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Realisation of a Final Impact Assessment Study for Horizon 2020 for the COST Association

Final Report

Patrick Eparvier, Aurélien Fichet de Clairfontaine, Gerwin Evers, Jan Biela, Yvan Meyer, Erika Van der Linden, Reem Ismail, Thorben Strähle, Elisabeth Zaparucha,

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Acronym table

AISBL	Association Internationale Sans But Lucratif
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Électrotechnique
COST non-ITC	COST countries without ITC
DOI	Digital Object Identifier
EC	European Commission
ECI	Early Career Investigators
EIC	European Innovation Council
EIT	European Institute of Innovation and Technology
ERA	European Research Area
ERC	European Research Council
ESF	European Science Foundation
FP6	6th Framework Programme
FP7	7th Framework Programme
GVA	Gross Value-Added
H2020	Horizon 2020
IPC	International Partner (Countries)
ITC	Inclusiveness Target (Countries)
JRC	Joint Research Centre
MC1	First Management Committee meeting 1
N/A	Not Available
NNCB	Near Neighbouring (Countries)
NUTS2	Nomenclature des Unités Territoriales –– 2
STSM	Short Term Scientific Mission
WPSE	Widening Participation and Spreading Excellence

Terms' definition

User	An individual participating to one or more Actions' activities
Instrument	The main connecting tool to bring Actions users together: a meeting, a conference grant, a training school, or a short-term scientific mission.
Degree centrality	A measure of a user's number of connections to other users.
Betweenness centrality	A measure of the intermediary role of a user.
Closeness centrality	A measure of the proximity of a user to all other users in the network.
Transitivity index (clustering coefficient)	A measure of the level of clustering of the network: if user 1 knows user 2, and user 2 knows 3, does user 1 know user 3?
Action network	A network of users participating in that Action activities and meeting through instruments.
Global COST Action network	The network of concatenated Action networks, interlinked thanks to users multi-Action memberships.
Inter-Action network	The fully connected version of the global COST Action network: users are connected to all other Action users.
Inter-instrument network	The subset of the inter-Action network, where connections are weighted by the number of instruments: users are connected only to other users through instruments.
Average path length	The average number of users needed to connect one user to any other user.
Assortativity	The trend that users of a certain rank are only connected to other users of the same rank.
Disconnected component	A group of users not connected to other group of users and forming their own network.

Key findings

- Within the COST network, knowledge and ideas spread efficiently and quickly thanks to a flat network structure resembling a 'small-world', where connectivity between participants is high.
- Career stage still drives a significant part of the connections made on Actions, but less so for connections made during individual meetings.
- About one out of two connections in the COST network is between a man and a woman, a higher share than in both FP7 and FP6. Also, when taking titles into account, male participants are not better connected to any other participant or more central to a network.
- The COST programme enables interactions between Inclusiveness Target Countries (ITC) and other COST countries, as seen by the high share of connections between participants from ITC and non-ITC. Within the EU, geographic separation and language barrier do not significantly impede cross-regional connections.
- More than half of the COST Actions are interdisciplinary (on average 5.8 different disciplines), and the COST programme enables more interdisciplinary Actions for Humanities and Social Sciences fields than Horizon 2020.
- Connections in COST activities tend to be slightly hierarchical (between participants bearing the same title) whereas the Horizon 2020 network is governed by a negative hierarchy (disassortative) effect.
- On average, Actions contributed to publishing a little bit more than 30 publications, based on self-reported data, and around 53 publications on average based on Scopus. Those spin-off publications generated over 200,000 citations and 89% of them have been cited at least once. COST publications have a collaborative nature (on average, 6.7 authors are listed on a COST publication).
- COST offers low entry barriers to Young Researchers and researchers from less research-intensive areas, which is seen as a defining feature. Furthermore, one quarter of COST publications' authors can be considered as Young Researchers.
- COST is perceived to be the primary networking tool in the European research and innovation landscape, spanning disciplines, countries, career stages and different types of actors.
- Participation to COST Actions increases the chance for success of applications to other European programmes, making COST a pre-portal to other European funding instruments since.

Executive summary

This final impact assessment purpose is manyfold. First, it aims to meet a requirement of the European Commission concerning a final impact assessment. Second, it provides an assessment of the networking, scientific and societal impacts of the COST activities over the seven years of Horizon 2020. Third, it informs third-party stakeholders on the impacts and relevance of the COST programme. Fourth, it serves to indicate to the COST Administration and governance areas and topics of development over the next Framework Programme.

Using social network analysis and econometric techniques, it analysed over 12.5 million participants' connections through Action membership and 4.6 million connections through networking activities such as meetings, Short Term Scientific Missions (STSMs), conference grants and training schools. It analysed COST Action final and intermediary reports together with bibliometric data to measure the generated scientific output and identify breakthrough research performed within the COST framework. Finally, an extensive literature review and 56 interviews with COST stakeholders have been conducted to provide a clear picture of the strategic position of COST and better understand the COST value-added activities.

Within the COST network, knowledge and ideas spread efficiently and quickly thanks to a flat network structure resembling a 'small-world', where connectivity is high. Indeed, the COST network is not composed of a core of super participants connecting in a hierarchical way (professors connecting with doctors, doctors connecting with others, etc.). Furthermore, connectivity level between participants is high and the average distance between them (average number of participants that can connect any two individuals) is low.

Regarding scientific domain and interdisciplinarity, COST is a bottom-up instrument open to accepting proposals for COST Actions from various academic disciplines, but also interested in attracting interdisciplinary projects. Natural sciences are the predominant scientific domain among those Actions in terms of Action size, followed by agricultural sciences and engineering and technology. COST Actions have an interdisciplinarity nature as an Action covers on average 5.8 different disciplines. However, interdisciplinarity seems more common between disciplines that are topic-wise closer together. This is also reflected in the volume and the collaborative nature of COST publications.

Connectivity is still driven by participants' characteristics, in terms of gender, title, age, and geographical localisation. However, gender appears to play only a minor role in explaining who get acquainted with whom. Almost half of participants' connections are between a man and a woman, but at meetings, men tend to connect to other men. Still, women are better connected through COST activities (meetings, training schools, conferences, STSMs) despite their underrepresentation in the highest ranks (42% of participants are women, those represent only 28% of professors). Nevertheless, some scientific fields of COST Actions are starting to approach a fifty-fifty gender balance and the gender balance seems to experience a rebalancing as we observe a more important share of women in the Early Career stage than in the Mid- or End-Career stage. Also, the COST network is slightly more gender inclusive than both FP7 and FP6, with a share of women participation of respectively 38% and 26% (compared to 42% for COST).

Most connections are cross-national, and participants from (less research intensive) Inclusiveness Target Countries (ITCs) are well integrated in the network. Moreover, we find that EU-13 countries[1] have a higher connection share in the COST network than in the Horizon 2020 network, and that both geographical distance and language barriers do not impede international connections as much as in FP networks (FP5 and FP6), co-patent networks and co-publication networks. COST is perceived by internal as well as external stakeholders and beneficiaries to be an instrument to facilitate brain circulation in EU and non-EU countries. It is also appreciated as a key instrument to opening European networks of researchers beyond Europe by not only being active in the European context, but also in the continent's neighbourhood.

As a result, four out of five countries that present the highest number of authors of COST publications, relatively to the number of inhabitants of the country, are ITCs (i.e., Slovenia, Portugal, Estonia, Czech Republic; Switzerland, is the only non-ITC among these five). In total, participants from ITCs represent 30% of the COST publication list of authors. This is a major result of COST Excellence and Inclusiveness Policies, that serves at expanding scientific networks and integrating in global knowledge streams, in particular for researchers from non-COST countries.

Regarding career stage, titles and age still matter. Participants bearing similar titles connect more often than with others. Doctors and professors (who are among the oldest participants in COST Actions and instruments) share the largest part of connections within Actions and through instruments. They are central to COST Actions where they play an important intermediary role linking participants to other participants but are not necessarily the best connected via activities such as meetings. Nevertheless, the majority of researcher interactions occur between participants in different career stages. This contrasts with the disassortative characteristic of Horizon 2020 (where participants tend to privilege collaborating with either higher or lower "ranked" participants). Finally, one quarter of the COST publications' authors can be considered as young researchers. In that regard, COST Academy is positively perceived as providing helpful and role-specific training to COST Action representatives. Young participants in the trainings felt they personally benefitted in their skills and personality development from the COST Academy, and that also the COST Actions themselves improved that way.

The low entry barriers for researchers from all career stages and a diverse set of geographical countries are seen as a defining feature of COST as they encourage participation of especially young researchers and researchers from Inclusiveness Target Countries (ITCs). Overall, as an instrument, COST is perceived to be the **primary networking tool in the European research and innovation landscape**, spanning disciplines, countries, career stages and different types of actors. Furthermore, the COST stewardship approach is perceived as a distinguishing unique feature, creating trust and inclusion atmosphere of ownership from the very start in the COST Actions. Hence it enhances the strength of the networks and the speed with which they can come together.

[1] Bulgaria, Czech Republic, Cyprus, Estonia, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovenia and Slovakia

1 Introduction

This document corresponds to the draft final report of the evaluation of the Final Impact Assessment Study for Horizon 2020 for the COST Association.

The evaluation started in December 2020.

This document presents the following:

1. An introduction discussing the purpose of the study and providing a quick overview of the methodological approach.
2. The methodological approach to assessing the scientific and societal impacts.
3. A summary of activities of COST Association.
4. The estimated impacts on participants.
5. The estimated scientific impacts.
6. The estimated societal impacts.
7. The conclusion of the study.

1.1 Purpose of this study

This study aims at providing the COST Association and its main stakeholders (the European Commission (EC), COST Member States, the research community) with an assessment of the scientific and societal impacts of the COST activities over Horizon 2020. This study also purports to meet a requirement of the European Commission concerning a final impact assessment as incorporated in the Framework Partnership Agreement.

COST, through its main instrument the COST Actions, connects people and organisations from different backgrounds and disciplines to create and diffuse knowledge (i.e., brain circulation) and generate innovation (i.e., lead to breakthrough science). It also contributes to capacity building and career advancement by allowing a networking platform for both early-career researchers or researchers from less research-intensive countries (regions which are less connected in terms of knowledge creation and diffusion). This impact assessment aims to estimate the added value of the COST framework, report it to the political and governmental stakeholders (Members States and EC) as well as communicate it to the research community, i.e., the third-party stakeholders in order to stress the relevance and legitimacy of the activities.

To this end, it provides an analysis of how the research networks built as a result of COST activities are structured: considering the geographical scope and professional backgrounds of the researchers that participate in these activities. Additionally, it evaluates the complementarity of the COST network with the Horizon 2020 network. Regarding the scientific impacts of the COST activities, an overview of knowledge creation – in terms of the number of outputs (conferences, workshops, scientific publications) generated by the COST Actions – and of knowledge diffusion – in terms of the size of networks, spin-off Horizon 2020 projects and the number of publications' citations – is performed and reported upon.

The results of this impact assessment aim to feed into COST reflections and perspectives on COST activities in Horizon Europe and how to further valorise these activities in terms of societal and scientific impact.

Also, as an originally intergovernmental programme, COST has been funded by the EC for the past Framework Programmes and will be again funded by the EC in the upcoming Framework Programme Horizon Europe. In this context, there can be different perspectives on the balance

of considerations of excellence and inclusiveness . The results of the impact assessment should help contribute to this question and provide elements of answers.

1.2 Method overview

The methodological approach to the assessment includes:

- A social network analysis at the participant and regional level that focuses on two aspects:
  - The links between participating researchers to COST activities and the factors that characterise those links: interdisciplinarity, early vs. advanced career stage (professional background), gender, geographical localisation, etc.
  - The extent to which the networks generated as a result of the COST activities compare to (public-funded) scientific collaboration networks and what the value-added of COST is regarding the original features of those COST network.
- In-depth interviews with internal and third-party stakeholders.
- A textual analysis to create an overview of structured and unstructured outputs of the COST Actions.
- Case studies alongside a bibliometric analysis to help identifying significant breakthroughs among COST Actions.
- A reporting upon all the previous tasks.

These steps will be further elaborated in the next sections, and the analytical tools for each Task are summarized in the Table below.

1.3 The structure of the study

This final report document is structured as follows:

- Section 2 provides a summary and detailed description of the COST Association, its programme and its strategic approach, the COST Impact model, the COST activities and descriptive statistics on Actions, instruments and participants' characteristics.
- Section 3 describes the methodological approaches for the network, output, and stakeholder analyses.
- The findings regarding:
  - Networking impact and impacts of added value activities on participants in Section 4.
  - Scientific impact in terms of outputs and breakthroughs in Section 5.
  - Societal impact in terms of breakthroughs and reputational/strategic impact in Section 6.
- Section 7 concludes.

2 COST Association: summary and context

The present study assesses the **impact on science and society of the activities deployed by the COST Association over the Horizon 2020 Framework Programme (2014-2021)**.

It uses **efficient data collection** and documentation and simultaneously an analytical framework for **systematic assessment** of COST Actions participants' experiences and needs to assess the scientific and societal impact of the activities of the COST Association.

2.1 COST Association

COST, established in 1971, is a programme dedicated to promoting **research networks** in Europe and beyond. According to its Strategic Plan, COST aims to promote and spread excellence, foster interdisciplinary research for breakthrough science and empower and retain Young Researchers and innovators. COST helps researchers to establish and extend their networks for scientific exchange. The programme's impact reflects on both researchers' individual careers and networking, as well as on research and innovation at-large.

COST was established as an intergovernmental initiative to enable **bottom-up networking** around nationally funded **research activities** in a broad variety of subject fields. The instrument is a founding pillar of the European Research Area (ERA). The programme's objective is to **promote transnational networks** among researchers from COST member countries[2] as well as from partner countries known as Near Neighbour Countries (NNC)[3] and International Partner Countries (IPC)[4]. These activities aim to promote excellence and interdisciplinarity of research, and the embeddedness of (young or less-well connected) researchers in an international research environment.

2.2 The programme

The long-term goal of the programme is to narrow the gap between science, politics, and society in Europe. In its 2017 Strategic Plan and 2018 COST Mission,[5] the COST Association has identified three strategic priorities in this regard:

- Promoting and spreading excellence,
- Foster interdisciplinary research for breakthrough science, and
- Empowering and retaining Young Researchers.

The main instrument of COST is the funding of **COST Actions**, which are networks of researchers and innovators. A distinct feature of COST is the number of participants working together in one Action. On average, a COST Action has 50 participants in the Management Committee. In

[2] COST today has 38 member states, among them the EU 27, as well as Albania, Bosnia and Herzegovina, Iceland, Moldova, Montenegro, North Macedonia, Norway, Serbia, Switzerland, Turkey, United Kingdom, and Israel (the latter as a Cooperating State).

[3] The Near Neighbour Countries (NNC) include Algeria, Armenia, Azerbaijan, Egypt, Georgia, Jordan, Kosovo, Lebanon, Libya, Morocco, Palestinian Territories, Russia, Syria, Tunisia, and Ukraine.

[4] The International Partner Countries (IPC) include Argentina, Australia, Bangladesh, Brazil, Chile, China, Colombia, Costa Rica, Hong Kong, India, Indonesia, Iraq, Japan, Korean Republic, Mauritius, Mexico, Namibia, New Zealand, Pakistan, Peru, Saudi-Arabia, Singapore, South Africa, Sudan, Thailand, United Arab Emirates, United States of America, and Uruguay.

[5] COST Association, 2017: COST Strategic Plan, COST 060/17, p. 17; accessible at: https://www.cost.eu/wp-content/uploads/2018/08/COST_StrategicPlan_WEB.pdf (last access: September 21, 2020).
COST Association, 2018, COST Mission, https://www.cost.eu/about/cost-mission/

general, COST Actions are funded for a period of four years. During the funding period, COST funding can be allocated to organise conferences and workshops and to cover related costs (travelling, accommodation, etc.). Moreover, COST promotes the careers of researchers through the funding of training schools or Short-Term Scientific Missions (STSM). Additionally, COST Action funds can be used to finance targeted activities which serve to disseminate the outcomes and results of the Action.

The programme is thematically open and structured in a bottom-up way. Apart from scientific excellence, applicants have to prove inclusion of those member countries designated as Inclusiveness Target Countries (ITCs),[6] female researchers, and Young Researchers[7]. COST is thus designed to bridge the innovation and participation gaps between well-established member countries on the one hand, and ITCs, IPCs and NNCs, on the other hand, as well as promoting gender equality and career development.

In 2013, COST was re-organised as an international non-profit organisation (the COST Association) under Belgian law (*Association internationale sans but lucratif, AISBL*), taking over from the European Science Foundation (ESF). It is administered by its Brussels-based bureau (the COST Administration) and is funded from the EU Framework Programme budget with roughly EUR 300 million for the 2014-20 period.

2.3 COST Activities

COST's main objective is to **promote transnational networks** among researchers from COST member countries[8] as well as from partner countries known as Near Neighbour Countries (NNC)[9] and International Partner Countries (IPC)[10]. These activities aim to promote excellence and interdisciplinarity of research, and the embeddedness of (young or less-well connected) researchers in an international research environment. The main instrument of COST is the funding of **COST Actions**, which are networks of researchers. In an average year, 60 new COST Actions are selected for funding. Over the course of Horizon 2020, 669 Actions with 92,280 participants benefitted from funding.

In order to support the COST Action's objectives, a number of networking tools are at the disposal of the research community. These include meetings, workshops and conferences, Short-Term Scientific Missions (STSM), training schools. Moreover, COST supports researcher mobility by offering conference grants, virtual networking support grants and virtual mobility

[6] The Inclusiveness Target Countries (ITC) include Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Macedonia, Montenegro, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, and Turkey.

[7] Over Horizon 2020, COST predominantly used the term "Early Career Investigator (ECI), which implied researchers having their PhD for 8 years or less. The COST Strategic Plan, however, refers to Young Researcher, meaning any researcher not yet having reached the age of 40"

[8] COST today has 38 member states, among them the EU 27, as well as Albania, Bosnia and Herzegovina, Iceland, Norway, Republic of Moldova, Republic of North Macedonia, Montenegro, Serbia, Switzerland, Turkey, United Kingdom. Israel is a Cooperating Member.

[9] The Near Neighbour Countries (NNC) include Algeria, Armenia, Azerbaijan, Egypt, Georgia, Jordan, Kosovo, Lebanon, Libya, Morocco, Palestinian Territories, Russia, Syria, Tunisia, and Ukraine.

[10] The International Partner Countries (IPC) include Argentina, Australia, Bangladesh, Brazil, Chile, China, Colombia, Costa Rica, Hong Kong, India, Indonesia, Iraq, Japan, Korean Republic, Mauritius, Mexico, Namibia, New Zealand, Pakistan, Peru, Saudi-Arabia, Singapore, South Africa, Sudan, Thailand, United Arab Emirates, United States of America, and Uruguay.

grants. In recent years, some added-value activities have been newly established. Moreover, the COST Association itself has taken a new, more support-oriented approach towards the COST Actions, internally called "stewardship approach". Below, these activities are described more in detail. In the following chapters, their impact onto the networking and knowledge production within and beyond COST Actions is evaluated.

2.3.1 The COST stewardship approach

During Horizon 2020, COST has developed and implemented the **COST stewardship approach which represents a shift in the philosophy of COST**. The approach is based on the notion of COST becoming an "*engaged investor*" facilitating the success of the COST Actions by empowering the COST Actions and their leadership to succeed. As a funding instrument, COST has thus chosen to move beyond a mere controller of funds, towards an active facilitator continuously engaging with its beneficiaries (the COST Actions participants). While the stewardship approach manifests itself in many aspects of the COST framework this analysis will focus on the central elements: **scientific stewardship and communication stewardship[11].**

As regards **scientific stewardship**, each COST Action has a dedicated COST Science Officer (from the COST Administration) who is in regular contact with the COST Action leadership. The COST Science Officer approves the yearly Work and Budget Plan as presented by the Action and advises Actions in implementation. An important change following the introduction of the COST scientific stewardship approach was that the **Management Committee meeting 1 (MC1) was changed**. In this meeting, the participants of the Actions come together for the first time and indeed many participants meet for the first time in person at this occasion. The format of the meeting used to be more focused on an informative presentation of the COST rules and regulations of importance over the COST Action lifetime. With the introduced scientific stewardship approach, the meeting was made more interactive, giving participants the opportunity to engage more actively with the COST representatives and each other. It also included a more open discussion on the suggested structure of the working groups and the general direction, objectives and goals of the COST Action. The intention of COST is that by changing the nature of the MC1 meeting towards a more inclusive and interactive format, trust will be built between COST Action participants from an early stage, but this approach should also strengthen the sense of ownership and agency among the leadership of the Action.

The stewardship approach also extends to the **communication activities** of the Actions. As part of this new philosophy, a new leadership position, the COST Action Science Communication Manager, was introduced. The **main objective of incorporating this function in the COST Actions is to increase the visibility of COST Actions and of the COST programme** by improving their communication and dissemination of results.

The **Science Communication Manager is responsible for developing a communication strategy** for the Action. The responsibilities include coordination and creation of the website, its contents and identifying potential and relevant channels to reach defined audiences. To fulfil those responsibilities, **COST gives support to the Science Communication Managers** by providing a communication toolbox, guidelines on best practices and direct advice through the specifically dedicated COST Communication Officer – a central coordination point for communication activities within the COST Association. Moreover, the Science Communication

[11] The COST Administration also provides stewardship to grant holders. This activity is outside the scope of this report.

Managers are also beneficiaries of the COST Academy, having the opportunity to follow modules and courses on communication.

2.3.2 *Added-value activities*

2.3.2.1 COST Academy

The **COST Academy** is an important added-value activity, which supplements and contributes to the COST stewardship approach. It is a training initiative developed to support the Actions, its leadership and its participants. Since its start in 2018, the COST Academy offers trainings, workshops, mentoring and webinars. The goal of the COST Academy, in **providing trainings to COST Action participants and leadership, is to improve the way COST Actions are managed**, thus indirectly facilitating their success. A further objective of the trainings is to **build up and advance individual skills of the researchers, which can be applied in other contexts**. The COST Academy structures the modules according to certain roles or target audiences as shown in Table 1.

Table 1 - Overview of modules offered by the COST Academy

Role orientation / Target audience	Modules
COST Grant holders	• Grant holder workshops • Grant holder seminars • Grant holder mentoring
COST Action Chairs	• Main Proposers workshops • COST Action Chairs' forum • COST Action sustainability networking event
COST Science Communication Managers	• Using social media to communicate your research • Working with the media. Mastering media interviews • Storytelling: spotting and writing a good story. Getting people to listen • Shooting and editing a video for your Action
Young and ITC researchers	• Leadership workshops • Management induction
COST Webinars and Online Trainings	• Diverse set of topics

The COST Academy events are **organised as full day events** on the Brussels-premises of the COST Association but have **taken place virtually in the recent past** due to the Covid pandemic. Often, COST also **invites external speakers or experts** to take part in the events to elaborate on specific topics, methodologies or tools.

2.3.2.2 COST Innovators Grant

The COST Innovators Grant was introduced in late 2019 and aims to **enhance the pace and success of breakthrough innovations by bridging the scientific research of the COST Actions to marketable applications**. The COST Innovators Grant is modelled after the ERC Proof of

Concept grant[12] which is also aimed at facilitating innovation and which was welcomed by ERC beneficiaries. Upon invitation by the COST Association, a COST Action can apply for an additional year of funding, focusing on activities related to the research network exploring their innovative potential. The COST Innovators Grant allows the continuation of the COST Action for a smaller group of previously involved COST members. It is often led by the COST Action Chair and involves approximately 10-15 further members of the COST Action. Throughout the year, a comprehensive business plan is developed to outline the transfer of scientific research towards marketable solutions. The ambition of COST is to award 5 Innovators Grants per year.

2.3.2.3 COST Connect

COST Connect is a series of workshops, attended by 50-70 participants and organised by the COST Association since 2017. **The objective of COST Connect is twofold: bringing together COST Actions participants (mostly COST Action Chairs) and connecting them to relevant stakeholders**. These stakeholders can be from organisations such as CEN-CENELEC, the European Infrastructure for Translational Medicine, the Joint Research Council or different Directorate Generals of the European Commission. In this way, it creates opportunities for multi-level networking between a broad set of actors from the COST Actions and the European Research Area (ERA).

At the time of writing 16 COST Connect events have been organised on a wide range of topics[13]. Most of these focus on a theme or field (e.g., digital cultural heritage or cancer research) and some have been dedicated to cross-cutting topics (e.g., standards). **For the purpose of the study, the COST Connects can be differentiated into thematic and cross-cutting events**, with different implications on the organisation and the broader context in which the events are embedded.

For the organised events, the **COST Association was responsible for conceiving the topics and timing of the events**. For the thematic events, the decision on a particular topic is often considered in light of a broader context, such as the preparation of political strategies and work programmes. In this way, the COST Connect event is seen as a building block and one of many events engaging the research community with policy makers. The cross-cutting events are not relating to any particular context but are of continuous relevance to the participants. Once a topic is selected, the COST Association might decide to **involve external stakeholders in the organising process**. The cross-cutting events, relevant for COST Actions from different disciplines, often centre on methods or tools which COST Actions can use or apply in their work. In the case of standardisation, COST decided to involve CEN-CENELEC and the Joint Research Council from the onset in the organisation of the event.

COST Connect events all follow the same "art-of-hosting principle", they are interactive by nature and generally set-up similarly in terms of format and agenda. COST Connect events aim to create an informal atmosphere encouraging participants to "think out loud". Due to the proximity to policy makers, most of the COST Connect events have so far taken place in Brussels. Mostly, the events take place on two half days, to ease travelling for the participants but also to create extra time for networking opportunities in the evening. Regarding the agenda, the events usually start by rounds of introductions and some initial plenary

[12] https://erc.europa.eu/funding/proof-concept

[13] COST Connect topics: Water in Agriculture and Food in the Mediterranean Area; Digitalisation, ICT, NGI; Digital Cultural heritage; Impact / R&I system; Quantum science; Urban Mobility; Climate Change and Forest Systems; Sustainable Energy in Danube Region; The Future of European Brain Research; Data Sharing; Cancer Research; Innovative Learning Practices; Oceans; Standards; European Green Deal; Climate-Neutral and Smart Cities

presentations of external stakeholders. At the start of the event, the participants are also asked to come up with and select the questions which they consider relevant to be discussed during the event. Some of these selected questions are subsequently discussed at several tables (in world-café-style) between a smaller group of participants.

In terms of participants, the **COST Connect events are mainly directed towards researchers who are in leading positions of the COST Actions** such as COST Actions Chairs, Vice-Chairs or Management Committee Members or are engaged with managing Working Groups.

2.3.2.4 COST Global Networking

Many of the current challenges are global in nature, such as health pandemics or the climate crisis, demanding global solutions which require engagement from many parts of the world. In this spirit, **COST aims to offer a platform for global cooperation, with a European centre of gravity**, for researchers to interact and form global networks. In practice, the Actions offer opportunities to build and maintain long-term international cooperation between European and international partners. In the COST framework, countries fall into different categories:

- **COST Full Member countries**[14] - These countries are represented in the COST Committee of Senior Officials (CSOs) which is the governing body of COST. Member countries have the right to assign researchers to any COST Action.
- **COST Cooperating Member country** (Israel) – Researchers enjoy member rights in the COST Action participation and Israel has non-voting rights in the COST CSO.
- **COST Partner Member country** (South Africa) – Researchers are eligible to participate in COST Actions. The participation is financed with a separate and dedicated budget from the responsible national authority. Thus, participation is not reimbursed by COST funds.
- **Near Neighbour Countries** (NNC)[15] – Researchers can participate in COST Actions and are eligible for reimbursement if they are associated to the COST Actions as observers.
- **International Partner Countries** (IPC)[16] - Researchers in IPCs can join COST Actions as observers but can only receive limited reimbursement.

In the global outlook, COST has set up the COST Global Networking which concerns the **cooperation of COST Actions with researchers and partners from the COST Partner Member country, the NNCs and IPCs (sometimes referred to as "non-COST countries")**. For this study, several interviews were conducted with COST Action Chairs to receive their perspective on the one hand, but also representatives from different COST and COST Partner Member countries, the NNCs and IPCs.

The Actions have the opportunity to engage in global networking, which means that researchers from non-COST countries can be involved. For example, researchers from IPCs can always be invited to participate in the work of the COST Actions. Depending on the type of country, these participations will be funded or solely invited without reimbursement (the latter applies to IPCs in most cases) to the activities over the course of the Action. The value that

[14] Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Republic of Moldova, Montenegro, The Netherlands, The Republic of North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom

[15] Armenia, Azerbaijan, Belarus, Georgia, Ukraine, Russia, Kosovo, Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Palestine, Syrian Arab Republic, Tunisia

[16] Some of those countries are the United States, Canada, Australia, Japan and South Korea. In principle, any country can qualify as an international partner country

COST perceives in this format are connecting with (scientific) peers globally, developing the field internationally, providing specific expertise to the COST Actions and exchanging data and facilitating access to the specific infrastructure and research centres[17].

2.4 Descriptive statistics of COST Activities

This section provides a global overview of the COST Action network through descriptive statistics. This overview is realised in terms of Action network size and participant attributes (gender, age, title, geographical localisation). These statistics provide a better understanding of the composition of the created global COST network (the network constituted by all the Actions and their activities).

- **Key indicators:**

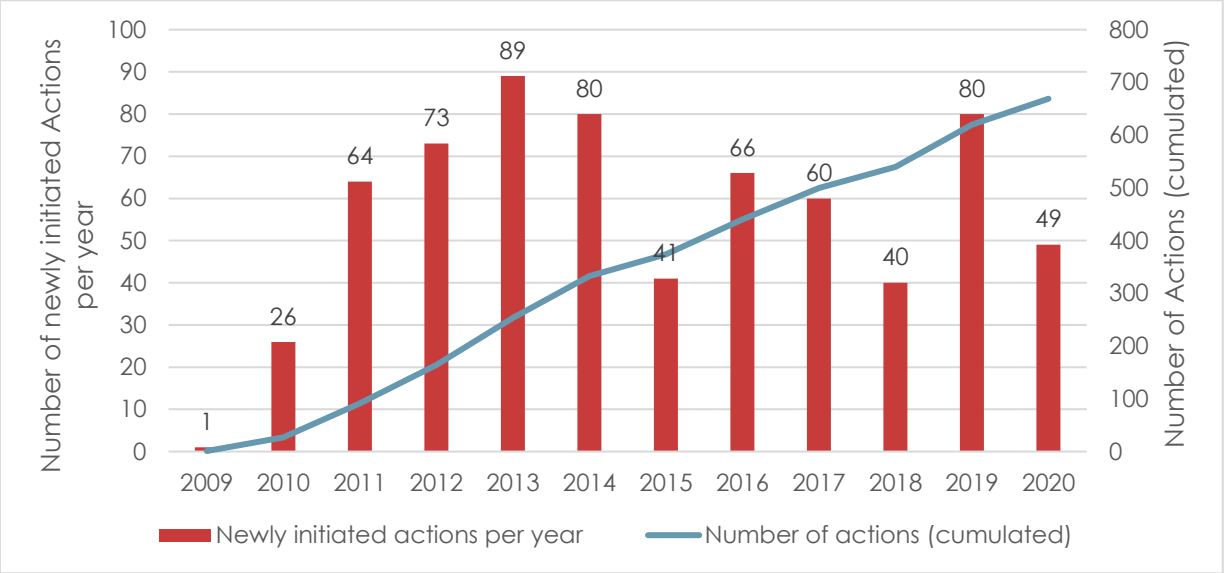
- In total, 669 Actions are identified, 621 for which data on participants and instruments are available.
- On average, the size of an Action is 174 participants.
- By the end of 2020, 62% of those Actions (416) have ended.
- STSMs represent the majority of the used instruments, followed by meetings, training schools and finally conference grants for ECIs and PhD researchers from Inclusiveness Target Countries (henceforth in this document named "conference grants").
- Whereas 42% of participants are women, those represent only 28% of professors.
- Natural sciences are the predominant scientific domain (with 208 Actions). In terms of Action size, natural sciences, agricultural sciences and engineering and technology are the three top scientific domains.

Overall, a total of 669 distinct Actions[18] were analysed in the study, with a peak number of new Actions starting in 2013 (89 Actions). 48 of those Actions are lacking instruments and participants data since they were initiated during the Covid-19 pandemic (later than April 2020). The annual growth of Actions is not linear and appears instead to follow an S curve. The evolution is illustrated in Figure 1 below.

