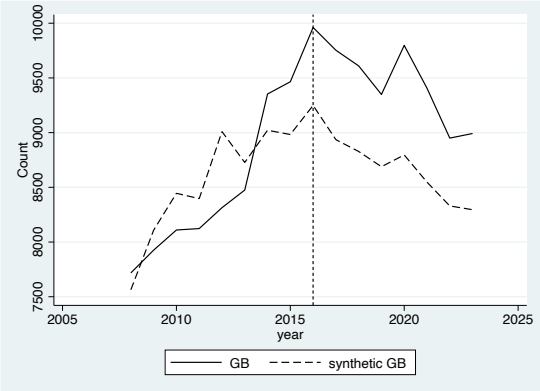
Field 27 Medicine



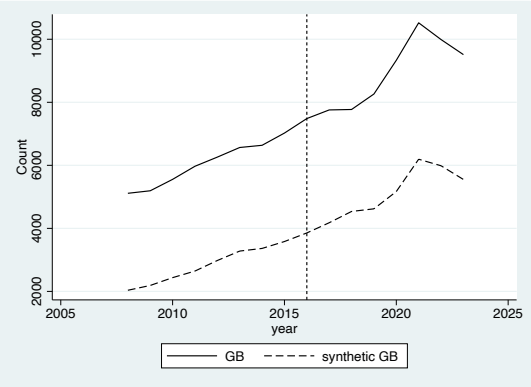
Field 28 Neuroscience



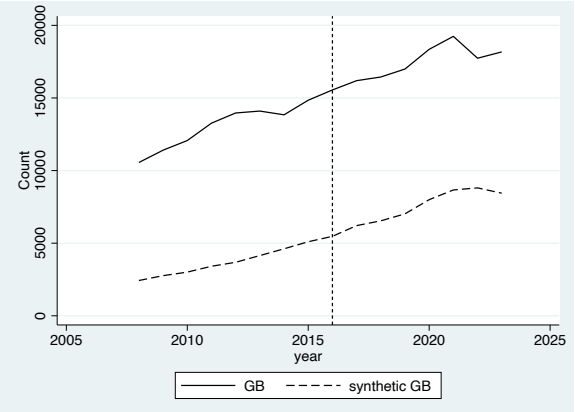
Field 31Physics and Astronomy



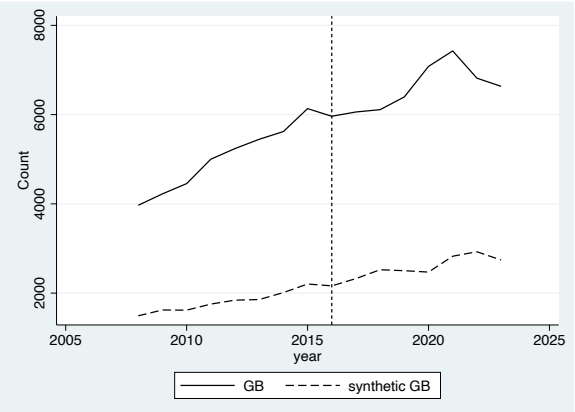
Field 32 Psychology



Field 33 Social Science



Field 36 Health Professions



Appendix F Case Studies

F.1. Introduction

This appendix presents four in-depth case studies that each explore a H2020 project (or group of projects) with UK involvement. These are:

- The Innovative Medicines Initiative **(IMI2),** where 29 universities and 32 companies from the UK participated in different projects. The case focuses on three projects: Conect4Children, DRAGON and INNODIA, which together saw €17.6m in EC contributions to UK participants.
- The Prototype System for a Copernicus CO_2 Service (**CoCO2**) project, a €9m initiative, coordinated from the UK
- **MicroQC**, a project combining world-leading expertise in quantum engineering, theoretical modelling, and microchip development from the UK and 3 other countries
- **EOSC-Life**, which brought together 50 organisations from 13 countries to create an open, digital, and collaborative space for biological and medical research. The case has a particular focus on impacts and outcomes associated with work packages 1, 2 and 3, which involved researchers from the University of Dundee, Historic England and the University of Manchester.

Each case presents a narrative on the activities supported via H2020 and the outputs, outcomes and impacts that have emerged. Importantly, each also explores the role and added value of H2020 in realising these benefits. The cases were developed on the basis of desk research and interviews with UK participants (10 interviews were undertaken in total across the four cases). The interviews were semi-structured, with questions aligned with the structure of the eventual case studies (which start with an overall summary, then explore the background and project activities, the outputs, outcomes and impacts that have emerged, and finally the added value of H2020 in each case).

F.2. Addressing Transnational Societal Challenges: Innovative Medicines Initiative (IMI2) Case Study

Summary

Access to healthcare is a central challenge in our society. **The Innovative Medicines Initiative (IMI2)** aimed to accelerate the development of safer and more effective medicines. IMI2 formed part of the world's largest public-private partnership in the healthcare sector and created a collaborative ecosystem for pharmaceutical research and development (R&D) in Europe.[21] IMI2 was built on a partnership between the European Commission and European Federation of Pharmaceutical Industries and Associations (EFPIA). The funding comprises a European Union (EU) contribution of €1.638 billion from Horizon 2020 (UK component: ~€150 million) with an additional commitment from the EFPIA members of €1.245 billion.

Through international collaboration between academia, industry, regulators and patient groups, **IMI2 projects have addressed bottlenecks in drug development, boosted innovation in areas of high unmet medical need and trained the next generation of biomedical researchers**. For example, IMI2 was pivotal in the development of new clinical tools, biomarkers, platforms and data standards in complex areas such as antimicrobial resistance and neurodegenerative and rare diseases. It has supported the development of innovative diagnostics, digital health solutions and patient-centred approaches to healthcare.

IMI2 represents **an early but crucial step in the logic model that will lead to improved quality of life for millions living with disease in the longer term**, through access to safer and more effective treatments. IMI2 projects included many activities aimed at enhancing the efficiency of clinical trials and accelerating the implementation of innovative healthcare treatments. These included basic and applied research, development of R&D infrastructure, and establishment of cross-sector R&D networks. Funded projects addressed both common conditions (e.g. diabetes) and areas of unmet medical needs, such as rare and paediatric diseases. IMI2 also strengthened Europe's capacity to respond to global health threats, contributing to the COVID-19 response.

The development of medicines for many diseases requires a co-ordinated, international approach, such as that provided by IMI2, which brings together scientific expertise, infrastructure and clinical data. No single country holds all the necessary capabilities across every disease area. IMI2 enables the UK and other participating countries to collectively tackle major healthcare challenges, including pandemic preparedness and the impacts of ageing populations. As IMI2 projects involve large multinational consortia and operate predominantly in the pre-competitive space, most benefits are shared equally across each participating country, such as access to patient databases, clinical trial advice and research findings. This case study highlights three examples of projects funded through IMI2 that demonstrate the importance of pan-European funding to address societal health challenges and the broad range of outcomes and impacts it enabled.

[21] https://www.efpia.eu/about-medicines/development-of-medicines/public-private-partnerships/

F.2.1. Background and Context

Developing new medicines in Europe remains slow, costly and difficult, especially in areas of unmet need such as paediatrics, infectious diseases, and autoimmune conditions.[22][23] In parallel, public health threats such as COVID-19 have revealed weaknesses in Europe's capacity to diagnose and respond quickly to emerging diseases, particularly where symptoms are inconsistent or evolving.[24]

One of the main barriers to delivering new treatments to patients is navigating the complex process of clinical trials.[25] Major hurdles exist throughout the process, from recruiting and retaining enough patients for the trial, designing the trial effectively, gaining approval from regulators and managing data appropriately.[26]

These barriers reduce incentives for industry to pursue new treatments, particularly for rare and paediatric diseases where the challenges are greater due to minimal patient data and greater complexity of disease. Patients with rare diseases often face delayed diagnoses, limited access to specialist care, and a lack of effective therapies. 95% of rare conditions do not yet have a treatment, resulting in substantial lifelong health complications and reduced quality of life.[27] Both industry and academia work on developing new treatments. However, difficulties in developing collaborations across sectors, scientific fields and countries means that expertise focused on any one disease is often fragmented.

Addressing these challenges requires frameworks that enable cross-sector collaboration to improve clinical trial efficiency and strengthen Europe's ability to respond to unmet medical needs and emerging public health threats.

F.2.2. The project

The Innovative Medicines Initiative (IMI2) aimed to accelerate the development of safer and more effective medicines for patients, particularly in areas of unmet medical or social need. Its primary role is to facilitate collaboration between the organisations involved in healthcare and biomedical R&D.

A key aspect of all IMI2 projects was the requirement for public-private partnerships. Effective disclosure agreements between academia and EFPIA members enabled safe exchange of knowledge and collaborative working for the benefit of clinical research in both the public and private sector. The partnerships ensured research efforts remained aligned with industry needs, resulting in greater buy-in from industry and high potential for translation. To ensure patient perspectives are integrated into the design of future clinical trials, close engagement with patient groups was another key focus.

IMI2 brought together hundreds of EFPIA companies, academic institutions, non-profit organisations, SMEs, patient groups and regulators. The programme was co-ordinated by the IMI2 Joint Undertaking located in Brussels. A total of 1,148 organisations participated from 48

[22] https://www.firmaclinicalresearch.com/wp-content/uploads/2019/11/Firma_WhitePaper_Pediatric_update_v3.pdf
[23] https://ojrd.biomedcentral.com/articles/10.1186/s13023-018-0990-4
[24] https://pmc.ncbi.nlm.nih.gov/articles/PMC8993495/
[25] https://systematicreviewsjournal.biomedcentral.com/articles/10.1186/s13643-024-02698-8
[26] https://www.nature.com/articles/s43586-022-00100-2
[27] https://www.efpia.eu/about-medicines/development-of-medicines/intellectual-property/help-us-make-rare-disease-even-rarer/

different countries, including EU member states (85.6%), Third Countries (7.9%) such as Brazil and Australia, and countries associated with Horizon 2020 (6.4%) such as Norway and Switzerland.

29 universities and 32 companies from the UK participated in IMI2 projects. The UK had the highest number of project co-ordinators of any country. The University of Oxford alone was involved in 38 different projects, which was the maximum number of participations of any academic organisation.[28]

IMI2 funded 123 projects over 23 calls for proposals between 2014 – 2020, which focused on topic areas such as cancer, neurodegeneration, respiratory and immunological diseases. Projects typically involved:

- developing new diagnostic tools
- identifying novel biomarkers of disease
- establishing centralised repositories of pan-European patient data
- improving access to clinical infrastructure and international expertise
- developing and co-ordinating clinical trial designs
- close engagement and co-development with patient groups
- adopting standardised clinical procedures across Europe.

F.2.3. IMI2 and the UK: C4C, DRAGON AND INNODIA

Table 1 below describes three projects funded through IMI2, which will be investigated throughout this case study to demonstrate the value of IMI2 in providing a collaborative framework and delivering unique impacts for the UK and Europe.

Table 1 Funding information and short description of the three IMI2 projects investigated in this case study.

Project Title	H2020 Funding	Description
Conect4Children (C4C)	**Total:** €140m **UK component:** €10.9m **Duration:** 7 years	**Challenge:** persistent bottlenecks in translating paediatric research through to clinical trials and child patient benefits. **Aim:** to accelerate the clinical trials process for paediatric diseases. **Key objective**: to establish a collaborative network of expertise, infrastructure and patient groups across Europe to develop innovative and co-ordinated approaches to paediatric clinical trials.
DRAGON	**Total:** €11.4m **UK component:** €3.8m **Duration:** 3.5 years	**Challenge**: response to the COVID-19 pandemic **Aim**: to improve the diagnosis, treatment, and management of COVID-19 **Key objective**: to develop and implement artificial intelligence and data-driven approaches to support rapid decision-making and personalised care for COVID-19 patients, whilst laying the foundation for future pandemic

[28] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ihi.europa.eu/sites/default/files/uploads/Documents/About/Reports/Evaluation_IMI2final_IHImidterm.pdf

		preparedness.
INNODIA	**Total:** €17.6m **UK component:** €2.9m **Duration:** 8 years	**Challenge**: type 1 diabetes (T1D) is a highly complex disease, dependent on genetic, environmental and immune factors. Currently no definitive cure exists. **Aim**: to advance our understanding of the basic mechanism underpinning T1D and to improve how we predict, evaluate and prevent the onset and progression of T1D. **Key objective**: to create a pan-European framework of experts, infrastructure, data, standards and protocols to enable translational approaches to type-1 diabetes.

For each of the projects described above, information about outputs, outcomes and impacts was gathered through desk research and interviews conducted with individuals employed by UK organisations and responsible for delivering work packages during the projects. Interviewees were also asked about the added value of UK participation in EU H2020 funding and the impact of EU Exit on their work.

Each project focused on the collaborative study of innovative medicines and therefore had similar objectives. Due to significant overlap of insights gathered, the remaining sections below are combined into different themes, drawing on specific examples from each of the three projects throughout.