[17] This was presented in the context of a COST Academy webinar on "How to promote international cooperation in your Action, published on 17. December 2019

[18] Including COST Innovator Grants, which are technically run as Actions

Figure 1 Number of Actions by year (left axis) and annual stock of Actions (right axis)

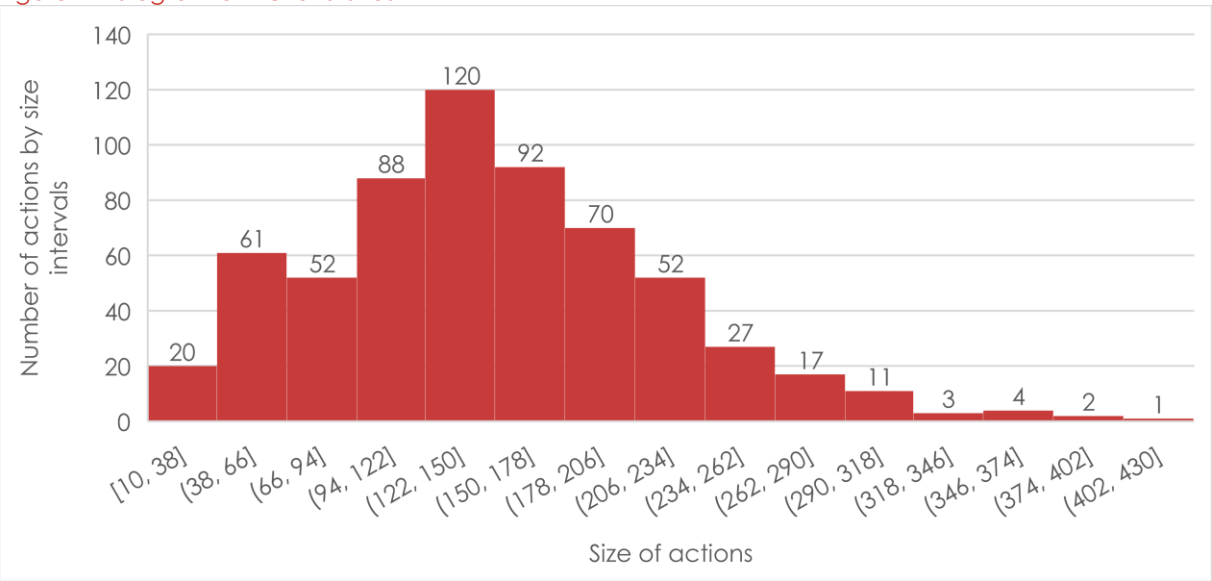


Source: COST Association

By the end of 2020, 62,2% of the started Actions have finished (416 out of 669).

Over 621 Actions for which participation data are available (identifiers of participants), the average number of participants is 176, the lowest is 26[19] and the maximum is 446. The histogram below illustrates the distribution of Actions by size.

Figure 2 Histogram of Actions' sizes



Source: COST Association

In total over 2009[20]-2020, 1 342 conference grants have been used as instruments, 1 685 training schools, 9 396 meetings and 18 971 STSMs. Over the years, the number of STSMs increased and

[19] Actions with a low number of participants are newly starting Actions.

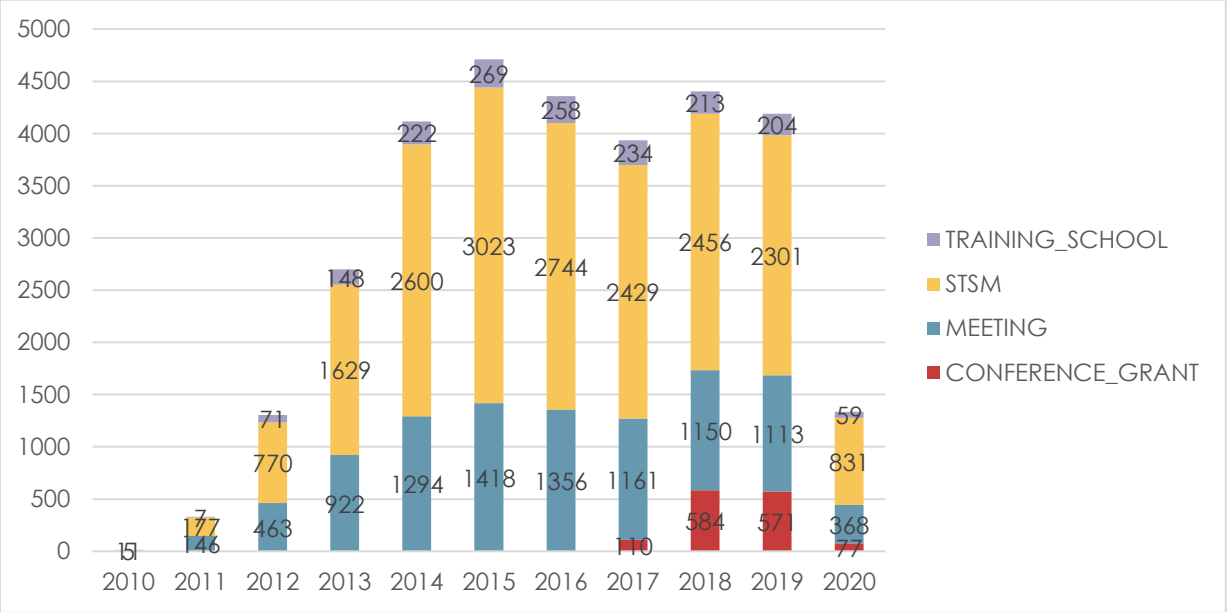
[20] The data only covers late 2010 to April 2020.

reached a peak in 2015 (3 023 missions), it oscillated around 2400 since (without taking 2020 into account due to Covid-19 pandemic). The same evolution characterises the organised meetings (peak in 2015, oscillation around 1130 since) and training school (peak in 2015, oscillation around 215 since). Conference grants are given from 2017 on and reached their peak in 2019 (571) before logically falling below their first year in 2020 (77 compared to 110).

It is important to note that this study's scope covers Actions that were still active in 2014 and onward, thus explaining the low figures for the earliest years.

The distribution of instruments by type and by year is illustrated in the Figure below.

Figure 3 Number of instruments (Meeting, conference grant, training school, STSMs)



Source: COST Association. Note: the low values of 2020 are mostly due to the Covid-19 pandemic. Note: Conference grants and Short-Term Scientific Missions (STSM) do not imply participant interactions. The number of early Actions' instruments from 2010, 2011 and 2013 is underestimated due to the fact that this study's scope covers Actions still active in 2014 and onward.

The total number of distinct Action participants (participants and managers) is 92 280 (more than three times the number of distinct participants of Horizon 2020 between 2014 and 2020[21]) for 621 Actions and 30 751 COST instruments (1.5 time the number of collaborative projects of Horizon 2020 between 2014 and 2020[21]) connecting them. Out of those 92 280 Action participants for whom gender data is available, we identify 38 657 women (42%) and 53 351 men (58%). Among the participants, 28% of professors and 42% of doctors are female.[22]

[21] Keeping our eyes on the Horizon. Monitoring flash series: a Horizon 2020 monitoring report (September 2020). https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/f164fa95-fed4-11ea-b44f-01aa75ed71a1

[22] We have three different classifications, one for 'female', one for 'male' and one coming from the lack of data or the will of participants to not indicate their gender, we name this one 'Unknown'.

Table 2 Number of participants by title and gender

Title	Female	Male	Share of female	Missing data	Unknown	Total
Dr	16 816	22 979	42%	97	27	39 919
Prof	4 623	11 616	28%	65	2	16 306
Other	17 218	18 756	48%	38	43	36 055
Total	38 657	53 351	42%	215	57	92 280

Source: COST Association

Regarding the type of instruments, all 621 Actions use meetings as connecting instruments, 96% use STSMs, 84% use Training schools and 39% have approved Conference Grants (we recall however that conference grants were given from 2017 onwards, 8 years after the first Actions were initiated and midway through Horizon 2020).

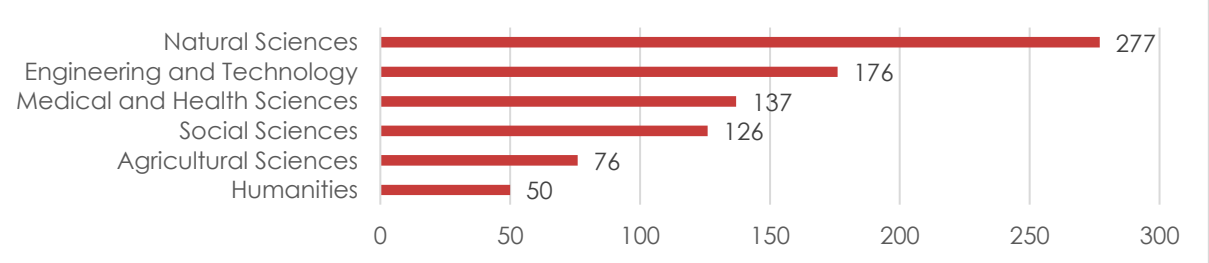
Table 3 Number of participants and Actions by instrument

Type of instruments	Number of participants	Number of Actions
Conference grant	1 060	246
Meeting	68 627	621
Short Term Scientific Mission (STSM)	14 514	598
Training school	31 244	523
Total	92 280	621

Source: COST Association

The Figure 4 below, shows the number of Actions by scientific domain included (as an Action can be multidisciplinary).

Figure 4 Number of Actions by OECD field included



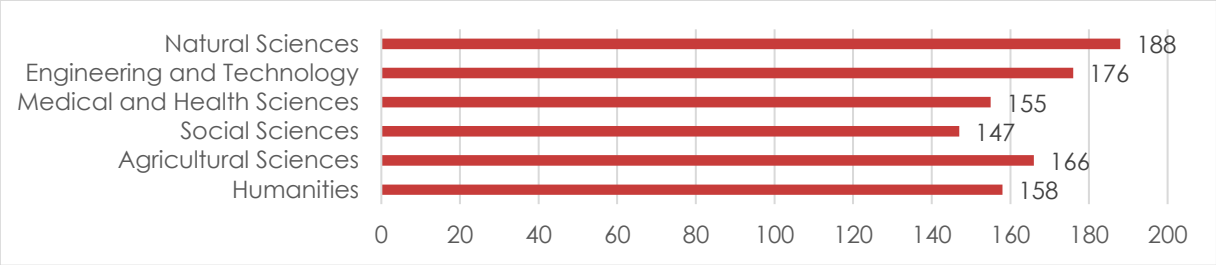
Source: COST Association; Note: OECD fields classification is used

Natural Sciences is the predominant scientific field as one third (32.9%; 277) of COST Actions included this specific field. Humanities and Agriculture sciences being the least included fields with a participation of respectively 5.9% and 9% to COST Actions.

The natural sciences, engineering & technology and agricultural sciences are the three top scientific domains in terms of Action size (multidisciplinary Actions are taken into account) with

respectively 188, 176 and 166 participants on average. The smallest average Action size is found for social sciences (147).

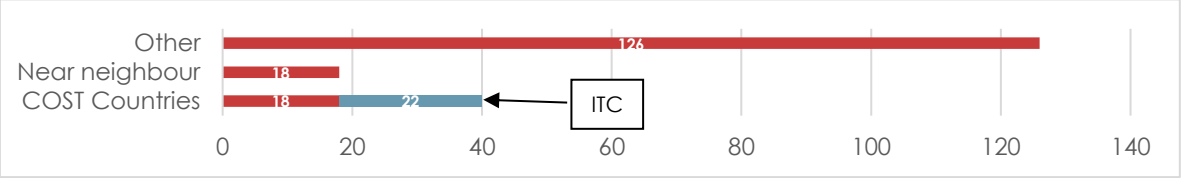
Figure 5 Mean Actions size in terms of participants by OECD fields



Source: COST Association; Note: OECD fields classification is used

Actions gather participants from 184 countries (Figure 6), among them 40 COST countries (among these 22 Inclusiveness Target Countries or ITC), 18 Near Neighbour Countries (NNCs) and 126 International Partner Countries (IPCs).

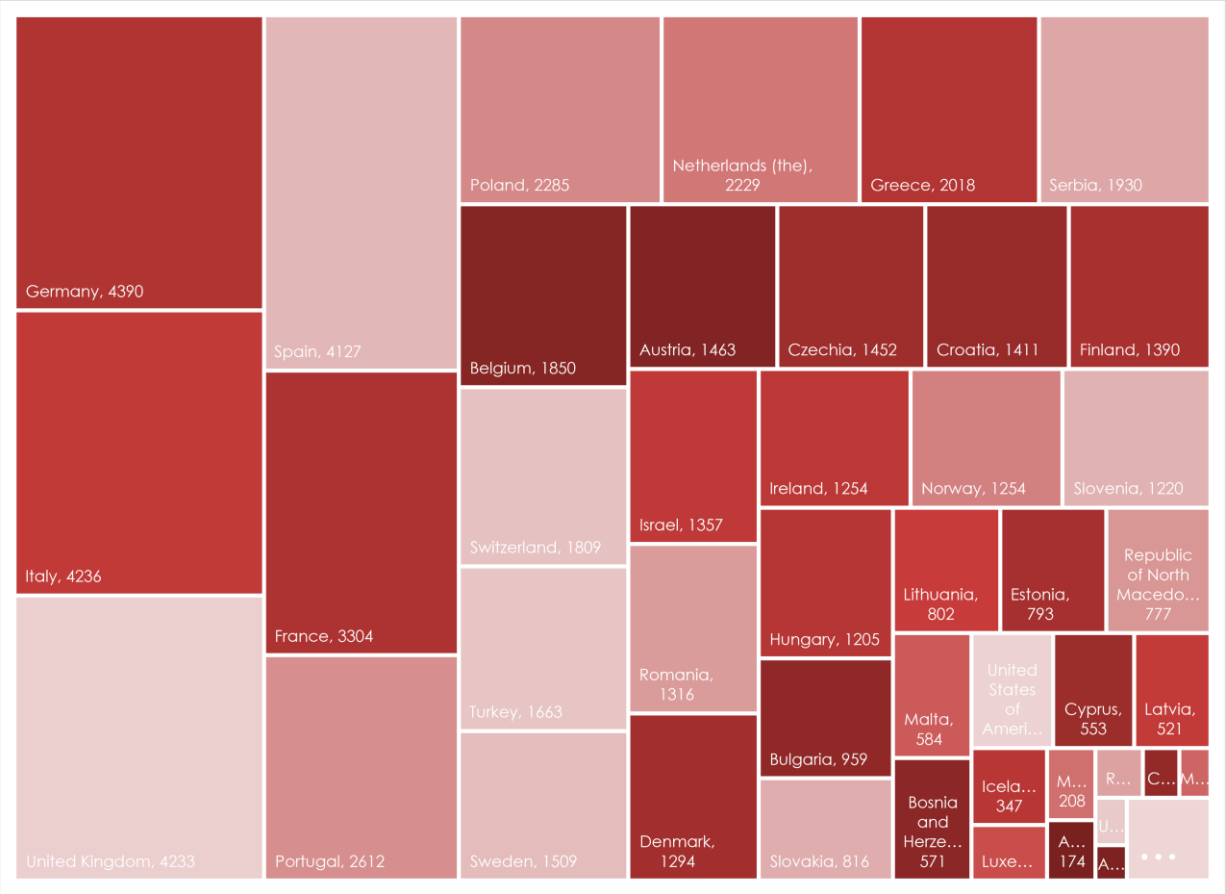
Figure 6 Number of countries by type



Source: COST Association

When looking at the number of participants (from Actions; Figure 7), Germany, Italy and the UK are in the top three countries with a total of 12 859 participants. The Figure below illustrates the distribution of participants by country.

Figure 7 Top countries by number of participants



Source: COST Association

3 Methodological approach

3.1 Network analysis

The main evaluation questions to be answered in this first task are the following:

- How do the networks look in terms of size?
- How do the networks look in terms of geographical composition?
- How do the networks look in terms of disciplines involved?
- How do the networks look in terms of professional backgrounds?
- How do the networks look in terms of other parameters?
- To which extent are "meta-networks" created through participants meeting in different Actions or activities organized directly by COST?
- To what extent do the networks constituted by the COST Actions have a unique character compared to other (European) networks in R&I? (i.e., comparative analysis)

To this end, the network analysis focuses therefore on two aspects:

- The connections between participating individuals to COST Actions and the factors that characterise the patterns of those connections: interdisciplinarity, early vs. advanced career stage (professional background), gender, geographical localisation, etc.
- The extent to which the networks generated as a result of COST activities differ from existing networks.

The aim of the network analysis task is twofold:

- First to provide a descriptive analysis of the networks underlying the COST Actions and characterise the structure of these networks.
- Second to compare networks constituted by the COST Actions with 'default' networks in science and technology.

In order to meet the second objective, we identify and review reports, research papers and syntheses on public-funded collaborative networks (FP and Horizon 2020), co-publication network (Brenner), co-patenting network and research mobility.

The following subtasks elaborate on how the analyses are conducted.

3.1.1 Collection and first analysis of data

Different networking activities occurs within COST Actions, including meetings, training schools, short-term scientific missions (STSMs), and conference grants. We refer to them in this present study as 'instruments', and to the individuals/participants/members as 'participants'.

As a first step, we collected data on participants and on instruments connecting them, grouped by Action. The data available to us englobes the following aspects:

- Characteristics of the Actions (date of start, date of end (if any[23]), scientific domain).
- Characteristics of the instruments (date, type of instrument).
- Characteristics of the participants (gender, age, title, country of affiliation, NUTS-2 region, type of organisational affiliation[24]).

We then used the unique identifiers for each Action, instrument, and participant to create our consolidated database. This database has two levels: a cross-section one and a dyadic one that we used to construct the COST Action network. **The cross-section** one refers solely to the participants and their attributes, and **the dyadic one** refers to the dyads (couples) of participants and the characteristics of their connection within one or more Action and through one or more instruments.

Both databases are illustrated on Table 1 and Table 2 with a subset of indicators.

Table 1 Head of the cross-section database

Participant id	Gender	Title	NUTS2 region	Country ISO	Birth year	Country label	Betweennes s centrality	Degree centrality	Closeness centrality
2	Male	Prof	DK04	DK	1950	Denmark	0	210	0,320
3	Male	Prof	HR01	HR	1964	Croatia	20498949,2	1246	0,356
7	Male	Prof			1947		2779979,6	498	0,329
8	Male	Prof	CZ08	CZ	1951	Czechia	725406,04	396	0,307
9	Male	Prof	MK00	MK	1962	Republic of North Macedonia	59986,2	289	0,314
13	Male	Prof	EL30	GR	1958	Greece	18394393,4	1820	0,374
17	Female	Other			1958		0	132	0,298
23	Male	Prof	IE06	IE	1938	Ireland	0	95	0,292
32	Female	Prof	SE11	SE	1946	Sweden	0	256	0,295

Note: The three network centrality measures refer here to the inter-Action network.

Table 2 Head of the dyadic database

Participant id 1	Participant id 2	Action id	Same gender ?	Age difference	Same title ?	Difference in Actions membership	Separation distance in meters	Instrument id	Instrument name	Number of connections through Actions	Number of connections through instruments
219	2	866	1	3	1	5	1756143			1	0
253	2	866	1	7	1	1	1010201			1	0
291	2	866	1	6	1	3	NA			1	0
608	2	866	1	1	1	0	566939			1	0
542	2	866	0	1	0	0	NA	8469	MEETING	1	1
533	2	866	1	17	1	0	1991663	8469	MEETING	1	1
589	2	866	1	43	0	0	2367783			1	0
145	2	866	1	8	1	1	1991663			1	0
913	2	866	1	25	1	4	2297214	8469	MEETING	1	1
931	2	866	1	23	1	1	2310881			1	0
669	2	866	1	34	0	1	NA			1	0

3.1.2 Descriptive network analysis

The first step of the network analysis task consists in the description of the global COST Action network, that is resulting from the concatenation of all 621 Actions (for the study period, i.e., 2014-2020). These Actions have been identified in the dataset provided by COST Association. To do so, we built a network for each COST Action and assemble them through inter-Action connections, generated by participants having more than one Action participation (see Figure 8 for an illustration).

To be more precise, for each COST Action, we created a network composed by the Action's participants. For each network, the nodes are the participants, and the edges are the Action

[23] All Actions have an end date, this data can either be in the past (the Action ended at the time of writing of this report) or in the future.

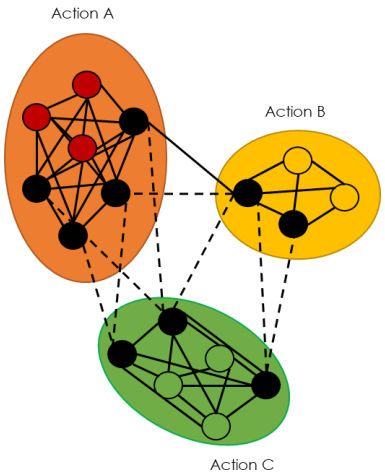
[24] Types of organisational affiliation comprise research/higher education, government, business etc.

co-memberships, implying that if you are a participant of an Action then there is an edge connecting you to all other participants of this same Action.

The edges between participants are weighted by the number of instruments two participants share, for instance if they have met at two meetings. An edge can be weighted down to zero if two participants are in the same Action but have never met through an instrument (no meeting, conference or training school).

We then connect all those Action networks into one single entity, dubbed the global COST Action network, where participants from different Actions are connected through cross-Action membership and weighted by instrument co-participation.

Figure 8 Illustration of the global COST Action network structure



The network structure is illustrated on Figure 8, where we can see three Actions (A, B and C) composed by seven, four and six participants, respectively.

Assuming full connectivity within Action, we calculate a total of 42 connections (21, 15 and six respectively), illustrated by the dark edges.

Nine participants are within more than one Action, allowing connections between all three Actions A, B and C (the dashed edges).

In the illustration, the network is 'closed', meaning any participant is connected to another one thanks to direct connections or intermediaries.

The global COST Action network for Horizon 2020 has more than 92 280 participants, connected within 621 Actions and weighted by more than 3 300 instruments. We then investigated the interconnectedness of the different Actions by considering both created networks resulting from all COST Actions gathered.

As a second step, we assessed the structure of both types of networks (a fully connected one and its instrument-weighted sub-network). We analysed nine network topologies that are likely to influence knowledge sharing, namely:

- Size in terms of participants by Action, and composition in terms of gender, title and geographical location of participants.
- Connectivity of participants as measured by degree centrality (number of direct connections).
- Intermediary role of participants, as measured by betweenness centrality.
- Clustering or transitivity (a measure of the degree to which nodes in a graph tend to cluster together).
- Proximity of participants to all other participants or "closeness".
- Level of small-worldness of the network (high clustering and closeness).
- Openness in terms of geographical inclusion.
- Hierarchy and assortativity (which refers to the importance of hierarchy in the network and the trend of participants to connect with other participants of the same rank in terms of number of connections or degree).

Table 4 below describes these networks topologies and the related (network) indicators we use to answer the evaluation questions.

Table 4 List of indicators for each evaluation question for the social network analysis

Network topologies	Evaluation questions	Description	Indicators/parameters
1- Size and composition	• How do the networks look like in terms of size?	The first structural property we investigated is the 'size and composition' of networks. This topology presents basics statistics on the size of networks underlying COST Actions in terms of (i) number of participants as well as (ii) number of connections between participants. Network composition focuses on the type of nodes that are present in the network. Node types are based on the available background data on the participants. Thus, depending on data availability, the following dimensions are considered: – Disciplines – Gender – Age – Title	• Number of organisations and participants by Actions (i.e., by network) • Number of connections/ties/connexions • Average degree (the average number of edges/connections per node/participant in the network)
	• How do the networks look like in terms of disciplines involved?		• Share of participants by discipline (OECD science and technology fields) • Mean degree by discipline
	• How do the networks look like in terms of professional backgrounds of the participants?		• Share of participants by professional background • Average degree by professional background (the average number of edges/connections per participant according to their professional background)
2- Connectivity	• How are participants embedded in the networks? • To which extent are participants in the network linked to one another constituting connected components?	This network topology indicates the extent to which the nodes or participants in the network are linked to one another constituting connected components. Thus, the focus here is on the intensity of connections between participants. This allows us for example to identify in each network the number of connected components, i.e., the portions of the network that are disconnected from each other.	• Betweenness • Size of the largest component • Density • Components, clusters (Ward technique)
3- Closeness	• What is the average social distance between participants in the network?	The closeness topology aims at capturing the social distance between participants. Social distance (also called social proximity) can be proxying by the path length which is simply the distance between two nodes. Path length is measured as the number of edges between two nodes. If *Participant A* is connected to *Participant B*, and *Participant B* is connected to *Participant C* , then the path	• Average path length

Network topologies	Evaluation questions	Description	Indicators/parameters
		length between *Participant A* and *Participant C* is 2 (assuming *Participant A* and *Participant C* are not connected through direct tie).	
4- Clustering	• Is there a formation of subgroups of participants highly interconnected among them?	High interconnection of participants or clustering measures the degree to which participants in a graph tend to cluster together. More Technically, it evaluates the existence of closed triplets (two neighbouring nodes/participants connected via an intermediary node/participant) and the formation of subgroups of nodes highly interconnected among them. Such clusters of highly interconnected nodes usually reveal the existence of strong and durable relationships among participants. The literature on social network analysis shows that networks with high clustering increases trust among actors, but high clustering can also generate potential redundant knowledge flows.	• Transitivity coefficient (or clustering coefficient)
5- Small world	• Do the networks present high levels of both clustering and closeness?	Small world networks are those with high levels of both clustering and closeness. Thus, this topology summarises the network structure depicted in the two previous topologies. Many real-world networks have small-word properties such as electric power grids, neural networks or air transport networks.	• Test for the presence of a low level of average path length and a high level of clustering.
6- Openness	• How do the networks look in terms of geographical composition?	The openness topology can refer to several types of openness, but we focus on the geographical openness of networks. We therefore describe the geographical scope of the networks.	• Average Euclidian distance (great circle distance) in kilometres between regions by network • Share of participants by country or regions
7- Hierarchy	• Does the network exhibit a core-periphery structure?	The presence of hierarchy in a network is reflected by an unequal distribution of degrees. In hierarchical networks, core actors have enough power to coordinate the whole network and lead the systemic scientific and technological process while peripheral ones can bring complementary modules to that process.	• Degree centralisation, Betweenness centralisation, Closeness centralisation • Assortativity coefficient (degree correlation)
8- Assortativity	• Do core participants interact with peripheral participants?	Hierarchical networks are relevant structures mainly for network coordination but the degree of openness among the core and the periphery of a network is also important to avoid lock-in effects. Assortativity captures the tendency of participants to be connected with other participants that have a similar degree, i.e., central (high-degree) nodes tend to interact with other central nodes, and decentral (low-degree) nodes with other decentral nodes.	• Assortativity coefficient (degree correlation)

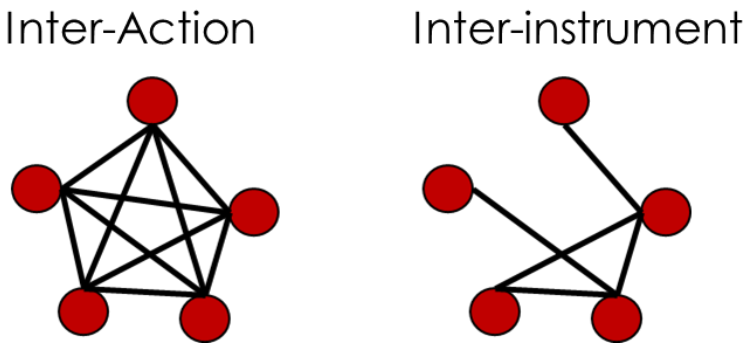
We use the above listed network indicators in order to characterise the global COST network and then respectively explore their determinants using econometric techniques in order to better explain the network' structure and the patterns behind inter-participant knowledge flows.

In our study, the global COST Action network is disentangled into two entities:

- an inter-Action network, assuming full connectivity of all participants of an Action.
- and an inter-instrument network where connections are weighted by the number of inter-participant instruments (meeting, training school). If two participants of a same Action never shared a same instrument, then the connection between does not exist in the inter-instrument network. By construction, the inter-instrument network is a subset of the inter-Action network, i.e., a subnetwork.

Both entities are illustrated on the Figure below: a fully connected network (left) depicting the inter-Action network (where the five participants of an Action are all assumed connected), and the inter-instruments network (right) where the five participants are connected only through instruments.

Figure 9 Two types of networks



Lecture: in the left panel all five participants registered as Action participants are connected, on the right one only five connections remain when taking instruments into account.

The purpose of distinguishing between connections through Action membership and connections through instruments is twofold. First, we intend to have a look at the participants' and networks' attributes driving Action composition and how it differs when weighted the connections with the instruments. Second, we want to analyse to what extent potential connections (that can occur) occurred (through instruments) and why.

The two networks are undirected, meaning a connection from participant 1 to participant 2 is assumed reciprocal, so that there exists a connection between participant 2 and participant 1.

3.1.3 Comparative network analysis

The second component of this task is of an analytical nature and aims at analysing the extent to which the networks underlying COST Actions look like 'default' networks in science and technology.

To this end we conduct a literature review and collect data on public-funded scientific collaboration networks (FP5, FP6, FP7 and Horizon 2020), innovation networks (proxied by co-patenting networks) and co-publication networks. The data we collect is limited to network

indicators in order to characterise the main network structures and oppose it to the network indicators computed for the global COST Action network (i.e., the network of Action networks).

3.2 Output analysis

The following sections describe the methodological approach for the output analysis. The first section introduces the different data sources used for the output analysis and presents an overview of the data available in the final reports of the COST Actions, complemented with scientometric data. The second section describes how we identified the most interesting scientific and societal breakthroughs.

3.2.1 Data collection

This section describes the data collection strategy employed for the output analysis. The output of the Actions based on three data sources:

- The COST Action final reports. For 261 of the 412 ending Actions, there is a report available in our database. The 151 Actions that are not part of this study did not file a report because the Action ended before the introduction of e-reporting and are therefore excluded from this study.
- Bibliometric data sourced from the bibliometric database Scopus: publications resulting from COST Actions are identified in two ways:
  - Funding information: the funding and acknowledgement information of publications is searched for COST Action code. If a COST Action code is mentioned, the publication is considered to be an output of the specific COST Action.
  - Digital Object Identifier (DOI): the complete[25] DOIs which are reported in the Final Action reports are used to find related publications.
- There is a considerable overlap between these two strategies, yet there is a substantial complementary value as some COST Actions do not list the (complete) DOIs for their publications, which in some cases can be attributed to the fact that the articles were only published after the final report was submitted. Since funding information can at times also be incomplete, using both DOIs and funding information offers us the best view of the scientific output related to the COST Actions. As the bibliometric analysis does not by default include data on gender, we estimated the gender of the authors based on their first names, which we were able to do for 69%[26] of the authors.
- Patent citation data provided by Lens: the DOIs available in the bibliometric data are used to identify the COST publications in the Lens database[27]. Subsequently, these publications have citation linkages to patents providing an indication of the possible impacts beyond the pure scientific impact.

[25] Some of the DOI's reported in the final reports are incomplete and only include the unique journal identifier and not the paper identifier.

[26] For some authors, the first name was not available, for others, the first name could indicate either a female or a male researcher.

[27] This database can be accessed at lens.org.

3.2.2 *Breakthroughs*

The methodological approach for identifying the scientific and economic/societal breakthroughs consists of two components: a bibliometric component, and a natural language processing component.

For the bibliometric component we took the following steps:

- For the two selected scientific breakthroughs:
  - For each field, we identified the mean citation count of COST publications. This is split up into field because citation practices differ widely across scientific fields, which makes the comparison across fields challenging[28]. For field we used the field categorisation of COST (as indicated by the first two characters of the Action code)[29].
  - For each Action, we both identified the publication with the highest number of citations and the average number of citations that the publications received.
  - Based on the comparison of the highest cited publication or the mean citation count of an Action with the mean citation count within their respective fields, we selected two Actions within two different fields as the breakthroughs.
- For one of the two economic/societal breakthroughs[30]:
  - Per Action, we analysed the number of patent citations of their publications.
  - We identified the Actions with the most citations by patents of a single publication.

As economic/societal breakthroughs are wider than the impact of COST Actions on patents, only 1 societal/economic breakthrough was selected using the bibliometric data. The other societal/economic breakthrough was selected using natural language processing. The used approach to automatically categorize text utilizes the frequency of words appearing in each document and tries to model these words into similar categories under different topics. We have used this method to identify the Actions whose reported impacts in the self-evaluation reports are the most similar to the topic of societal impact.

3.3 Stakeholder analysis

3.3.1 *Document analysis*

For the stakeholder analysis, a document analysis was conducted of available documents supporting the various elements of this task. The goal of the analysis was to develop a better understanding of the positioning of COST in its wider political context but also to prepare the research on the COST value-added activities. Besides the better understanding, the objective of the document analysis was to triangulate other data sources, in particular the interviews conducted with a focus on the strategic position and the value-added activities.

To obtain a **clearer picture on the strategic position of COST** in relation to other EU-funded Horizon instruments we first considered relevant and insightful internal documents such as the COST Strategic Plan. These documents form the basis of an understanding of where COST is

[28] Patience, G., Patience, C., Blais, B. & Bertrand, F. (2019). Citation analysis of scientific categories. *Heliyon, 5*(3), doi: 10.1016/j.heliyon.2017.e00300

[29] In general, this provided a good correction for field specific citation dynamics except for Actions that were not classified to disciplinary fields (such as Action codes starting with CA)

[30] Societal and economic breakthroughs are wider than just the breakthroughs observed in this study.

currently positioned and what future priorities are emphasised. Moreover, past impact assessments of the COST programme were considered to understand the development and trajectory of the COST programme over the last years. But also, academic literature and other studies on the European Union Framework Programmes (Horizon 2020 and Horizon Europe) were identified and examined as useful background information.

Furthermore, documents and data were analysed to **better understand the COST value-added activities**. For each of the activities, COST provided a short concept note, outlining the basic information, goals, and processes of the value-added activities. Complementing these, documents were provided such as the note "COST as an engaged investor" or booklets for the COST Connect events. Moreover, the results of a survey on the global networking were transmitted to better inform the evaluators in particular on the perception of the global networking approach of COST.

3.3.2 *Interview Programme*

Complementing the document analysis, an **extensive interview programme with internal and external COST stakeholders** was conducted covering the strategic position of COST within the European context as well as more operational and administrative evaluation questions, including the viewpoints of various COST Actions. The first aspect concerns the strategic position of COST and how stakeholders in- and outside of the COST framework see the role of COST in the broader context of the European Research Area. Next to the COST strategic position, the COST Stewardship approach was investigated in more detail. This entails a shift in the general approach of the COST Administration towards the COST Actions and will be elaborated on in more detail below. Also, three added-value activities of COST have been subject to investigation in the context of this study: COST Connect, COST Global Networking and the COST Academy. For all these different aspects, a tailored interview guide was prepared. The interview guides comprised the following aspects as shown in Table 5.

Table 5 Overview of the interview guides in relation to different aspects of Task 3

Interview Modules	Strategic position	COST Connect	COST Academy	Stewardship approach	COST Global Networking
Introduction	■	■	■	■	■
Role and Position of COST in ERA	■				
Participants and Activities		■	■		
Outcomes and added value		■	■		
General understanding of the stewardship			■	■	
Scientific and communication Stewardship			■	■	
Perspectives of COST Actions / Participants on the Global Networking approach					■
Future of COST	■	■	■	■	■
Recommendations and comments	■	■	■	■	■

Interview partners were identified jointly with the COST Association. They were contacted by email and phone calls. The interviews themselves were 30-45 min. of length and conducted by phone and in the English language.

In total, 56 interviews were conducted with a range of different actors, such as COST Policy and Science Officers, internal stakeholders (e.g., current, and former COST officials), COST beneficiaries (e.g., COST Action Chairs, Management Committee Members, Science Communication Managers, and event participants), external stakeholders (e.g., representatives of relevant European organisations) and representatives of partnering countries. Per task, the distribution of interviewees was as follows:

- 18 interviews for the strategic position
- 9 interviews for COST Connect
- 9 interviews for COST Global Networking
- 20 interviews for the Stewardship approach (including the COST Academy, scientific stewardship, communication stewardship and the Innovators Grant)

4 Impact on participants

Key messages

- The COST stewardship approach was perceived positively as a distinguishing unique feature.
  - The stewardship approach creates a trusting and inclusive atmosphere of ownership from the very start in the COST Actions.
  - It enhances the strength of the network and the speed with which it can come together.
- COST Connect is generally well perceived, whilst preparation is resource intensive. Since the purpose and format differs, there is a need to differentiate between thematic and cross-cutting COST Connect events.
- The introduction of the Science Communication Manager is a right step to increase the visibility of the results and impacts throughout and after the COST Action. It is recommended to foster opportunities for peer-to-peer learning in order to improve the Science Communications Officers' skills.
- COST Academy is positively perceived as providing helpful and role-specific training to COST Action representatives.
- COST Global Networking serves to expand scientific networks and to integrate in global knowledge streams, in particular for researchers from non-COST countries.
- Almost half of connections within the COST network is between a man and a woman. Gender is not a determinant of better connectivity or of higher intermediary role in the COST network.
- Connectivity is still driven by participants' characteristics, in terms of gender, title, age, and geographical localisation. However, gender appears to play only a minor role in explaining who get acquainted with whom. Almost half of participant's connections are between a man and a woman, but at meetings, men tend to connect to other men.
- Doctors and professors represent a large part of the total number of participants' connections.
- The COST program enables interactions between Inclusiveness Target Countries and other COST countries.
- An important share of Actions is interdisciplinary, and the COST program enables more interdisciplinary Actions for Humanities and Social Sciences fields than Horizon 2020.
- Instruments enable more interactions between participants with a different title and are therefore more inclusive than Action membership (being included as an Action participant).
- Connections in physical meetings through instruments tend to be slightly hierarchical, i.e., tend to occur slightly more often between participants bearing the same title, whereas the Horizon 2020 network is governed by a negative hierarchy (disassortative) effect.

4.1 Networking effects

This section investigates the networking effect that result from COST activities. It makes use of participant and Action data provided by COST Association to perform a social network analysis and uncover the main network structure characteristics of the COST network. The results are then compared to findings and indicators collected from desk and literature research.

The key descriptive statistics of two investigated networks are listed below:

- There exist 12.5 million participants' connections through Action membership, when taking instruments into account (meetings, conferences, training school, STSM) this figure drops to 4.6 million.
- 36.8% of the connections between Actions' participants exist through instruments. This implies that 2/3 of total connections were never realised (this result can be explained by the average size of an Action, 149 participants on average, which make it difficult for all participants to meet all other participants).
- Almost half of participants' connections are between a man and a woman. If we observe the inter-Action network, 7 784 529 connections involve at least one woman (62,1% against 81,2% for men) and 2 863 716 connections in the inter-instrument network (62,4% against 80,7% for men).
- Doctors and professors share the largest part of connections within Action and through instruments as they both represent 60% of the total of participants.
- Researchers without a doctoral degree are present in 56% of connections. However, when using instruments this share fall to 40%.
- Half of participants are aged less than 44 years old and a third are between 30 and 40 years old.
- Most connections are cross-national (95.1%). The largest share of connections is between ITC and non-ITC COST countries, followed by intra-non-ITC COST countries and intra-ITC.
- Almost half of Actions (46%) are interdisciplinary. Natural science is the most included field with 58.9% of total interdisciplinarity Actions.
- The assortativity coefficient is twice as high for the inter-Action network than for the inter-instrument network, meaning hierarchy seems stronger for the first one (where participants of the same hierarchy seem keener to interact with their pairs than with other participants lower or higher in the hierarchy). Also, this result means that the use of instruments enables participants with different level of connectivity (average degree) to connect between each other's.

The key analytical results regarding the network structure are given below:

- The COST network is a 'small world' network:
  - Participants are well-connected to each other: on average slightly more than three participants are needed as intermediary (or bridge) to connect anyone to anyone.
  - A high probability of being connected to anyone (clustering index equals to 0.5). This coefficient is the probability of two participants to be connected to each other knowing that they have a common neighbour.
  - There is no clear core-periphery structure because of a flat hierarchy structure and a low assortativity (tendency of participants to relate to best connected participants). In other words: participants are connecting to each other's regardless to their rank (number of connection or degree centrality).
- The COST network structure is driven by age, gender and title:
  - The older the participant is the more he/she connect participants together (betweenness or bridge).
  - Despite a higher number of men having Action multi-membership, women are better connected through instruments (meeting, training school, conference, STSM).
  - Instruments bring participants of the same 'rank' together (doctor, professor or others).

- Professors are central to COST Actions but are not necessarily better connected to other participants via instruments.

- A last mile problem subsists:
  - On average one third of potential inter-Action interactions are realised through COST instruments.
  - The two other thirds never physically met within a COST Action.
  - 96% of the connections are made between two participants coming from a COST country (59% of these connections involve at least one ITC country). Participants from ITC (Inclusiveness Target Countries) are better connected, closer to everyone and are "bridge builders".

Table 6 provides a quick overview on the main network indicators for both networks as well as the centralisation measures, that is to say their size (proxied by the number of edges), their betweenness, closeness, degree centralisation as well as the mean distance between each participant, the transitivity index (that measures clustering) and finally the assortativity (presence of a hierarchical driver).

As previously stated, Action participants seem to share an equal level of connectivity with others in the networks, and this level of connectivity is high according to a high transitivity coefficient, high closeness centralisation and low mean distance (on average in both networks 3.7 participants needed as intermediary to connect anyone to anyone). This means that the network is characterised by well-integrated participants who interact with each other, including indirectly with participants outside their own Actions.

Both networks are not characterised by a cluster (a core) composed of better-connected Action participants, meaning that connectivity seems equally distributed among participants, as seen with both betweenness and degree centralisation indicator that are less than 0.1.

Finally, the assortativity coefficient is twice as high for the fully connected network than for the instrument network, meaning hierarchy seems stronger for the first one (where participants of the same hierarchy seem keener to interact with their peers than with other participants lower or higher in the hierarchy).

Table 6 Centralisation index of both networks

	Number of participants	**Number of connections**	**Betweenness centralisation**	**Closeness centralisation**	**Degree centralisation**	**Transitivity**	**Mean distance**	**Assortativity**
Inter-Action network	91 70131	12 535 013	0.049	0.28	0.047	0.76	3.33	0.15
Inter-instrument	82 012	4 592 954	0.046	0.23	0.016	0.5	4.13	0.068

[31] This number slightly differs from the total number of participants, 92 280, since 579 participants seem isolated from others because they do not rely on connection instruments.

network								

Source: COST Association. Betweenness centralisation refers to the intermediary role of participants, computed by the number of shortest paths going through them. Closeness centralisation refers to the average farness of participants in the network, i.e., the mean inverted distance of participants to any other participants. Degree centralisation refers to the average number of direct connection of participants. Transitivity measures the extent to which participants are clustered together in the network. Mean distance is average number of participants needed to connect anyone to anyone. Assortativity index measures the extent to which participants tend to connect only with participants having similar network characteristics.

Characterisation aspects of both networks are described in detail in the following subsections.

Furthermore, statistical analyses at the participant, network and regional levels add to our findings by providing evidence regarding determinants of network characteristics (degree, betweenness, closeness), of bilateral connections between participants and of cross-regional connections flows. Results are provided in Appendix D.

4.1.1 Connectivity – How are participants embedded in the networks?

The level of connectivity, measured by participants' centrality degree in both networks, permits to answer the two following evaluation questions:

- How are participants embedded in the networks?
- To which extent participants in the network are linked to one another constituting connected components?

This network topology indicates the extent to which participants in the network are connected to one another constituting integrated-connected components. Thus, the focus here is on the intensity of connections between participants. This allows us for example to identify in each network the number of connected components, i.e., the portions of the network that are disconnected from each other.

We recall that there is a total number of 621 Actions for 92 280 participants. By excluding participants of individual Actions (only conference grants and/or STSMs) we count 91 701 participants that can potentially interact with others through common or shared Actions and a total of 12 535 013 potential (undirected and unrepeated) connections. When weighted those connections by instruments, the number of connections falls back to 4 592 954 (through meetings and training schools,).

Based on the number of inter-Action and inter-instrument connections: 36.8% of Actions' participants are connected through instruments which implies that about 63.2% of Actions' participants have so far never met with others.

An important check before pursuing our investigation is to identify whether the global COST Action network is composed by large unconnected components that we would have to analyse separately. While nearly all the participants form one large network, 43 isolated groups are identified in the inter-instrument network, but their sizes are so small that their impact on the analysis is negligible. More specifically, even if most of these connections are indirect and have not been made possible through an instrument, the inter-Action network is not composed by isolated components disconnected from the whole structure. Thus, implying that it forms an entirely 'closed' network where any participant can by connected to any other one.

4.1.1.1 Gender

We start with a description of connections by gender. Table 3 below summarises the share of connections by gender for our two networks. The numbers indicate that the configuration of connections remains the same between both networks, and that cross-gender connections represent the majority of connections.

On average, almost half of participants' connections are between a man and a woman (43%), followed by only men connections (37%).

In the inter-Action network, 2 294 671 (18.3 %) connections are made between two women, 4 690 365 (37.4 %) connections are made between two men, 5 489 858 (43.8 %) connections are made between one woman and one man and finally, 60 119 (0.5 %) connections do not have gender affiliation. In our second network, we have 864 457 (18.8 %) connections between two women, 1 706 112 (37.1%) connections between two men, 1 999 259 (43.5%) connections between one woman and one man and 23 126 (0.5%) connections do not have gender information.

By comparing both networks, it appears that the share of connections between and within genders does not significantly differ.[32]

Table 3 Percentage of gender type of connections between the two networks

Connection type	Inter-Action network	Inter-instrument network
Woman-Woman	18.3%	18.8%
Man-Man	37.4%	37.1%
Woman-Man	43.8%	43.5%
N/A	0.5%	0.5%

Source: COST Association

Regarding the position within the network of male and female participants, an econometric analysis at the participant level provided in Appendix D.1 reveals that there are on average fewer women participants in Actions than men, but women exhibit higher centrality degree when looking at their connections through instruments, meaning they tend to better use meetings/STSM/conference than men.

4.1.1.2 Participants' titles

There are three different participant's titles in the data: 'Doctor', 'Professor' and neither, that we referred to as 'Other'.

Table 4 below presents the percentage of connections between the three different categories.

[32] The tiny differences in the percentages between both networks seems mostly explained by the larger share of females in the second network (40.3 % of female and 59.5 % of male in the inter-Action network against 40.7 % of female and 59.0 % of male in the inter-instrument network).

Table 4 Percentage of title type of connections between the two networks

Connection type	Inter-Action network	Inter-instrument network
Doctor together	20.5 %	25.4 %
Doctor – Professor	18.3 %	26.3 %
Doctor – Other	29.6 %	21.4 %
Professor together	4.9 %	8.3 %
Professor – Other	13.4 %	10.4 %
Other together	13.4 %	8.2 %

Source: COST Association

Despite being overrepresented in our study sample (doctors and professors share the largest part of connections within Actions and through instruments as they both represent 60% of the total of participants), participants who are neither doctor nor professor are present in 56% of inter-Action connections. However, instruments seem to impact those connection patterns, as this share falls to 40% when weighting connections by instruments.

The use of instruments enables doctors to connect with other doctors or professors, as well as professors with other professors. It however reduces the likelihood of connection between researchers without a doctoral degree and researchers with doctoral degree.

The statistical analysis at the participant level (provided in Appendix D) validates those findings:

- All things equal, doctors and professors are more central to the network than others, i.e., they connect to a larger number of participants through their Action memberships. Both categories of participants connect more often in instruments (meetings or training school) than non-doctors and non-professors. This finding highlights their strong intermediate role (especially seen through instruments);

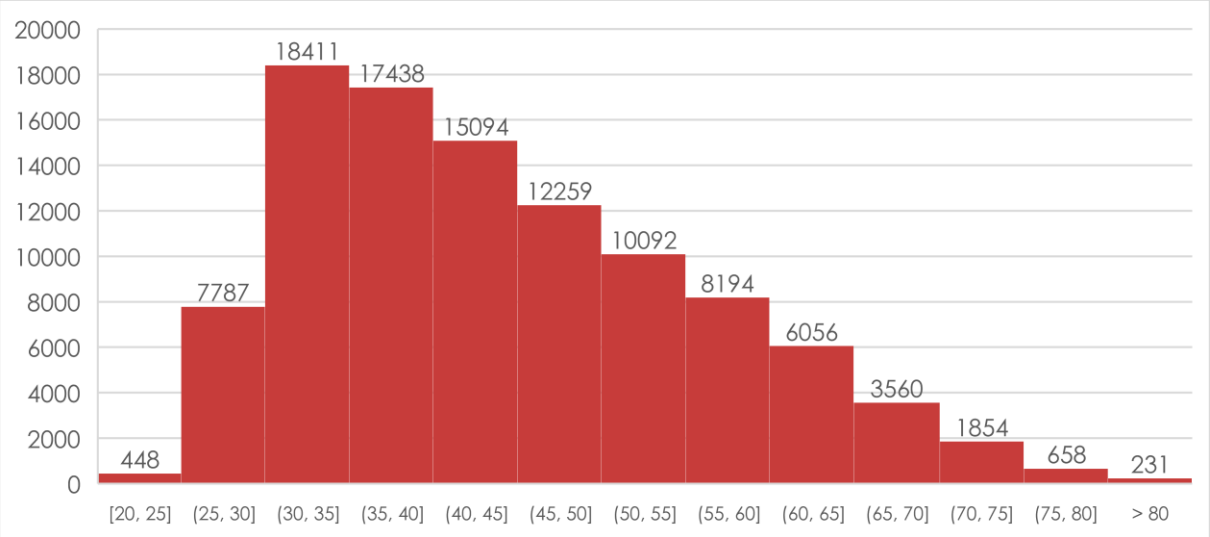
4.1.1.3 Age of participants

According to participants' birthyears, the average participant's age is (significantly equal to) 44, with the youngest participant being 20 years old[33]. Skewness on the histogram below (Figure 10 Histogram of participants' age), which illustrates the distribution of participants by age, indicates that most participants in our sample are younger than 44 years old. One third of participants are between 30 and 40 years old.

Based on a regression this study finds a negligeable negative effect of age difference on connections, meaning that on average age difference between participants at physical meetings (instruments) is not significantly high (see Annex D.2).

[33] Assuming the provided birth year is correct and that earlier birth rates were erroneous.

Figure 10 Histogram of participants' age



Source: COST Association. The retained calculation range for participants age is 21 to 90 years old.

Table 5 and Table 6 below show the distribution of connections between participants, conditional on their age group. We used six different age ranges, '20-25', '26-30', '31-40', '41-50', '51-60' and '60+' years old.

Table 5 Percentage of the connections by age range in the inter-Action network

Inter-Action network	20-25	26-30	31-40	41-50	51-60	60+
20-25	0.0%	—	—	—	—	—
26-30	0.1%	1.0%	—	—	—	—
31-40	0.3%	5.2%	12.9%	—	—	—
41-50	0.2%	3.4%	17.8%	7.3%	—	—
51-60	0.1%	2.2%	11.8%	10.1%	3.7%	—
60+	0.1%	1.4%	8.1%	7.0%	5.3%	2.0%

Source: COST Association

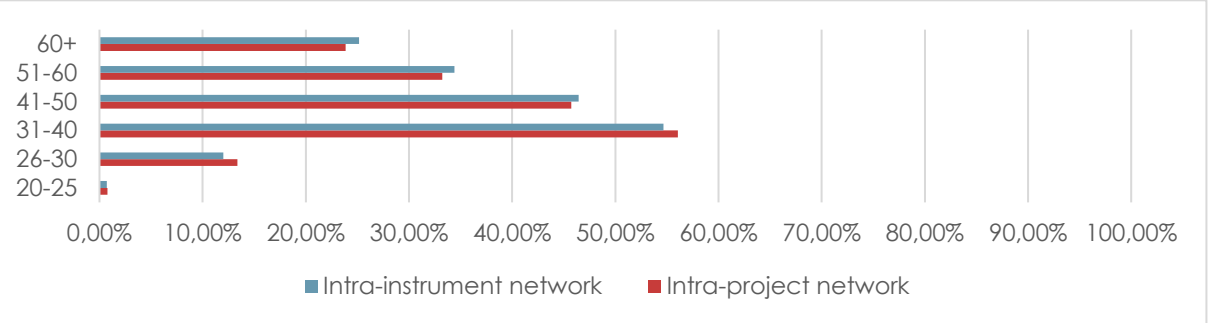
Table 6 Percentage of the connections by age range in the inter-instrument network

Inter-instrument network	20-25	26-30	31-40	41-50	51-60	60+
20-25	0.0%	—	—	—	—	—
26-30	0.1%	0.8%	—	—	—	—
31-40	0.2%	4.5%	12.1%	—	—	—
41-50	0.2%	3.2%	17.6%	7.5%	—	—
51-60	0.1%	2.1%	12.0%	10.6%	4.0%	—
60+	0.1%	1.4%	8.4%	7.4%	5.7%	2.2%

Source: COST Association

Comparison between both networks does not reveal a large difference in connection distribution by age, although it reveals that the oldest half (40 and older) takes a slightly larger share of connections through instruments than within Actions. This might correlate with the fact that doctors and professors tend to meet more through instruments than non-doctors and non-professors (see 4.1.1.2).

Figure 11 Share (overlapping) of age group in both networks



Source: COST Association

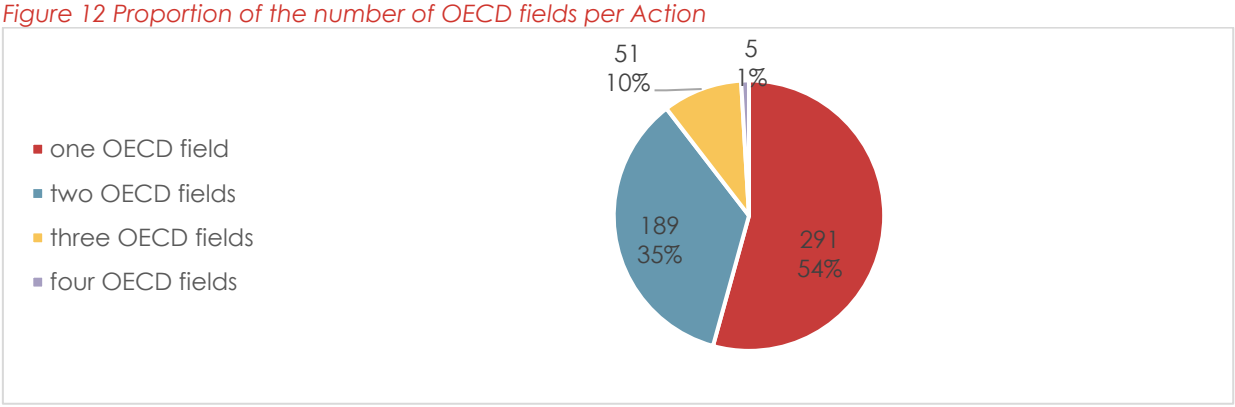
According to the statistical analysis at the participant level (provided in Appendix D), the older the participant:

- the more bridging power he or she has,
- the more central he or she is thanks to meetings/conferences,
- the better connected he or she is through physical meetings.

4.1.1.4 Disciplines

Referring to the data provided by COST Association, 536 Actions out of 621 provide information about their research areas/scientific fields and subfields to which they relate. The data set presents 448 unique research areas, 41 unique OECD subfields and 6 unique OECD fields. Only OECD fields will be analysed in this section as OECD subfields and research areas are too elaborated to draw a relevant analysis. 54% of the total number of Actions present one unique OECD field (against 18% for Action who present only one unique OECD subfield), the mean number of OECD fields per Action is 1.5 (against 3.4 for OECD subfields).

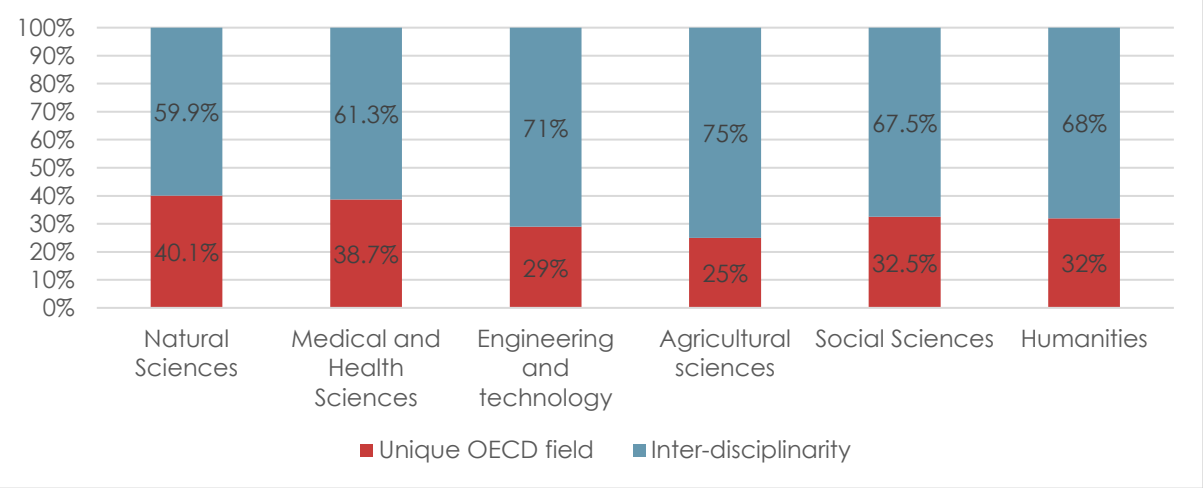
Figure 12 Proportion of the number of OECD fields per Action



Source: COST Association

Looking at the number of participants to interdisciplinarity Action, we measured the same distribution as for the proportion of the number of OECD fields per Action (54%/35%/10% and 1%). Thus, an Action related to several fields does not lead to the highest number of participations.

Figure 13 Distribution of the composition of Actions by field



Source: COST Association

In terms of share between unique field Action and interdisciplinarity Action by OECD field, agriculture sciences and engineering and technology are the two OECD fields with the highest proportion of interdisciplinarity Action with respectively 75% and 71%[34].

In terms of number of participations per combination of different fields, note that some participants can be recorded several times for the same Action, so we observe here (Table 7) the number of unique participants[35]. Also, the sum of each cell entry logically exceeds the number of participants since the number of fields related to an Action varies between one and four[36].

Interdisciplinarity concerns primarily the natural sciences combined with engineering and technology but also with medical and health sciences. On the other hand, humanities recorded the lowest number of participation when combined with medical and health sciences, agricultural sciences and engineering and technology.

Table 7 Number of participants by discipline combinations

OECD fields	Natural Sciences	Medical and Health Sciences	Engineering and Technology	Agricultural Sciences	Social Sciences	Humanities
Natural Sciences	20 957	—	—	—	—	—
Medical and Health Sciences	8 592	6 454	—	—	—	—
Engineering and Technology	15 681	5 713	7 254	—	—	—
Agricultural Sciences	5 139	1 725	2 656	3 443	—	—
Social Sciences	4 542	2 285	3 078	1 540	4 817	—
Humanities	1 884	156	821	467	3 539	1 703

Source: COST Association

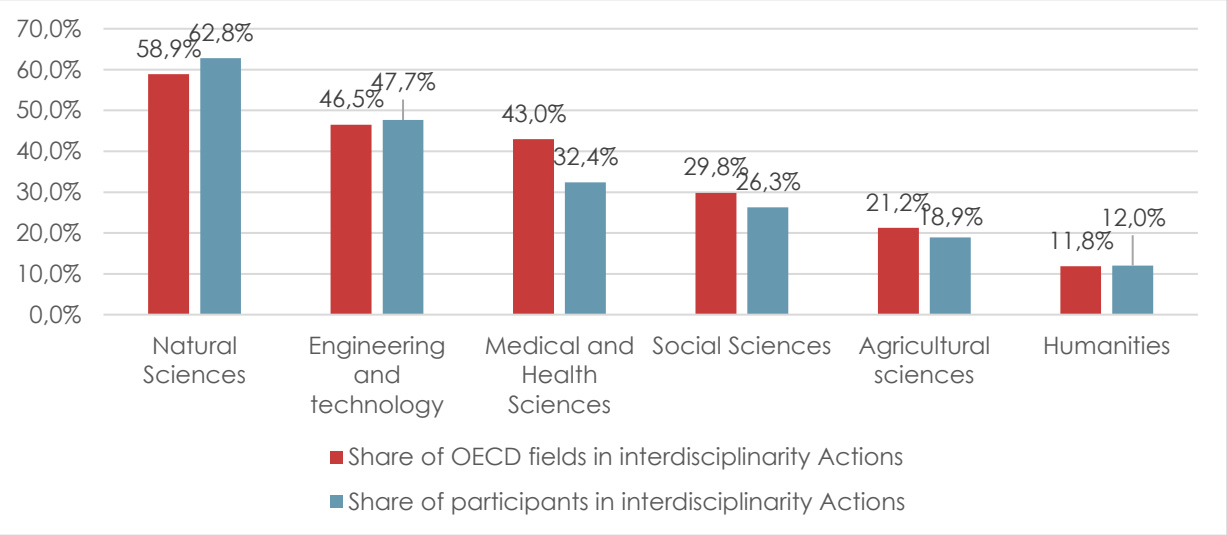
[34] Note that we do not find the same proportions as in Figure 12 cause an interdisciplinary Action between three OECD fields for example, will be counted as one interdisciplinary Action for each one of them.

[35] If the same user id is recorded three times for an Action, it counts only for one participant.

[36] A participant to an Action related to 'Agriculture Sciences', 'Humanities' and 'Natural Sciences' fields will be counted for the combination 'Agriculture Sciences and Humanities', 'Agriculture Sciences and Natural Sciences' and 'Humanities and Natural Sciences'.

In terms of participation of OECD fields to interdisciplinarity Actions, the natural sciences field is present in 58.9% of the total number of interdisciplinarity Actions, followed by engineering and technology with 46.5%. The field of humanities is the least present with a participation of 11.8% to these specific Actions. However, the share of participants to interdisciplinarity Actions is less important for three OECD fields, especially medical and health sciences. On the other hand, the share of participant is proportionally higher for natural sciences, engineering and technology and humanities.

Figure 14 Number and share of OECD fields and participants on total number of interdisciplinarity Actions



Source: COST Association

4.1.2 Closeness - What is the average social distance between participants in the network?

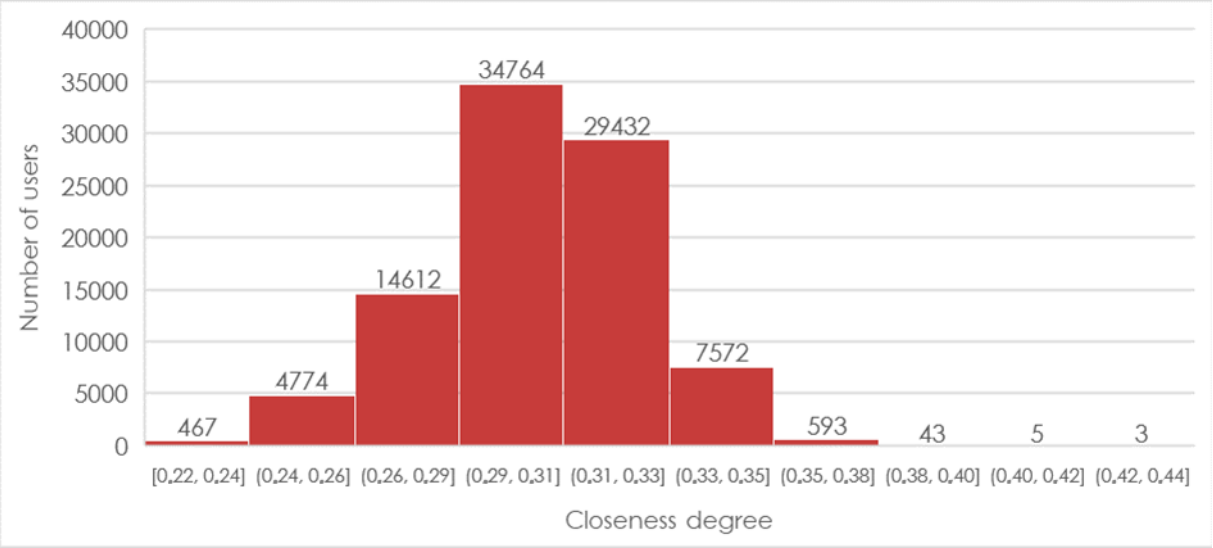
The closeness characteristic of the networks is proxied by two indicators:

- The closeness degree that measures the proximity of each participant to all other participants (range between 0, disconnected, to 1, connected).
- The average path length that measures, for each connection between any two participants, the average number of intermediaries needed to enable a connection.

The average closeness degree of participants if 0.30, the maximum value 0.44 and the minimum 0.21. It is complex to characterise those statistics without comparing them to other networks (which will be performed in the benchmarking exercise). However, by looking at the distribution of the indicator on the histogram below (Figure 15) we can already stress that there is not much variance, implying that participants seem connected to the same extent to other participants in the network.

In summary participants are well connected and integrated to the network, and this result do not seem to vary based on their characteristics.

Figure 15 Distribution of closeness degree



Source: COST Association. Interpretation: the degree of connectivity in the inter-Action network is clustered around 0.30 (30% of probability that one participant connects to any other participant in the network). This likelihood does not vary much according to the minimum and maximum observed closeness degree (0.22 and 0.44), meaning that the high level of connectivity is shared by the majority of participants.