F.2.4. Project Outputs

Standardisation of clinical data

A key challenge of IMI2 projects was to address the fragmented approach to clinical data management across Europe and lack of adoption of FAIR principles.[29] Interviewees agreed that international collaboration is crucial to ensure clinical data is collected, analysed, stored and re-used in a consistent way.

For example, the C4C network developed several protocols and guides that enable researchers to generate their data in a standardised way and ensure consistency across paediatric clinical trials. In 2022, the network setup the GLObal PAediatric Data Forum (GLOPAD), aiming to standardise cross-cutting clinical trial data that is routinely collected across all types of clinical trials. In 2023, C4C brought academia and industry partners together to publish the Paediatric User Guide (PUG). The PUG described how to collect and structure data from trials involving specific paediatric diseases and was added to a suite of global standards developed by the Clinical Data Interchange Standards Consortium (CDISC).[30]

The INNODIA project established a master protocol to help clinicians evaluate the use of medicinal products for cases of newly formed T1D. The master protocol has standardised the way clinical trials are performed across treatment candidates for T1D, from recruiting patient cohorts through to sample collection and data analysis.

[29] FAIR principles are guidelines for making data Findable, Accessible, Interoperable, and Reusable to enhance data sharing and reuse. See https://www.nature.com/articles/sdata201618

[30] https://www.jscdm.org/article/id/218/

Guidance for clinical trial design

Translating research into new treatments is often hindered by poor clinical trial design. Access to appropriate information and expert advice can be challenging and inconsistent.[31]

C4C has pioneered a pan-European network involving 21 countries and over 400 paediatric experts to aid medicine developers when designing paediatric clinical trials. The network connects clinicians to academia who specialise in areas such as oncology, neonatology and rare diseases, experts in study design, statistical analysis and modelling, and parents. This helps improve the feasibility of trials and accelerate their development and implementation whilst ensuring trials are made as ethical as possible for children, young people and families.[32]

Alongside expert advice, access to clinical infrastructure is crucial. Both INNODIA and C4C networks provide access to accredited clinical trial sites across Europe and advice on site identification, feasibility and support in delivering clinical trials. Training materials such as online courses and workshops have been developed through these projects. For example, C4C established an e-Learning Academy Platform which hosts over 40 training courses, which include both generic and disease-specific training for paediatric trials.[33]

Research into biology of diseases

Molecular signatures of disease onset and progression – termed biomarkers - are complex and rarely isolated at the genomic (DNA) level. They involve complex interplay with RNA transcription and protein translation. Additionally, patient outcomes can vary depending on factors such as age, geography and socioeconomic background of the patient. European collaboration has been fundamental to enable data collection across different omics modalities (incl. genomics), geographies and demographics to develop a comprehensive set of disease biomarkers that inform diagnostics and clinical intervention strategies.

For example, INNODIA launched a Natural History Study, which integrated omics data collected from T1D patients across multiple sites in Europe to characterise age-dependent differences in treatment response over time. The project was the first of its kind in Europe where study procedures across clinical sites were identical. The project led to the discovery of new age-related biomarkers associated with rate of T1D progression shortly after diagnosis.[34]

Findings from IMI2 disease research have also been applied more broadly to other diseases. For example, research into autoimmune disease typically focuses on mechanisms within the immune system. However, INNODIA research highlighted the importance of considering systems within the target tissue itself. Researchers identified gene activity changes in the beta cells of the pancreas of T1D patients and found similar changes in affected tissue of arthritis and multiple sclerosis patients.[35] The findings from INNODIA have influenced how research into autoimmune disease is conducted, showing wider impact of IMI2 on basic research.

[31] https://ascpt.onlinelibrary.wiley.com/doi/10.1111/cts.13459

[32] https://conect4children.eu/#services

[33] https://pmc.ncbi.nlm.nih.gov/articles/PMC7979601/

[34] https://link.springer.com/article/10.1007/s00125-024-06124-5

[35] https://www.ihi.europa.eu/news-events/newsroom/innodia-diabetes-findings-prompt-new-research-other-autoimmune-diseases#:~:text=In%20a%202019%20paper%20in,to%20be%20involved%20in%20diabetes.

Educational tools for researchers, clinicians, patients and wider public

The C4C established a patient and public involvement (PPI) database, to include the opinions of patients and parents/carers, helping clinicians to understand their practical needs and factor this into the design of clinical trials.

The European Lung Foundation (ELF) is based in Sheffield and formed part of the DRAGON consortium. They developed lay communications about COVID-19 and the project's progress. For example, they produced a video series on patient stories to help raise awareness of the challenges of living with COVID-19.[36] The ELF served as a conduit between DRAGON researchers and patient groups, incorporating their perspectives into the work packages and wider policy. Patient representatives are also included on the ELF board and a Patient Advisory Group was setup to help people understand personal impact of COVID-19 and to inform those concerned about COVID-19.

INNODIA setup a Patient Advisory Committee, the first of its kind in an IMI project, whose role was to deliver an informed perspective on patient relevant activities such as designing clinical trials, creating educational materials, raising public awareness and influencing direction of future research priorities.[37]

F.2.5. Project Outcomes (1-7 years)

International data resources to support medicine development

The standardisation of data is a central outcome of all three projects and will create a wealth of clinical information to draw from going forward. As a result, drug development will benefit from standardised data analysis across trials, re-use of trial data and reduced duplication efforts.

Projects such as DRAGON have developed distributed learning infrastructures, which enable data science approaches to obtain insights from patient data across borders without the data having to leave the clinical centre. They are crucial for ensuring patient data is harnessed across Europe safely and securely and will serve as a model for other health communities to follow. Consolidated data will accelerate the pace at which trials can be designed and approved, being able to draw on methodologies used in previous trials. Through these pan-European networks, drug developers will also be able to capitalise on access to large patient cohorts to cut down on recruitment time.

Innovation in clinical trial design

The protocols, standards and tools developed during these projects will serve as a blueprint for other communities to adopt for their own clinical trials. Outputs such as INNODIA's Master Protocol and C4C's Paediatric User Guide will ensure consistency in the way clinical trials are run. Drug developers intending to explore future treatments will benefit from standardised trial procedures adopted across Europe that ensure the resulting data is interoperable and re-usable. Lessons learned will be shared through international knowledge exchange, thereby minimising time and cost required to complete clinical trials. The next generation of researchers and clinicians across Europe are being trained in adopting using these innovative approaches, helping to preserve best practice longer-term.

[36] https://europeanlung.org/en/people-and-partners/your-experiences/helen-parks-my-covid-19-story/

[37] https://www.efpia.eu/news-events/the-efpia-view/blog-articles/innodia-a-success-story-in-type-1-diabetes-research-and-treatment/

Standardisation of clinical trial methodologies will enable control groups to be shared across multiple trials, having undergone identical trial procedures. Additionally, large collections of structured data developed through international coordination are suitable for machine learning approaches. This enables production of synthetic data, which can simulate control arms of trials. Synthetic controls can play a particularly important role in rare diseases, where limited data exists from real patients. These innovations will ensure future clinical trials are more ethical as patients will not be subjected unnecessarily to placebos instead in place of proven treatments.

The discovery of new biomarkers will improve efficacy of trial design by enabling clinicians to stratify clinical trial participants into more defined trial groups based on factors such as age and disease progression. A more comprehensive set of biomarkers for a disease helps to determine patient endpoints and thereby minimise time required for patient participation in the trial, further improving the ethics of future studies and enhancing the patient experience.

Another important outcome of IMI2 is the shift towards adaptive clinical trials. Adaptive trials offer several advantages compared to traditional randomised control trials. They are more efficient, informative and ethical than trials with a fixed design.[38] They involve taking decisions during the interim stages and modifying the direction of the trial. Adaptive trials require larger volumes of patient data to accelerate the accumulation clinical outcomes and enable interim decisions to be made, such as dividing trials into more treatment sub-groups or discarding ineffective or unsafe compounds. European collaboration around patient data has therefore been essential to support adaptive clinical trials, particularly by rare and paediatric disease communities.

Improved decision making in healthcare

IMI2 has made substantial contributions to the field of digital health by supporting the development of digital health technologies and their integration into practice.[39] This provides opportunities for the UK to adopt new predictive modelling and decision support tools developed through IMI2, which assist doctors in personalising advice and treatment strategies for patients. For example, two Dutch industry partners in the DRAGON project, Thirona and Delfy Imaging, developed an AI tool for CHEST CT imaging called CAD4COVID-CT, supporting doctors internationally to assess the severity of COVID-19 infection on chest CT scans.[40] The performance of this tool is comparable to six radiologists with between 5 – 24 years of experience[41]. Additionally, an open-source repository of AI models called Covid19Risk.ai was developed at Maastricht University during the DRAGON project. It combines and validates predictive models for COVID-19 risk and outcomes developed by researchers globally. The repository provides a user-friendly format to assist doctors in advising patients on aspects such as whether to quarantine or go to hospital, which promotes efficient use of hospital resources[42].

[38] https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-018-1017-7

[39] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ihi.europa.eu/sites/default/files/uploads/Documents/About/Reports/EvaluationStudy_HE_ResilientEurope_Annexes.pdf

[40] https://thirona.eu/product-news/cad4covid-xray-performs-comparable-to-radiologists/

[41] https://www.checktb.com/cad4covid

[42] https://www.mdpi.com/2673-8430/1/1/3

Long-term sustainability

IMI2 has also supported the formation of non-profit organisations from initial networks, which continue their legacy of improving clinical trial designing, boosting adoption of new therapies and addressing global health challenges through their services.

C4C-Stichting (C4C-S) has completed over 60 requests for advice on clinical trials across the whole paediatric spectrum. Through a spin-out formed in 2022, called INNODIA iVZW, INNODIA continues to support researchers and clinicians developing new T1D treatments; from identifying the appropriate accredited clinical trial sites and labs for analysis, to designing and executing their clinical trial and benefiting from access to data and samples collected through the INNODIA network. Due to the success of DRAGON, many involved in the project have fed into establishment of a new Connected Respiratory Care (CRC) network launched by European Respiratory Society. The network consists of over 800 partners across Europe with the aim of improving digital healthcare for respiratory diseases and preparing for future pandemics[43].

Stronger industry engagement with UK and EU

IMI2 projects have helped to make the UK and EU a more attractive ecosystem for industry to engage with when developing new treatments. A comprehensive understanding of disease biomarkers is an important step in de-risking new clinical trials and encouraging potential trial sponsors to engage. IMI2 provided essential support for early-stage, pre-competitive research into disease mechanisms, which helped to promote translation. For example, INNODIA HARVEST was a follow-on project that is currently using new T1D biomarkers identified during INNODIA to run 4 clinical trials for people with newly diagnosed T1D. The studies involved collaborations with industry partners such as Novartis Pharmaceuticals and Sanofi that will help to accelerate use of new T1D treatments.

UK industry is also benefitting directly from IMI2 projects. For example, a spinout company from University of Southampton, TopMD, leveraged COVID-19 patient cohorts gathered from members of the DRAGON consortium in Italy and Belgium. They used gene expression data to develop new models, which preliminary findings suggest can predict outcomes for COVID-19 patients. As a proof of concept, the model has been added to a suite of tools developed during the DRAGON project, which provide disease management advice for clinicians and patients.[44]

New protocols and data standards have encouraged industry to share knowledge and data more openly with academia and embrace the need to make successful and unsuccessful data accessible. Pharmaceutical companies developing new paediatric treatments are required to adopt global standards developed by Clinical Data Interchange Standards Consortium (CDISC) when submitting their clinical data to regulators. C4C's Paediatric User Guide was developed in collaboration with CDISC and industry partners. It has provided disease-specific guidance on trial design and execution that streamlines the work of industry and academia in paediatric diseases, thereby promoting collaborations.

[43] https://www.ersnet.org/science-and-research/clinical-research-collaboration-application-programme/connect-moving-multiple-digital-innovations-towards-connected-respiratory-care-addressing-the-over-arching-challenges-of-whole-systems-implementation/

[44] https://www.medrxiv.org/content/10.1101/2024.04.15.24305820v2

Enhanced patient-centred approach

IMI2 funding has set a new standard for patient-centred research in Europe by ensuring their voices are represented at all stages; from prioritisation of research areas, design of clinical trials to delivering new treatments at the point-of-care. Through the work of C4C's e-Learning Academy Platform, paediatric patients and parents receive better education on diseases and are empowered to contribute to the development of new treatments.

Similarly, the DRAGON project changed the way patient advocacy groups such as ELF engaged with the public to address their concerns. For example, online Q&A sessions were delivered during the pandemic to connect the public with experts who were able to answer questions, helping to mitigate against the spread of misinformation on social media.

ELF also conducted a systematic review of patient perceptions of digital tools and whether they improve their relationship with healthcare professionals or not. This led to an understanding of aspects of digital care that work well for patients and those that don't, which helped to remove perceptions about the lack of agency patients have in influencing their care and broader healthcare policy.