Regarding average path length, in our inter-Action network, composed by 91 701 unique participants, the average path length is 3.3. This means that on average, a participant has to go through a little bit more than three intermediaries, to be able to reach any other participant in the network. The COST Action network average path length is close to the Horizon 2020 one, which is equal to 3 as reported in the monitoring flash note of November 2018[37]

Overall, path length between participants of any Action on the inter-Action network ranges between a minimum value of 2.2 and maximum of 4.5 and has an average path length of 3.3. In comparison, the inter-instrument network has an average path length slightly higher, of 4.12 participants. This result confirms the efficacy of knowledge diffusion within the network, despite its size. It is also the first indication that the COST Action network might be characterised by '*small-worldness*', i.e., participants are well connected to each other, and knowledge is diffused rapidly even given the significant size of potential connections (more than 8 billion connections possible for 91 701 participants)

According to a statistical analysis of the closeness degree distribution, men are on average less interconnected to other participants than women.

4.1.3 *Clustering - Is there a formation of subgroups of participants highly interconnected among them?*

'*Am I connected to my partners' partners?*' To measure the extent to which the network is 'clustered', in other words the probability that one participant is connected to another within the network, given its size and the edges, we computed the global version of the transitivity index (or clustering coefficient). This index lies between 0 and 1: the closer of 1 it is, the higher

[37] From Horizon 2020 to Horizon Europe. Monitoring flash (2.1 Dynamic network analysis) November 2018 https://ec.europa.eu/info/sites/default/files/research_and_innovation/knowledge_publications_tools_and_data/documents/h2020_monitoring_flash_112018_0.pdf

the probability to have cluster in the network. It is also important to note that a high probability of clusters can lead to the development of "cliques", which are subgroups of connected participants where adding another participant will inevitably make the clique less connected.

This index is high for both our networks, being equal for 0.76 the inter-Action network and 0.5 for the inter-instrument network, implying that participants in the COST Action networks tend to be well-clustered to each other. A potential explanation would be that the use of instruments gives participants the opportunity to connect with other participants they otherwise would not meet without those connection instruments.

The Gini coefficient of the participants' degree centrality also validates this finding. It measures the level of structural inequality in the network and ranges between 0 (perfect equality, each participant has the same connectivity) to 1 (perfect inequality, one participant concentrates all connections). In our case it is equal to 0.26 for the inter-Action network, which is a third of the same measure for Horizon 2020 (0.64[38]) and indicates that few participants have a lot of connections while a lot of participants share the same level of connectivity. It is however higher for the inter-instrument network, around 0.41, which highlights that compared to the inter-Action network, a larger group of participants are connecting through instruments significantly more than others.

Finally, according to a statistical analysis at the participant level (provided in Appendix D), clustering seems influenced by the number of Actions participations (or Action memberships) as it positively impacts both participants' intermediary and centrality roles in the network.

4.1.4 Small world - Do the networks present high levels of both clustering and closeness?

As mentioned in the former subsection, the networks have low levels of average path length and a high level of clustering. The networks then fulfil the conditions for a "small world" network, where knowledge is assumed to flow faster and is less distorted by intermediaries.

To be a small world, a network must also have a mean distance smaller than the logarithm of the number of nodes (participants here), i.e., the ratio of both indicators must be significantly smaller than one.

For the first network (inter-Action network), the ratio is equal to 0.66 (mean distance of 3.32 divided by logged number of participants 4.96[39]).

For the second network (inter-instrument network), the same ratio is equal to 0.83 (Mean distance 4.12 divided by logged number of participants 4.93[40]).

Thus, conditions for a "small world" are fulfilled for both networks.

The difference between the two networks' ratios can attributed to the larger participations and connectivity of the former (inter-Action network) compared to the latter (inter-instrument network, since a share of Action members never meet).

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[38] Pierre-Alexandre Balland, Ron Boschma & Julien Ravet (2019) Network dynamics in collaborative research in the EU, 2003–2017, European Planning Studies, 27:9, 1811-1837

[39] log(92265)=4.96

[40] log(87089)=4.93

4.1.5 *Openness - How do the networks look in terms of geographical composition?*

We look at the share of connections of both networks by type of countries. There are four different group of countries:

- A group 'COST' for countries which are member of COST but non-ITC.
- A group 'ITC' for COST members which are less research-intensive, entitled 'Inclusiveness Target Countries'.
- A group named 'NNC', for countries which are near neighbours of a COST country.
- Finally, a group 'IPCs' for countries which are neither a COST country, an ITC, nor a NNC but entitled as 'International Partner Countries'.

Table 7 describes the part of connections that are made between two participants from the same country for both the inter-Action and the inter-instrument network.[41]

Table 7 Number of connections in the same country in the inter-Action network

Inter-Action network	Different countries	Same country
Connections (inter-Action)	4 365 524 (95.1%)	225 126 (4.9%)
Connections (inter-instrument)	2 456 466 (95.3%)	120 273 (4.7%)

Source: COST Association

Most of the connections are cross-national (95.1% and 95.3%). Moreover, the introduction of instruments enables to slightly reduce the connections within the same country, from 4.9% to 4.7%.

Table 8 and Table 9 summarise the share of connections between the four categories of countries (COST non-ITC, ITC, NNC and IPCs) for the two networks.

For both networks, the largest share of connections is between ITC and non-ITC COST countries (43% on average for both networks), followed by intra-non-ITC COST countries (38%) and intra-ITC (15.5%).

Table 8 Percentage of the connections by country type in the inter-Action network

Inter-Action network	COST non-ITC	COST-ITC	NNC	IPC
COST non-ITC	39.4%	—	—	—
COST-ITC	42.5%	14.4%	—	—
NNC	0.7%	0.4%	0.01%	—
IPCs	1.8%	0.8%	0.02%	0.05%

Source: COST Association

Table 9 Percentage of the connections by country type in the inter-instrument network

Inter-instrument network	COST non-ITC	COST-ITC	NNC	IPC
COST non-ITC	37%	—	—	—

[41] Due to a lack of data on the participants' affiliation country, 7.9 million connections are dropped from our sample, which implies losing 60% of the observations.

COST-ITC	44.5%	16.5%	—	—
NNC	0.5%	0.3%	0.01%	—
IPCs	0.8%	0.4%	0.01%	0.01%

Source: COST Association

These tables show that the use of instruments reinforce the lead of COST-ITC and enable them to connect even more with COST non-ITC. However, the share of connections falls for both NNC and IPCs.

The statistical analyses (at the participant, network and regional level provided in Appendix D) confirms that, compared to COST non-ITC, participants from ITC are significantly better at bridging all kind of participants (playing the intermediary role), are overall better connected and more central than others through instruments.

Furthermore, geographical separation (as measured by distance in kilometres between two EU NUTS2 region) is a significant but small barrier to cross-regional connection, compared to trade networks and innovation networks (scientific collaboration). Indeed, the estimate for the COST network is 8 times smaller than the estimate for co-publication network within FP5 (Fichet de clairfontaine et al, 2016) and 12 times smaller than the lowest estimate for intra-European trade network (Serlenga and Shin, 2007).

4.1.6 Hierarchy - Do the networks exhibit a core-periphery structure?

According to our calculation the global Action COST network has the characteristic of a flat network: it is not characterised by a core of better-connected participants, better intermediaries or participants significantly closer to others (and this in spite of previous results regarding the privileged positions of participants with a doctoral title and ITC-originating researchers).

We rely on centralisation measures in order to characterise the overall structure of the network. Centralisation is the equivalent of mean calculation of network indicators for an entire network:

- Degree centralisation refers to the degree distribution within a network: a high value close to one implies that the network has a strong core where high-ranked participants are concentrating all connections. A low degree centralisation implies a flat structure where connections are more evenly distributed among participants.
- Betweenness centralisation measures the extent to which a group of participants in the network has a much stronger *intermediary* role than others, it is equal one if one participant in the network is unavoidable in order to connect participants together.
- And finally, closeness centralization that measures to what extent the network is "closed", meaning the global proximity of participants.

For the inter-Action network, we have a degree centralisation equal to 0.04, a betweenness centralization of 0.04 and a closeness centralisation egal to 0.28. For the inter-instrument network, we have a degree centralisation equal to 0.01, a betweenness centralisation of 0.04 and a closeness centralisation egal to 0.22.

Overall physical meetings (proxied by the instrument network) are less driven by central participants with a strong intermediary role than the inter-Action network. More specifically, comparing indices of both networks, every centralisation index is smaller for the inter-instrument network and especially for the degree centralisation index. These results reflect that the distribution of degrees is more unequal in the inter-Action network and that active participation

to meetings or trainings enables the hierarchy of the network to be flattened, i.e., the share of core participants, highly connected with others or having a significant intermediary role, is smaller.

4.1.7 Assortativity - Do core participants interact with peripheral participants?

The assortativity of the inter-Action network is equal to 0.147 compared to 0.068 (about half) for the inter-instrument network. Assortativity captures the tendency of participants to be connected with other participants that have a similar degree which means that high degree nodes tend to interact with high degree nodes and reciprocity for low degree nodes.

Hence the COST network has a low but significant assortative pattern, where connections tend to occur more often between participants bearing the same titles.

As we can see, considering edges only through common participation negatively impacted this coefficient, meaning that the tendency of high degree participant connecting mostly with others high degree participants fades.

4.2 Comparative network analysis

Key messages:

- EU-13 countries have a higher connection share in the COST inter-Action network than in the Horizon 2020 network.
- The collaborative network of Horizon 2020 facilitates connections between participants with different titles (or hierarchical ranks) but restrains connections between peers, whereas the composition of COST Actions or instruments seems slightly more hierarchical.
- The COST network is more gender inclusive than both FP7 and FP6, with a share of women participation of respectively 38% and 26% compared to 40.3% for the inter-Action network.
- The Social Sciences, i.e., the least covered research fields of Horizon 2020, are significantly more represented in the COST network.
- Geographical and language distance do not impede cross-country COST Action connection compared to FP networks, co-patent network and co-publication network.

4.2.1 Geographical aspects

Over 2014-2018, Horizon 2020 funded more than 30 000 collaborative projects with participants from 149 distinct countries, compared to 134 countries covered by the COST framework. The core of the Horizon 2020 network is mainly composed of EU-15[42] participants with Germany, France, the United Kingdom, Italy, and Spain as key players. On the other hand, EU-13[43] participants have a substantial number of collaborations with these key players of the EU-15 countries[44].

Overall, 79.3% of the collaborations involve participants from EU-15 countries against 9.8% for EU-13 countries and respectively 6.6% and 4.2% for associated and third countries.

In the COST Action network, 82% connections involve EU-15 countries (+2 pt. higher than Horizon 2020) and 40% involve EU-13 countries (+30pt. higher than Horizon 2020). 32% involve other associated countries (non-COST countries and ITC non included in EU-13 or EU-15), which is three times larger than for Horizon 2020. Those differences in shares between COST inter-Action network and Horizon 2020 are explained by the fact that connections between COST countries and ITC countries represent the overall higher share (42.5%).

As a reminder, COST countries which are ITCS are key players in the COST Action network as they are included in 84.4% of connections against 58.1% for non-ITC COST countries.

If we look in terms of size to understand the position of a country in the network, Figure 16 shows that the most connected countries are also the largest ones. However, some countries with similar size perform differently in terms of collaboration. For example, Romania and the Netherlands are close in terms of country size, but Dutch participants are responsible for a much

[42] Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom, Austria, Finland and Sweden

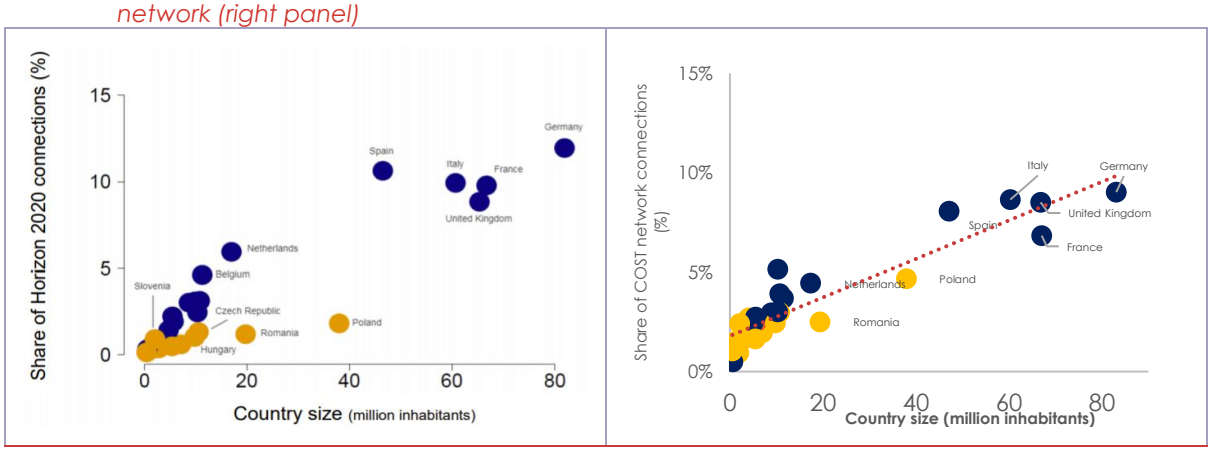
[43] Bulgaria, Czech Republic, Cyprus, Estonia, Croatia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovenia and Slovakia

[44] Directorate – General for Research and Innovation (European Commission), Ravet Julien, Balland Pierre-Alexandre (2018), Dynamic network analysis of the EU R&I Framework Programme; accessible at: https://op.europa.eu/en/publication-detail/-/publication/0323a3e3-fdc2-11e8-a96d-01aa75ed71a1/language-en/format-PDF/source-82692556

higher share of connections in the Programme (6%) than Romanian participants (1.2%). Also, if we observe countries from the same group as EU-13, Slovenia presents almost as many connections as countries with a population that is five times larger or more like Hungary, Czech Republic, and Romania.

The same relationship applies to the COST inter-Action network, with Germany, the United Kingdom, France, Italy, and Spain in the top five. However as seen on the right panel, the share of connections is lower for those big fives under the COST framework than within Horizon 2020 whereas the share of connections of EU13 is higher given their population size.

Figure 16 Country size and share of connections under Horizon 2020 (left panel) and COST inter-Action network (right panel)



Source: Dynamic Network Analysis of the EU R&I Framework Programme – European Commission – 2018. Own calculation Technopolis group (based on COST Association data). Share of connections on total EU13 and EU15 connections (no external countries considered). Blue circles: EU15 countries. Yellow circles: EU13 countries.

Finally, geography plays a stronger role in explaining cross-country connection in Horizon 2020 than in the COST network. Our findings in Appendix B reveal that for connections made through COST Actions a 1% increase in geographical distance is linked with 0.04% decrease in the number of cross regional connections, whereas for FP5 the same impact on cross regional connections is estimated at 0.17% (at least, see Fichet de Clairfontaine et al., 2015), 0.20% for FP6, 0.24% for the co-patent network and 0.25% for the co-publication network (see Lata et al., 2015). In summary remoteness does not significantly impede connections between participants of networks constituted by COST Actions. Language is also less of a barrier in the COST network (differences in spoken languages lead to 0.02% drop in shared COST Action membership compared to 0.3% for FP5, 0.16% for FP6, 0.75% for co-patent network and 0.94% for co-publication network).

4.2.2 Career stage

To observe interactions between participants at different career stages, we focus on the network assortativity score. As a reminder: this indicator measures the extent to which a participant is likely to connect with another participant sharing the same rank (in terms of number of connections).

As we previously observed in Table 4, doctors and professors share the largest part of connections in the COST network. Thus, we can assume that the more important the title is, the larger the number of connections will be and that doctors have on average more connections than professors who have themselves more connections than non-doctor/non-professor

participants[45]. In this case, a high assortativity score will mean that participants are keener to interact with other participants sharing the same title as them (doctors with doctors, professors with professors and non-doctor/non-professor with non-doctor/non-professor), and vice versa for a low score.

For the COST network, the assortativity score is estimated equal to 0.15 for the Action network and 0.068 for the instrument network. These estimations mean that participants with a high (low) number of connections, doctors, or professors, are more willing to connect with participants with a lower (higher) number of connections, non-doctor/non-professor participants, in the inter-instrument network than the inter-Action network. In comparison, assortativity scores for Horizon 2020, FP6 and FP7 are lower with respectively -0.08, -0.1 and -0.11[46]. In this situation, a negative score means that participants are keener to interact with participants at a different career stage rather than with their peers.

4.2.3 Gender

The European Commission is committed to promoting gender equality in research and innovation as equality between women and men is a fundamental European value. In 1999, the European Commission set a target of 40% female participation in Marie Curie Actions[47]. This target has almost been met with 38%[48] of women participation in FP7 projects on average and a significant increase since FP5 and FP6 with a share of women participation of respectively 20%[49] and 26%[47]. In comparison, if we refer to Table 3, the share of women participation in the COST network is slightly higher than for FP7 with 40.3% of women in the inter-Action network and 40.7% for the inter-instrument network. However, a 'glass ceiling effect' still exists in the share of women participation.

If we have a more in-depth look at the data, we observe that the higher the position in a project, the lower the share of women occupying that position. In 2006, only 16-17% of FP6 project coordinators were women against 19.2% in FP7. This correlation is less pronounced for the COST network, where the share of women is equal to 33% for Action chairs (the highest position within an Action), 44% for Action vice-chairs and 56% for Action science communication managers.

4.2.4 Interdisciplinarity

Interdisciplinarity has been considered as a central quality of EU's Horizon 2020 programme, which targets societal challenges designed to cross disciplinary boundaries in order to address complex and interdependent problems[50]. However, although social sciences and humanities

[45] Both assumptions are needed since individual data on Horizon 2020 networking activities are not freely available.

[46] Dynamic Network Analysis of the EU R&I Framework Programme – European Commission - 2018

[47] Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002-2006 – Report of the Expert Group – European Commission - 2009

[48] Ex-Post Evaluation of the 7th EU Framework Programme (2007-2013) – European Commission - 2015

[49] Gender impact assessment of the Fifth Framework programme specific programmes – European Commission - 2001

[50] Recommendations on Integrating Interdisciplinarity, the Social Sciences and the Humanities and Responsible Research and Innovation in EU Research, May 2017

have been part of Horizon 2020, social sciences are included in only 25%[51] of interdisciplinarity projects, while this share increases to 90% for humanities.

In comparison, social sciences represent almost 30% of interdisciplinarity Action in the COST network and 11.8% for humanities with 12% of total participants in interdisciplinarity Actions (see Figure 14).

There is no data available regarding the number of interdisciplinary projects within Horizon 2020. The EC however reported on the share of Horizon 2020 interdisciplinary publications: 7.55% (the EU15 share is 7.29%, and the EU13 share 10.19%). If one assumes the share of interdisciplinary publications is proportional to the share of interdisciplinary projects (if 50% of the publications are interdisciplinary then it is subsequently assumed that 50% of the projects are interdisciplinary): then interdisciplinarity is a strong feature of COST Actions compared to Horizon 2020, with 46% of the projects.

4.2.5 Network structure

The average centrality degree of participants slightly decreased from FP6 (50.22) to FP7 (46.01) and Horizon 2020 (47.06). This might signal the entry of smaller participants and indicate that the network tends to be opening to less connected participants.

When comparing the Horizon 2020 network structure to the COST interaction one:

- Firstly, it appears that the COST network is less hierarchical that the Horizon 2020 network, despite being driven by it (collaborations seem counter-hierarchical in the Horizon 2020 network whereas it does significantly impact the COST network).
- Secondly, as measured by the transitivity index, on average a COST participant is (at least) three times better connected in the COST network (easier to reach out to any other participants) than scientists and project members from Horizon 2020 participating organisations.
- Finally, the COST network is less unequal than the Horizon 2020 network regarding the distribution of connections between participants.

More specifically, assortativity and average path length are slightly higher in the latter than in former with an assortativity score of 0.068 in the inter-instrument network (compared to -0.08 for Horizon 2020) and an average path length of 3.33 (compared to 2.81 for Horizon 2020). This implies that the COST Action network tend to be slightly more hierarchical than the Horizon 2020 network, and that the exchange efficiency (velocity of information flowing from one participant to another) is 1,18 times slower. This last finding could also reflect the overall low betweenness centralisation of COST network, i.e., there is little evidence of a core of participants playing the role of community builders (having a high intermediary role).

Regarding the connection degree of participants: compared to the COST network, transitivity is significantly lower for FP6/FP7/Horizon 2020 with respectively 0.17, 0.12 and 0.16 against 0.5 for the inter-instrument network and 0.76 for the inter-Action network.

[51] Social Sciences, Humanities and Interdisciplinary Research. A Showcase of Excellent Research Projects from LERU Universities. [cited 2020 Oct 5].

Regarding network inequality (reminder from the previous section): it is estimated equal 0.26 for the COST inter-Action network, which is three times lower than for Horizon 2020 (0.64[52]). This finding implies that few participants have a lot of connections in the COST inter-Action network. It is however higher for the inter-instrument network, around 0.41, which highlights that compared to the inter-Action network, a larger group of participants are connecting through instruments significantly more than others.

Table 8 Network indicators for FP6, FP7 and Horizon 2020

Framework Programme	Average degree centrality	Transitivity	Assortativity	Inequality	Average path length
FP6	50.22	0.17	-0.1	0.66	2.79
FP7	46.01	0.12	-0.11	0.67	2.79
Horizon 2020	47.06	0.16	-0.08	0.65	2.81

Source: Dynamic Network Analysis of the EU R&I Framework Programme – European Commission – 2018

4.3 Satisfaction of COST Action participants

Based on a stakeholder analysis, this section investigates the level of satisfaction of COST Action participants with a special focus on the COST stewardship approach and COST Academy.

Overall, within the COST Actions framework, the COST stewardship approach was perceived positively. It is appreciated and recognised that this supportive, facilitating, and empowering approach of COST helps the COST Actions to achieve their goals. Importantly, it was not seen as micromanagement but rather as a well-meant offer which COST Actions can but are not obliged to take up. Moreover, **in comparison to other funding programmes, this non-financial form of support is highlighted as a distinguishing unique feature**, which is hardly ever found in national or European funding programmes. Especially, the high flexibility of COST regarding the content of the Actions such as their deliverables and timeline and suggested adjustments from the side of the COST Action management was considered to be helpful and advantageous.

4.3.1 Scientific stewardship

All of the interviewed **COST Action Chairs all highly appreciate the changed MC1 meeting as a more interactive and inclusive event**. This holds true for those COST Action Chairs who have a longer history with COST and have seen several COST Actions as well as for those having their first encounter with COST. More specifically, the interviewees commented that it **sets the "right tone" for the following COST Action**, underlining the importance of cooperation and integration in working towards shared goals. Moreover, by extending the function of the MC1 meeting from a more informative character towards an interactive meeting, the COST participants were already able to get to know each other early on. This is particularly important because the gained familiarity can **build trust among previously unacquainted researchers** from different European countries and disciplines. This early focus on trust building, one interviewee analysed, noticeably shortened the start-up phase of the COST Action because the key participants were already familiar and trusted people.

[52] Pierre-Alexandre Balland, Ron Boschma & Julien Ravet (2019) Network dynamics in collaborative research in the EU, 2003–2017, European Planning Studies, 27:9, 1811-1837

While the COST Actions are proposed by a distinct group of people, any COST member state has the right to assign researchers to the COST Action. Thus, at times, COST Actions encompassed different groups that were unfamiliar with each other and did not integrate easily. With the changed MC1 meeting, COST opens the discussion on the content and structure of the COST Action itself (e.g., the working groups). The effect on the participants was that their **perceived ownership of the COST Actions was significantly elevated** because from the very first meeting onwards, participants got the clear sense that they can actively influence the direction of the COST Action and ultimately its success. With the sense of being able to influence comes the responsibility to help the COST Action succeed. Some of the COST Action Chairs were initially more cautious about this (potential) re-directing of their submitted proposal. However, in hindsight, they agreed that the better integration of all researchers contributed to the overall quality of the COST Action, and they appreciate this procedure.

In conclusion, the main contribution of the scientific stewardship approach is to create a trusting and inclusive atmosphere of ownership from the very start in the COST Actions. Furthermore, the evidence collected in the context of this study suggests that the **scientific stewardship approach enhances the strength of the network and the speed with which it can come together**.

4.3.2 Communication stewardship

The interviewed COST Action Chairs and other stakeholders asked on the matter, stated that they **appreciate the institutionalised post of the Science Communication Manager**. Firstly, communication is seen as a useful contributor to COST Actions' success. The communication and dissemination activities aid in positioning the Action and its researchers as influential in their respective fields. Moreover, communication is also used as a tool to facilitate the direct impact of the Action through effectively engaging with e.g., policy makers. Secondly, given that the recommendation by external stakeholders for COST is to strengthen the communication of results of the COST Actions, incorporating this role makes sense from a COST perspective.

When considering the communications strategy of the COST Actions, the impression from the interviews reveals that **while some COST Actions have a clear communications strategy including target audience, selected communication channels and tailored messages, others are still taking a less strategic approach to communication**. Therefore, having a dedicated person in the COST Action who is responsible for communication is certainly a first step into the right direction regarding the implementation of a communication strategy for each COST Action. In fact, overall, the institutionalisation of the COST Action Science Communication Manager offered an active reflection on the importance of communication for the success of the COST Action.

Despite the support offered by COST through the COST Academy or the central contact point, the **interviews revealed that some additional factors play a role in successful communication management of the COST Actions**. One such factor influencing the success of the Science Communication Manager, is the **quality of cooperation between the COST Action Chair and the Science Communication Manager**. Aligning these roles is important because through a good working relationship with the COST Action Chair, the relevant messages and (internal and external) stakeholders can more easily be identified, approached, and mobilised. Moreover, the interviews revealed that **some Science Communication Managers bring prior experience** to the role, while others are engaging with science communication for the first time. The implication of this is that training modules might be basic for some Science Communication Managers while being advanced for others. This needs to be taken into account when designing the trainings and deciding on the participation of the trainings.

For the **future development of the science communication of COST**, the interviewees identified some possibilities for improvements of the efficiency of the communication work within a COST Action. Firstly, especially less experienced Science Communication Managers emphasised the benefits of exchanging experiences, tools and strategies with Science Communication Managers from other COST Actions. COST could facilitate such an exchange even further through informal or semi-structured online sessions. Secondly, several Science Communication Managers hinted at the difficulty of building their own website with the skills and funding that was available to them. Providing more website-related and other communication templates could possibly enhance the efficiency of the COST Actions' communication work. Thirdly, the interviewees hinted at the importance of the COST Academy for improving their communication work. The observations and suggestions concerning the COST Academy are further elaborated below.

4.4 Perception and impact of the value-added activities

4.4.1 COST Academy

In general, the **COST Academy is positively perceived by the participants** who were interviewed in the context of this study. The COST Academy is appreciated because it **supports the development of the COST Action on multiple levels**. For the COST Action Chairs, the early and continuous support throughout the COST Action lifetime is appreciated, starting from the inception and general leadership of the COST Action to thinking about the sustainability of COST Actions after the funding period. The COST Academy especially helps less experienced COST Action Chairs to better understand the process and to identify the right questions to ask at the respective stages of the COST Action. It complements well the personalised support which the COST Action Chairs receive through their Science Officer. Further, the Science Communication Managers' work benefitted from the dedicated training modules. Most of the interviewees have indicated that they were able to better identify their target audiences, determine appropriate channels for communication and dissemination and formulate concise messages to inform and engage external stakeholders. Interestingly, several of the participants, especially Science Communication Managers, have developed processes to share their learnings with the other participants of the COST Action. This sharing of learnings was mainly attempted for the technical or methodological modules, such as for preparing presentations for policy makers.

The participants of the trainings felt they **personally benefited in their skills and personality development from the COST Academy**. For many Young Researchers, COST provides the first leadership and administration experience with larger research projects, which presents them an opportunity to learn about management. In fact, researchers see their personal development as an important result of their participation in COST, as 88% of researchers indicated in the customer satisfaction survey that their participation has led to career advancement. An anecdotal illustration of the impact of the COST Academy is the case of an ITC-based researcher who joined a leadership training, learning about the concept of servant leadership. The training changed her entire understanding of and perspective on good leadership. At the time of the interview, she was imminent to receive a promotion to lead the research institute she had been working at. COST and the participation in the COST Academy equipped her with the theory and practice needed in this new assignment. This example illustrates how the COST Academy can contribute to the personal development beyond the context of the COST Action. Overall, it can be concluded that the **COST Academy has supported the development of the COST Actions and the personal development of the participants.**

For the **future of the COST Academy and its further development**, the interviewed participants but also the COST Staff have voiced certain ideas.

- Firstly, COST needs to **continue to communicate well about the COST Academy events**, making sure the invitations reach the target audience, especially when this target audience is not part of the COST Action management. With more training modules and webinars added, formats will become more diverse and frequent, increasing the complexity of the event schedule. One interviewee suggested the creation of a training timetable for each COST Action, which is made available well ahead of the events and comprises a standardised set of modules for each COST Action.
- Secondly, as more modules are developed over the years, COST will need to **continuously monitor the relevance of the modules** for the researchers and be open to and identify new modules relevant to the different COST Actions participants. This also includes the consideration that different modules are relevant for COST Actions at different stages. For instance, some COST Actions only think about communication with policy makers towards the end of their activities, while for others it is relevant from the first day onwards.
- Thirdly, the COST Academy has started only in 2018 and is highly appreciated by those who participated. For the next phase, COST will need to think about the topic of **scalability of the COST Academy** to make it available, in some shape or form, to more COST participants. Compared with the entirety of researchers currently involved in COST Actions, only relatively few have participated in COST Academy trainings (approximately 1000 participants over the first year). Additionally, it was highlighted in the interviews that the participants appreciate the on-site events with a small group and a dedicated presenter or trainer. Thus, COST needs to deliberate how value can best be provided to the participants while still giving the opportunity to participate to as many COST participants as possible. One consideration is to differentiate the more information-focused modules from skill and training-focused modules. For the informative modules, COST could institute an online library of webinars with different modules on administrative and other frequently asked questions (e.g., reimbursement of travel cost). The skills and training focused modules could continue to be offered on a smaller scale on the COST premises. Moreover, hybrid events could make it possible to have participants join the on-site events virtually for some parts of the programme.

4.4.2 The COST Innovators Grant

The **general perception of the participants in the COST Innovators Grant is positive**, they appreciate the possibility of commercialising an innovation worked on during the COST Action. Since the introduction of the COST Innovators Grant, five COST Actions were awarded the grant. For two of them, the COST Action Chair was interviewed for the purpose of this impact assessment. Both strongly emphasised that the **Covid-19 pandemic** and the consequential travel-restrictions have impeded the full implementation of their work plans in the framework of the COST Innovators Grant. Some of the interviewed stakeholders were worried that with the introduction of the Innovators Grant by COST and moving towards more market-focused and applied innovation funding, COST is leaving its core activities. Moreover, other European instruments, one example being the recently funded European Innovation Council (EIC), exist which are primarily concerned with the funding of innovation-oriented projects.

Nevertheless, the interviewees could **identify some future potential for the development of the COST Innovators Grant** in better aligning the grants' ends with its means. The goal of the COST Innovators Grant is to plan the advancement of an innovation towards the market and to produce a business plan outlining this process. While this goal is different from those of the COST Actions, the means provided by COST remain the same: providing funding for networking

events. The need for this relatively small and already familiar group of people (10-15) lies not only in networking but also in receiving professional advice on business modelling or receiving support with specific tasks concerning the implementation of their business plan (e.g., developing an app). Furthermore, the interviewed participants experienced difficulties in identifying and convincing partners from the private sector to participate in the programme. Since COST is a programme for researchers primarily, businesses are often not actively participating in the COST Actions in the first place. Due to this circumstance, the investigated COST Actions had to externally recruit businesses for the COST Innovators Grant. Indeed, here, the COST Innovators Grant could be of more help in the future. In the medium-term, it could be argued, the COST Innovators Grant might have the effect of attracting more businesses to participate actively in the COST Actions, because such businesses could recognise the possibility to transfer an idea or product from a COST Action towards a marketable application. At this point, however, such assumptions are rather speculative.

All in all, it can be constituted that the COST Innovators Grant is appreciated. Furthermore, some avenues for future development were identified. Nevertheless, given the travel restrictions because of the COVID-19 pandemic, no final assessment can be provided on the COST Innovators Grant.

4.4.3 COST Connect

In COST Connect, COST Action representatives are supposed to get in touch with external stakeholders relevant for the field of their COST Action. The **primary outcome of COST Connect are new (or renewed) connections between different COST Action-related researchers, policy makers and other R&I stakeholders**. These could produce academic papers, research collaborations, proposals for funding, new COST Actions, webinars or input for standardisation or policy processes. Furthermore, outcomes of the COST Connect events are:

- The outcomes of **COST Connect events are research papers, summarising (in part) the discussions which were ongoing at the different tables**. This may be on account of the initiative of the participants or led by appointed rapporteurs. The rapporteurs can be more junior researchers who are participating in the discussions, collect and synthesize findings and publish a paper accordingly. Besides papers summarizing the discussions from a purely scientific perspective, they can also take the form of policy briefs or position papers, taking advantage of the involvement of political decision makers in the events. In the context of the study, papers were mainly relevant for the theme-oriented events as they bring together and are focused on a particular scientific field.
- Another outcome of **COST Connect can be training modules, such as webinars or COST Academy training sessions**. The discussions at the tables can give valuable insights into the needs and knowledge gaps regarding the implementation of certain methodological tools, such as standards. Bringing together the demand-side (e.g., COST Actions interested in working with standards) of researchers who are in need of supporting formats for their work with the supply-side of institutions (e.g., JRC and CEN-CENELEC) proving and operating such tools can lead to the identification of training needs.
- The **COST Connect events can also increase the visibility of COST as a reference point in certain topics**. This is achieved by the event itself but also by disseminating the outcomes, such as papers or opening up webinars and trainings. By organising the event on certain topics, COST can demonstrate openness to those particular topics. In the past, COST has funded mainly projects from the natural, engineering or life sciences. COST Connect presents an opportunity to bring previously less engaged social sciences towards COST. In fact, especially the COST Connect on Cultural Heritage resulted in recognition of COST's activities in this field and a surge in applications for new COST Actions on the topic. Seeing

the increased visibility through COST Connect, these events could provide an additional strategic tool for COST to build a profile on selected relevant topics.

Keeping in mind that COST Connect is a relatively new instrument: impacts might still be due to materialise. Moreover, it is not easy for the COST Association to track all the impact which was due to new connections at a COST Connect event. This descriptive part of the COST Connect is summarised in Table 9 for the three COST Connect events studied in more depth.

Table 9 - Summary of follow-up initiatives of selected COST Connect events

	COST Connect on Standards *(28-29 November 2019)*	**COST Connect on Cultural Heritage in the Digital Era** *(25 October 2017)*	**COST Connect on Cancer Research** *(21-22 May 2020)*
Type	Cross-cutting	Thematic	Thematic
Stakeholders involved in organising the event	COST Association, CEN-CENELEC, European Commission's Joint Research Centre (JRC)	COST Association	COST Association
Context	None	Organised in the lead up to European Year of Cultural Heritage in 2018	Organised in the context of the European Week Against Cancer
Follow up initiatives	• Connections between COST Actions of various calls who could exchange experiences for using standards in COST Actions • Establishing relations between COST Actions and standardisation bodies • COST Academy training on IP • COST Academy training on standardisation	• Participation in high-level events (EuroMED 2018, Future sustainable international cooperation in digital heritage in 2019, Europe Day Cultural Heritage in 2020) • Input into the strategic planning process of Horizon Europe on the topic of digital cultural heritage • Relations between (European) institutions and researchers from COST Actions • Establishing COST as a reference point in cultural heritage	• Paper on the event by several participants • Webinar on the EU's R&I 'Mission on Cancer' – discussion between researchers and key policy makers

In the following, the considerations of COST concerning some elements are provided, before turning to the perspectives of COST Action participants and policy makers.

The COST Policy and Science Officers responsible for organising the COST Connect recognise the value created by the events for COST Action participants and policy makers alike. They are heavily involved in the entire process of conceptualising, planning, preparing and holding the event on the actual day. Each event requires a considerable amount of work, despite the informal nature and the focus of the events being on the content creation by the participants (bottom-up nature). This also includes the follow-up process after the COST Connect events which is often driven by the COST Administration with the goal of creating sustainable and tangible outcomes and impacts. From the perspective of the COST Staff, having external stakeholders co-designing the event ensures buy-in of key institutions involved but can also create challenges such as increased coordination with externals before the event. Another, more general challenge occasionally met by COST staff in the organising process, was to convince external stakeholders of the suitability of the suggested, more innovative and interactive discussion formats, such as world-cafés. The COST Staff members express the ambition that with an increasing number of events successfully conducted and COST Connect will build a profile, becoming more recognised and the format more easily recognised.

From the **perspective of the participating COST Action members, the COST Connect events are valuable occasions**. Their main motivation to participate was to find out the scientific state of

the art in similar fields from their peers. The event also is perceived as an opportunity to build bridges for future collaboration. Importantly, the COST Action members also highlighted the importance to them of meeting representatives from different DGs of the European Commission, the European agencies and other relevant policy institutions. By meeting them, there is a possibility to clearly understand their vision and engage with them in discussions about this vision. A differentiation can be made regarding the different motives to participate for the thematic and cross-cutting events. The interest of participants in the thematic COST Connect events was to network in order to get to know new potential partners for future proposals and to meet policy makers relevant in the field. For the cross-cutting COST Connect events, the function of the events was to learn from other COST Actions how they are using certain methodologies, tools or solutions. The intention was also to learn from the policy makers, in the investigated case about the practical aspects of the standardisation process.

The **researchers see the uniqueness in the networking with their peers in adjacent fields and, simultaneously, with relevant policy makers**. Comparable events organised by recognised public institutions often mobilise the scientific community vis-à-vis only one policy stakeholder. Moreover, the **uniqueness of COST Connect is seen in its open and informal atmosphere which easily creates trust between previously unfamiliar researchers from different backgrounds**, which serves as the basis for meaningful exchanges of ideas. This was facilitated by the world-café-styled set up which allows for the researchers to openly discuss the questions deemed relevant. Moreover, COST Connect is considered to be a **complementary format to the networking opportunities of COST Actions**. Although COST Actions sometimes themselves organise conference cycles which are open to academics and practitioners, COST Connect events are, according to the interviews, not considered substitutes or duplications but supplements to other event and networking activities. Furthermore, a difference can be made with regard to the new connections between thematic and cross-cutting events, from the perspective of the researchers. In the **thematic COST Connect events, the involved researchers were familiar with around half of the researchers at the event**. Given the topic, it was easy to connect with peers on different facets of the question currently prevailing in the field. For the **cross-cutting events, researchers mostly were not acquainted with each other, but could use the format to discuss different aspects of standardisation in similar academic disciplines.** In fact, the COST Connect could in these instances also function as an event to connect COST Actions in different degrees of maturity, from those having just started, to those closer to the end. Lastly, the **content, format and timing were seen in a positive light by the participants from the research community**. It secures the interest and relevance of the discussions by giving ownership to the attendees. Despite only meeting for two half days, participants have had the impression that enough time was available to have meaningful discussions, share ideas and also to present and learn about COST Actions.

From the **perspective of the participating policy makers**, the main motivation to participate was to better understand the synergies between different streams of research. While the interviews showed that policy makers appreciate the informal, trusted atmosphere and the diversity of the COST Actions, COST Connect is one of many events available for policy makers to engage with the research community. The uniqueness of COST Connect events is the access to a diverse and interdisciplinary research community of top European researchers on a broad range of topics which COST can offer to policy makers. Some of the interviewed policy makers displayed initial scepticism regarding the interactive and relatively innovative nature of the event (mainly referring to world-café-styled discussions). After the event they were however convinced of the suitability of the format.

In sum, COST Connect is well-perceived by the involved participating stakeholder groups, all of them underlined the value of attending the event and their continued interest in future

events. For the future of the COST Connect events, there are some additional suggestions. On the operational level, the recommendation includes a further differentiation of the COST Connect events according to their functions: thematic or cross-cutting. With slightly different organisational processes, motivations for participation and more generally functions of the events, COST could investigate further and modify the agenda of the COST Connect events to better serve its respective purpose. Secondly, more resources could be dedicated to the post-event facilitation of outcomes by the COST staff: this could be an interesting consideration in order to transform more of the discussions into concrete Action. It needs to be carefully monitored and weighted however, how much effort is invested in organising the COST Connect events. What has worked well, was to involve participants in the documentation of the discussions and support them in exploiting the outputs of the COST Connect events. On a strategic level, the COST Connect fits well with the approach and strategy of COST. Policy impact is an important dimension of the Actions and to find formats of engaging with policy makers.

4.4.4 COST Global Networking

The **perspective of the COST Actions** on the COST Global Networking approach showed a **general appreciation and recognition of the value of international cooperation for the work of COST Actions**. Diversity and inclusion are seen as key drivers for innovation, science and knowledge which facilitate and spur creativity. A diverse set of participants included in the COST Actions through the COST Global Networking will thus create value for people and topics alike. It is perceived as generally beneficial to include scientific experience and knowledge in the COST Actions, also from Young Researchers joining the COST Action from non-COST countries. Moreover, COST Action participants recognise the **opportunity to expand professional networks beyond Europe** by including researchers and partners from non-COST countries in the COST Actions. Interestingly, COST Actions working on topics of global scope, relevance or outlook perceive the COST Global Networking as an important component for advancing the topic. On these topics, researchers and institutions from **non-COST countries may have a long scientific tradition and substantial knowledge, complementary data and different methodological approaches**. An additional aspect for some social science-oriented COST Actions is that researchers from non-COST countries can also make a valuable contribution to **diminish a Euro-centric perspective.** This can allow for new insights, understanding and knowledge.

From the **perspective of researchers from non-COST countries** there are several advantages to the participation in COST Actions. First and foremost, researchers regard the COST Actions as an **opportunity to expand and diversify their professional networks.** COST Actions offer a low entry barrier to become a member of a European network while at the same time remaining based in the home country. The participation in a COST Action also increases the chances to participate or be included in consortia for other Horizon 2020-funded projects at a later stage. Often, the COST Action also serves as an **initial meeting point for researchers** who seek to maintain these connections also after the lifetime of the COST Action. Moreover, besides the networking itself, COST is also seen as a way to **increase the visibility in the scientific community** for researchers from non-COST countries. By participating in COST, the researchers' work and specialisation are put on the map and the researcher might be invited for co-publications, workshops, or conferences. By engaging more actively in the scientific community, researchers can get a **better understanding of the state of play of the international research agenda and feel a connectedness to the research community**. In this way, researchers from non-COST countries can make their contributions more relevant and might also increase the number and quality of publications and other research outputs. Particularly also for Young Researchers the COST programme is attractive because they receive a good overview of relevant stakeholders

in their discipline. COST also increasingly, in the context of the stewardship approach, offers opportunities to **develop and advance individual careers** by participating in leadership positions in managing the COST Action. Interestingly, according to the Global Networking Survey, the vast majority of participants from non-COST countries did not initially have problems in joining a COST Action. However, most of those joining were invited by someone they already knew to join the COST Action.

When comparing the cooperation with different types of countries, some differences could be observed. **Countries with long-standing scientific communities (IPCs such as Brazil, Canada) are less inclined to participate in COST Actions compared to those countries dependent on the interaction with Europe (NNCs such as Tunisia or Georgia)**. This is also related to the funding possibilities which COST is offering, where the participation of researchers from NNCs can normally get funded while researchers from IPCs are not funded. In some more prominent IPCs, the research infrastructure and funding for research and researcher mobility is rather strong. Often NNCs can provide only modest research infrastructure and funding options for researchers. Connected to this circumstance, the brain drain from NNCs to Europe is stronger – a dynamic COST is seeking to change towards brain circulation by allowing for e.g., Short-Term Scientific Missions (STSMs).

The interview partners could also identify some particular **features of the COST framework which stimulate international cooperation**. Before participating in the COST Action, many researchers attend the **COST Awareness Days** which are frequently organised in different locations and highly appreciated by the participants which were interviewed in the context of this study. Often, international cooperation is stimulated by these days, encouraging researchers to engage with COST in the first place. Moreover, the fact that there are **national contact points** which are dedicated to promoting COST in some countries (mostly the NNCs) significantly stimulates international cooperation according to the interviewed researchers from non-COST countries. Another feature of the COST framework which is facilitating international cooperation is the **interaction, inclusiveness and the level of support provided by the COST Staff (stewardship approach)**. Because researchers are made aware of the set-up of the Action by colleagues or by the national contact point, they feel encouraged to join an Action. Moreover, COST is perceived to be a platform for science diplomacy and fosters interest, good will, and trust specifically among scientists from politically divergent countries, too.

When making the comparison with other **similar mechanisms to foster global or international cooperation**, the interviewees could identify some **national bilateral (funding) instruments for researcher mobility**, such as the German Academic Exchange Service. In spanning mobility across many European countries and internationally, the interviewees mentioned the already addressed MSCA programme on the EU-level, and also the Research and Innovation Staff Exchange (RISE). Compared to these networks, the uniqueness of COST is that the COST Actions are large networks which involve different kinds of partners and disciplines.

5 Scientific impact

Key messages

- On average, Actions contributed to publishing a little bit more than 30 publications, based on self-reported data, and around 53 publications on average based on Scopus.
- COST Action spin-off publications generated 202,898 citations as 89% of them have received at least one citation.
- COST Actions have an interdisciplinarity nature as an Action covers, on average, 5.8 different disciplines. Interdisciplinarity is however more common between disciplines that are topic-wise closer together.
- COST publications have a collaborative nature (on average, 6.7 authors are listed on a COST publication).
- One quarter of COST publications' authors can be considered as younger researchers.
- Four out of five countries that present the highest number of COST publications authors, relatively to the number of inhabitants of the country, belong to the Inclusiveness Target Countries (i.e., Slovenia, Portugal, Estonia and Czech Republic).
- The inclusion of Inclusiveness Target Countries authors of COST publications is stable across COST fields as it represents around 30% for each field.
- Some fields of COST Actions are starting to approach a fifty-fifty gender balance.
- The gender balance is experiencing a rebalancing as we observe a more important share of women among Early Career stage than End or Mid-Career stage.
- More than half (57%) of reported impacts of COST Actions have been achieved, mainly in scientific and technological type.
- Analysing the coverage on the Action level shows us the interdisciplinarity nature of the COST Actions. While there are eight Actions that cover only one discipline, on average a COST Action covers 5.8 different disciplines, while five Actions cover 13 disciplines.

This section assesses the scientific impact of COST Activities through an output analysis based on Actions final and intermediary reports and the identification of (two) significant breakthrough achieved within the COST framework.

The first sub-section presents the main findings on generated scientific output and the second sub-option described the two identified scientific breakthroughs.

5.1 Scientific output

This section presents the analysis of the output data regarding its scientific dimension. The first subsection provides a quantitative mapping of the COST Actions based on self-reported output[53] from the Actions' final achievement reports complemented with scientometric data. The second subsection provides some qualitative insights into the scientific and societal breakthroughs that have been identified with the help of the quantitative study.

It is important to note that this study only covers part of the ended Actions over Horizon 2020, and that all findings should be interpreted with this caveat in mind.

[53] Next to the direct outputs of the Actions, this section will also provide an overview of the self-reported impact and success which can be positioned at the impact level of the COST impact model.

5.1.1 *Descriptive statistics of self-reported outputs*

Each Action has various types of outputs: publications, self-reported impacts/successes, and dissemination activities which can include a variety of outputs such as patents or interactions with external stakeholders at events. For each Action, a various number of these outputs have been reported.

Table 10 presents the total number of outputs and the average, median, minimum, and maximum number of outputs per Action, specified for each type of output. The number of publications per Action is the highest: on average, each Action has contributed to publishing a little more than 30 publications in the self-reported data (53.6 in Scopus). The maximum number of publications related to one COST Action is 306 in the self-reported data (361 in Scopus). The average number of impacts is 5.5 reported impacts per Action, while the maximum number of reported impacts for one Action is 27. There were more dissemination activities reported: on average 9.5 per Action, with the maximum being 103. Each of the Actions reported at least one output for each category. For each of the types of output, the distribution seems to have long right tail, as there are a few Actions that score well above the average.

Table 10 Summary of descriptive statistics for the various types of outputs: publications, impacts/successes, and disseminations

Descriptive statistic	Reported publications (with numbers based on Scopus in brackets)	Impacts/successes	Dissemination activities
Total	7970	1437	2470
Average per Action	30.6 (53.6)	5.5	9.5
Median per Action	22 (36)	4	6
Minimum per Action	0 (0)	1	1
Maximum per Action	306 (361)	27	103

Source: COST Association final achievement reports (2020), Scopus 2020

5.1.2 *Scientific output*

Publications are a commonly used metric to assess scientific output. As realising scientific impact is one of the envisioned impacts in the COST impact model, further inspection can provide us with a better understanding in the extent to which COST Actions are contributing to this pathway of the COST impact model. The importance of publication data in the evaluation of the Actions also emerges from the final Action reports, in which publications take a considerable place. Next to the publication data available in these reports, the bibliometric data from the Scopus database also provides data on the publication resulting from the COST Actions.

While, as expected, there is a considerable overlap between the Scopus and self-reported data, there are some notable differences, which could be explained by the following:

- Scopus applies a quality filter and contains primarily publications written in English.
- Scopus also captures COST publications that are published in the period after the final report has been submitted.
- Self-reported publications can be double counted if they are the result of inter-Action collaboration and submitted by multiple Actions in their final report (undoubling these is

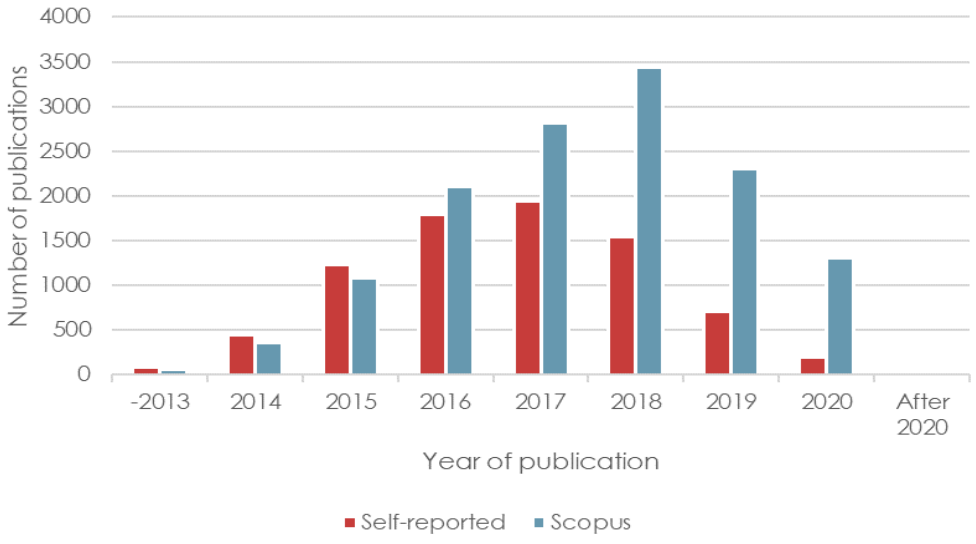
challenging as the authors can use different reference notations). The Scopus data shows that these inter-Action publications account for 3.6% of the total number of publications.

5.1.2.1 Quantity of publications

For the 261 Actions included in the analysis, 8006 publications are self-reported compared to 13,522 publications available in the Scopus database. Figure 17 provides an overview of the distribution of these publications over time. For both data sources, most of the publications are published in the timeframe 2014-2020. A look at the distribution over time shows that until 2015 the self-reported publications outnumber the Scopus publications, while the opposite is true for the latter years. The initial larger number of self-reported publications could possibly be due (1) the quality bias in the Scopus database (e.g., 4% of the self-reported publications is not peer-reviewed and are therefore not in Scopus) and (2) potential double counting of self-reported publications. The reversal in the latter years is likely to be due to publications that were only published after the final report was already submitted and which are hence not part of the self-reported publications.

For the further analyses it is also important to keep in mind that there might be differing definitions between authors and Actions in what is to be considered a COST publication. Some authors might attribute all their publication output to the COST Action they are part of, while others might be more selective. The same applies for the publications that are attributed in the final achievement reports to an Action, which is likely to be influenced by what the drafters of the Action's final report, which is in principle the chair of the Action's management committee, consider to be a publication that can be (partly) attributed to the Action.

Figure 17 Number of publications over time



Source: COST Association final achievement reports (2020), Scopus 2020 Note that some publications published online can have an official publication date in the future.

Moving from the overall scientific output of COST to the level of the individual Actions, Figure 18 shows how the publication output is distributed over Actions. A few Actions, do not self-report any publication and have neither any publication in Scopus. The large majority of Actions has less than 50 publications. There are also outliers with more than 100 publications. The comparison between the self-reported and Scopus publications might indicate a reporting fatigue among the participants, as self-reported publications spike in the category 11-20 and

only 6 projects report more than 100 publications, while according to the Scopus data, there are 32 projects to which more than 100 publications are attributed. Another explanation would be that in larger Actions the Management Committee members responsible for drafting the final report can (due to the size of the Action) not maintain a complete overview of all scientific output related to the project.

Figure 18 Number of publications per Action

Source: COST Association final achievement reports (2020), Scopus 2020

A part of the in Figure 18 reported publications per Action are double counted due to these being the joint result of multiple Actions[54]. While the self-reported data do not offer the possibility for an examination of these inter-Action collaborations, the Scopus data can provide some insights into this. 489 (3.6%) publications on a total of 13,605 COST publications are the result of multiple Actions. In 449 cases this is a bilateral interaction, 39 trilateral and 1 publication is the joint result of four Actions. The attribution of a publication does not necessarily imply a collaboration between individuals from the different Actions, as some individuals themselves are involved in multiple Actions.

5.1.2.2 Quality of publications

Although the quantity of the publications can tell us about the scientific output of the Actions, the assessment of the citations of these publications can tell us more about the quality and scientific impact of the scientific output of the Actions. The citation data available in the Scopus data can help us in providing a picture of the impact of COST as a whole and the most impactful Actions. In total, 89% of the 13,522 COST publications have received at least one citation, accumulating to a total of 202,898 citations. The citation counts for individual publications ranges from 0 to 947 per publication with a mean of 15.0 and a median of 7.0. Table 11 provides an overview of the descriptive statistics of citations aggregated to the Action

[54] Undoubling these would be a manual task due to inconsistencies in the formatting of references and is hence not feasible given the large number of publications.

level. Between brackets is mentioned the same value for projects that finished in 2016-2017 to give an indication of potential influences of time lag in citations.

Table 11 Citations by Actions

	Total citations by Action 2016-2020 (2016-2017)	Highest cited by Action 2016-2020 (2016-2017)	Mean citations per publication by Action 2016-2020 (2016-2017)	Lowest cited publication by Action 2016-2020 (2016-2017)
Min	0 (0)	0 (0)	0 (0)	0 (0)
Median	438 (459)	67 (82)	11.4 (13.5)	0 (0)
Mean	800 (907)	120 (128)	14.0 (16.1)	0.4 (0.4)
Max	6,161 (6,161)	947 (764)	70.7 (70.7)	55 (5)

Source: Scopus 2020

5.1.2.3 Multidisciplinary of publications

For this study, publications are assigned to disciplines based on the journals in which they are published. Journals are assigned to a discipline based on the subject area of the journal in the Scimago Journal Ranking[55]. In total, there are 26 different subject areas[56] ranging from "computer science" to "nursing". While all subject areas are covered by the Actions, the extent to which this happens varies considerably between the subject areas; just one Action has scientific output in the "dentistry" subject area, while 146 Actions have scientific output in the subject area of "medicine"[57]. To some extent this also reflects the overall size differences between these scientific fields.

Analysing the coverage on the Action level shows us the interdisciplinarity nature of the COST Actions. While there are eight Actions that cover only one discipline, on average a COST Action covers 5.8 different disciplines, while five Actions cover 13 disciplines.

Figure 19 provides an overview of the inter-disciplinary nature of the COST based on the number of inter-discipline dyads present in the COST Actions[58]. The diagonal is the number of COST Actions that have published in each discipline. The other figures represent the number of Actions that published in both disciplines. The most frequent disciplines combined in the publication output of COST Actions are disciplines that are naturally presumed to be closer together such as (bio)chemistry and medicine, while intra-project combinations between more distant subject areas such as "Economics" and "Veterinary" are less common.

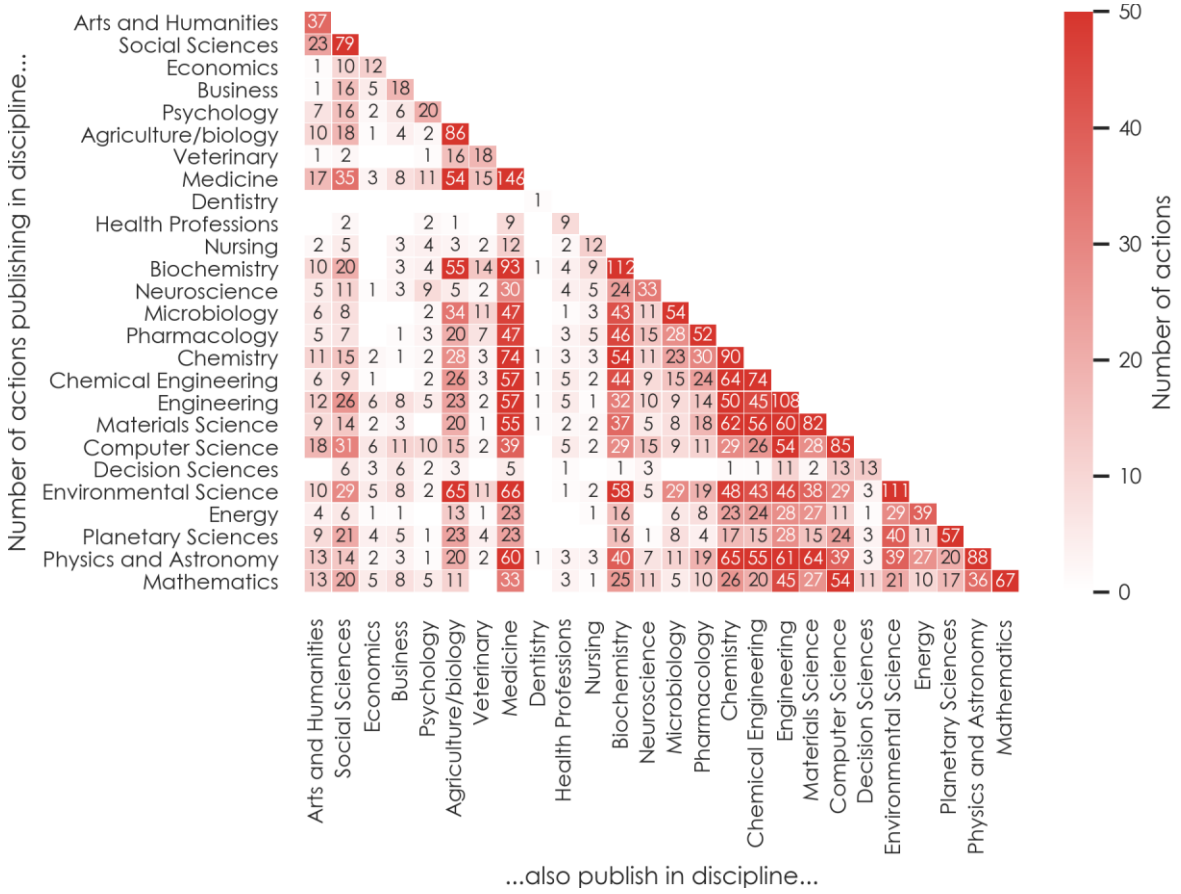
[55] The ranking is available at scimagojr.com/journalrank.php

[56] Excluding multidisciplinary as discipline as these are rather publishing work that is covering multiple disciplines, rather than inter-disciplinary work.

[57] These single-authored papers can include publications that are the outcome of a COST funded STSM

[58] An Action covering disciplines A, B, C will have three inter-discipline dyads: A-B, A-C, and B-C

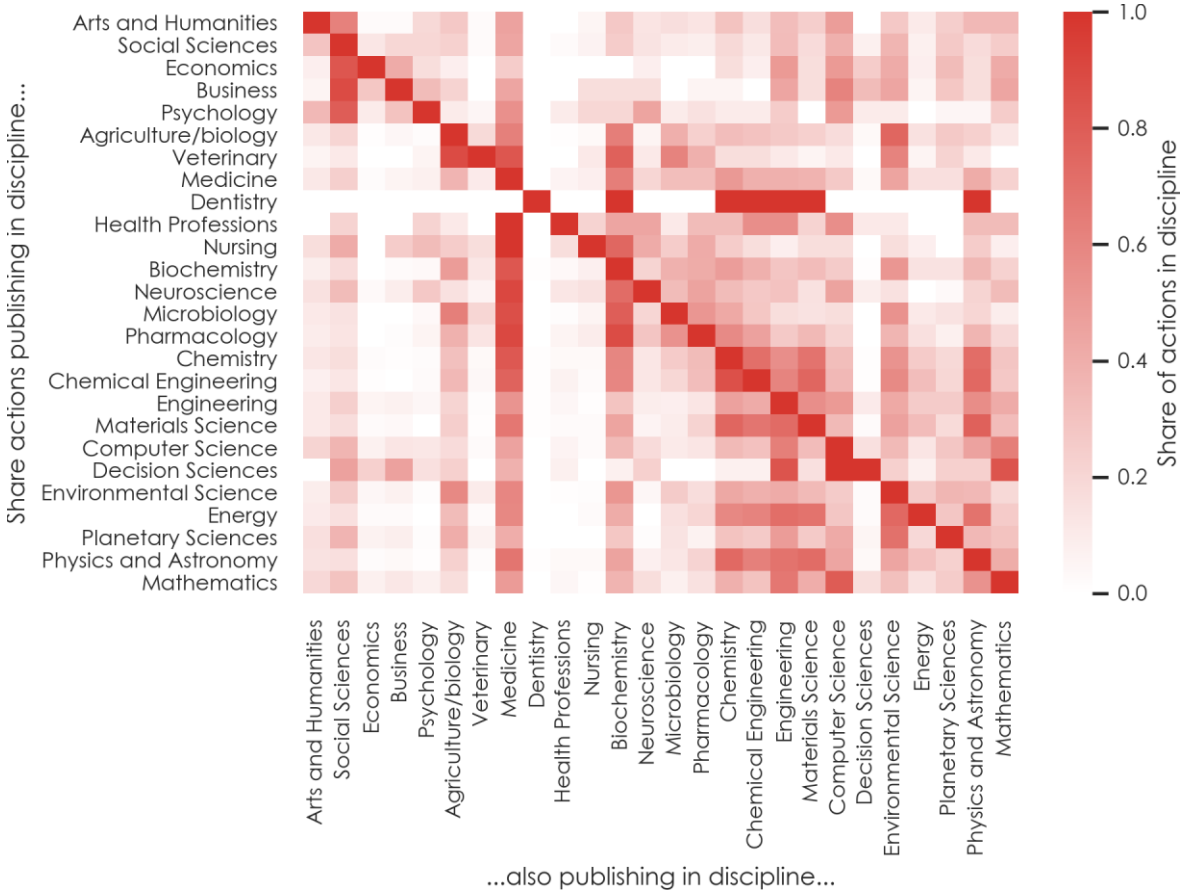
Figure 19 Number of COST Actions in which disciplines are combined



Source: COST Association final achievement reports (2020), Scopus 2020

Figure 20 presents the relative figures indicating the share of Actions publishing in a specific discipline, that also publish in another discipline. The diagonal in the figure is by definition always equal to unity. Apart from the diagonal, the darker areas tend to be clustered around the diagonal, indicating that disciplines that are topic-wise closer together, are also more likely to be both present in the publication output of an Action.

Figure 20 Share of Actions in discipline also publishing in other disciplines



Source: COST Association final achievement reports (2020), Scopus 2020

5.1.3 Authors of COST publications

The bibliometric data also provides some insights into the researchers involved in the COST publications. While a considerable part of these researchers will have been directly involved in the COST Actions, co-authors are included while having no connection with COST. Distinguishing between authors who were involved in COST Action(s) and other co-authors has not been possible due to data constraints. Therefore, this might lead to differences between these analyses and the analyses at the individual level presented as part of task I.