F.2.6. Project Impacts (7+ years)

It typically takes over 10 years for a potential drug candidate to reach the market, and costs are regularly in excess of €1 billion, rising considerably for rare and paediatric diseases. While IMI2 projects such as C4C, DRAGON and INNODIA are considerable investments, they are not capable of producing new medicines on their own. Instead, they enable the underpinning activities that contributed to quicker approval of medicines at lower costs, through effective clinical trials that are currently a significant barrier across Europe. Interviewees highlighted the collaborative nature of IMI2 projects that are designed to deliver shared impact across participating countries. Therefore, the majority of impacts presented here are applicable across the EU, not solely for the UK.

Recent evidence has shown targeted benefits to the UK in terms of accelerated approvals for new drugs since 2020.[45] This could, in part, be linked to the UK's involvement in European programmes such as IMI2. However, the greater urgency and risk tolerance of regulatory bodies industry and public research organisations in response to COVID-19 is another likely factor.[46] Nevertheless, these early indicators could have the potential to lead to economic gains for UK companies, who will be able to utilise organisations such as C4C-S and INNODIA-iVZW to overcome lengthy trial procedures and reduce the overall cost of drug development. Furthermore, UK involvement in the development of European and global data standards, methods and regulations are reducing barriers to collaboration with industry and improve UK access to global pharmaceutical markets.

IMI2 project results are likely to contribute to the improvement of the health and the productivity of the UK population. For example, over 450,000 people have T1D in the UK.[47] The cumulative economic burden of diabetes in the UK, including type 1, type 2 and gestational diabetes, amounts to approximately £14 billion per year.[48] INNODIA has laid the groundwork for improved interventions and public understanding of how to manage T1D. Current research

[45] https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2835887

[46] https://www.mdpi.com/1422-0067/22/11/5457

[47] https://www.diabetes.org.uk/about-us/about-the-charity/our-strategy/statistics

[48] https://onlinelibrary.wiley.com/doi/epdf/10.1111/dme.15326

focuses on the development of new treatments to preserve beta cell function in the pancreas and delay reliance on insulin injections, which can be problematic for patients. Clinical trials are ongoing but are already showing early success that could lead to benefits for the health, wellbeing and productivity of the UK.[49]

IMI2 is an example of the increasing role of patients and patient organisations in the development of new medicines. The programme represented a shift from bilateral collaborations between academia and industry, towards an open innovation environment that considers the views of all actors.[50] As a result, UK patients are more likely to have better access to personalised medicines, improved management strategies and public information about their disease. UK-based patient advocacy groups such as ELF have consolidated COVID-19 information from across Europe to produce clear and accessible guidance for the public. During clinical trials, fewer patients will have proven treatments withheld from them in place of placebo controls. Instead, powerful computational approaches, enabled through large European patient databases, will construct synthetic control groups to minimise impact on patients. Patient-centred tools, such as those developed during the DRAGON project, are scalable and reusable for future respiratory pandemics. The UK's readiness to respond flexibly to future health emergencies will improve through deploying these tools, co-ordinating an international response and adopting a patient-centred approach.

F.2.7. H2020 Added Value and Impact from EU Exit

Interviewees were asked to provide feedback on the additionality of H2020 funding in comparison to what could be achieved through national funding initiatives. There was consensus across interviewees that developing new treatments and improving healthcare systems is a challenge that can be best addressed through a co-ordinated international framework.

Knowledge exchange

Interviewees highlighted the need for European collaboration to enable the UK to learn from the success and failures of other countries. Individuals added that insights into how healthcare systems operate in other countries provide useful evidence to justify future improvements being implemented in the UK. Whilst the UK approach is seen as best practice in many areas of health, interviewees referred to notable examples of other countries adopting best practice and opportunities for the UK to learn. For example, in 2019, France established their Health Data Hub to integrate multiple French health databases into a single, centralised point of access.[51] This approach could serve as a model for the UK, which faces challenges in managing data held separately across each of the devolved nations.[52] Additionally, the Netherlands have particularly strong expertise in paediatric diseases and Estonia is a European leader in digital healthcare.[53] Interviewees commented that international collaboration through IMI2 could make it easier for stakeholders across the health care system to influence national healthcare

[49] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.imcyse.com/images/technology/PDF/Posters/IDS%202023_Vertical.pdf

[50] https://link.springer.com/chapter/10.1007/164_2024_730

[51] https://rwr-regs.com/rwe-201-france-health-data-hub-facilitating-access-to-real-world-data/

[52] https://blog.ons.gov.uk/2024/02/28/bringing-together-uk-health-statistics/

[53] https://sifted.eu/articles/estonia-digital-health

policy, by being able to draw from larger pan-European evidence bases such as patient studies and public surveys.

Another benefit of IMI2 is how careers are enhanced from interacting with a wide network of researchers internationally. Interviewees commented on how IMI2 projects have enabled greater mentoring and support, particularly for early career researchers who can interact with more experienced senior researchers to develop their careers. It was highlighted that seemingly small, low-impact knowledge exchange activities, such as funding to attend international conferences, are in fact crucial to ensure lessons learned from Europe flow back to the UK.

Leveraging large pan-European patient data and repositories

Few countries have the individual capacity to recruit enough participants for clinical studies. These challenges are increased in the study of rare diseases, for which population sizes are significantly smaller in any single country. For paediatric diseases, child physiology changes rapidly in just a short number of years, meaning drug developers need to run trials over short durations and across a wide variety of age groups. Interviewees highlighted the importance of international collaboration to enable rapid recruitment of large patient cohorts for a wide range of diseases.

The C4C network enabled countries to combine their patient data by increasing interoperability and re-use. This was crucial to understanding enough about previous understudied paediatric conditions, it enabled clinicians to effectively plan clinical trials and identify biomarkers of successful outcomes. For many paediatric diseases addressed in C4C, the multinational collaboration multiplied the number of study participants by a factor of 10.

Incorporating the full variation of T1D is crucial to ensure the effective design of clinical trials. During their Natural History Study, the INNODIA network recruited large participant cohorts recently diagnosed with T1D across a wide age range from 1 to 45 years old. Interviewees commented on how INNODIA provided a unique opportunity to perform a large-scale, longitudinal study into age-related differences across European countries. It meant the study could capture the geographic, ethnic, socioeconomic variation across T1D populations. Performing the same experiments only in the UK would have limited the results because disease variants would be missed, making any findings less conclusive and reducing their applicability to other populations across Europe.

Counterfactual analysis

All interviewees highlighted the value of H2020 funding to enable countries to pool investment, resources and knowledge towards delivering treatments. Without the ability to test new standards and procedures for clinical trials across multiple countries at the same time, these resources such as the C4C's Paediatric User Guide could not have been properly validated and implemented across different healthcare systems. Without access to patient groups and trial sites across Europe, many studies would not have been possible, particularly for rare and paediatric diseases.

Each of the IMI2 projects formed very large consortia. For example, INNODIA created a network of more than 30 different clinical centres across 15 European countries. Interviewees commented that the administrative burden of setting up multiple bilateral agreements instead would have slowed down progress considerably. Trying to collaborate on a bilateral basis would have been significantly more time consuming to organise effectively and would have slowed down progress considerably. Having centralised agreements across EU countries cut down on administrative load and made it easier to connect people to right expertise.

Public-private partnerships across EU countries promoted engagement with industry. Standardised contractual agreements enabled companies to share knowledge freely with partners across Europe under a single disclosure agreement without risking infringement of intellectual property. During the early stages of formation, project consortia benefited from previous templates and examples provided by the European Commission that had been established since the initial European PPPs were launched in the early 2000s. This helped accelerate contracting timelines by greatly reducing the administrative burden of establishing these agreements.

Despite considerable national funding being mobilised during the COVID-19 pandemic, for example UKRI's COVID-19 Rapid Response, interviewees commented that the pace of response to the pandemic could not have been achieved without European co-ordination. For example, during the early stages of the pandemic, significantly more COVID cases occurred in countries such as Italy and Spain. International collaboration enabled large datasets of CT chest scans to be gathered across different countries to build powerful predictive models. Interviewees commented on the benefits of leveraging knowledge gained from multiple COVID-19 projects working in parallel across the IMI2 portfolio, which helped to achieve individual project objectives.

impact of the EU referendum and UK exit from the EU

Interviewees were asked about the impact of the UK's exit from the EU on their ability to collaborate with EU countries and how this has affected their work. Most commented that, despite efforts to align UK research and healthcare with EU nations, they experienced several limitations due to the UK's exit. For example, the UK is no longer able to lead on Europe Reference Networks (ERNs), which bring together healthcare providers across Europe with a focus on improving diagnosis and treatments of rare and complex diseases. UK research organisations led on 6 ERNs until 2020, before having to withdraw. This has impacted the ability of the NHS to leverage international expert panels and therefore diminishes quality of care for patients in the UK, particularly those with rare and complex diseases.

The EU exit has impacted the ability of contract research organisations (CROs) to engage with industry sponsors for clinical trials. UK-based CROs must now establish themselves within EU nations to operate there. This increases the risk of NHS patients having delayed access to innovative treatments and the UK's reputation for clinical research becoming weaker.[54]

It has also created a barrier to the UK's involvement in new EU initiatives. For example, the European Health Data Space (EHDS) was established in March 2025 to co-ordinate sharing of international health data across EU nations.[55] Whilst the UK have shown interest in third party participation - with the NHS confederation releasing a report surveying public opinion on joining EHDS - participation is by no means a guarantee and could lead to setbacks for UK healthcare research and innovation.[56]

[54] https://www.appliedclinicaltrialsonline.com/view/consequences-of-brexit-for-clinical-trials-in-europe

[55] https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space-regulation-ehds_en

[56] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://understandingpatientdata.org.uk/sites/default/files/2024-03/Lessons%20from%20EHDS%20report%20final.pdf

F.3. Addressing Transnational Societal Challenges: Prototype system for a Copernicus CO2 Service (CoCO2)

Summary

The **Prototype System for a Copernicus CO_2 Service (henceforth: CoCO2)** was a climate technology project funded to develop a pre-operational prototype system to monitor anthropogenic carbon dioxide (CO_2) emissions (i.e. those released by human activity).

The project formed part of a wider, ongoing EU initiative to establish a CO_2 monitoring and verification support (CO2MVS) capacity to support national climate reporting under the Paris Agreement, which itself is being developed within the EU's Copernicus Atmospheric Monitoring Service (CAMS). The overarching aims of CO2MVS are to standardise, complement and help to independently verify national emissions monitoring and reporting across Europe.

Total H2020 investment in CoCO2 was just below €9m. The project was coordinated by the European Centre for Medium-Range Weather Forecasts (ECMWF) — an independent intergovernmental organisation based in the UK — who received ~€2.7m. The University of Edinburgh also participated (€210k). The project ran from January 2021 to January 2023.

The project delivered on its objective to develop a comprehensive prototype system for the CO2MVS capacity. This involved assessing the current state of in-situ observation sites, integrating existing emissions knowledge and observational data, creating new methods to validate data quality for emissions that are not directly observable, and developing a user interface for CO2MVS that is tailored to both policy and scientific needs.

The work of CoCO2 is now being continued through further EU funding via projects such as CORSO (also with UK involvement) to refine and operationalise key components of the system. It is then expected to become fully operational by 2026 and be used by scientists and policymakers to inform mitigation strategies and collectively assess progress towards goals set under the Paris Agreement. The project has also helped to enable a ESA/EUMETSTAT satellite constellation mission for monitoring CO_2 emissions and formed the informational basis for a UK-led initiative known as GEMMA to develop a national emissions dashboard of total UK emissions.

The CoCO2 project has directly supported efforts to address and mitigate the effects of climate change as it has provided the foundation to develop a system that can enable more accurate, observations-based assessments of progress toward national and local emission reduction targets. This has also strengthened the scientific foundation for evidence-based climate policy, as well as Europe's global leadership in climate monitoring.

H2020 collaboration enabled the CoCO2 project to bring together a large and diverse group of experts and institutions around a common goal and to address this transnational societal challenge. This would not have been possible through national funding alone, as no single European country has sufficient expertise, data and the research infrastructure to have met the project's objectives. The project also benefited from the strong coordination of ECMWF, whose leadership added credibility and alignment with wider Copernicus objectives.

F.3.1. Background and Context

Climate change presents a pressing global threat and reducing (man-made) greenhouse gas emissions is essential to mitigating its impacts. To support this, countries need accurate data on their emissions to track progress and implement effective mitigation strategies. The need for accurate measurements is increased by commitments made by signatory countries to the 2015 Paris Agreement in their Nationally Determined Contributions (NDCs)[57] and the need to assess collective progress towards its goals using a five-year Global Stocktake (GST).

The concept of an operational anthropogenic (i.e. human generated) CO_2 emissions monitoring and verification system capacity was formally conceived in a 2015 expert report[58] for the Copernicus Unit of the European Commission. This outlined a way to enhance the accuracy of national emission inventories and complement existing reporting frameworks through top-down verification models by linking human activities with high resolution Earth observation (EO) data. The CO_2 Human Emissions (CHE) and VERIFY projects, both funded by H2020, developed the scientific foundations that were then prototyped by the CoCO2 project.