The author data of the 13,522 COST publications shows the collaborative nature of scientific research; only 3% of the COST publications is single authored[59], while on average, 6.7 authors (median=5.0) are listed on a COST publication. The publication with the largest authors list has 301 authors. In the acknowledgement section of this article with the title *"Early-stage litter decomposition across biomes"* the authors express their gratitude to *"COST Action ClimMani for scientific discussions, adoption and support to the idea of TeaComposition as a common metric", highlighting the importance of COST for bringing research communities together.*

[59] These single-authored papers can include publications that are the outcome of a COST funded STSM

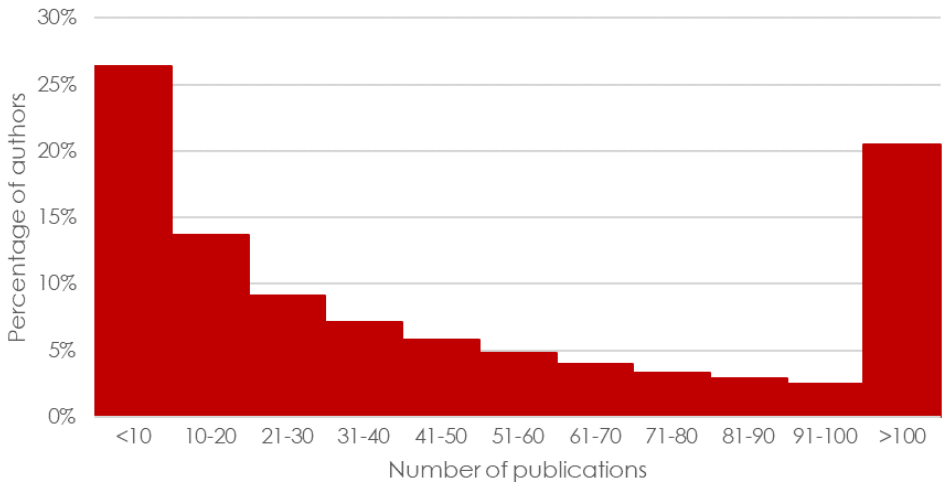
In total, the bibliometric data included 50,267 unique authors[60]. The large majority of these authors contributed to one (n=34,340) or two (n=7,905) COST publications. On the other side of the scale are the 81 authors who were listed as co-author on more than 20 publications, from which one author is listed on 51 publications.

While two-thirds of the authors only publish in the context of a single Action, the other third of the author population is involved in multiple Actions. About 1% of the authors is publishing in the context of more than 10 different Actions.

5.1.3.1 Younger researchers

One of the COST objectives on the researcher level is to support younger researchers. The number of publications a researcher has written within and outside the COST Actions context, gives us a good indication of the level of experience of the researchers involved. The fewer publications, the earlier the career stage of the author. Authors with fewer than 10 publications are likely to be still in their PhD, post-doc, or other early career position. Figure 21 shows that just over one quarter of the authors falls within this category and can thereby considered to be younger researchers.

Figure 21 Number of publications by author



Scopus (2020)

5.1.3.2 Geographical representation of authors

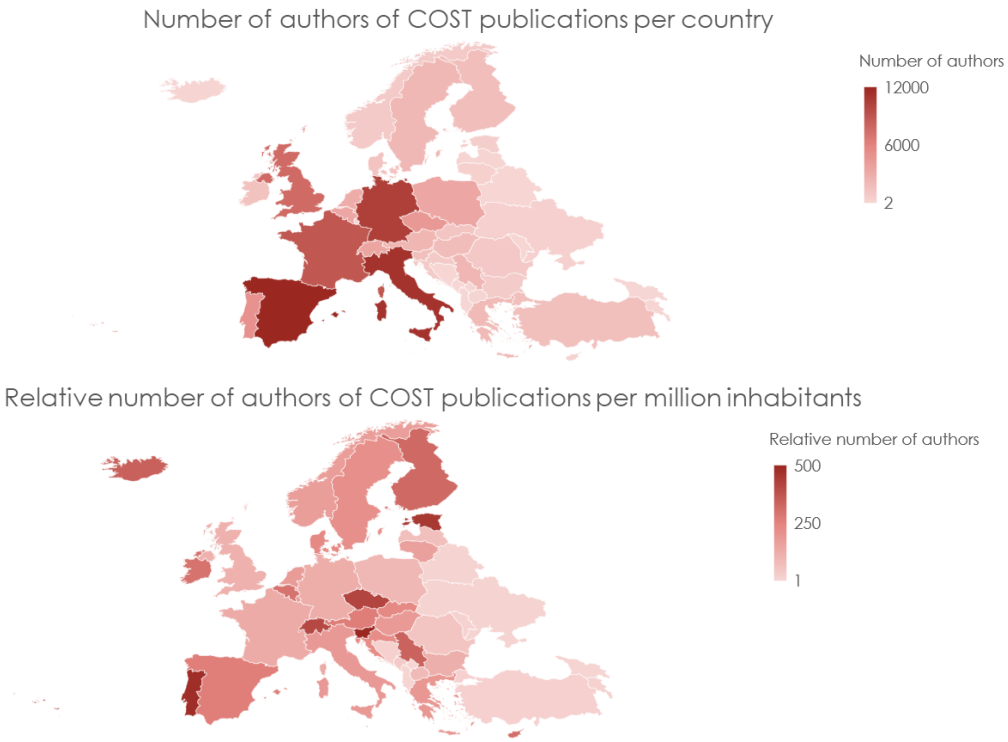
Within Europe, some countries are more active within COST Actions than others. Relatively speaking, the highest number of authors of COST publications based on the location of their affiliation are in Slovenia, Portugal, Estonia, Czech Republic, and Switzerland. Notable is that four of these countries belong to the Inclusiveness Target Countries (ICTs).

Figure 22.A shows that in absolute numbers, countries with the highest numbers of authors with an affiliation in those countries are Spain, Italy, Germany, France, and the UK. However, the relative number of authors, i.e., the number of authors divided by the number of inhabitants of a country, shows a different picture (see Figure 22.B). Relatively speaking, the highest number

[60] Unique authors are identified based on their Scopus author ID. In a few cases, authors have been assigned two ID's, but this is only likely to happen in seldom cases such as substantial name changes.

of authors of COST publications based on the location of their affiliation are in Slovenia, Portugal, Estonia, Czech Republic and Switzerland. Notable is that four of these countries belong to the Inclusiveness Target Countries (ITCs).

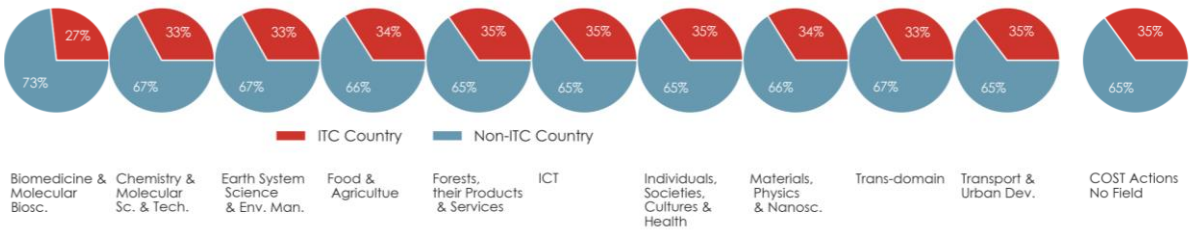
Figure 22 Number of authors of COST publications per country in Europe. N.B.: this map excludes a significant number of authors from the Rest of the World.



Technopolis, Scopus (2021)

The inclusion of Inclusiveness Target Countries (ITCs) is rather stable across COST fields: around 30% of the authors of COST publications are from ITCs, as visualized in Figure 23. In the field of Biomedicine and Molecular Biosciences, the percentage of ITC authors is slightly less than in the other fields (27%), but the difference is small. This might be due to the fact that biomedicine is a rather capital-intensive field of research. Note that since 2016, COST Actions are not pooled per field anymore under the new SESA (Submission, Evaluation, Selection and Approval) system. The data on these Actions without field are shown on the right of the graph.

Figure 23 Distribution of COST publication authors over Inclusiveness Target Countries (ITCs)



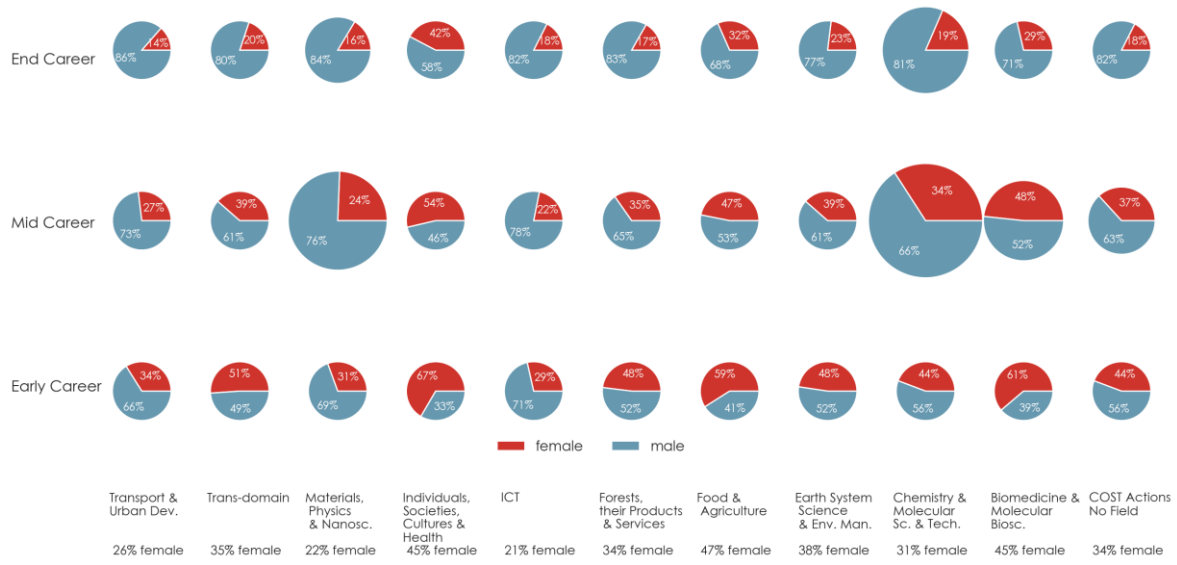
Technopolis, Scopus (2021)

5.1.3.3 Gender balance among authors

Although some fields of COST Actions are starting to approach a fifty-fifty gender balance, there are still quite some fields in which there are predominantly male researchers writing publications for the Actions. As visible in Figure 24, the fields of Food and Agriculture (47%), Biomedicine and Molecular Biosciences (45% female), and Individuals, Societies, Cultures & Health (45%) are approaching a fifty-fifty balance, even though all of these fields still show more male than female authors. Laggard fields are Information and Communication Technologies with 21% female authors, Materials, Physics and Nanoscience with 22%, and Transport and Urban Development with 26%. The COST Actions that started after 2016 are without a specified field, and therefore reflect the average percentage of 34% across fields. This is relatively low and approximately equal to the average over the fields before 2016 (33%), which shows that no real progress has been made there.

There are hopeful developments visible when zooming in on the gender balance per career level. While the End Career researchers are overwhelmingly male, the Mid Career show a more balanced author population, and especially among the Early Career researchers, female authors are more represented and sometimes even in a majority. The latter is the case for the field of Individuals, Societies, Cultures & Health, in which the percentage of female Early Career authors is as high as 67%, Biomedicine and Molecular Biosciences (61%) and Trans-domain proposals (59%).

Figure 24 Pie charts showing the gender distribution of COST publication authors per career stage and per academic field. The size of the pies represents differences in numbers of researchers across fields (with a maximum and minimum size defined to ensure readability).



Technopolis, Scopus (2021)

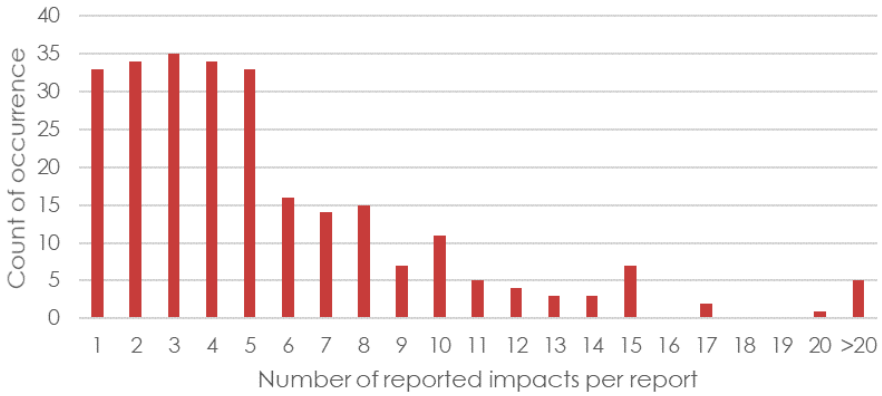
5.1.4 Successes, impacts and disseminations

5.1.4.1 Impacts and successes

Each Action has reported its impacts, when the impacts have happened or are supposed to happen, what kind of impact it was and of what type the resulting success was.

Most of the Actions, namely 169 out of the 261 (65%) had between 1 and 5 reported impacts per Action (Figure 25). Five of the Actions (2%) published more than 20 impacts, with 27 impacts per Action being the maximum.

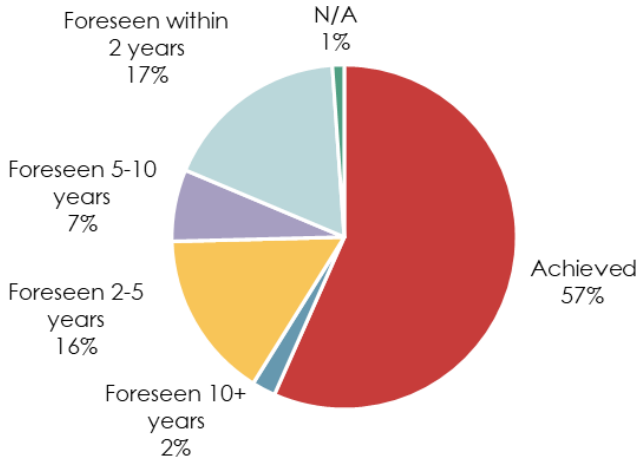
Figure 25 Histogram of self-reported impacts per Action



Technopolis Group, 2020

Of the total of 1 437 reported impacts, more than half (814, 57%) were reported to have been achieved (Figure 26). Most of the other impacts are expected to be achieved in the coming 2, 5 and 10 years: respectively 17%, 16% and 7%, totalling 40%. Finally, 2% of the impacts is expected to be realised in 10+ years. Note that these numbers were provided when the final reports were published, which can be several years from now, meaning that some impacts might be realized in present time.

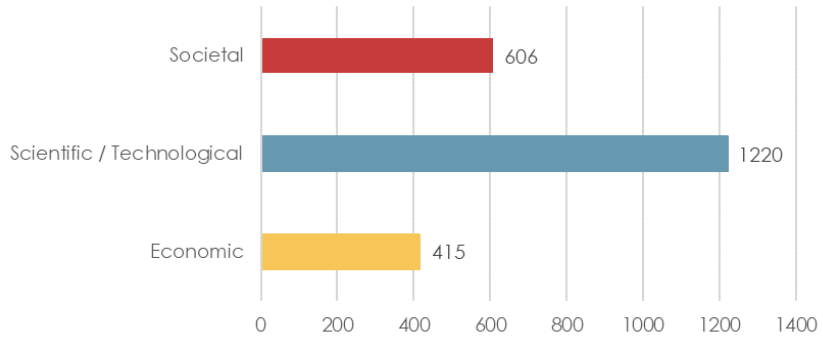
Figure 26 Distribution of self-reported timing and type of self-reported impacts of COST Actions



Technopolis Group, 2020

Each impact was reported to be classified along one or more categories: whether it was economic, societal and/or scientific/ technological. For 606 of the impacts, the societal impact category was reported (Figure 27). 1 220 and 415 impacts were classified as respectively scientific/technological impacts, and/or economic impacts.

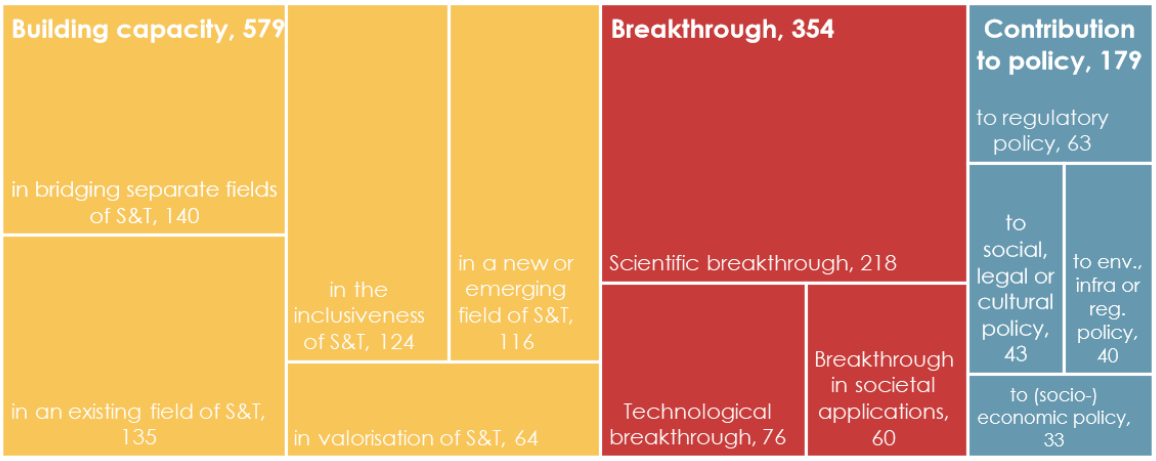
Figure 27 Number of self-reported impacts for each type of impact



Technopolis Group,2020

For each of the impacts it was reported as what category, or multiple categories of success it was classified. The types of success could be either a breakthrough in socio-economic or societal applications, a scientific or technological breakthrough, a contribution to policy, or building capacity in something related to Science & Technology. Most of the successes (579) were reported to have a dimension related to building capacity in a field related to science and technology (S&T) (Figure 28). Of these, 140 reported successes in building capacity in bridging separate fields of S&T, 135 within an existing field of S&T, 135 in an existing field, and 116 in a new or emerging field of S&T. The scientific breakthroughs, the technological breakthroughs and the breakthroughs in socio-economic or societal applications have been reported for respectively 218, 76 and 60 of the successes (Figure 28). For 179 of the successes, a contribution to policy was reported. Of these, 43 were reported to have made a contribution to social, legal or cultural policy and 63 to regulatory policy; 40 to environmental, infrastructural or regulatory policy and 33 to economic or socio-economic policy.

Figure 28 Number of self-reported success dimensions. S&T = science and technology.



Technopolis Group, 2020

5.1.4.2 Patents derived from COST scientific output

One of the ways in which scientific literature can realise economic impacts is by forming an input for later innovations. Citation relationships between patents and the scientific literature can provide insight into this impact pathway. Patents cite scientific literature to establish their

own novelty by stating how they differ from the current state of art. A patent citation clearly indicates thereby that a publication has gained traction beyond the scientific field and is considered to be on the innovation frontier.

Using DOIs in the Scopus bibliometric data shows that 909 patent families[61] have cited COST publications. Most of these citations comes from patents that are still in the application phase. Only 365 citations come from granted patents.

These granted patents cover all sections of the International Patent Classification (IPCR). Yet, the distribution of the patents displayed in Table 12 shows a strong concentration in section C (Chemistry) and H (Electricity) while only few patents are classified in sections D (Textiles, paper), E (Fixed Constructions), and F (Mechanical engineering). Most of the patents is assigned to multiple sections, indicating the interdisciplinarity nature of these patents.

Table 12 Patent citations by patent class

IPCR section	Frequency	Number of IPCR sections	Frequency
A Human necessities	100	One class	147
B Performing operations; transporting	39	Two classes	159
C Chemistry; metallurgy	189	Three classes	25
D Textiles; paper	5	Four classes	3
E Fixed constructions	1	Five classes	1
F Mechanical engineering; lighting; heating; weapons; blasting	6	Not classified	1
G Physics	72		
H Electricity	145		

Technopolis Group, 2020

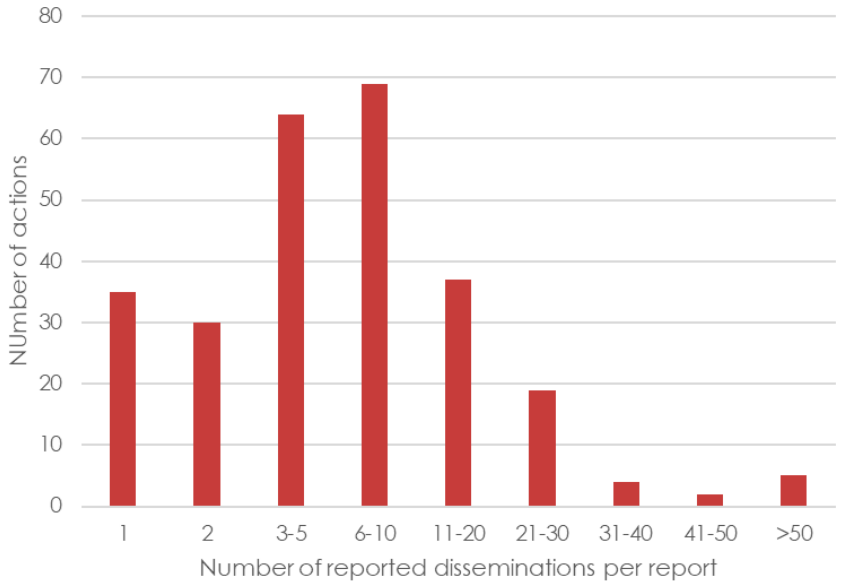
The citations tend to be clustered in a few projects with 10 or more citations. In most cases, these citations are within these projects further concentrated to just one publication. For the identification of breakthroughs, we will investigate more detail into some of these cases.

5.1.4.3 Dissemination activities of Actions

The Actions also reported on the number of dissemination activities per Action. The total number of reported dissemination activities is 2 470, with the majority (76%) of the Actions reporting 10 or less dissemination activities (Figure 29). Only 4% of the Actions reported more than 30 dissemination activities.

[61] National variants of patents are grouped together to prevent "duplicate" citations. Prior to grouping by patent family there were 1,115 patents citing the COST publications

Figure 29 Self-reported disseminations per Action



Source: COST Association, Technopolis Group, 2020

5.2 Scientific breakthroughs through COST Actions

Based on the output analysis, we identified two scientific and two societal breakthroughs resulting from the COST Actions. Vignettes summarising these breakthroughs have been developed based on desk review of documents relevant for the Action, such as related publications, the final achievement reports, a group interview with the key stakeholders involved in these Actions (e.g., Chair, Vice-Chair, and the author of a highly cited document), and documents the interviewees shared with us. In general, these studies provided insight into the various ways Action participants try to integrate researchers from both academia and the business community to realise scientific and societal impact. COST enabled the breakthroughs to take place mainly through providing connections and interaction between researchers, which led to valuable knowledge-exchange and new insights. The following pages present the vignettes, with some key notes on why these Actions are considered to be breakthroughs.

5.2.1 Scientific breakthrough 1: BM1405 - Non-globular proteins - from sequence to structure, function, and application in molecular physiopathology (NGP-NET)

Action BM1405 - Non-globular proteins - from sequence to structure, function, and application in molecular physiopathology (NGP-NET) lists 'The Pfam protein families database in 2019' among its publications. This publication has been cited 947 times, which is 37 times the mean citation count of COST publications in the *Biomedical and Molecular Biosciences* field. According to our interviewees, COST contributed to the formation of a community of researchers in this field, which allowed for the creation and expansion of the classifications of protein families.

Figure 30 Vignette for COST Action BM1405

Scientific Breakthrough

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Non-globular proteins – from sequence to structure, function and application in molecular physiopathology – NGP-NET (BM1405)

The Action

Biomedical Sciences

March 2015 – March 2019

NGP-NET aimed **to create a pan-European scientific network** of groups that work on **Non-Globular Proteins (NGPs)** to strengthen, focus and coordinate research in this field. NGP-NET furthered the classification of NGPs and organised several types of meetings on the topic.

60 publications attributed to Action

947 citations

Action participants

+ Japan & Argentine

The Breakthrough

- This COST Action brought **structure** to the field of NGPs, where there was little collaboration and consistency before. The structuring allowed for the creation and expansion of multiple databases as proteins that could not be classified before, were classified in collaboration between scientists.
- The Action has generated a paper that has been highly cited: it is the most cited publications with **947 citations**, which is 37 times the mean citation count of COST publications in the BM field.
- The paper is a biannually recurring paper, reporting on the progress made in the classification within the Pfam database of protein families. It reports the creation of 825 new protein families and connected Pfam entries to the Sequence Ontology (SO) through mapping of the Pfam type definitions to SO terms.

The role of COST

- The Action has played a fundamental role in the above breakthrough through the recurring meetings where **cutting edge research** was discussed.
- The Action allowed for mobility to conferences, which provided researchers from various countries, including ITCs, to **learn** from each other
- **Short Term Scientific Missions** supported the creation of the databases
- It established **a scientific community** with a high scientific level

COST is supported by the EU Framework Programme Horizon 2020

Technopolis Group, 2021

5.2.2 *Scientific breakthrough 2: IS1309 - Innovations in Climate Governance: Sources, Patterns and Effects (INOGOV)*

Action IS1309 has been selected based on its high citation count per paper: for the 53 publications it has produced, the average citation count was 25. This is 3.3 times as high as the mean citation count for the former domain of *Individuals, Societies, Cultures, and Health*. The interviewees for this Action mentioned that every time they got together for a meeting, this resulted in the publication of multiple papers. This implies that the resulting papers would have an interdisciplinarity and connecting nature, which might explain the high citation count. Also, they were among the first to apply the work by Nobel-laureate Elinor Ostrom and her following on polycentric governance and governance of the commons to the climate change challenge. Because the timeline of the Action coincided with the attention for COP21 in Paris, the policy relevance of this Action was very clear and the attention for the papers high.

Figure 31 Vignette for COST Action IS1309

Scientific Breakthrough

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Innovations in Climate Governance: Sources, Patterns and Effects – INOGOV (IS1309)

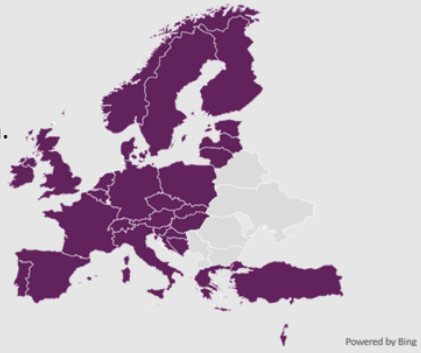
The Action

innovation, climate change, polycentric governance

June 2014 – June 2018

INOGOV aimed to explore Europe's potential for innovation in the climate governance domain. This implies engaging in innovative forms of policy, against a backdrop of more polycentric systems of climate governance.

Action participants



Output

53 publications

1356 citations

9 STMS

Book publication (59781 views)

The Breakthrough

- The Action has generated **4 working groups,** each running workshops to develop a shared terminology and common characterizations of policy, which had immediate policy impact because of the collaboration with policy experts
- It has completed two **Spring Schools** on governance, policy and climate change in which 48 early career researchers (from 18 countries) participated
- The Action led to an **ERC Advanced Grant** on the topic of *Deep Decarbonization: The Democratic Challenge of Navigating Governance Traps*.
- It led to the publication of 2 **special issues** in scientific journals
- The **creation of the book** *"Governing climate change"*, that brings together contributions from the world's foremost experts to provide the first systematic test of the ability of polycentric thinking to explain and enhance societal attempts to govern climate change(downloaded more than a 1000 times)

The role of COST

- The Action has played a fundamental role in the breakthrough by bringing a large group of international researchers together and thus creating a **network**
- The Action enabled **ambitious researchers** to **bring people together** and produce 2 special issues in collaborative effort, as well as a book.
- The **COST Science Officer** was available to having discussions on what was possible and thus played a role in enabling the researchers to publish the book.

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6 Societal Impact

This section assessed the societal impact of COST Activities achieved through COST Actions (with two case studies of significant societal breakthroughs) and a stakeholder analysis focusing on reputation and strategic positioning.

6.1 Societal breakthroughs through COST Actions

6.1.1 *Societal breakthrough 1: Hooking together European research in atomic layer deposition (HERALD)*

Action MP1402 lists "Atomic Layer Deposition of Silicon Nitride from Bis(tert-butylamino)-silane and N2 Plasma" among its publications. This publication has been cited by 96 patent families, making it by large the publication with the most citations by patents. The 96 citing patents are on average also cited on average nearly 27 times by other patents. In this way, this publication provides part of the scientific foundation for 2 583 of these subsequent patents, thereby underpinning a strong technological development.

Figure 32 Vignette for COST Action MP1402

Societal Breakthrough

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

HERALD – Hooking together European Research in Atomic Layer Deposition (MP1402)

The Action

Materials, Physical and Nanosciences
December 2014 – December 2018

HERALD **structured and integrated European research activity in atomic layer deposition** (ALD) from both the scientific and business communities. ALD is a unique technique for growing ultra-thin films that is enabling new developments in high-tech manufacturing sectors such as electronics, energy and coatings.

Action participants

+ Russia, Canada, USA, South Korea, New Zealand & China

Output

468 citations
2 patent applications
Annual workshop series
49 publications attributed to Action

The Breakthrough

- The Action not only fostered scientific collaborations and interactions but also has generated **considerable uptake by industry**. The Action has led to several **patent (applications)** and one of these patents is currently exploited in the **spin-off** SME Atlant 3D Nanotechnology, based in Denmark. This company, which already has paying customers, aims to reshape micro and nanofabrication processing at a prototyping stage
- The work of HERALD on novel ways of realizing "Atomic Layer Deposition of Silicon Nitride" has shown its industrial relevance by one of the Action's publications being **cited by 114 patent families**
- HERALD provided researchers and companies a fruitful platform for interaction, **fostering university-industry ties**, paving the way for later recruitment of scholars by industry and thereby the uptake of their scientific knowledge.

The role of COST

- The Action has played a fundamental role in the above breakthroughs by **offering a platform** for networking and the discussion of the scientific ideas and their potential application **that laid the foundation** for these breakthroughs
- **Short Term Scientific Missions** supported the further development of the ideas
- It established **a community that continues** to cooperate on new projects, while the individuals involved benefit from their increased connectedness in the field.

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6.1.2 *Societal breakthrough 2: FP1203 - European non-wood forest products network (NWFPs)*

Action FP1203 has been identified using the natural language processing approach as being an Action with a strong policy component. Our further triangulation showed that scientific work resulting from the Action was also being cited in policy documents, thereby showcasing the strong policy dimension of the Action.

Figure 33 Vignette for COST Action FP1203

Societal Breakthrough

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

NWFPs – European Non-Wood Forest Products Network (FP1203)

The Action

Ecology, sustainable forest management

April 2013 – April 2017

The Action aimed to build a broad multidisciplinary network of European NWFPs researchers and managers to share information and experience, identify research topics, and increase the European-wide theoretical and practical understanding of NWFPs.

Action participants

+ Australia, Chile, New Zealand, Morocco, Georgia & the U.S.

Output

- 15 publications
- 119 citations
- 35 STSMs
- Training school

The Breakthrough

- The Action **realized policy impact at several levels**, through involvement in policy forums, interactions with local policy makers and policy makers reading and citing the academic output of the project.
- The built and strengthened network ties between the Action members **fostered the circulation of knowledge** on common challenges and allowed them to tap into this knowledge pool when new challenges emerged in their locality. This circulation of knowledge on policy options led among others to lessons learned in Finland to be applied in Wales.
- The creation of the **book "Non-wood forest products in Europe"** provided the general public and students a comprehensive overview of NWFPs.
- The Action has generated a **database and interactive map** of existing data and models on NWFPs which identified gaps and led to new protocols for NWFP data collection and modelling. These resources are publicly available and present detailed information about the European NWFPs knowledge and actors.

The role of COST

- The Action offered a platform that **facilitated the interaction with policy makers**, thereby offering opportunities to disseminate insights to policy
- Facilitated meetings, workshops and training schools and thereby contributed to **integrating and strengthening the European NWFPs community**
- Supported **Short Term Scientific Missions** that furthered research on NWFPs

COST is supported by the EU Framework Programme Horizon 2020

Technopolis Group, 2021

6.2 Reputation and strategic positioning

This sub-section provides a historical background in the development of COST and explores its overall purpose, embeddedness in European Framework Programme (with a focus on its complementarity), its position within the European Research Area and the opportunities and challenges it faces.

This review bases itself on desk and literature research as well as on extensive interviews conducted with COST stakeholders.

6.2.1 Background and development of COST

COST was **founded in 1971 with an intergovernmental agreement** to close the technological gap between Europe and the United States of America. At the time, the European research landscape was fragmented and barely coordinated. The introduction of COST was part of a broader movement to foster a process of Europeanisation of research and technology, such as the European Organisation for Nuclear Research (CERN), the European Southern Observatory (ESO) and the European Molecular Biology Organisation (EMBO). In this way, COST became one of the first instruments of European science policy[62]. Since their introduction in the 1980s, COST has benefitted from direct funding under the various European Framework Programmes and the European Commission provided the operational secretariat for COST until 2003.

Today, **COST has its own implementation structure**, being an Association under Belgian law under the direct governance of the Committee of Senior Officials (CSO) to manage the EU support to the COST activities. Still today, **COST is an integral and important element of the European Framework Programmes** which are funding research, science and innovation. Under the 8th Framework Programme (Horizon 2020), from 2014–2020, COST was funded 50% by the Spreading Excellence and Widening Participation (SEWP) programme and is spending half of the budget to benefit "widening countries"[63]. In its successor, the 9th Framework Programme (Horizon Europe), from 2021-2027, COST is funded fully from the Widening Participation and Spreading Excellence (WPSE). This means that 80% of the budget will be devoted to widening Actions and 50% of the budget is invested in "widening countries". With Horizon Europe just in the early stages at the time of writing, it is too early for a comprehensive and final assessment of the implications of this shift in the positioning.

The WPSE is an important element of Horizon Europe, next to the three pillars: Excellent Science, Global Challenges & European Industrial Competitiveness and Innovative Europe. Alongside **COST, the WPSE also includes Teaming, Twinning and the ERA Chairs**. The key objectives of the WSPE in Horizon Europe include among others.

- to raise the bar for excellence of R&I actors in widening countries in partnership with outstanding European and international institutions,

[62] In the early years, COST was seen as potentially fulfilling the task later taken on by the European Framework Programmes – extending to research funding, not just networking as in COST's current form. However, each COST Action required primary legislation in the parliaments of the cooperating countries and this complexity made it incredible to expect effective or speedy management. The Council resolution of 14 January 1974 establishing a Community policy for R&D put an end to the funding ambition. By the late 1970s, COST was focused on organising research and technology networks – still known as Actions, because of this early potential to fund research.

[63] Equivalent to the Inclusiveness Target Countries (ITCs) as defined by COST.

- increasing the number of participations and success rates of widening actors in research and innovation projects in other parts of Horizon Europe and
- to foster brain circulation, including inter-sectoral mobility for researchers and innovators.

Addressing these and other objectives of the pillar, the COST Strategic Plan[64] puts forward three strategic priorities for its position in the Horizon Europe[65]:

- Promoting and spreading excellence,
- Fostering interdisciplinary research for breakthrough science,
- Empowering and retaining Young Researchers and innovators.

For COST, an important consideration with regard to the positioning in the WPSE pillar is the balancing of interests of the ITCs (more interested in inclusion and widening) and the EU-15 (more interested in excellence). It is imperative for COST to remain attractive for both types of countries, forming a platform for researchers from both types of countries to interact. A disproportional tilt towards more inclusion risks a lack of interest on the part of the excellence-oriented EU-15 countries such as Germany, France or the Netherlands.

6.2.2 Positioning within the ERA

Within the European Research Area, COST is perceived as a **pre-portal to other European funding instruments** by internal as well as external stakeholders. It has been statistically shown that participating in COST Actions significantly increases the chance for success of applications to other European programmes[66]. This fact was mentioned by several interviewees and is widely understood as an advantage of participating in the COST programme. By increasing the success rates for other European programmes, COST aims to contribute to a key objective of the WSPE part of Horizon Europe. It is important for researchers from outside of Europe to gain access to potential consortia for Horizon calls. Interestingly, also more excellence-based organisations (such as top EU-15 universities) see the advantage of scouting for and identifying potential partners to diversify a consortium for a competitive Horizon call. Thus, COST is perceived to be the **largest and most important networking instrument for researchers on European level**. COST is also appreciated as a key instrument to **opening European networks of researchers beyond Europe** by not only being active in the European context, but also in the continent's neighbourhood.

Moreover, COST is perceived by internal as well as external stakeholders and beneficiaries to be an **instrument to facilitate brain circulation in EU and non-EU countries**. With tools such as Short-Term Scientific Missions (STSMs), COST allows for researchers to continue to be based in their respective country while forging exchange and connections with the scientific community elsewhere. Particularly researchers from Inclusiveness Target Countries (ITC) reason that this is a valuable feature enabling them to enrich their own national scientific community while occasionally travelling to more research-intensive countries on a temporary basis. Also, COST has traditionally functioned as an instrument to coordinate research agendas across borders.

Especially the **low entry barriers for researchers** from all career stages and a diverse set of geographical countries are seen as a defining feature because these encourage participation

[64] Source: COST Strategic Plan (COST 060/17) from 12th December 2017.

[65] Although the COST Strategic Plan was published in 2017, the strategic priorities were defined for the 8th (Horizon 2020) and 9th Framework Programme (Horizon Europe).

[66] For instance, mentioned in the COST Investor Brochure "COST as an engaged investor" (p. 3)

especially of Young Researchers and researchers from Inclusiveness Target Countries (ITCs). The openness to all interested researchers allows access to otherwise "closed clubs", opening partnerships and networks to previously excluded partners.

COST is **a bottom-up instrument** open to accepting proposals for COST Actions from various academic disciplines, but also interested in attracting interdisciplinary projects. In many European funding instruments under the Framework Programmes researchers need to wait for calls to be published in their respective topics. The bottom-up approach is not strictly unique for COST since other funding programmes also use it. But interviewees described it as an important and recognisable feature when characterising the COST programme.

Compared to other national and European funding programmes, COST has started in recent years to provide **increasing support to the COST Action leadership**. This shift of philosophy coined "stewardship approach", which is elaborated on further at an earlier in this report (Chapter 2.3.1 - The COST stewardship approach), is perceived as a uniquely positive feature of COST, especially by the beneficiaries (e.g., COST Action Chairs).

As an instrument, **COST is seeking and cultivating connections and synergies with other relevant funding programmes**. It can be considered compatible and has further built-up interfaces with other fields of activity in the form of its value-added activities. COST Actions are considered a pre-portal in general to research projects funded under the EU Framework Programmes. In fact, 37% of the Horizon 2020 proposals submitted by a consortium created from a COST Action are successful[67]. More specifically, participating in a COST Action provides the opportunity to meet a wide range of partners, allowing partners to form networks for calls in the Framework Programme (Horizon Europe). In the following, a few more concrete examples are provided for interesting connections and synergies. Firstly, an important follow-up to COST Actions are **Marie Skłodowska-Curie Actions (MSCA)** which are networks focused on individual career development of researchers. In some cases, COST Actions have followed up with Innovative Training Networks (ITN) which are awarded to consortia and target mainly Young Researchers. Besides the ITNs, MSCA also encompasses Staff Exchanges or Postdoctoral Fellowships. Secondly, for the individual researcher, the **European Research Council (ERC)** grants have been highlighted by some interviewees to offer a possible follow-up for COST Actions participants, especially Young Researchers. While COST is broad in topics and participation, the ERC is focused on funding individual researchers on the basis of excellence. Thirdly, the **Joint Research Centre (JRC)** was identified by the interviewees as an instrument in the European funding landscape with high synergies potential. For instance, joint information events or workshops are organised between both organisations and for instance a COST Connect event was organised together. Also, in Horizon Europe some innovation-oriented instruments are funded, such as the **European Institute of Innovation and Technology (EIT)** and the, under Horizon Europe, newly introduced **European Innovation Council (EIC)**. With the COST Innovators Grant, COST has introduced a mechanism which might serve as an interesting interface to the EIT's Knowledge and Innovation Communities (EIT KICs) or the EIC Pathfinder. A new element of Horizon Europe are the five **Missions**, which were introduced on the following topics: (1) adaptation to climate change, including societal transformation, (2) cancer, (3) healthy oceans, seas, coastal and inland waters, (4) climate-neutral and smart cities and (5) soil health & food. These missions require interdisciplinary and broad collaborations – a set up where COST could make a valuable contribution. Finally, while COST connects researchers, there are complementary initiatives to strengthen the European networks between higher education

[67] Note: COST as an engaged investor, COST Association

institutions, e.g., Erasmus+ or the European Universities Initiative. It might be worth to seek potentials for collaboration between COST and the named programmes.

As interviewees constituted, networking continues to be an important element of the European research landscape, especially due to the increasing interdisciplinarity and internationalization of research. As an instrument, the interviewees perceive COST to be the **primary networking tool in the European research and innovation landscape**, spanning disciplines, countries, career stages and also different types of actors.

6.2.3 Opportunities and Challenges

More generally, **COST has the potential to engage more actively in the field of science diplomacy**, especially with other parts of the world that are actively funding research, such as China or the United States of America. Also, while the United Kingdom has officially left the European Union, it is retaining full membership of COST, meaning that British researchers are still actively participating in the COST Actions. This means that COST will continue to function as a platform to engage with the scientific community in the United Kingdom. Especially non-ITC countries appreciate this development because they value the full membership of the United Kingdom in COST.

The principal function of COST is to fund networks and researcher mobility, but not to fund research itself. The administrative aspects of COST are regarded as high by the participants but also by the designated grant holder managers. COST has identified the **bureaucratic and administrative burden for the COST Actions** as an internal challenge which they are in the process of addressing with simplification of processes and reporting regulations. In this spirit, the COST stewardship approach, which positions COST as an engaged investor, facilitating the success of the COST Actions, rather than controlling funds, is contributing to the simplification process by changing the mindset of COST Staff to become more service- and customer-oriented towards the COST Actions.

Another challenge for COST indicated by in the interviews is for COST to **better communicate the impacts and achievements of COST Actions towards the policymaker community and other important and relevant stakeholders**. This was a point especially raised by many of the external stakeholders who are not familiar in detail with the work of COST and the COST Actions. Here, a more general point can be made about external stakeholders often not being aware of the COST governance structure. The fact that COST was set up before the Framework Programmes came into existence means that it operates with a different logic. The implication of this lack of understanding of this principal functioning of COST is that from an external perspective the decisions can be wrongly perceived (e.g., decisions on the topics of COST Actions or the inclusion of participants). Communication might also be key to put COST higher on the agenda for higher education institutions, in particular from research-intensive countries. As evidence suggests, researchers benefit from the openness of COST Actions and improve their chance to both get involved in larger research consortia and to get funding from other European programmes.

7 Conclusion

This final impact assessment study was commissioned by the COST Association for four specific purposes. First it aims to meet a requirement of the European Commission concerning a final impact assessment. Second, it provides an assessment of the networking, scientific and societal impacts of the COST activities over the 7 years of Horizon 2020. Third, it will inform third-party stakeholders on the impacts and relevance of the COST programme. Fourth, it serves to indicate to the COST Administration and governance areas and topics of development over the next Framework Programme (Horizon Europe).

It is both a backward- and forward-looking study: backward-looking since it evaluates impact of COST activities over the past seven years, and forward-looking as it aims to provide an overview of future challenges faced by COST as well as recommendations to the COST Administration on how to further valorise these activities in terms of societal and scientific impact over Horizon Europe.

As an integral and complementary element of the European Framework Programmes, COST has three priorities: to enable the spread of excellence, with small bottom-up networks of excellence; to foster interdisciplinary research for breakthrough science; and to allow to integrate researchers of different career stage and geographical origins (ITCs and beyond) as well as innovators within the framework of the European Research Area. Those three priorities are defined by the COST Strategic Plan, adopted in 2017 that highlights the importance of interdisciplinary bottom-up networks as impactful tools to bridge the participation gap and close the innovation divide in Europe while providing opportunities for young researchers.

As a means to reach the objectives described in the COST Strategic plan, the COST impact model was approved in spring 2018. It follows a five-components framework in its practical approach to impact: inputs (researchers, ideas, and financial resources), activities (meetings, training schools, STSMs, dissemination tools and conference grants), outputs (network effects, idea, and knowledge creation), outcomes (capacity building, development of new research collaborations and of new research infrastructure), and impacts (breakthrough science, ERA). All those five components are interlinked.

Moreover, a more support-oriented approach towards the COST Actions (in terms of needs of the Actions and of their specific research community) has been taken over Horizon 2020, namely the "COST stewardship approach".

Hence this impact assessment evaluates all five components of the COST Impact model framework over the 2014-2020 period. First, it provides summary statistics on key indicators related to the inputs and the three COST priorities (as defined in the COST Strategic Plan): the overall number of Actions, participations and connections, the level of interdisciplinarity of Actions, the level of interaction of researchers, at distinct career stage, of different genders and from different categories of country. Second, using a social network analysis approach, it investigates the extent to which activities (also referred to as "instruments") help connect researchers within, between and across Actions and whether the resulting global network structure allows for efficient idea and knowledge diffusion. Third, by means of bibliometric and textual analysis techniques, it reviews the overall scientific outputs in terms of scientific publications, patents and innovations and identities four resulting breakthroughs. Finally, by

conducting extensive stakeholders' consultations (56 interviews) it assesses both outcomes and impacts of the COST programme.

Overall, the findings on networking impact on participants indicate that knowledge and ideas spread efficiently and quickly in a flat network structure resembling a 'small-world', where connectivity between participants is high and not limited to a core of well-connected researchers. Furthermore, participants networking activities are close to gender equality (connections being equally shared between men and women) while the overall participation of women is higher than in Horizon 2020. Activities enable more interactions between participants at different career stages (proxied by titles and age) and are therefore more inclusive. However, physical interactions of researchers at meetings tend to be slightly hierarchical: they occur between participants bearing the same title, whereas the Horizon 2020 network is governed by a negative disassortative effect.

Interactions between researchers are not driven by geographical proximity, since most of them are international and take place between participants from Inclusiveness Target Countries and other COST countries, thus complying with the integration objectives of less research-intensive countries within the ERA. Finally, an important share of Actions is interdisciplinary, and the COST programme enables more interdisciplinary Actions for Humanities and Social Sciences fields than Horizon 2020.

Globally, the COST stewardship approach was perceived positively as a distinguishing unique feature by stakeholders. It creates a trusting and inclusive atmosphere of ownership from the very start in the COST Actions and enhances the strength of the network and the speed with which they can come together. COST Connect is generally well perceived, whilst preparation is resource intensive. COST Academy is positively perceived as providing helpful and role-specific training to COST Action representatives and finally the COST Global Networking benefits non-COST countries participant by expanding scientific networks integrating global knowledge streams.

COST has identified the bureaucratic and administrative burden for the COST Actions as an internal challenge, which is currently addressed by COST with simplification of processes and reporting regulations. In this spirit, the COST stewardship approach, which positions COST as an engaged investor, facilitating the success of the COST Actions, rather than controlling funds, is contributing to the simplification process by changing the mindset of COST staff to become more service- and customer-oriented towards the COST Actions.

The assessment of COST scientific impact reveals that COST Actions have an interdisciplinarity and collaborative nature (on average six different disciplines by Action and on average close to seven authors by publication). Interdisciplinarity is however more common between disciplines that are topic-wise closer together. Young researchers and researchers from ITCs significantly contribute the creation of knowledge, representing one quarter of COST publications' authors for the former and four ITC in the top five publishing countries (i.e., Slovenia, Portugal, Estonia, and Czech Republic).

The evaluation of COST societal impact highlights the fact that COST is perceived to be the primary networking tool in the European research and innovation landscape, spanning disciplines, countries, career stages and different types of actors.

Within the European Research Area, COST is seen as a pre-portal to other European funding instruments since participation to COST Actions increases the chance for success of applications to other European programmes. Hence by increasing the success rates for other European programmes, COST aims to contribute to a key objective of the WPSE part of Horizon Europe. It seeks and encourages connections and synergies with other relevant funding programmes, with as natural follow-up the ERC, Marie Sklodowska-Curie Actions and JRC projects. Additionally, COST is perceived to be the largest and most important networking instrument for researchers on the European level, providing an instrument facilitating brain circulation in both EU and non-EU countries. More specifically it offers low entry barriers to young researchers and researchers from less research-intensive areas, which is seen as a defining feature.

This study concludes that the three priorities of COST are met: to build a network of researchers in order to enable knowledge diffusion and the spread to excellence, to foster interdisciplinarity of research and to provide a networking platform that integrates young and remote researchers from less research-intensive countries. It proves to be an integral and complementary element of Horizon 2020 and a significant tool for the development of the European Research Area by further integrating young researchers and researchers from ITCs into research networks and significantly increasing their chance of obtaining funding.

Still, room for improvement is foreseen, hence **the following recommendations, drawn** on the conclusions of this impact assessment's networking, scientific and societal analyses. First, balancing off the interest between ITCs and non-ITCs (e.g., COST countries that are not ITC): it is imperative for COST to remain attractive for both types of countries, forming a platform for researchers from both types of countries to interact. A tilt towards more inclusion risks a lack of interest on the part of the excellence-oriented EU-15 countries such as Germany, France, or the Netherlands. Second, while COST helps connecting researchers, there are complementary initiatives to strengthen the European networks between higher education institutions, e.g., Erasmus+ or the European Universities Initiative. It might be worth to seek potentials for collaboration between COST and the named programmes. On the same topic, it is recommended to foster opportunities for peer-to-peer learning within the COST Academy framework in order to improve the Science Communications Managers' skills. Additionally, it is recommended to make the COST Academy instrument available to even more participants, since so far it operates at a scale where only a modest part of the Action participants is reached. Third, COST has the potential to engage more actively in the field of science diplomacy, especially with other parts of the world that are actively funding research, such as China or the United States of America

Appendix A Reference list

- Balland, P-A,. Boschma, R., Ravet, J., (2019). Network dynamics in collaborative research in the EU, 2003–2017, European Planning Studies, 27:9, 1811-1837; accessible at: https://doi.org/10.1080/09654313.2019.1641187
- Bina, O., (2017). 1st INTREPID Policy Brief: Recommendations on Integrating Interdisciplinarity, the Social Sciences and the Humanities and Responsible Research and Innovation in EU Research; accessible at: http://intrepid-cost.ics.ulisboa.pt/wp-content/uploads/2017/05/EU-research-ID-SSH-RRI-Policy-BRIEF.pdf
- Bralić, A., (2017). Social Network Analysis of Country Participation in Horizon 2020 Programme, Central European Conference on Information and Intelligent Systems; Varazdin : 285-291, Croatia.
- COST Association (2017). COST Strategic Plan, COST 060/17; accessible at: https://www.cost.eu/wp-content/uploads/2018/08/COST_StrategicPlan_WEB.pdf
- COST Association (2018) COST Impact Model, COST 057/18; accessible at: https://www.cost.eu/uploads/2018/08/COST_impact_model.pdf
- Directorate – General for Entreprise and Industry (European Commission) (2001). Gender impact assessment of the Fifth Framework programme specific programmes; accessible at: https://op.europa.eu/en/publication-detail/-/publication/eb6e08f8-9269-48ff-9762-bdc13b6a156a
- Directorate – General for Research and Innovation (European Commission) (2015). Ex-Post Evaluation of the 7th EU Framework Programme (2007-2013); accessible at: https://op.europa.eu/en/publication-detail/-/publication/7e74df87-ebb0-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-80689114
- Fichet de Clairfontaine, A., Fischer, M.M., Lata, R., Paier, M. (2015). Barriers to cross-region research and development collaborations in Europe: evidence from the fifth European Framework Programme. The Annals of Regional Science.
- Lata, R., Scherngell, T. and Brenner, T. (2015), Integration Processes in European Research and Development: A Comparative Spatial Interaction Approach Using Project Based Research and Development Networks, Co-Patent Networks and Co-Publication Networks. Geographical Analysis, 47: 349-375. https://doi.org/10.1111/gean.12079
- LERU Universities (2014). Policy breif : Social Sciences, Humanities and Interdisciplinary Research; accessible at: https://www.leru.org/publications/ssh-and-interdisciplinary-research-a-showcase-of-excellent-research-projects-from-leru-universities
- Patience, G., Patience, C., Blais, B. & Bertrand, F. (2019). Citation analysis of scientific categories. Heliyon, 5(3); accessible at: doi: 10.1016/j.heliyon.2017.e00300
- Ravet, J., Balland, P-A., Directorate – General for Research and Innovation (European Commission), (2018). Dynamic network analysis of the EU R&I Framework Programme; accessible at: https://op.europa.eu/en/publication-detail/-/publication/0323a3e3-fdc2-11e8-a96d-01aa75ed71a1/language-en/format-PDF/source-82692556
- Ravet, J., From Horizon 2020 to Horizon Europe. Monitoring flash (2.1 Dynamic network analysis), (November 2018). ; accessible at: https://ec.europa.eu/info/sites/default/files/research_and_innovation/knowledge_publications_tools_and_data/documents/h2020_monitoring_flash_112018_0.pdf
- Rietschel, E.T., Arnold, E., expert group, (2009). Evaluation of the Sixth Framework Programmes for Research and Technological Development 2002-2006; accessible at:

https://www.europarl.europa.eu/meetdocs/2009_2014/documents/itre/dv/evaluation_report_fp6_/evaluation_report_fp6_en.pdf

- SCOPUS database (Elsevier, 2021); accessible at: https://www.scopus.com/home.uri?zone=header&origin=.
- Serlenga, L., Shin, Y. (2007). Gravity Models of Intra-EU Trade: Application of the CCEP-HT Estimation in Heterogeneous Panels with Unobserved Common Time-Specific Factors. Journal of Applied Econometrics, 22(2), 361-381. Retrieved July 13, 2021, from http://www.jstor.org/stable/25146520

Appendix B List of Interviews

Category	Name	Organisation
Strategic Position	Prof. Arif Adli	COST Association, Country representative for Turkey; Gazi University
Strategic Position	Prof. John Bartzis	COST Association, Interim Vice-President, Executive Board Member, Country representative for Greece; University of Western Macedonia
Strategic Position	Friederike Beulshausen	COST Association, Country representative for Germany; DLR Project Management Agency
Strategic Position	Dr Lidia Borrell-Damian	Science Europe, Secretary General
Strategic Position	Prof. Sierd Cloetingh	COST Association, former President; Academia Europea; Utrecht University
Strategic Position	Prof. Paulo Ferrao	COST Association, President; Instituto Superior Tecnico
Strategic Position	Prof. Jari Hämäläinen	COST Association, former COST Scientific Committee Chair; LUT University
Strategic Position	Dr Josef Janda	COST Association, Executive Board Member, Country representative for the Czech Republic
Strategic Position	Dr Georges Klein	COST Association, Country representative for Switzerland; Swiss National Science Foundation
Strategic Position	Prof. Eva Kondorosi	Hungarian Academy of the Sciences; Academia Europaea; Scientific Council, European Research Council
Strategic Position	Dr Claire Morel	DG EAC, Heads of Unit
Strategic Position	Prof. Jan Palmowski	The Guild, Secretary General
Strategic Position	Tatiana Panteli	EuroTech; Heads of Brussels Office
Strategic Position	Dr Emmanuel Pasco-Viel	COST Association, former Vice-President; Université de Paris
Strategic Position	Dr Elwin Reimink, Bart Veys, Ursula Castro	COST Association, Policy and Communications Unit
Strategic Position	Katerina Sereti	European Institute of Innovation & Technology (EIT), Head of Stakeholder Relations
Strategic Position	Dr Stefan Weiers	DG RTD, Head of Sector "Widening, ERA and Research Infrastructure Programming"
Strategic Position	Wolfgang Wittke	Eureka; DG R&I
COST Connect	Dr Antonio Andreu	EATRIS, Scientific Directior
COST Connect	Estelle Emeriau	COST Association, Science Officer
COST Connect	Judith Litjens	COST Association, Policy Officer
COST Connect	Prof. Joao Martins	Nova University Lisbon (TD1406), Associate Professor

COST Connect	Prof. Sascha Nehr	European University of Applied Sciences (CA17136), Head of Studies
COST Connect	Federica Ortelli	COST Association, Science Officer
COST Connect	Dr Mafalda Quintas	COST Association, Science Officer
COST Connect	Fabio Taucer, Andreas Jenet	Joint Research Centre, Scientific officers
COST Connect	Luc Van den Berghe	CEN-CENELEC, Programme Manager
Global Networking	Katalin Alföldi	COST Association, Global Networking Task Leader
Global Networking	Dr Sara Basart	Barcelona Supercomputing Center (CA16202), Postdoc researcher
Global Networking	Amani Charrad	COST Association, National Correspondent; Ministry of Higher Education and Scientific Research Tunisia
Global Networking	Dr Nana De Graaff	Vrije Universiteit Amsterdam (CA18215), Associate professor
Global Networking	Prof. Ivan Dodovski	University American College Skopje (CA18114), Dean
Global Networking	Dr Andreas Gombert	University of Campinas (CA18229, CA18113)
Global Networking	Prof. Bella Japoshvili	Ilia State University (CA20105, CA15219), Associate professor
Global Networking	Olga Meerovskaya	COST Association, National Correspondent, Belarus
Global Networking	Dr Nikolas Thomopoulos	University of Surrey (CA16222), Senior Lecturer
Stewardship / Academy	Prof. Boris Antunović	Josip Juraj Strossmayer University of Osijek (CA18105), University Professor
Stewardship / Academy	Karima Ben Salah	COST Association, Senior Communication Manager
Stewardship / Academy	Dr Cristina Borca	Aquatim (CA18221, CA18109), Public relations and communications
Stewardship / Academy	Dr Chiara Buratti	University of Bologna (CA15104, IG15104), Associate Professor
Stewardship / Academy	Prof. Simon Dufour	University of Rennes 2 (CA16208), Associate professor
Stewardship / Academy	Pat Griffin	Health and Safety Authority (CA16123), Senior Inspector
Stewardship / Academy	Leonor Hernandez Lopez	University Jaume I (CA15119), Professor
Stewardship / Academy	Dr Isadora Jimenez	Barcelona Supercomputing Center (CA16202), Communication officer
Stewardship / Academy	Prof. Catherine Kanellopoulou	Ionion University (CA19119), Director of Studies
Stewardship / Academy	Dr Ralf Koebnik	Institut de Recherche pour le Développement Montpellier (CA16107), Research director
Stewardship / Academy	Dr Agnese Kukela	University of Latvia (CA17131), Researcher
Stewardship / Academy	Prof. Ines Liebscher	Leipzig University (CA18240), Professor
Stewardship / Academy	Alicia Miguélez	Nova University Lisbon (CA18129), Assistant Professor

Stewardship / Academy	Dr Aine Ni Leime	National University of Ireland Galway (IS1409), Deputy Director
Stewardship / Academy	Dr Mafalda Quintas	COST Association, Science Officer
Stewardship / Academy	Dr Ana Rotter	National Institute of Biology, Slovenia (CA18238), Senior Research Associate
Stewardship / Academy	Prof. Helen Roy	United Kingdom Research and Innovation, Swindon (CA17122), Co-chair
Stewardship / Academy	Dr David Russell	Senckenberg Museum of Natural History (CA18237), Head of Section
Stewardship / Academy	Prof. Mariano Soler Porta	University Málaga (CA18214, CA18213), Associate Professor
Stewardship / Academy	Anna Toivonen	COST Association, Coordinator COST Academy

Appendix C Interview guidelines

C.1. Interviews with manager of breakthrough Actions (Task II)

C.2. Interviews for the COST Strategic Position

Introduction

- Purpose of the interview
- Please *briefly* describe your relation to the COST Association

Role and Position of COST

- What were the recent relevant developments and milestones of COST in your view?
- How would you describe the position of COST within ERA today?
- How does COST integrate with other European and national instruments? With which initiatives can you see synergies? (*Examples: DAAD, ERC, EIT, JRC, SAPEA, MSCA)*
- What is the unique selling point of COST in comparison to other programmes?
- Optional: What reputation and brand does COST have within ERA? Amongst different groups (academics, policy makers)? What is the perception of COST in the NNCs and ITCs?

Future of COST

- In what ways will COST be affected under the new Horizon Europe Framework Programme? (*Note: funding will come 100% from widening pillar, not excellence anymore*)
- What are the main challenges that you see for cost in the years ahead?

Recommendations and comments

- What other aspects about COST do you consider relevant?
- What additional resources and documents would you recommend?

C.3. Interviews for the COST Stewardship (scientific / COST Academy)

Introduction

- Purpose of the interview
- Introduction of the impact assessment
- Briefly introduce the general idea of the stewardship approach (*if unfamiliar*)

General stewardship approach

- What is your experience with the COST scientific stewardship approach?
- How do you perceive and appreciate the stewardship towards the COST Actions?
- In how far is the stewardship approach of COST unique, also compared to different other EU and national funding programmes?
- How did the MC1 Meeting contribute to the rollout of the Action?
- With prior experiences: In your opinion, how does the stewardship approach differ from your previous COST experiences?
- With prior experiences: How has the stewardship approach changed the general dynamics of COST Actions?

Scientific stewardship

- How does the stewardship affect the procedures, atmosphere and organisation of the COST Action?
- In how far does the stewardship approach contribute to the success of the COST Action?
  - How does it improve the scientific outputs of the COST Actions?
  - How does it enhance the networking activities during the COST Action?
  - How does it promote inclusiveness of the COST Action?
- How did the MC1 Meeting contribute to the rollout of the Action?
- What are the implications of the stewardship approach?
- What lasting impacts do you expect the stewardship approach to have?
- How have you yourself experienced growth in terms of leadership because of chairing the COST Action?

COST Academy

- What was your experiences with participating in the COST Academy trainings?
- What did you learn from the COST Academy training which you attended?
- In how far can your COST Action benefit from your participating in the COST Academy?

COST Communication Stewardship

- What is your perspective on the COST communication stewardship? How important do you assess the introduction of the position of Action Science Communication Manager?

- How has the communication stewardship changed the communication strategy/activities of your COST Action?

Future potential

- What opportunities and challenges can you identify regarding the implementation of the stewardship approach, including the scientific and communication stewardship and the COST Academy?
- Do you have any further suggestions or topics you would like to mention?

C.4. Interviews for COST Stewardship (Communication / Academy)

Introduction

- Purpose of the interview
- Introduction of the impact assessment
- Briefly introduce the general idea of the stewardship approach (*if unfamiliar*)

General stewardship approach / communication

- What is your experience with the COST scientific stewardship approach (and particularly the communication)?
- What is your perception of and experience with the new role of science communications manager?
- How would you characterise your relationship with the COST Association? In what ways is COST supporting your communication activities?
- With prior experiences: In your opinion, how does the approach to communication differ from your previous COST experiences?

COST Action communication strategy & activities

- What is the communication strategy of your COST Action? How have the communication strategy and activities evolved over time?
- What are the goals of the communication strategy? How would you describe your target audience?
- What are the contents that you are communicating / disseminating?
- What tools and means of communication are you aware of and actively using?
- To what extent are members of your COST Action actively communicating and disseminating? What is their individual motivation?
- How well are you connected to other science communications managers?
- Were you familiar with the target audience before?

Communication trainings

- What was your experiences with participating in the trainings on communication?
- What did you learn from the COST Academy training which you attended?
- In how far can your COST Action benefit from your participating in the COST Academy?
- Do you see scope for more training areas?

Effects of communication

- How does the communication contribute to the success of the COST Action?
- What are the internal and external results (maybe even impacts) that you can identify?

Future potential

- What opportunities and challenges can you identify regarding the implementation of the stewardship approach, including the scientific, communication and training stewardship?
- Do you have any further suggestions or topics you would like to mention?

C.5. Interviews for COST Connect

Introduction

- Purpose of the interview
- Introduction of the COST Connect Event (reminder for interviewees)
- Please briefly describe the COST Connect event which participated in

Participants

- How did you learn about COST Connect and this event in particular?
- Why did you want to participate? What were your expectations? What were your goals?

Activities

- How did you experience the activities?
- What elements of the programme were the most valuable?
- What other activities could you imagine in the context of COST Connect?
- How would you describe the atmosphere at the event?

Outcomes and added value

- What were the most valuable follow-ups (if any)? Note to interviewer: use cues when necessary
  - …follow-up events (conferences, training schools within/outside COST, etc.);
  - …research projects and/or publications (both among COST Action members not already collaborating and between COST Action participants and participating stakeholders);
  - …new COST Actions;
  - …learnings for individual participants.
- How relevant were the outcomes for your COST Action / work?
- Were you aware of and/or in contact with the other participating COST Actions?
- How many people/organisations did you already know and how many new encounters did you have at the event?
- What's the uniqueness of COST Connect? What similar initiatives do you know at national and/or European level?
- In general, what is the added value of COST Connect events compared to similar in the field? (Note: target the added value of COST Connect in European R&I)?

Impact pathways and future potential

- What impacts are you expecting to come from COST Connect?
- What are your lessons learned?
- Do you believe COST Connect should change? How should it change?

Recommendations for other follow-up stakeholders

- Which other stakeholders can you recommend for an interview in the context of this COST Connect?

C.6. Interviews for COST Global Networking

Introduction

- Purpose of the interview
- Introductions of participants

Perspective of the COST Actions

- Why do COST Actions want to cooperate with researchers from non-COST countries? What is the value-added of including non-COST countries?
- What are the main advantages for the COST Actions?
- What are the difficulties, from the perspective of the Actions to participate with non-COST members?
- Are some COST Actions more interested in cooperating than others?
- How do COST Actions view the different types of partner countries? What are the implications for their willingness to cooperate?
- What are the results and impacts from the inclusion of non-COST researchers?

Perspective of the non-COST countries

- How well is COST generally known and what is the perception of the non-COST researchers?
- Which are the main advantages for the non-COST partners?
- What are the difficulties, which they experience, with regard to the collaboration?
- Who are the researchers for who COST is particularly appealing?
- Is collaboration more frequent in some particular disciplines or are researchers in interdisciplinarity?