Previously, there was no integrated system capable of combining satellite, in situ, and prior emissions data at a global scale to accurately and consistently estimate anthropogenic CO_2 emissions. There were also significant gaps in methods for uncertainty quantification and quality assurance of indirect emissions data, plus a lack of user-friendly tools to exploit the data.

F.3.2. The project

The Prototype System for a Copernicus CO_2 Service (CoCO2) was a climate technology project to develop a pre-operational prototype system to monitor anthropogenic CO_2 emissions.

It received an EU contribution of €8,999,718.75.[59] The main objective of the project was to build pre-operational prototype systems for a CO_2 Monitoring and Verification Support (CO2MVS) capacity. In this respect, CoCO2 is part of a chain of H2020 and Horizon projects, whose funding was/is channelled through the EU's Copernicus Programme. The end goals of this research pipeline are to standardise high-quality emissions monitoring/reporting, establish independence of emissions monitoring information for Europe, and improve the credibility of nationally reported progress towards the Paris Agreement goals.

The project included 25 project partners from 15 different countries[60], and was led by the European Centre for Medium-Range Weather Forecasts (ECMWF) – an independent intergovernmental organisation based in Reading, UK. Funding was predominantly awarded to research organisations (69%), with just over a quarter (26%) awarded to universities, and the remainder split between private companies and public bodies.

Beyond ECMWF, the UK also participated in CoCO2 through Professor Paul Palmer's research group at the University of Edinburgh, which was awarded €210,000.[61] The group co-led the work package focused on using satellite data to estimate the quantity of CO_2 emissions from

[57] NDCs are the national climate action plans of each signatory country. They detail how each country will contribute to the global effort to reduce greenhouse gas emissions and adapt to the effects of climate change.

[58] Ciais, P., *Towards a European operational observing system to monitor fossil – CO2 emissions – Final report from the expert group*, Publications Office, 2015, https://data.europa.eu/doi/10.2788/52148

[59] https://cordis.europa.eu/project/id/958927

[60] Belgium, Cyprus, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and the United Kingdom

[61] This is equivalent to the median EU contribution value for this project.

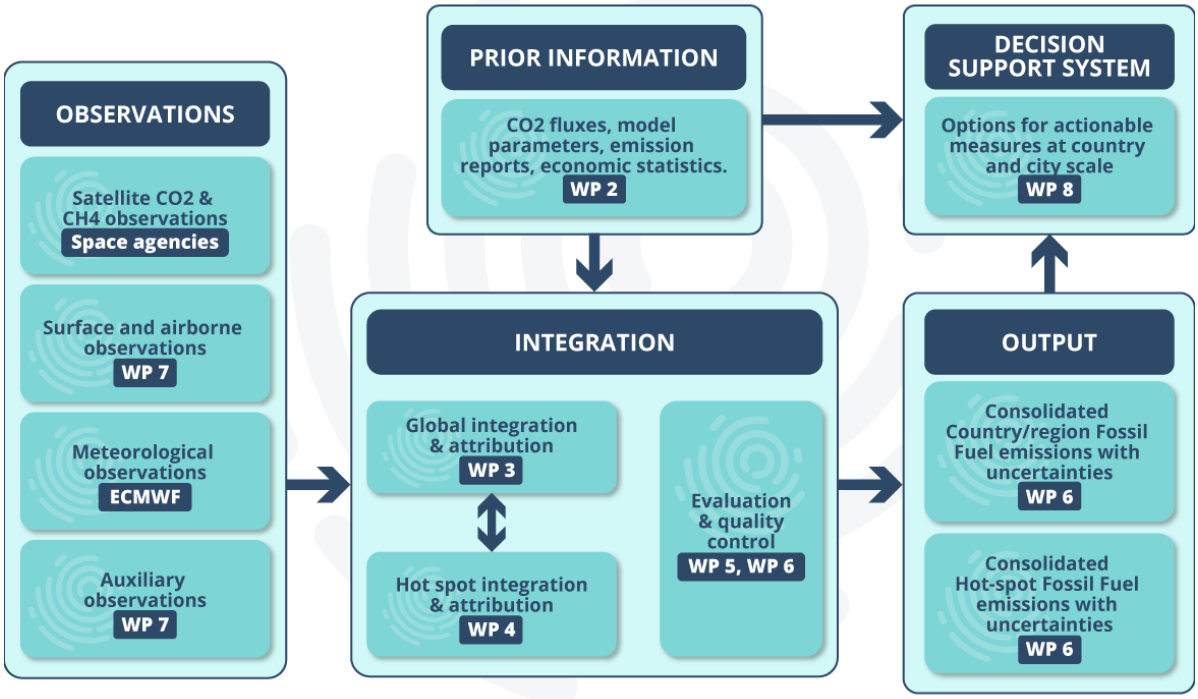
European countries, and also contributed to other work packages, including those related to examining hotspot emissions and integrating information.

Project Objectives and Approach

The primary objective of the project was to develop a pre-operational prototype system that could measure global and regional anthropogenic CO_2 and methane (CH_4) emissions. The system would use data assimilation techniques to combine information from observational datasets (both satellite and in-situ data), past data from previous emissions inventories, and earth system modelling to account for uncertainties and deliver accurate, near-real time emissions estimates across different spatial scales. The project approach also aimed to improve attribution to individual processes or sectors.

Overall, the project employed a novel, wholesale approach to monitoring anthropogenic greenhouse gas emissions, contrasting previous efforts that had been more piecemeal. The structure for the activities undertaken in CoCO2 can be seen in Figure 18.

Figure 18 Structural overview of CoCO2 work packages



Source: CoCO2; https://www.coco2-project.eu/structure

F.3.3. Project outputs and early outcomes (1-3 years post-project)

Tangible immediate outputs from CoCO2 include over 40 reports, 41-peer-reviewed articles, 15 datasets, and software disseminated via the project website and open access repositories.[62]

The short-term outcomes can be seen in the further development of work on emissions data appraisal and integration that began in previous H2020 projects (i.e. CHE and VERIFY). The project advanced data assimilation capacity to establish a system that can distinguish anthropogenic CO_2 emissions from natural carbon fluxes and improve attribution to specific

[62] For example, the CoCO2 Data Portal: https://coco2-project.eu/index.php/data-portal

processes or sectors. It also supported the design and implementation of an 'Evaluation and Quality Control' tool to ensure data reliability, while identifying current capability gaps and additional data needs for the CO2MVS. These advancements represent significant progress toward developing the fully-operational CO2MVS capacity.

In addition, CoCO2 provided an opportunity to strengthen pan-European research networks, including helping to maintain UK involvement in a longer term research process. For example, the University of Edinburgh, together with the University of Bristol, are now partners in the CO2MVS Research on Supplementary Observations (CORSO) project – one of three ongoing Horizon projects that build on the work of CoCO2 and is also coordinated by ECMWF.

Beyond work on CO2MVS, UK representation in the provision of services within the wider EU Copernicus programme is vital for maintaining scientific leadership and securing access to environmental data and operational infrastructures that support UK policy objectives.

F.3.4. Medium-term Outcomes (3-7 years)

CoCO2 was itself a significant research project with substantial monetary backing, but it is also a link in a long-running and varied chain of H2020 and Horizon projects working towards the development of an operational CO2MVS capacity. For this reason, the outcomes of CoCO2 are ultimately tied to those of other projects.

The future outcomes of CoCO2 are inherently tied to the eventual outputs and application of the follow-on projects and the CO2MVS capacity which is expected to become fully operational by 2026. The CO2MVS is expected to influence climate policy and reporting by enhancing the quality and transparency of national greenhouse gas inventories, supporting more effective implementation of EU and international climate commitments defined in the 2015 Paris Agreement and the assessment of the Global Stocktake due to take place in 2028.

To this end, the CoCO2 project has helped to enable a significant European investment in an ESA/EUMETSTAT satellite constellation mission for monitoring CO_2 emissions (the Copernicus Anthropogenic Carbon Dioxide Monitoring, CO2M).[63]

For the UK, involvement in this research pipeline offers the chance to be amongst the global leaders in accuracy of emissions quantification and to enter collaborations on projects that would make use of an eventual operational emissions monitoring platform. The CoCO2 project has also formed the informational basis for a UK-led initiative known as the Greenhouse Gas Emissions Measurement and Modelling Advancement (GEMMA) Programme. GEMMA is formed by a consortium of researchers in the UK led by the National Physical Laboratory (NPL)[64] working to deliver a holistic total of measured UK emissions to be disseminated through a national emissions dashboard. When complete, it will enable the UK to see changes in greenhouse gas emissions, as well as the sectors to which these emissions can be attributed.[65]

F.3.5. Impacts (7+ years, where available)

It is too early to determine the long-term impacts of the CoCO2 project. Again, these will depend on the development and subsequent outcomes of an operational CO2MVS capacity.

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[63] CO2M (EUMETSTAT); https://www.eumetsat.int/co2m

[64] The Greenhouse Gas Emissions Measurement and Modelling Advancement (GEMMA) Programme; https://www.npl.co.uk/campaigns/greenhouse-gas-emissions-measurement-modelling

[65] Current official measurements of UK greenhouse gas emissions are limited to territorial, residence and footprint; https://www.ons.gov.uk/economy/environmentalaccounts/methodologies/measuringukgreenhousegasemissions

It is expected that the foundations set by the CoCO2 project have the potential to enable a more accurate tracking of emissions, stronger accountability, and more targeted climate action. Environmental and societal benefits could be realised in the project's potential to accelerate the implementation of policies aimed at reducing emission, supporting global efforts to limit warming and, thus, mitigate the effect of climate change.

F.3.6. Main EU added value

Advantages of H2020 collaboration

H2020 collaboration presented the CoCO2 project, and its UK-based participants, with significant advantages. Importantly, the expertise and data-related demands to achieve the objectives of the CoCO2 project could not have been fulfilled by a single country acting alone. H2020 enabled a collaboration between leading researchers from across Europe that is unlikely to have occurred solely through national funding mechanisms. This is important in the context of the CoCO2 project as its outcomes have global implications.

One project member highlighted the advantages that international collaboration from H2020 involvement gave to the project's working patterns. Having multiple, separate groups working together to reach conclusions meant that those working on the project could have their conclusions verified independently by others who had previously worked independently on similar tasks. The same individual highlighted that CoCO2, and projects like it, are enabling collaboration between entities that would otherwise compete with each other. Within the project, these entities could be more open with each other about what they were doing.

> *'These big projects are a kind of temporary alignment of competing groups… It's a really positive experience for my group… Literally all of them [international partners] are fantastic researchers.'* - UK CoCO2 Project Participant

The project coordination by ECMWF was also highlighted as a significant upside, as they were organising research which would go on to inform and support future work that they're also leading through CAMS. The ECMWF leadership also added credibility to enact policy influence.

The work completed in CoCO2 also has positive implications for the accuracy of the UK's own emissions monitoring systems. GEMMA, CO2M, and a recently launched MicroCarb satellite mission provide additional data sources that will add to the national reporting inventories and standardised using the methods which CoCO2 has effectively prototyped.

Counterfactual Analysis

A project member reflected that running CoCO2 exclusively through UK national funding would have been difficult. While it is unlikely that the quality of the research completed would have been affected, the UK may have been left behind because of the speed of H2020 activities. The same individual reflected that bilateral collaboration would also not have been a viable alternative either, owing to a mutual scepticism of efforts to start two-country research collaborations within Europe that would prevent a project like CoCO2 from being possible.

F.4. Advancing critical technology case study: MicroQC

Summary

MicroQC was a European research and innovation project funded under Horizon 2020. It focused on advancing microwave-based trapped-ion quantum computing as a scalable, fault-tolerant alternative to more conventional laser-controlled systems. The project had a total cost of €2.3M, including €500k allocated to a UK partner, the University of Sussex. It ran from October 2018 to June 2022, and was coordinated by the University of Sofia, Bulgaria. The project brought together additional partners from Germany and Israel, combining world-leading expertise in quantum engineering, theoretical modelling, and microchip development.

The MicroQC project addressed the central challenge of **scaling ion-trap quantum computers, by demonstrating fast, fault-tolerant quantum gates using microwave control**. The University of Sussex team produced a clear roadmap to utility-scale quantum computing, defined system specifications for a quantum computer that could solve real-world problems like nitrogen fixation (responsible for ~2% of the world's energy production), and assessed security implications such as the potential to break Bitcoin encryption. Technical outputs from Sussex included a seminal paper on coherent control, microchip designs capable of cutting-edge magnetic field gradients, and experimental work that enabled a world-record gate fidelity demonstration.

MicroQC directly supported the early development of Universal Quantum, a spinout from Sussex that has since raised over £100 million and grown to more than 100 employees. Since the project's inception, microwave-controlled trapped-ion quantum computing has moved towards a viable and competitive platform for industrial adoption, as showcased by Universal Quantum's rapid growth and other microwave-based quantum computing companies being acquired. The project has contributed to building the UK's capacity for highly-skilled quantum researchers, supporting highly employable PhDs and postdocs. It has also supported policy engagement and the Sussex team's award-winning public outreach that helped to raise awareness of quantum technologies and to share strategy at the national and international levels.

At the time MicroQC began in 2018, microwave-based trapped-ion quantum computing was still an emerging and highly specialised field. **The UK on its own lacked the breadth of expertise needed to support a project of this scale.** Horizon 2020 enabled the University of Sussex to collaborate with "some of the most important research groups in the world", bringing together essential capabilities that were critical to the project's success.

F.4.1. Background and Context

Quantum computing promises to solve complex problems beyond the reach of today's supercomputers, from modelling new drugs and materials to optimising logistics, climate modelling, and energy use. Quantum computers leverage the principles of quantum mechanics to perform calculations that are infeasible for classical computers. They are based on quantum bits (qubits), which can exist in superpositions of states, as opposed to classical computers which leverage bits, a logical state which can only be one of two possible values (0 or 1) at one time. However, building scalable, fault-tolerant quantum computers remains an incredibly demanding technical challenge.

Among the various hardware platforms being explored (neutral atoms, photonics, semiconductors etc.), trapped-ion-based quantum computing is recognised for being a relatively mature architecture, with long coherence times, high gate fidelities, and simple fabrication processes[66]. Gate fidelity refers to how accurately quantum operations (or "gates") are performed on qubits. High fidelity means operations are carried out with minimal errors, despite the presence of 'noise' from environmental disturbances. Whilst Ion-trapped qubits have held world records for their gate fidelity and coherence times, innovation is required to scale up the number of qubits to yield a useful quantum computer. Traditionally, these systems have relied on lasers to manipulate qubits, a method that becomes increasingly complex as the number of qubits grows. In response, a promising alternative has emerged: microwave-based ion trap quantum computing. Instead of directing hundreds or thousands of laser beams, the approach can control an arbitrary number of qubits with only a handful of microwave fields which are easier to generate and control.

Quantum technology has been identified as a frontier technology in the UK's recent Digital and Technologies Sector Plan[67], with the quantum computing sector consisting of more than one hundred thousand employees, and producing more than £10bn of turnover[68]. Prior to this, the UK National Quantum Technologies Programme (NQTP) was established in 2014, pledging a £1billion partnership between government, academia and industry[69], including the Quantum Industrial Strategy Challenge Fund (ISCF)[70]. In the UK, trapped-ion architecture is being used in one of the seven testbeds supplied to the National Quantum Computing Centre (NQCC) – supplied by Oxford Ionics[71]. In the US, trapped-ion architecture companies constitute a significant portion of the market share of the quantum computing industry, through companies such as Quantinuum (which was founded by UK researchers, and is now valued at $5bn[72]), and IonQ (which has recently acquired Oxford Ionics for $1.075bn[73].)

F.4.2. The project

The MicroQC project ran from October 2018 to June 2022, and was part of the Quantum Flagship programme. It received an EU contribution of €2.3M, €500k of which was given to the

[66] https://www.nqcc.ac.uk/trapped-ion-quantum-computing

[67] https://www.gov.uk/government/publications/digital-and-technologies-sector-plan

[68] https://thedatacity.com/rtics/quantum-economy-rtic0051/

[69] https://uknqt.ukri.org/about-us/

[70] https://www.gov.uk/government/news/new-153-million-programme-to-commercialise-uks-quantum-tech

[71] https://www.oxionics.com/announcements/oxford-ionics-selected-for-quantum-missions-pilot

[72] https://www.quantinuum.com/press-releases/honeywell-announces-the-closing-of-300-million-equity-investment-round-for-quantinuum-at-5b-pre-money-valuation

[73] https://www.oxionics.com/announcements/ionq-announces-agreement-to-acquire-oxford-ionics

UK partner, the University of Sussex. The main objective of the project was to demonstrate the use of microwaves, as opposed to the more traditional laser systems, to control qubits, especially in multi-qubit architectures.[74]

The project team consisted of five partners from four countries. It was led by Sofia University in Bulgaria and included participation from the University of Siegen and the Leibniz University Hannover in Germany, and The Hebrew University of Jerusalem, Israel, in addition to the University of Sussex. The fact that all project participants were universities reflects the early, pre-commercial stage of microwave-controlled trapped-ion quantum computing at the time the project began; in contrast; the field today includes many commercial entities. The University of Sussex team, led by Professor Winfried Hensinger, developed the experimental platform including chip design and microwave gate implementation, and wrote the architectural roadmap for microwave ion-trapped quantum computers. Sofia University, led by Professor Nikolay V. Vitanov, contributed advanced theoretical work on coherent control. They were joined by Professor Alex Retzker's group in Israel who also developed key theory relating to quantum logic. Professor Christof Wunderlich led the Universität Siegen team in contributing to the experimental realisation of microwave-based quantum logic gates, particularly focusing on static magnetic field gradients. Professor Christian Ospelkaus led the Leibniz Universität Hannover team in microwave quantum logic using oscillating gradients.

Project Objectives and Approach

Traditional trapped-ion systems rely on precisely aligned laser beams to manipulate qubits, a method that is likely to become impractical for the hundreds of qubits needed for useful quantum computation. As an alternative, the core objective of MicroQC was to use cutting-edge quantum engineering to demonstrate fast, fault-tolerant two-qubit and multi-qubit gates using microwave control, and to design scalable hardware components capable of applying these techniques within multi-qubit quantum processors.

Prior to the project's launch in 2018, the University of Sussex team had published a key 'blueprint' for building utility-scale quantum computers using microwave-controlled trapped ions[75], as part of a European project under FP7[76]. One of the main objectives of MicroQC was to build upon this blueprint and create a roadmap for advancing microwave quantum computation to high technology readiness levels.

To overcome the technical challenge of achieving precise qubit control using global microwave radiation, strong, localised magnetic field gradients are needed. Another project objective was to innovate in microfabricated ion trap chips to handle these conditions. At the same time, the project aimed to address the architectural demands of scalable quantum computing by developing high-fidelity ion transport protocols within modular chip designs, where individual qubits can interact with their neighbours[77].

F.4.3. Outputs and early outcomes (1-3 years post-project)

The MicroQC project delivered several key scientific and technical achievements that advanced the viability of microwave-based trapped-ion quantum computing. A major milestone was the successful fabrication of microchips capable of generating world-leading

[74] https://cordis.europa.eu/project/id/820314

[75] https://www.science.org/doi/10.1126/sciadv.1601540

[76] https://cordis.europa.eu/project/id/270843

[77] https://cordis.europa.eu/article/id/442405-microwave-driven-trapped-ion-quantum-computing-sets-new-records

magnetic field gradients, a prerequisite for high-fidelity quantum logic using microwaves. Researchers at Sussex specialised in developing innovative coherent control techniques that significantly improved the resilience of quantum gates to environmental noise, allowing them to achieve a world record for error rates. These results provided experimental validation for core elements of the microwave-based architecture and helped establish its credibility as an alternative to laser-driven systems.

As part of the MicroQC project, the team investigated the computational resources needed to solve real-world problems. Most notably, the quantum simulation of nitrogen fixation, a process essential to fertiliser production and responsible for roughly 2% of global energy use[78]. This involved specifying the scale and architecture of a quantum computer capable of performing such a task and is a key step to realising the utility of quantum computers. In parallel, the team calculated the resources required to break Bitcoin encryption, an exercise that attracted attention from Interpol.

The MicroQC project significantly deepened existing relationships between researchers at Sussex and the European research groups at partner universities. While these collaborations predated the project, Horizon 2020 funding "facilitated a collaboration that otherwise would have happened only at a very small scale or not at all".

The research activities and outputs from the MicroQC project are also heavily linked to the spinoff company Universal Quantum from the University of Sussex. Founded in 2018, the company is dedicated to commercialising microwave-controlled trapped-ion technology and was established by Professor Sebastian Weidt and Professor Winfried Hensinger. The conceptual groundwork, namely Sussex's "blueprint" for a utility-scale quantum computer preceded the project, but the formal founding of the company occurred just after MicroQC began. Professor Hensinger noted that the process of founding the company (including when their first investor approached him, raising venture capital, and initial scaleup) all occurred during the course of MicroQC. The blueprint (and subsequently the "roadmap") towards utility-scale quantum computers developed by Sussex, as well as the greater credibility in the technology from the project were pivotal to the growth of Universal Quantum, and also essential in securing early venture capital, by demonstrating to investors that it promised a "tangible" plan that could translate advanced research into an industrial product.

F.4.4. Medium-term Outcomes (3-7 years)

The MicroQC project has fed into policy influence at both national and international levels. The Sussex team were the subject of a REF impact case study, examining the impact of quantum computing research on the adoption of public policy[79]. While policy engagement activities were underway prior to the project start in 2018, the period following MicroQC's launch saw Sussex researchers continue to advise the UK government, the US Department of Energy, and German policymakers, in addition to contributing to the UK's National Quantum Technologies Programme and Germany's €2 billion national investment plan. The REF case study notes that the Sussex blueprint and associated research (including contributions developed and demonstrated through MicroQC) were cited in policy consultations and evidence submissions throughout this time, directly informing funding decisions and strategic direction for quantum computing technologies.

[78] https://planet-tracker.org/nitrogen-fertiliser-production-outstrips-global-needs-and-exceeds-planetary-boundaries-by-factor-of-two/

[79] https://results2021.ref.ac.uk/impact/fc9b4b3b-1090-4009-8600-712c661190e8?page=1

The funding and developments derived from the MicroQC project also contributed to Sussex's extensive award-winning public engagement initiatives pertaining to their research in quantum computing[80],[81]. Highlights include a collaboration with London's Science Museum to develop a dedicated exhibition about quantum computing, measuring 70,000 interactions with the exhibition items, and an invitation to return to the Science Museum to contribute to an exhibition on breaking encryptions.

During the course of MicroQC and the years following, Universal Quantum secured over £100m in private and public funding, including ~£70M in customer contracts and has established subsidiaries in Germany, Denmark and USA. It has established a quantum computing supply chain with more than 15 suppliers in the UK, Europe, and the US. It has also grown in size to employ over 100 staff. The MicroQC project has been a direct contributor to this capacity building in the UK quantum sector, particularly by supporting highly skilled and sought-after PhD students and postdoctoral researchers. Professor Hensinger stated that many of his PhD students secure roles even before they graduate.

F.4.5. Impacts (7+ years)

The MicroQC project laid critical groundwork for several long-term outcomes that are beginning to take shape across the UK and global quantum sectors.

Most significantly, MicroQC helped position microwave-controlled trapped-ion quantum computing as a viable and competitive platform for industrial adoption. While laser-based ion trap systems were dominant at the project's start, industry perception has since shifted markedly. Professor Hensinger noted that companies that were focused on lasers (namely IonQ), have since acquired microwave-based firms, suggesting growing commercial recognition of the approach developed in MicroQC. Over time, this is expected to support broader adoption of scalable, manufacturable quantum computing platforms, for use in sectors like pharmaceuticals, finance, energy, and logistics, where large-scale quantum computers could deliver massive performance advantages.

The project contributed to the foundations for long-term economic growth, through Universal Quantum's attracting customer contracts from overseas (such as two successful tender contracts from the German Aerospace Centre's €67m[82]) and the continued development of high-value jobs in quantum engineering, chip design, and systems architecture. Universal Quantum and its associated supply chain will help anchor a portion of the global quantum economy in the UK. Recently, the University of Sussex has been at the heart of an initiative to create a 'Quantum Silicon Valley' in Greater Brighton[83][84][85], positioning the south coast region as a key player in the UK's quantum ecosystem, and a global hub for quantum research. At the national policy level, MicroQC has played a role, through both its scientific outputs and

[80] https://www.sussex.ac.uk/physics/iqt/media-appearances/

[81] https://results2021.ref.ac.uk/impact/26373e55-94e1-43d6-9c85-76ec51d18b17?page=1

[82] https://universalquantum.com/knowledge-hub/development-of-a-scalable-user-friendly-quantum-processor-with-ion-trap-technology-for-dlr-qci

[83] https://thequantuminsider.com/2025/03/05/government-minister-praises-university-of-sussex-plan-to-create-quantum-silicon-valley-on-the-south-coast/

[84] https://quantumzeitgeist.com/sussex-aims-to-become-the-quantum-silicon-valley-of-the-uk-with-ambitious-plans/

[85] https://www.youtube.com/watch?v=9y1qpiXCpxM/

contribution to public engagement, ensuring that quantum computing is embedded in long-term R&D planning, including the UK's 10-year National Quantum Strategy[86].

F.4.6. Main EU added value

Advantages of H2020 collaboration

Horizon 2020 delivered critical added value to microwave-based trapped-ion quantum computing research and the University of Sussex. At the time the project began in 2018, microwave-based trapped-ion quantum computing was an emerging and highly specialised field. In the UK, the pool of researchers with the required theoretical and experimental expertise was relatively small, limiting the ability to support a broad, multi-institutional research programme. Participation in H2020 collaborations provided access to a wider range of expertise across Europe, enabling partners to form consortia based on complementary skills and capabilities. H2020 enabled Sussex to collaborate with "some of the most important research groups in the world", bringing together capabilities necessary for the development of the MicroQC project (coherent control, chip fabrication, magnetic field engineering etc.).