COST Perspective

- How do the opportunities for international cooperation through COST and COST Actions compare to other existing mechanisms for worldwide cooperation research and innovation?
- In how far is COST unique for researchers in non-COST countries?
- Are there particular features to the COST framework which stimulate international cooperation? What are areas for improvement?
- How can the brand of COST be more systematically be spread in the non-COST countries?
- What are ideas to add / change in the future?

Appendix D Statistical network analysis

This appendix contains the results of three statistical analyses performed at three different levels as a way to answer the following questions:

- Do participants' characteristics determine their connectivity within the COST Action network?
- Do participant's characteristics determine whether they will interact with common Actions' participants through instruments (meeting, STSM, conference grant, training school)?
- Do geographical characteristics determine how Actions' member are chosen?

It is based on econometric techniques in order to evaluate the potential role of participants' characteristics as well as geographical characteristics in explaining the structure of both COST Action networks (inter-Action and inter-instrument networks), *ceteris paribus*.

Three separate models are estimated at three separate levels with three distinct datasets.

1. The first level is the participant level where the unit of observation is a COST Action participant along with its attributes and the attributes of the Action, she or he is member of. The indicators to be investigated are the participants' network indicators (computed in Section 4.1), reflecting on their connectivity (degree and closeness) and their role as intermediary (betweenness). We regress those indicators on the participants' attributes to determine whether their position and role in the network can be explained by their own characteristics (gender, title, affiliation country).
2. The second level is the network level where the unit of observation is a dyad (couple) of participants along with both shared or distinct attributes regarding their geographical proximity, shared gender, title, and age class. We regress different connectivity indicators such as the use of instruments (*do two participants of the same Action meet through an instrument or not?*), the number of instruments they share (*do two participants of the same Action have met more than once using instruments?*), the number of Action they share (*how many Action membership do the two participants share?*) and the ratio instruments to Action in order to measure the completeness of their connection (*observed connection through instruments on the total number of instruments*).
3. Finally, the last level is the EU regional level, where the dataset is composed by EU NUTS2 regions only, for which bilateral geographical data is available[68]. The unit of observation of this third dataset is a dyad (couple) of NUTS2 regions, along with their shared or distinct attributes (language similarity, distance in kilometres, sharing a contiguous country border, etc.). We regress the number of Actions shared between two NUTS2 regions on a set of bilateral regional indicators mentioned above, in order to explore which spatial factor enhance or impede cross-regional connections. The model we estimate to do so resembles a spatial interaction model[69].

D.1. At the participant level: determinants of participants' network characteristics

The analysis at the participant level was performed in two steps. First, we extracted the network indicators of all Action participants from Table 4, then we regressed those indicators on

[68] http://www.cepii.fr/CEPII/en/bdd_modele/bdd.asp

[69] see Condone, P. (1996) General linear gravity models for the impact of casualty unit closures. *Urban Studies* 33 (9), 1707-1728

participants' characteristics (gender, age, number of Action membership, title, category of country) in order to measure how many of them have a significant impact on a participant's connectivity within the COST Action network.

Furthermore, we distinguished between the inter-Action network, where everyone is assumed to connect with everyone assuming they share an Action membership, and the inter-instrument network where participants only connect through instruments (within Actions). The purpose of distinguishing both networks here is to explore whether this has an impact on the explanatory role of the participants' characteristics.

Finally, the three network indicators, whose determinants we investigate, are the following:

- Betweenness: the level of intermediary of a participant within the network (without the participant, knowledge flows slower).
- Degree centrality: the centrality role of a participant within the network measured by the number of direct connections (without the participant, part of the network collapses).
- Closeness: the size of a participant's own network within the COST Action network (or the mean probability that this participant knows any other participant).

The **key results** are the following:

- Gender matters only for centrality and closeness degree:
  - Men have on average lower closeness degree than women, in order words women seem to be better directly or indirectly connected than men to any other participant.
  - They are on average fewer women participants in Actions than men, but women exhibit higher centrality degree when looking at their connections through instruments, meaning they tend to better use meetings/STSM/conference than men.
- Doctors and Professors are more central to the network than others, i.e., they connect to a larger number of participants through their Action memberships. Both categories of participants connect more often in instruments (meetings or training school) than non-doctors and non-professors. This finding highlights their strong intermediate role (especially seen through instruments).
- A participant's high number of Actions (or Action memberships) positively impacts their intermediary role and their core role (centrality degree) to a lesser extent. However, it does seem to have any effect on the overall connectivity of the participant to all other participants (closeness).
- The older the participant:
  - the more bridging power they have,
  - the more central he or she is thanks to meetings/conferences,
  - the better connected he or she is through meetings.
- Compared to COST countries that are not ITCs:
  - ITCs are better at bridging, better connected, more central through instruments.
  - NNC are less central and less connected through instruments.
  - IPCs are less bridging, less connected, less central through meetings.

Table 13 Statistical analysis of determinants of participants' network characteristics

	(1)	(2)	(3)	(4)	(5)	(6)
Network	Action	Instrument	Action	Instrument	Action	Instrument
Indicators	Betweenness	Betweenness	Degree	Degree	Closeness	Closeness
Gender: Male	-0.068	-0.041	0.042***	-0.026***	-0.000**	-0.001***
Title: Other (baseline: Doctor)	-1.017***	-1.203***	-0.035**	-0.274***	-0.002***	-0.007***
Title: Professor (baseline: Doctor)	0.149	0.202*	0.061***	0.025*	0.001***	0.000
Number of Actions	0.435***	0.427***	0.255***	0.270***	0.014***	0.013***
Age (logged)	0.655**	1.029***	-0.101***	0.448***	-0.005***	0.010***
Country: ITC (baseline: COST non-ITC)	0.761***	0.656***	0.005	0.113***	0.003***	0.005***
Country: NNC (baseline: COST non-ITC)	-0.093	-0.410	0.004	-0.195***	-0.000	-0.003***
Country: IPCs (baseline: COST non-ITC)	-1.837***	-2.284***	-0.006	-0.682***	-0.002**	-0.013***
Observations	49,258	47,359	49,258	47,359	49,258	47,359
R-squared	NA	NA	NA	NA	0.202	0.224
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Note: Estimated using Quasi-Poisson ML (1 to 4) and OLS (5 to 6), significance is conditional on White-robust standard errors. Lecture: In (2), having the title 'Professor' increases participant's betweenness through instruments by 20% compared to holding a doctor title. In (4) participants from near neighbouring countries have 19.5% less direct connections than participants from COST countries (non-ITCs).

D.2. At the network level: how participants meet through instruments?

This section aims at studying whether participants' attributes determine whether they interact with other participants through instruments. The unit of observation is a dyad (couple) of participants from a common Action. Within an Action, we investigated whether participant's characteristics determines the use of instruments to interact with other participants.

To this end we used different indicators:

- **Use of instruments:** A binary indicator equal to zero if two participants of the same Action have never met through instruments, equal to unity if they have (models (1) and (2)).
- **Ratio of instruments over Actions:** A ratio indicator that indicated how many times two participants have met through instruments on how many common Actions these two participants share (models (3) and (4)).
- **Number of shared instruments:** A count indicator equal to the number of times two participants have met through instruments (model (5) and (6)).
- **Number of shared Actions:** A count indicator equal to the number of common Actions two participants share (model (7)).

The **key results** are the following:

- Participants from the same category of country (COST non-ITC, COST ITC, NNC or IPC) tend to meet more often through instruments than others. However, this might result from the fact that participants from the same category of country also tend to be in the same Actions (they share a higher number of Actions than with others).
- All things equal, participants of the same gender are likelier to meet through instruments.
- Participants with the same title are likelier to meet through instruments and share overall a higher number of instruments and a higher number of Actions than with participants with other titles.
- The wider the age gap the less likely participants from the same Action will meet at COST instruments.

We purposefully omit to control for scientific domain, as one in five Action and one in four participants do not have a clear scientific domain affiliated to them.

Table 14 Statistical analysis of Actions characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Use of instrument		**Ratio of instruments over Actions**		**Number of shared instruments**		**Number of shared Actions**
Same country category	0.025***	-0.005***	0.025***	-0.005***	0.221***	-0.029***	0.117***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
Same gender	0.001**	0.001***	0.001**	0.001***	0.001	0.008***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Same Title	0.080***	0.037***	0.080***	0.037***	0.296***	0.055***	0.139***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Age diff	-0.000***	-0.000***	-0.000***	-0.000***	-0.005***	-0.000***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Number of shared Actions		0.491***		0.492***		1.603***	
		(0.000)		(0.000)		(0.000)	
Constant	0.333***	0.242***	0.333***	0.242***	-0.013***	-1.097***	0.398***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.000)
R-squared	0.118	0.361	0.119	0.364			

Number of observations: 12,492,797. Note: Estimated using Logit (1 to 2), OLS (3 to 4) and Quasi-Poisson ML (5 to 7). Significance is conditional on White-robust standard errors. Lecture: In (X), participants from the same type of country (COST non-ITC, ITC, NNC, IPC) have a higher odd of 1.025 of being connected through an instrument (meeting, conference, etc.).

Disaggregating the results by gender, titles, and country of origins, we identified the following trends (in terms of instrument connections):

- Men together tend to connect +1.6% more than with women or women together as measured by the number of instruments.
- Professors together tend to connect +14.9% more than with doctors together. Non-doctor and non-professors connect with each-other -29.2% less.
- Compared to non-ITC COST countries, participants from ITC share together +4.1% more instruments, NNC together -26.9% less and IPCs: -32.2% less.

This confirms our findings in Section 4.1.1, that gender, title, and country similarity are drivers of instruments connections.

D.3. At the EU regional level: what factors enhance or impede Action co-membership between EU regions?

This analysis is at the NUTS2 level, where we counted the number of Actions shared by couples of EU regions (proxied by NUTS2) and evaluated their distribution patterns conditional on geographical or spatial barriers: geographical distance, institutional border (the two regions are in two different countries, i.e., are separated by an institutional border), common shared language, contiguity of countries (the two regions are in contiguous countries), differences in regional income (proxied by regional gross value added) and whether they are ITCs or not.

This analysis excludes non-COST countries, since for those no open-access regional data is available for the above-mentioned indicators.

The key results are the following:

- Geographical separation is a small but significant barrier to Action sharing between NUTS2 compared to trade networks and innovation networks (scientific collaboration). Indeed, the estimate is equal to -0.03, which is 8 times lower than the estimate for co-publication network within FP5 (Fichet de clairfontaine et al, 2016) and 12 times lower than the lowest estimate for intra-European trade network (Serlenga and Shin, 2007).
- Language is a negligeable barrier close to insignificancy (i.e., close to zero).
- ITCs tends to share more Actions together than the non-ITCs in our sample.
- Contiguous countries share more Actions than others.
- They are more Actions between EU regions with different level of income (proxied by Gross Value Added[70]) than with similar level of income.
- Differential of level of education (proxied by regional share of tertiary educated participants) tends to weaken Action sharing, i.e., regions with similar 'educational endowments' tend to share more Actions than others.

Table 15 Statistical analysis of shared Actions between NUTS2

Number of shared Actions between NUTS2 couples	Coefficient	Standard Errors	p-Value
Out-degree (Mass variable)	0,961***	0,002	0,000
In-degree (Mass variable)	0,961***	0,002	0,000
Geographical distance (log)	-0,040***	0,003	0,000
Are both regions in ITCs	0,076***	0,007	0,000
Home bias (intra-regional flow)	1,792***	0,023	0,000
Common shared language	-0,066***	0,008	0,000

[70] Gross Value Added (GVA) is a proxy of GDP at the NUTS level.

Contiguity	0,027***	0,005	0,000
Differential of regional educational endowment (in level)	-0,021***	0,002	0,000
Differential of regional income (log GVA)	0,003***	0,001	0,003
Alpha parameter of overdispersion (logged)	-3,679	0,016	0,000
Alpha parameter of overdispersion	0,025	0,000	0,000
Observation	64 262		
Pseudo R^2	0,368		

Note: estimated using Negative binomial estimator and a spatial interaction approach. Data from CEPII, EUROSTAT, COST. Lecture: an increase of geographical distance between two regions negatively impacts the number of shared Actions by 4%. Contiguous countries share on average 2,7% more Actions than non-contiguous countries.

Appendix E Team of consultants

E.1. Project manager: Dr. Patrick Eparvier

Patrick Eparvier is principal consultant at Technopolis since January 2006. Patrick holds a PhD in economics from the University Lyon 2 (2002). At Technopolis, he leads and works on projects mainly related to evaluation and strategy in public policies for research and innovation.

He has lead 50+ complex evaluations of programmes/policies at regional, national, European or international level. Patrick has a long experience in the management of large international teams involving experts from different nationalities and from different organisations.

Patrick often works on large projects for the European Commission (DG RTD, DG Energy, JRC IPTS, DG REGIO, DG INFSO, DG Environment) or for international organisations (AFDB):

- Ex-post evaluation of the Nuclear Decommissioning Assistance Programme Energy Window 2007 – 2013 (EC, DG Energy), 2018/9
- Support to the Tunisian Ministry of Research and Higher Education in defining a strategy and action plan for the structuring of the Tunisian scientific community with a view to greater participation in the European Union's Horizon 2020 Programme (with CIHEAM), European Commission, 2018
- Analysis of practices on open data in energy research projects (EC, DG RTD), 2016/7
- Evaluation of the FP7 ex post evaluation / Horizon 2020 mid-term evaluation of the Marie Curie Sklodowska Actions, DG EAC, 2016/7
- Mid-term evaluation of the 2009 Emergency Oil Stocks Directive (DG Energy, 2015/6)
- Evaluation of the African Development Bank's activities in the energy sector (with Mott McDonald), African Development Bank, 2015

He is often involved in projects dealing with research:

- Assistance with the writing of the ERDF OP for the period 2021-2027, Normandy Region, 2020
- Evaluation of the impact of European funds - Lot 3 Research, Innovation and Economic Development, OP Auvergne and OP Rhône-Alpes, AURA Regional Council, 2020
- Evaluation of the Space programme in the context of the Investments for the Future programme, National Centre for Space Studies, 2019-2020
- Econometric evaluation of the French Institutes for Energy Transition, National Research Agency, 2019-2020
- Applied research project on the technological transformation and transition of regional economies, case studies in Pays-de-Loire and Auvergne-Rhône Alpes, ESPON 2020 Cooperation Programme, 2019-2020Evaluation of the French TTOs (with Finance Consult): SATT Sud-Est and TTT in 2014, SATT Nord and AxLR in 2015, Pulsalys and Paris Saclay in 2017, Ouest Valorisation, Lutech and Conectus in 2018, Sayens and Linksium in 2019, National Research Agency
- Analysis of the economic and territorial impacts of competitiveness clusters by territory (with Eurolio), CGET and France Stratégie, 2017

- Study on the effects of the Erasmus Mundus programme on the internationalisation of French higher education institutions, Erasmus Agency, 2017

Before joining Technopolis Patrick worked as an economist for the Institute for Prospective Technological Studies (IPTS – EC) in 2004/5. From 2000 to 2004, he worked for the OECD's Directorate of Science, Technology and Industry. In 1999, for the DAFSA Group in Paris, he worked as an industrial and sectoral analyst. From 1997 to 1999, he was a researcher in economics of technical change for a joint research lab of CNRS and University Lyon 2.

E.2. Lead on Task I: Aurélien Fichet de Clairfontaine

Aurélien Fichet de Clairfontaine has expertise in policy evaluation with a particular interest in regional, innovation and trade policy.

At Technopolis |group| Aurélien applies a range of quantitative methods of analysis such as econometric and statistical analysis, survey techniques, semantics and social network analysis. He contributes to impact assessment, evaluations, and studies for international, European and national public bodies. He conducts statistical analyses, gleans and arranges data as well as designs surveys and of the collected responses for program evaluation. He participated in 2019 to the Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe (DG RTD, 2019)

Prior to joining Technopolis Group, Aurélien worked at the International Economics institute of the WU WIEN in Vienna, Austria. During this time, he published scientific articles in peer-reviewed journals where he analysed patterns and determinants of international trade flows as well as trade balances responses to changes in exchange rates and national fiscal rules. He also worked as a project collaborator at the Innovation Systems & Policy department of the Austrian Institute of Technology (AIT) where he performed an evaluation of the fifth Framework Program and developed new approaches to social network construction.

Aurélien is fluent in both spoken and written English, French and German. obtained his undergraduate diploma in Economics from the **Université de Rennes 1**, in France and then pursued his Master and PhD studies at the **Karl-Franzens Universität Graz** and **Vienna University of Economics and Business** in Austria.

Previous relevant studies include:

At Technopolis |group|:

- Analysis of Open Public Consultation results on the Communication on stepping up EU Action against Deforestation and Forest Degradation. (DG Environment, 2019)
- Survey of CIFRE beneficiaries, doctoral students, company tutors and thesis directors. (ANRT, 2019-2020)
- Evaluation of the impact of European funds - Lot 3 Research, Innovation and Economic Development, OP Auvergne and OP Rhône-Alpes (Région Auvergne-Rhône-Alpes, 2020)
- Impact Assessment Study for Institutionalised European Partnerships under Horizon Europe. (DG RTD, 2019)

- Impact evaluation of the French "Aid to reindustrialization" program (Bpifrance, 2019)
- Digitalization in ErUM ("Exploration of Universe and Matter") – a comparative study. (BMBF, 2019)
- Econometric evaluation of *French* Technological Research Institutes and Institutes for the Energy Transition. (Agence Nationale de la Recherche, 2019)
- Evaluation of the Middle East and North Africa Scholarship programme. (Friedrich Ebert Stiftung, 2019)
- Study on unlocking the Potential for the Fourth Industrial Revolution in Africa. (African Development Bank, 2019)
- Study on the causes of loan defaults of SME in Sub-Saharan Africa: the ARIZ example. (Agence Française de Développement, 2018-2019, France)
- Audit of environmental, energy, health and safety regulations applicable to industries. (DGE, UIC, UFIP, COPACEL, 2018, France)
- Development of a methodology to study the impact of the 14 SATT. (Agence Nationale de la Recherche, 2018, France)

- At Austrian Institute of Technology (AIT):
  - **Innovation Economics Vienna**: Barriers to R&D Collaboration (financed jointly by the AIT and WU Vienna, 2012-2014, Austria)

- At Vienna University of Economics and Business (WU Vienna):
  - Essays on gravity model of international trade (ongoing, financed by the WU Vienna, Austria)
  - **Fiscal Rules**: Measurement, Determinants and Effects (financed by the OeNB, 2014-2016, Austria)

Scientific publications:

- Barriers to cross-region research and development collaborations in Europe: Evidence from the fifth European Framework Programme. (2015) Aurélien Fichet de Clairfontaine, Manfred M. Fischer, Rafael Lata, Manfred Paier. *Annals of Regional Science* 54:577–590
- Scientific collaboration and European Framework Programmes: A novel way to constructing scientific collaboration networks. (2014) Aurélien Fichet de Clairfontaine. *Innovation Economics Vienna* 21:1–50
- **Dynamics of the trade balance: In search of the J-curve with a structural gravity equation**. (2019) Harald Badinger, Aurélien Fichet de Clairfontaine. *Review of International Economics.* 2019; 27:1268–1293
- **Is the wage equation spatial enough?: Evidence from a regional bilateral trade dataset**. (2017) Aurélien Fichet de Clairfontaine, Christoph Hammer. *Review of International Economics.* 2017:1–24
- **Fiscal rules and twin deficits: The link between fiscal and external balances**. (2016) Harald Badinger, Aurélien Fichet de Clairfontaine, Wolf H. Reuter. *World Economy* 40(1):21–35

- **Summarizing data using Partially Ordered Set Theory: An application to fiscal frameworks in 97 countries**. (2015) Julia Bachtrögler, Harald Badinger, Aurélien Fichet de Clairfontaine, Wolf H. Reuter. *Statistical Journal of the IAOS* 32:383–402

E.3. Support on Task I: Yvan Meyer

Yvan MEYER is a consultant at Technopolis | France | since February 2021 and is specialised in the evaluation of economic policies with a particular interest in development and trade policies. He contributes to evaluations and quantitative impact assessments for international, European and national public bodies. Yvan uses data analysis, econometric analysis and social network analysis in his work.

He has recently participated in several studies using a quantitative approach: impact study of the export support system of the Bourgogne-Franche-Comté region, econometric analyses for the study of financial instruments at the service of public policies of the Provence-Alpes-Côte d'Azur region, design of a Dashboard as part of the impact assessment of the Interreg V France-Switzerland programme 2014-2020.

He has also participated in several reports on the economic impact of Brexit on the UK economy as well as the effect of population ageing in Africa.

Yvan has a degree in economics and is currently finalising his master's degree in economic analysis and policy specialising in macroeconomics and European policies at the Faculty of Economics in Strasbourg. He is fluent in French and English and has some knowledge of German.

E.4. Lead on Task II: Dr. Gerwin Evers

Dr. Gerwin Evers works as a consultant at Technopolis Group in Amsterdam. Gerwin focuses on the evaluation of science and innovation policy. Within this field, Gerwin has a broad interest ranging from the green economy, health & life sciences to regional development, with a special interest in the role of universities in science and innovation policy. Gerwin takes a systemic perspective and tries to incorporate a wide range of quantitative methods (including relevant machine learning tools), while he also has experience with, and sees the (complementary) value of, qualitative methods such as interviews.

Prior to joining Technopolis Group, Gerwin was as PhD Fellow at Aalborg University part of the Horizon2020 funded Marie-Curie Innovative Training Network that studied the Role of Universities in Regional Development and Innovation (RUNIN). Gerwin's research during his PhD focused on understanding how universities, through their provision of human capital and research collaboration (and the interaction between these two channels), can foster industrial development in their locality. Most of the studies conducted during his PhD utilised registry and Community Innovation Survey (CIS) data, while interviews and other qualitative methods also played an important role. After handing in his dissertation Gerwin worked on a project evaluating the impact of university-industry collaborations on innovation input, innovation output and performance at the firm level.

Gerwin worked previously as a junior researcher at the Copernicus Institute of Utrecht University on a project commissioned by ZonMw which aimed to map the innovation system for rare

diseases by employing a bibliometric analysis complemented with interviews and other qualitative methods. Gerwin has a bachelor's in science and Innovation Management with a specialisation in energy and transport from Utrecht University, and a master in Innovation Sciences from the same university. For his master thesis, Gerwin conducted for the Netherlands Enterprise Agency a study on knowledge sharing dynamics in publicly funded smart grid pilot projects.

Gerwin is fluent in Dutch and English, and he has basic knowledge of Danish and German.

Recent and current projects:

- Study at the functioning of the ICON-instrument, an instrument that aims to spur innovation by facilitating collaborations between knowledge institutes and private actors (VLAIO, Flanders, Belgium)
- International benchmark for the evaluation of the five national Dutch Applied Research Institutes (TO2, Ministry of Economic Affairs, The Netherlands)
- Climate assessment of the European Regional Development Fund (DG Clima)

E.5. Support on Task II: Reem Ismail

Reem Ismail is a consultant based in the Paris office of Technopolis Group. She is experienced in developing methods of quantitative and qualitative measures for innovation using textual machine learning, case studies, design thinking workshops, researches, and literature reviews. She is also experienced in innovation, research, and development funding strategies.

Reem has developed an interest in innovation policies, corporate strategies of innovation management, start-up eco system strategies and sustainable development goals. Her work has included assignments on European scientific research networks and breakthrough innovation. She has worked on national and international projects for clients including the United Nations development program, local authority of Martinique, National Research Agency (ANR) and for other type of projects in the innovation tech industry such as piloting projects on virtual assistants and chatbots in the artificial intelligence domain.

Prior to joining Technopolis Group, Reem worked for Talan Consulting based in Paris as a junior consultant and worked with clients on audits, data management, innovation strategies and robotic process automatization. She had also worked for the incubator and the social hub of Tripoli based in Lebanon as a strategy manager for innovation in the aim of helping start-ups grow faster through their business development plan. She interned as a junior project manager in the department of technology & global innovation Unit of Orange Group to work on Artificial intelligence and natural language processing projects. In addition, she Co-founded during her master 1 the junior consulting enterprise "UPS Junior Conseil" for students of Paris Sud university and held the position general secretary.

Reem obtained her bachelor's degree in Physics from the Lebanese University. During her bachelor, she worked on a research project for artificial intelligence modelling based on astrophysics data from NASA with Paris Diderot university. She holds a Master 1 from Ecole polytechnic and Paris Saclay university focused on Innovation enterprise and society for Business & Management, a Master 2 from Paris Dauphine business school, Telecom Paris tech,

Central Supélec specialized in numerical economics and innovation management, and she is pursuing a PhD in parallel of her consulting career at Paris dauphine in measuring innovation using machine learning technics. She is fluent in English, French and Arabic.

E.6. Support in Task II: Erika Van der Linden

Erika van der Linden is a research analyst at Technopolis Group, based in Amsterdam. She has a strong quantitative background in modelling societal challenges. Her focus areas are green economy, technology and innovation in emerging markets. Erika's core skills are data analysis, system dynamics analysis, and econometrics.

Currently, Erika is working on a project for the VLAIO, the Flamish agency for innovation and entrepreneurship, to research the way innovation collaboration projects between universities and companies. A second project is for the RVO, the Dutch agency for entrepreneurship, to research the research on the Knowledge and Innovation Agenda for security. Also, she is a PhD candidate at Radboud University in Nijmegen, where she focuses on challenge-driven innovation such as innovation for the SDGs.

Prior to joining Technopolis Group, Erika studied at Delft University of Technology, Leiden University and Università di Bologna; respectively a BSc and Msc in Engineering and Policy Analysis, a BSc in Sustainability, and an exchange semester in Resource Economics. She interned at ING Bank, and worked at Delft University of Technology as a researcher of metal markets and at Nationale Nederlanden as a Financial Analyst. She was a manager of startup Green Tickets (focus on sustainable travelling) and worked at startup Disdrometrics (focus on supporting farmers in emerging markets to optimize their harvests). Erika is fluent in Dutch and English.

E.7. Lead of Task III: Dr. Jan Biela

Dr. Jan Biela is a senior consultant with Technopolis Group Germany. He has a broad expertise and project leadership experience in innovation and research policy as well as impact assessments and evaluations of national and European funding programmes. He has a vast academic background in comparative analysis of policies and political institutions. A case in point is a comparative analysis of regional policies of Austria, Denmark, Ireland and Switzerland in the light of their respective subnational governance structures. In numerous other projects, he has dealt with the effects of political institutions on policy outcomes.

Before joining Technopolis Group, he was engaged at Prognos AG as a consultant for research and innovation policies. He holds a PhD in Political Science from the University of Lausanne and a Diploma (MA equivalent) in Regional Sciences from the University of Cologne. Prior to his consultancy career, he worked as a researcher at the Universities of Cologne, Zurich, Lausanne, and Utrecht, as well as at the London School of Economics and Political Science.

Jan is skilled in a wide range of qualitative as well as statistical social science research methods such as case studies, survey design, semi-structured interviews and analysis of Time series, cross-sectional and panel data. He is fluent in German and English, has an advanced knowledge of Spanish and basic knowledge of French.

Jan Biela just recently finalised the 2020 Targeted Impact Assessment for the COST Association.

Research and Consultancy Projects:

- Evaluation Women Professors Programme (project manager, client: German Federal Ministry for Education and Research, 2020/21).
- Evaluation of the funding initiative "Innovative University" (Innovative Hochschule) (project team member, client: German Federal Ministry for Education and Research, 2020/21).
- COST Targeted Impact Assessment 2020 (project manager, COST Association, 2019/20).
- Ex-ante evaluation and strategic audit of the federal funding programme on innovation in vocational training, JOBSTARTER plus (project manager, client: German Federal Ministry for Education and Research, 2019/20).
- Evaluation of international R&D networks and cooperation projects funded by the Central Innovation Programme for SMEs (ZIM) (project manager, client: German Federal Ministry for Economic Affairs and Energy (BMWi), 2019/20).
- Digitisation in research on matter and the universe (ErUM) - a comparative study (project manager, client: German Federal Ministry for Education and Research, 2019).
- Market Study: Smart Home, Smart Building, Smart Living in the German State of Hesse (project manager, client: Hessian Ministry of Economics, Energy, Transport and Regional Development, 2019).
- Utility and Impact of COST for Germany (project manager, client: German Federal Ministry of Education and Research, 2018).
- Impact Assessment of EUREKA Network Projects and Clusters Projects (project team member, client: EUREKA secretariat, 2017).

- Evaluation of the BMBF and DFG overheads funding line (project manager, client: German Federal Ministry of Education and Research, 2018).
- Evaluation of the Specialised Information Services Programme (project manager, client: German Research Foundation, 2017-2018).
- Long-term impact assessment of the research programme "Development of digital technologies " (project team member, client: German Federal Ministry for Economic Affairs and Energy, 2017).
- Impact Assessment of the Health Research Framework Programme (project team member, client: German Federal Ministry of Education and Research, 2017).
- Analysis of Regional Potential for Transfer and Innovation (project team member, client: Cologne University of Applied Sciences, 2016-2017).
- Increase of Business R&D Expenditures in Saxony-Anhalt (project team member, client: Ministry of Economy, Science and Digitalization Saxony-Anhalt, 2016).
- Internationalization, Mediatisation, and the Accountability of Regulatory Agencies, research project at the Universities of Zurich and Lausanne (funded by the Swiss National Fund, 2009-2013).
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E.8. Support on Task III: Thorben Strähle

Thorben Strähle is an analyst based in the Berlin office of Technopolis Group. He is experienced in research methods such as case studies, interviews, desk research and literature reviews.

He has developed an interest and expertise in innovation policy, corporate innovation management, innovation ecosystems, entrepreneurship education policy and impact assessment. His work has included assignments on SME policy, digitalisation and ICT, European scientific research networks and breakthrough innovation. He has worked on national and international projects for clients including the German Federal Ministry of Education and Research (BMBF), the German Federal Ministry for Economic Affairs and Energy (BMWi), EUREKA and the COST Association.

Prior to joining Technopolis Group, Thorben interned for Audi AG, Hering Schuppener Consulting and Horváth & Partners Management Consultants. He also completed a traineeship in the Strategy & Impact Unit of the European Institute of Innovation and Technology (EIT) in Budapest.

Thorben obtained his bachelor's degree in International Business from Maastricht University. During his bachelor, he spent one semester at the Universidad del Pacifico in Lima. He holds a Dual Degree Master from Sciences Po Paris and Stockholm School of Economics focusing on International Public Management and Business & Management. He is fluent in German and English and has knowledge of French and Spanish.

Thorben Strähle was directly involved as an analyst in the recently finalised 2020 Targeted Impact Assessment of the COST Association.

Recent and current assignments include:

- Study on the international STI cooperation between Europe and Taiwan (Client: Industrial Technology Research Institute, Taiwan; Role: Project Manager, 2020)

- Evaluation of three pilot innovation challenges of the German Agency for Breakthrough Innovation (2020), conducting interviews and analysis of applications for the competition, Bundesministerium für Bildung und Forschung.
- Study on the state of play of research and innovation in the area of digitalisation in Africa (2020): collecting information and drafting country and institutional profiles, preparing and conducting workshop, drafting of analysis and case studies, Bundesministerium für Bildung und Forschung
- COST Targeted Impact Assessment (2020): Conducting interviews, writing of five case studies on the follow-ups of COST Actions, drafting of comparative analysis and presentation of final results, COST Association
- Development of a brochure on standardisation and environmental protection (2020): conducting interviews, preparing and conducting workshop on the topic, drafting brochure and preparing the layout, Deutsches Institut für Normung
- Impact assessment for institutionalised European Partnerships under Horizon Europe (2019): Evaluating the EUREKA programme Eurostars-2 and preparing a Innovative SME scheme, EUREKA
- Evaluation of communication activities for international cooperation (2019): Collect and analyse qualitative data to evaluate the success of communication measures about research in Europe, European Commission

E.9. Quality control: Elisabeth Zaparucha

Elisabeth is Managing Partner and Director of the Paris office of Technopolis group. Her experience is built on studying and evaluating public policies as well providing policy advice. She has a solid experience in project management. The main fields she works for are innovation, research, entrepreneurship, technology transfer and higher education at national, European and international levels. She joined Technopolis in January 2006. She develops and implements qualitative and quantitative investigation tools and manages large teams of consultants. She is also regularly training students in evaluation and impact assessment methods.

Elisabeth has major references in the field of public policies to support innovation as well as in policies fostering competitiveness, start-up creation and entrepreneurship (capacity building and funding). She has several recent references in the field of impact assessment of which the impact assessment of the Joint Programming Initiative Health Diet for a Healthy Life (French National Research Agency, ongoing), the socio-economic Impact assessment of the Technology transfer Technology Transfer Acceleration Companies in France (ANR, 2020) or the impact assessment of the French competitiveness cluster policy (CGET, France Stratégie, 2017).

Elisabeth works in French and English.

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