One interviewee noted that the European referendum vote introduced a deep uncertainty around the UK's access to EU research funding and its role in the European quantum ecosystem. They explained that following the UK referendum, many European researchers ended their collaborations with UK partners, leading to a significant negative impact. Researchers from Europe who had previously visited the University of Sussex regularly, ceased their engagement. As a result, Universal Quantum established an office in Germany to maintain access to the European job market and to facilitate continued collaboration with German partners.

Counterfactual Analysis

In the event that MicroQC had not gone ahead, Professor Hensinger noted that it would have been "certainly harder" for the project to get off the ground, and much more difficult to make a "meaningful" collaboration with the European partners. Sussex would have likely continued to pursue isolated elements of the work, but without the collaborative element that MicroQC required. Without the European collaboration fostered by MicroQC, microwave-based trapped-ion computing might not have advanced to the point of commercial viability it is today.

[86] https://www.gov.uk/government/publications/national-quantum-strategy

F.5. Exploiting Transnational Infrastructure: EOSC-Life Case Study

Summary

The European Open Science Cloud (EOSC) is a digital platform designed to provide researchers and innovators in Europe (and beyond) with a trusted environment for sharing, finding and reusing research data and services. The **EOSC-Life project** is part of that wider initiative and emerged in response to the growing challenge of the volume of data that is generated from life sciences research. To mitigate against these challenges, EOSC-Life coordinated thirteen research infrastructures in the Life Sciences, with the ultimate goal of developing an open and collaborative space to support life sciences research. In doing so, the project provided access to FAIR (Findable, Accessible, Interoperable, Reusable) data and analytical tools within the EOSC, making these resources accessible through the UK and the European Research Area.

Under Horizon 2020, EOSC-Life ran from March 2019 until July 2023, with a total investment of €26.1 million (of which the UK received €2.4 million).

The project delivered important outcomes for both individual participants and the broader research community. Many UK project participants leveraged their involvement in EOSC-Life to secure additional funding through Horizon Europe and national funding schemes. More broadly, the initiative established comprehensive training programs and guidelines that enhanced the life sciences community's capacity to develop and use open science databases and tools. Amongst its many achievements, the project created important underpinning infrastructure and a unified registry and Hub for computational workflows (e.g. genome annotation workflows, workflows that process sequencing data to identify and quantify gene editing outcomes) to provide to support long-term data sharing and reuse in the life sciences, which is particularly important given the growing importance of AI applications that require access to structured, interoperable data.

The project has demonstrated substantial measurable impact, both through tangible research outputs and outcomes, and broader strategic benefits for the UK. The WorkflowHub registry was designed to be discipline and workflow type agnostic, meaning that the registry is open to adoption by a wide spectrum of researchers and other stakeholders. For example, there are now contributions from researchers from astronomy, engineering, earth and computer sciences. The EOSC-Life WorkflowHub registry is one of the services contained within the broader Workflow Collaboratory. The Collaboratory provides access to other tools, including metadata standards (RO-Crate, for example) and training resources. Both the Workflow Hub registry and the Workflow Collaboratory are direct outputs of the EOSC-Life project. This success has since influenced other major infrastructure developments, demonstrating how underlying data infrastructure projects can generate valuable spillover effects across multiple disciplines.

H2020 funding proved valuable as all interviewees agreed that infrastructure project funding is challenging to secure through national channels, providing evidence of EU value. The breadth of expertise accessible through European collaborations across 13 infrastructures, combined with the protective effect of infrastructure projects against political and research landscape changes, makes such participation particularly important for UK researchers' long-term sustainability and competitiveness.

F.5.1. Background and Context

The EOSC-Life project emerged as a collaborative response to the mounting challenge of effectively using the vast amounts of data generated by life sciences research. As genomics, proteomics, imaging, and other life science technologies have advanced, they have (and still are) producing data at unprecedented scales and at volumes that individual institutions struggle to manage, share and derive meaningful insights from. Additionally, there are growing concerns about transnational compliance with GDPR regulations, particularly when sharing sensitive biological and medical data across European borders.

EOSC-Life aimed to bridge this gap through a novel access model that would provide direct access to FAIR (Findable, Accessible, Interoperable, Reusable) data and analytical tools within the European Open Science Cloud[87] (an open, multi-disciplinary platform for the sharing, storing and reuse of research outputs), making these resources accessible through the UK and the European Research Area. The project aligned with several key European and UK policy priorities, including the strong push for open and FAIR data sharing practices across the research community.

The project represented a novel and important approach to addressing long-term structural challenges in research infrastructure. Importantly, it operated within a funding environment that traditionally prioritises projects with immediate, tangible outcomes and individual achievement over collaborative infrastructure investments. The longer-term, collaborative benefits of infrastructure projects like EOSC-Life are less immediately visible than traditional research outputs, making it more difficult to secure ongoing support despite their fundamental importance to the research ecosystem.

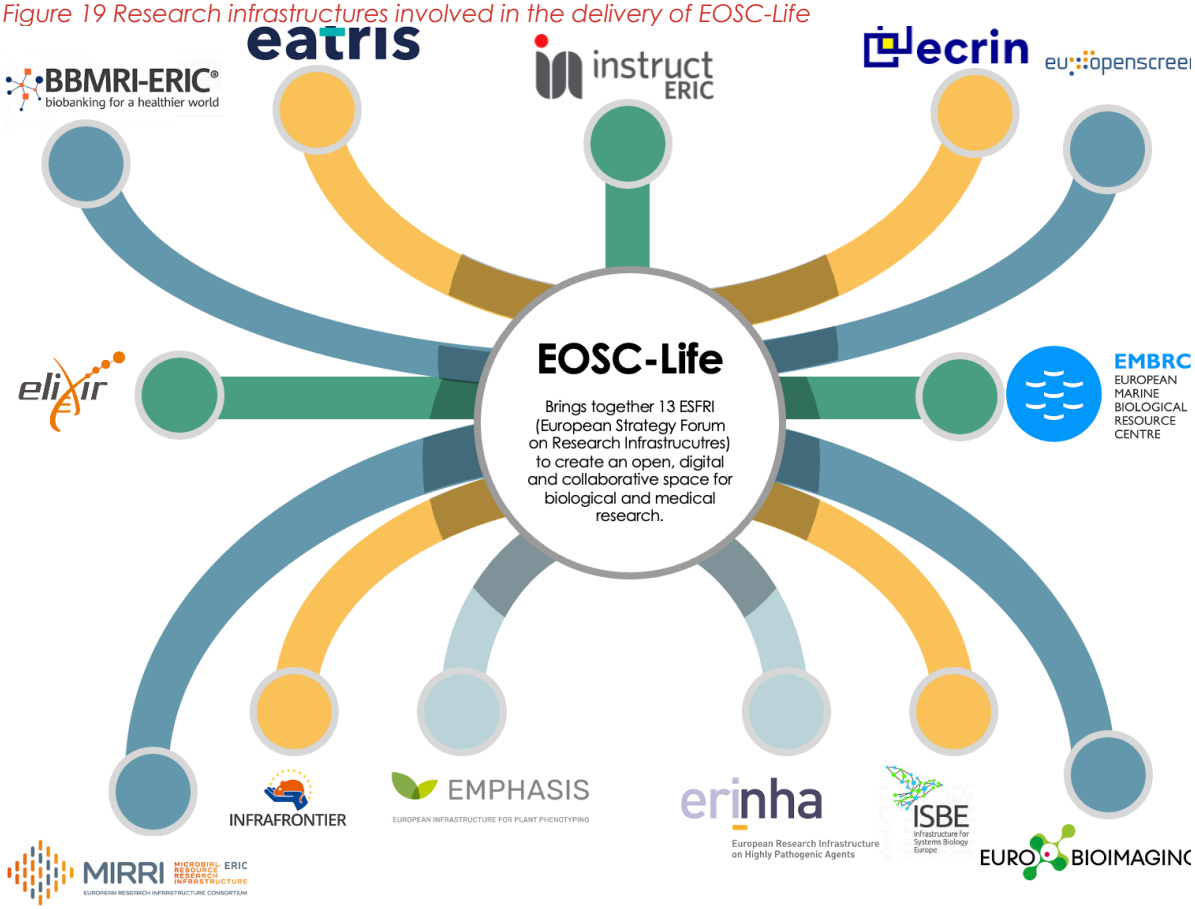
F.5.2. The project

EOSC-Life brought together 13 existing ESFRI (European Strategy Forum on Research Infrastructures) research infrastructures to create an open, digital, and collaborative space for biological and medical research. With a total budget of EUR 26,145,996.25, the project published and made available FAIR data and maintained and developed a catalogue of services provided by participating research infrastructures to enable effective data management[88]. A summary of the goals of the EOSC-Life project and the participating RIs is presented in the figure below.

[87] https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/our-digital-future/open-science/european-open-science-cloud-eosc_en

[88] https://cordis.europa.eu/project/id/824087/reporting

Figure 19 Research infrastructures involved in the delivery of EOSC-Life



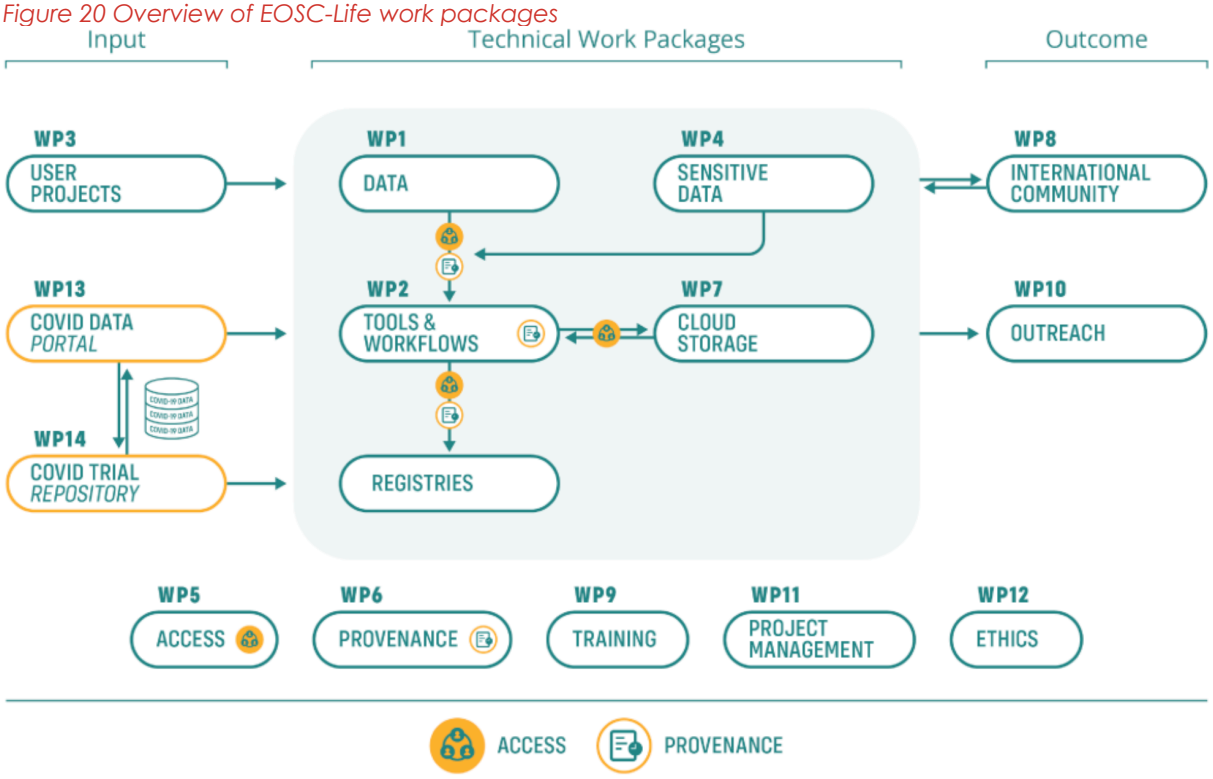
Source: Technopolis (2025)

EOSC-Life involved 50 partner organisations, with 70 total participants across 16 countries, including the UK. This case study examines the impacts and outcomes associated with work packages 1, 2 and 3 within the EOSC-Life project, which involved researchers from the University of Dundee, Historic England and the University of Manchester (among others). The consortium was coordinated by the European Molecular Biology Laboratory (an intergovernmental research institution operating across six European sites). Each research infrastructure (RI) operates through a hub and spoke model, where each RI has an in-country nodes - national organisations that represent the infrastructure within their respective countries. These nodes coordinate and bring together the resources, technologies, and databases that each country contributes to the research infrastructure. Not every country participates or contributes to all RIs in the cluster; the UK subscribes to a handful of these.

The EOSC-Life project provided funding for core activities funded within each RI, but the participating RI also issued open calls to support additional projects and activities, expanding the scope and impact of their work through competitive funding mechanisms.

EOSC-Life was delivered across twelve work packages, which ranged from providing access to data, developing protocols and computational workflows to handle and manage sensitive data (including for cloud storage), as well as training and outreach activities. These work packages are summarised in the figure below.

Figure 20 Overview of EOSC-Life work packages



Source: EOSC-Life[89]

Given the extensive scope and complexity of the overall programme, this case study has used a targeted approach, concentrating on these specific work packages rather than attempting to capture the full breadth of activities across the entire consortium. The outputs, outcomes and benefits explored serve as representative examples of the value of UK participation in Horizon 2020 projects, illustrating key themes and impact pathways rather than providing an exhaustive inventory of all project outputs. As such, the impacts and outcomes documented reflect only a subset of the project's total contributions and may not encompass the experiences and outputs of all consortium members, or longer-term benefits that continue to emerge past the project's formal completion.

F.5.3. Outputs and immediate outcomes (1-3 years post-project)

The main outcomes of the project have been improvements in the data capabilities of participating organisations and the development of interoperable data, tools and digital infrastructure to support researchers in the life sciences. Examples of how these benefits have translated into tangible outcomes for UK researchers are presented below including those emerging from: (1) The WorkflowHub, (2) Open calls run by EOSC-Life.

ELIXIR and the WorkflowHub

An example of how these benefits have translated into tangible outcomes for UK researchers is illustrated through the specific contributions and achievements of one of the largest and most established research infrastructures in the consortium, ELIXIR.

[89] https://www.eosc-life.eu/about/work-packages/

ELIXIR is a life sciences RI that coordinates and develops life science resources across Europe, to support researchers in finding, analysing and sharing data. The RI operates across seven main scientific domains: (1) chemical biology, (2) enzymes, interactions and pathways, (3) evolution and phylogeny, (4) genes and genomes, (5) literature, (6) molecular and cellular structures and (7) proteins and proteomes.[90] The UK node of ELIXIR, co-led by Professor Carole Goble, provides platforms and guidance for research data management, reproducible data analysis, FAIR data and software management services. One of the key outputs that emerged from UK participation (through ELIXIR) in the EOSC-Life project was **the EOSC-Life Workflow Collaboratory**; a cloud-based ecosystem of computational workflow services and standards that is built on the EOSC infrastructure. In practical terms, the Collaboratory acts as both a digital library and a collaborative workspace where scientists can make, execute, deposit and share the step-by-step computational processes they use to analyse data, making these workflows available for others to discover, use, and adapt for their own research.

The EOSC-Life WorkflowHub, led by the University of Manchester (as member of ELIXIR-UK), functions as a cloud-based registry that allows researchers to share computational workflows and data analysis processes. It is now a prime service of the European Open Science Cloud infrastructure and the Australian BioCommons who collaborate in its development and operation.[91]

The WorkflowHub delivers significant benefits to computational researchers across both academic and industrial settings. Rather than each researcher developing their own analysis methods from scratch, scientists can now find and build upon existing workflows, dramatically reducing duplication of effort and accelerating research progress. This approach mirrors the advantages of open-source software, where collaborative development produces better tools more efficiently than isolated efforts. The Collaboratory of standards and tools integrates several specialised tools that enhance its effectiveness: for example, Galaxy Europe provides a platform for executing workflows over cloud and HPC infrastructures; LifeMonitor provides automated testing to ensure workflows continue to function correctly over time, while RO-Crate offers a standardised way to package workflows with comprehensive metadata that makes them easier to find and understand. These components work together with the WorkflowHub, a comprehensive registry that has expanded beyond life sciences to serve researchers across all scientific domains, demonstrating how the project's innovations have created value far beyond their original scope.

While EOSC-Life served as the initial driver and key use case for developing the Workflow Collaboratory and WorkflowHub, the platform's success has attracted numerous other research projects and communities, and forms the basis of the UKRI DRI BioFAIR national investment. The infrastructure developed through EOSC-Life has proven its value by becoming the foundation for workflow sharing across multiple large-scale international research initiatives, demonstrating the project's lasting impact on the global research landscape. The development and operation of the WorkflowHub and the Collaboratory of workflow services has continued and thrived, with numerous European and national projects using the platform and sustaining it. Many (EuroScienceGateway, ClimateAdapt4EOSC, Biodiversity Digital Twins) are non-Life Science projects involving UK partners.

[90] https://elixir-europe.org/services

[91] WorkflowHub: a registry for computational workflows (2025)

EOSC-Life Open Calls: Increasing the FAIRness of Phytolith Data

Beyond the core work packages, EOSC-Life included open calls that funded smaller projects to develop and deploy data resources, tools and workflows. One such project was led by Dr Emma Karoune at Historic England, focusing on improving FAIR data practices in phytolith research. Phytoliths are silica deposits formed in plant cells that researchers in archaeology, palaeoecology and plant sciences use to study past plant use and environmental changes. Karoune's project aimed to increase knowledge and adoption of FAIR data principles within this specialized field, improving how researchers share methods, data and archiving practices across the discipline.

The project produced a number of technical guidelines and training materials, including development of FAIR recommendations for the phytolith community, 13 talks at international conferences, and training workshops on Open Science skills. The project led to the establishment of the International Committee on Open Phytolith Science (ICOPS), which has since grown and led to increased international collaboration in Phytolith research. In addition to the technical outcome, one of the important reported outcomes for the project was the development of professional networks. These have continued to support sustainable outcomes, including follow-on funding through the newly launched OSCARS (Open Science Research Clusters Action for Research and Society) under Horizon Europe, which one interviewee attributed to the strength and endurance of relationships developed under Horizon 2020.

F.5.4. Medium-term Outcomes (3-7 years)

EOSC-Life resources have played a part in shaping GDPR-compliant policy development in the life sciences. The EOSC-Life toolbox for sensitive data sharing has supported international efforts in removing barriers to the sharing of biomedical and health research data, whilst ensuring patients and trial participants are safeguarded. In addition to this, the project has had a sustained impact on the behaviour and attitudes towards open research practices. As a result of outreach and training in the FAIR Phytoliths project, project partners have observed a notable increase in the desire of peers to openly publish research outputs.

EOSC-Life has contributed to important policy developments beyond its immediate technical outputs. The project's toolbox for sensitive data sharing has sought to inform international efforts to develop GDPR-compliant approaches to biomedical and health research data sharing. For example, a paper published on sensitive data in digital pathology has provided a new risk-analysis method for the use of real-world imaging data and recommendations for how image data could then be shared. [92]This work begins to address a critical challenge in medical research: how to enable data sharing that advances scientific understanding while protecting patient privacy and ensuring trial participants' rights remain safeguarded.

WorkflowHub

WorkflowHub has experienced remarkable growth since the project's completion, with published workflows increasing from 380 in 2023 to 1,317 as of July 2025. The platform now serves 1,102 registered users from 305 organisations across 40 countries, with adoption extending well beyond the life sciences to encompass researchers from multiple disciplines. Interviewees shared that industrial research organisations, including pharmaceutical and genomics service companies, have also begun using these cloud-based services, recognising their potential for

[92] Holub, P., Müller, H., Bíl, T. et al. Privacy risks of whole-slide image sharing in digital pathology. Nat Commun 14, 2577 (2023). https://doi.org/10.1038/s41467-023-37991-y

substantial cost savings. The continued expansion of tools developed through the project demonstrates the lasting value of UK participation in EOSC-Life.

This growth translates into direct benefits for the UK's scientific community. The UK ranks third globally for registered users on the platform, illustrating the significant value the country derives from its participation. The services continue to receive support through new Horizon Europe projects and sponsorship from multiple European research infrastructures. Since UK organisations played central roles in developing and maintaining these tools, this ongoing support represents additional funding streams for UK science alongside the reputational advantages of leading large-scale international collaborations in the life sciences.

EOSC-Life Open Calls: Increasing the FAIRness of Phytolith Data

EOSC-Life has also influenced research culture and practices within participating communities. The FAIR Phytoliths project exemplifies this impact through its outreach and training activities, which have led to observable changes in researcher behaviour. Project partners report a notable increase in their peers' willingness to openly publish research outputs, demonstrating how targeted training and support can shift disciplinary attitudes toward more open research practices.

F.5.5. Impacts (7+ years)

WorkflowHub

Project interviewees highlighted how the WorkflowHub has influenced other major infrastructure developments[93], demonstrating the potential for underlying data infrastructure projects to generate spillover effects across different disciplines. This cross-disciplinary impact exemplifies how investments in one research area can create benefits that extend far beyond the original scope.

The Distributed System of Scientific Collections (DiSSCo) provides a useful example of this spillover effect. DiSSCo represents a new world-class research infrastructure for natural science collections that aims to create a unified European approach to digitising and managing natural history assets. The initiative seeks to establish a new business model that brings together all European natural science collections under common access protocols, curation standards, and data management practices that ensure collections data meets FAIR principles. This approach reflects lessons learned from projects like EOSC-Life about the importance of creating user-centred infrastructure that facilitates collaboration and knowledge sharing across institutional boundaries. For UK researchers, the use and recognition of the WorkflowHub also has significant reputational benefits, which in turn helps to attract further opportunities for collaboration (and funding).

Broader long-term impacts

UK participation in EOSC-Life and similar transnational research infrastructures delivers significant strategic advantages that extend beyond the immediate project outcomes. By adopting EOSC standards and practices, UK organisations can reduce technical and regulatory barriers when accessing European markets and funding opportunities. Importantly, this participation also provides the UK with continued access to complementary expertise from

[93] For example, the EOSC-Life WorkflowHub is the standard service for Australian BioCommons.

across Europe, ensuring that UK researchers can draw upon the specialised knowledge and capabilities of international partners to support and enhance their own research outcomes.

Interviewees suggested that increased access to open science outputs in the life sciences (including computational workflows, training material and guidance for handling sensitive clinical information) could translate to the increased competitiveness of UK researchers. As the Hub is still under active development, impacts are likely to continue to emerge on a longer timescale. Interviewees expect that the Hub will increase to improved efficiency, as researchers are able to identify and use computational workflows that have already been developed, without the need to replicate them.

The technical focus of EOSC-Life also generates valuable skills development opportunities that align with broader strategic national objectives. The project's emphasis on sustainable data infrastructure builds expertise in areas critical to the UK's digital future, including big data management, artificial intelligence applications, and high-performance computing capabilities.

F.5.6. Main EU added value

Advantages of H2020 collaboration

All interviewees agreed that international collaboration through Horizon 2020 proved essential to EOSC-Life's success. They attributed this success to the **scale of the project** – larger digital data spaces (such as that delivered through EOSC-Life) are generally more valuable because they attract more users, who in turn contribute more data, tools and workflows. This creates a self-reinforcing cycle where increased participation builds a deeper pool of knowledge that benefits all users.

Project partners also highlighted that the international approach delivered significant cost advantages. EOSC-Life built on and coordinated across existing ESFRI life science research infrastructure (rather than building new systems from scratch), meaning that the project could make use of existing, proven and known infrastructure. The **economies of scale** achieved by bringing together 50 project partners across 13 organisations further enhanced these **efficiency benefits**. Interviewees also shared that the **international consortium structure helped manage the considerable risks inherent in such an ambitious undertaking**. While they acknowledged that coordinating 13 organisations with different capacities, expertise areas, and operational models presented substantial challenges, they emphasised that distributing project risks across multiple partners reduced the exposure faced by any individual participant, including those in the UK. For example, the project faced delays due to COVID-19 and changed slightly in scope, with a more significant push for workflows that might support an improved understanding and handling of COVID-19 data. The WorkflowHub was developed as a collaboration with partners in Belgium, Spain, Germany, Italy and the UK, (and later Australia). Its development was accelerated to address the sharing of COVID-19 processing pipelines – an achievement made possible due to international collaboration.

The breadth of expertise available through EU collaboration was also highlighted by interviewees as an important success factor. The combination of 13 different life science research infrastructures enabled the project to draw upon diverse **international specialisms and experiences** that would have been impossible to replicate at a national level. Some objectives, such as cloud deployment of digital data spaces, can be achieved nationally, but others (e.g. establishing standardised practices for sharing sensitive patient data) are inherently international activities.

Project partners were asked to reflect on the effects of EU Exit on both the EOSC-Life project and their longer-term European collaborations. Interviewees described significant uncertainty within the UK scientific community, with many researchers unsure if they were even able to participate in EU-funded projects. However, they emphasised that the distributed nature of digital research infrastructure and the unique specialised capabilities that each project partner brought to the consortium helped mitigate these uncertainties. The inherently collaborative requirements of infrastructure projects (where each partner contributes distinct technical expertise, data resources, and specialised skills that cannot be easily replicated) created a level of interdependence that provided some protection against political disruptions.

Interviewees shared their belief that this protective effect would not have occurred in other types of research projects where teams are more interchangeable. In those cases, they suggested that if EU partners perceived the UK as risky collaborators due to EU Exit uncertainties, they would simply exclude UK organisations from consortia. However, in infrastructure projects like EOSC-Life, the unique selling points and specialised capabilities of each partner (including UK organisations) made such exclusion more difficult without compromising the project's overall objectives and technical capabilities.

Counterfactual Analysis

To understand whether similar outcomes could have been achieved through a national-only approach, project participants were asked whether a project like EOSC-Life would have been possible without Horizon 2020 funding, and what alternative funding options might have existed. There was strong consensus among interviewees that a project of EOSC-Life's scope and ambition would not have been possible without Horizon 2020 participation. All interviewees emphasised the importance of EU Framework Programme involvement to UK science.

Interviewees highlighted that UK funding for establishing and maintaining underlying digital infrastructure remains inadequate. While national data repositories exist, the fundamental infrastructure that supports them often receives insufficient investment. Interviewees suggested that this is because investment in data infrastructure, is because investment in data infrastructure, that enables critical research, is often overlooked, with resources instead drawn to "groundbreaking" research that would not be possible without this foundational support.

When discussing alternative international collaboration models, participants acknowledged that while global efforts to develop collaborative life science research infrastructures exist, including in health and biomedical sciences, they face significant challenges. Digital sovereignty efforts from national approaches create barriers to international cooperation, as global differences in data sharing standards make implementing common practices difficult. Varying strategic objectives between different countries and regions can prevent the unified efforts necessary for establishing shared facilities.

The political climate also affects the perceived viability of alternative collaboration models. In the context of global instability, pan-European infrastructures like EOSC-Life become critical for maintaining existing knowledge repositories while continuing to promote FAIR and open science principles internationally.

Appendix G Survey questionnaires

A.1. Questionnaire for successful applicants

A.1.1. ABOUT YOU AND YOUR ORGANISATION

1. Please provide the following information about yourself

- Your full name
- Your job title

2. Which of the following best describes your organisation

Drop down menu

- [PRC] SME (<250 employees)
- [PRC] Large company (>250 employees)
- [PRC] Private research and technology organisation
- [HE] Higher Education (e.g. university or institute of technology)
- [PRO] Public research institute or establishment (e.g Alan Turing Institute)
- [PUB] Other public sector (e.g. government agency)
- [CSO] Civil Society Organisations or Learned Societies (e.g. Royal Society)
- Other (specify)

3. Which of the following best describes your sector of operations?

[Routing: for PRC, PRO, and CSO only]

Drop down menu

- Advanced manufacturing
- Clean energy industries
- Creative industries
- Defence
- Digital and technologies
- Financial services
- Life sciences
- Professional and business services
- Other (please specify)]

A.1.2. YOUR EXPERIENCE AS A H2020 APPLICANT

4. To what extent did each of the following act as a driver, encouraging you to bid for an H2020 grant?

Options: Significant driver, moderate driver, not a driver, not applicable.

- Potential access to funds
- Potential access to specialist skills
- Potential access to specialist facilities
- Potential access to European markets
- Potential access to technology suppliers
- Potential access to end-users
- Career progression
- Develop research skills through collaboration
- Develop international scientific networks
- Enhance in-house skills
- Enhance visibility in international markets
- Enhance technological reputation
- Monitor wider technological developments
- Support organisational strategic ambitions
- Progress development of innovations
- Internationalise locally devised innovations
- Test innovative solutions in an international context
- Enhance your research reputation
- Contribute to joint programming decisions (joint programming activities only))

5. Did any of the following change after the UK's EU referendum vote:

Options: significantly reduced, slightly reduced, no change, slightly increased, significantly increased, don't know / not applicable

- Your ability to participate fully in pre-existing H2020 projects
- Your interest in applying for H2020 funding
- Your ability to coordinate an application for H2020 funding
- Your ability to join or form consortia for H2020 applications (incl. willingness of others to partner with UK organisations)
- Your perceived chances of success in applying to H2020
- Your organisation's support to apply for H2020 funding

6. If any of these areas were reduced, could you say more about why this was the case?

[Open text]

A.1.3. BENEFITS

The following questions address the potential organisational benefits from H2020 participation. Please answer based on the one or more H2020 projects you were involved in.

7. Did H2020 benefit **your organisation (department/unit/subsidiary)** in any of the following ways?

Options: high impact, medium impact, low impact, no impact, not applicable.

Research and knowledge

- Increased our understanding about the subject
- Increased our scientific capacity
- Increased our technological capacity
- Increased our awareness of technological trajectories
- Increased our ability to participate in higher risk R&D
- Increased our ability to access international experts
- Improved our ability to collaborate on R&D
- Improved our research management capabilities
- Improved our ability to attract / retain national research staff
- Improved our ability to attract / retain international research staff

Reputation and networks

- Improved our international reputation
- Improved our EU networks
- Improved our international networks (beyond the EU)

Innovation and commercialisation

- Increased our R&D investment
- Increased investment in innovation
- Improved our product (services) portfolio
- Enabled us to increase our turnover
- Enabled us to increase our employment
- Improved our productivity
- Improved our commercial opportunities
- Increase access to international markets or supply chains
- Improved our competitive position nationally
- Improved our competitive position internationally

8. Please briefly describe the most important benefits that **your organisation** derived from its participation in H2020?

[Open text]

9. Please briefly describe the single most important benefit that **you derived personally from** your participation in H2020?

[Open text]

A.1.4. IMPACTS

Commercialisation

10. Did your participation in H2020 lead to any specific commercialisation outcomes?

Enter number. Please feel free to skip any that are not relevant.

- Number of patent applications made as a result of your participation in H2020
- Number of licence agreements made linked with FP-enabled patents or other IP
- Value of licence income linked to your H2020 IP (€m, in 2024)
- Combined value of external investments (e.g. angel, VC, IPO, etc.) secured following H2020 (€m)
- Number of spinout companies launched as a result of your participation in H2020
- Combined employment at those spinouts (at the end of 2014)
- Combined turnover of those spinouts (€m, in 2014)
- Estimated combined value of those spinouts (€m, in 2015)

11. Please briefly describe the **single most important commercialisation** outcome (if any) that has been realised in the UK as a result of your participation in H2020

[Open text]

Societal benefits

12. Please briefly describe any **important societal impact** that has been realised in the UK as a result of your participation in H2020 [and that required this type of international funding or collaboration]. We would be grateful if you could add any relevant link / url.

[Open text]

A.1.5. WITHOUT H2020 FUNDING

13. Thinking about the H2020 project in which you participated (or the most recent of these, if there was more than one), please indicate which of the below scenarios would have been most likely if you had <u>not</u> received H2020 funding for this project.

☐ We would have progressed with the project at the same scale, timeline and location (within the UK)

☐ We would have progressed with the project at the same scale and timeline, but at a different location (outside of the UK)

☐ We would have delayed the project, but would have progressed it later at the same scale, timeline and location outside the UK

☐ We would have progressed the project at a reduced scale

☐ We would have abandoned the project

14. Could you briefly explain your answer

[Open text]

A.1.6. LINKS BETWEEN HORIZON 2020 AND NATIONAL FUNDING LANDSCAPE

15. What were the main differences between H2020 funding and funding available through national funding programmes?

[Tick all that apply]

In comparison with national funding available at the time, H2020 provided support to

☐ larger scale projects in terms of funding

☐ larger scale projects in terms of size of the partneship

☐ projects with a more varied partneship in terms of type of organisaitons involved

☐ projects with a more varied partneship in terms of location of partners

☐ research topics and activities not covered nationally (or at least not to same extent)

☐ projects that allowed access to research infrastructure not available nationally

☐ other

16. Please briefly describe the **most important points of synergy or complementarity between** the UK R&D system and the funding opportunities in H2020.

[Open text]

A.1.7. Future association

17. Do you you think that it is important that the UK continues to participate in EU Framework programmes. If so, why? (i.e. what is the main added value of this funding route)?

[Open text]

18. Assuming the UK continues to associate to the EU framework programmes. What do you see as:

The main barriers and challenges to application /participation

☐ Complexity of the framework programmes

☐ Complexity of the application proccess

☐ Success rates

☐ Finding international partners

☐ Finding UK partners

☐ Securing co-funding at the national level (UK)

☐ Lack of support offered during application process

☐ Other

☐ Do not know

Could you please briefly explain your answer?

[Open text]

The main barriers and challenges to realising benefits from participation

☐ Access to IP / IP arrangements

☐ Follow on public funding to progress activities

☐ Follow on internal private funding to progress activities

☐ Follow on external private funding to progress activities

☐ Other

☐ Do not know

19. Could you please briefly explain your answer?

[Open text]

A.1.8. FINAL COMMENTS

20. Is there anything further you would like to add that has not been addressed through previous questions?

[Open text]

A.2. Questionnaire for unsuccessful applicants

1. Please provide the following information about yourself

- Your full name
- Your job title

2. Which of the following best describes your organisation

Drop down menu

- [PRC] SME (<250 employees)
- [PRC] Large company (>250 employees)
- [PRC] Private research and technology organisation
- [HE] Higher Education (e.g. university or institute of technology)
- [PRO] Public research institute or establishment (e.g Alan Turing Institute)
- [PUB] Other public sector (e.g. government agency)
- [CSO] Civil Society Organisations or Learned Societies (e.g. Royal Society)
- Other (specify)

3. Which of the following best describes your sector of operations?

[Routing: for PRC, PRO, and CSO only]

Drop down menu

- Advanced manufacturing
- Clean energy industries
- Creative industries
- Defence
- Digital and technologies
- Financial services
- Life sciences
- Professional and business services
- Other (please specify)]

A.2.1. YOUR EXPERIENCE AS A H2020 APPLICANT

4. To what extent did each of the following act as a driver, encouraging you to bid for an H2020 grant?

Options: Significant driver, moderate driver, not a driver, not applicable.

- Potential access to funds
- Potential access to specialist skills
- Potential access to specialist facilities

- Potential access to European markets
- Potential access to technology suppliers
- Potential access to end-users
- Career progression
- Develop research skills through collaboration
- Develop international scientific networks
- Enhance in-house skills
- Enhance visibility in international markets
- Enhance technological reputation
- Monitor wider technological developments
- Support organisational strategic ambitions
- Progress development of innovations
- Internationalise locally devised innovations
- Test innovative solutions in an international context
- Enhance your research reputation
- Contribute to joint programming decisions (joint programming activities only))

5. Did any of the following change after the UK's EU referendum vote:

Options: significantly reduced, slightly reduced, no change, slightly increased, significantly increased

- Your interest in applying for H2020 funding
- Your ability to coordinate an application for H2020 funding
- Your ability to join or form consortia for H2020 applications (incl. willingness of others to partner with UK organisations)
- Your perceived chances of success in applying to H2020
- Your organisation's support to apply for H2020 funding

6. If any of these areas were reduced, could you say more about why this was the case?

[Open text]

A.2.2. WITHOUT H2020 FUNDING

7. Thinking about the H2020 application in which you were involved (or the most recent of these, if there was more than one), please indicate which of the below scenarios have occurred after you were unsuccessful.

☐ The project idea was progressed via other means (with little or no change to the scale, timeline or location of participants) [skip to to Q9]

☐ The project idea was progressed via other means (but with changes in the scale, timeline or location of participants) [skip to to Q8]

☐ The project was abandoned [skip to to Q10]

A.2.3. WITHOUT H2020 FUNDING

8. Which of the following changes were made to the project?

☐ Reduced scale

☐ Delayed timeline

☐ No UK involvement

Could you briefly explain your answer

[Open text]

A.2.4. WITHOUT H2020 FUNDING

9. Where was funding secured from to take the project forward?

[Open text]

A.2.5. WITHOUT H2020 FUNDING

10. What was the most significant negative consquence (if any) from not securing H2020 funding for the project?

[Open text]

A.2.6. LINKS BETWEEN HORIZON 2020 AND NATIONAL FUNDING LANDSCAPE

11. What were the main differences between H2020 funding and funding available through national funding programmes?

[Tick all that apply]

In comparison with national funding available at the time, H2020 provided support to

☐ larger scale projects in terms of funding

☐ larger scale projects in terms of size of the partneship

☐ projects with a more varied partneship in terms of type of organisaitons involved

☐ projects with a more varied partneship in terms of location of partners

☐ research topics and activities not covered nationally (or at least not to same extent)

☐ projects that allowed access to research infrastructure not available nationally

☐ other

12. Please briefly describe the **most important points of synergy or complementarity between** the UK R&D system and the funding opportunities in H2020.

[Open text]

A.2.7. Future association

13. Do you you think that it is important that the UK continues to participate in EU Framework programmes. If so, why? (i.e. what is the main added value of this funding route)?

[Open text]

14. Assuming the UK continues to associate to the EU framework programmes. What do you see as:

The main barriers and challenges to application /participation

☐ Complexity of the framework programmes

☐ Complexity of the application proccess

☐ Success rates

☐ Finding international partners

☐ Finding UK partners

☐ Securing co-funding at the national level (UK)

☐ Lack of support offered during application process

☐ Other

☐ Do not know

The main barriers and challenges to realising benefits from participation

☐ Access to IP / IP arrangements

☐ Follow on public funding to progress activities

☐ Follow on internal private funding to progress activities

☐ Follow on external private funding to progress activities

☐ Other

☐ Do not know

15. Could you please briefly explain your answer?

[Open text]

A.2.8. FINAL COMMENTS

16. Is there anything further you would like to add that has not been addressed through previous questions?