Ana Sofia Coutinho de Almeida Dinis Esteves

Mestre em Biotecnologia

A RESEARCH IMPACT FRAMEWORK FOR HIGHER EDUCATION INSTITUTIONS

Dissertação para obtenção do Grau de Doutor em
Engenharia Industrial

Orientador: Virgílio Cruz Machado, Professor Catedrático,
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FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Outubro 2019

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Dedication

Dedicated to all who do not give up flying! To all those that aim and trace goals to positively impact the world while developing themselves.

Resumo

De forma genérica, o modelo e operação e financiamento às Universidades tem sofrido, na última década, intensas alterações devido à exigência de uma nova missão destas organizações, que inclui a produção de impacto socio-económico. Esta transformação tem sido intensificada pela adoção de uma agenda baseada no impacto da investigação, a qual tem vindo a ser operacionalizada de diversas formas em diferentes partes do mundo.

Apesar da importância atribuída ao "impacto societal" que deverá resultar das atividades de investigação académica, a definição deste conceito, bem como as abordagens e modelos de avaliação do mesmo, são tema de discussão e de grande controvérsia entre académicos, gestores de universidades e *policymakers*.

Atendendo a esta situação e aos desafios da agenda de investigação baseada no impacto, esta tese propôs, o desenvolvimento de uma *framework* conceptual para o impacto da investigação que possa dar resposta a alguns dos desafios existentes e assim promover o impacto da investigação produzida nas instituições de ensino superior.

Para tal, foi realizada uma primeira fase de investigação que permitiu aprofundar o conhecimento existente sobre os desafios de implementação desta agenda, como também conhecer um conjunto de crenças e valores da comunidade académica, que independentemente do contexto de investigação, podem entrar em tensão com políticas e instrumentos de promoção do impacto. Os resultados obtidos nesta primeira fase de investigação permitiram ainda validar a necessidade e interesse no desenvolvimento de uma *framework* para o impacto centrada na análise do processo de investigação académica.

Assim sendo, numa segunda fase da investigação, foram analisadas as condições (recursos) que poderão ter efeitos na produção de diferentes tipos de impacto, aqui designadas por condições de impacto. As oitos categorias de condições de impacto aqui obtidas, categorizadas em três diferentes categorias, serviram de base para o desenvolvimento de uma f*ramework* conceptual do impacto da investigação académica.

Esta *framework* juntamente com a ferramenta de avaliação do impacto aqui proposta poderá vir a ser utilizada por equipas de gestão das instituições de ensino superior e organizações de investigação, para avaliar a atual situação das organizações, bem como para fundamentar a

definição e implementação de estratégias que possam melhorar o seu desempenho no que respeita à produção de impacto da investigação.

Os resultados obtidos neste estudo poderão ainda, no futuro, produzir efeitos nas políticas e procedimentos de avaliação do impacto da investigação e contribuir para um maior envolvimento da comunidade académica neste assunto, e desta forma aumentar a eficiência e eficácia do impacto produzido pelos resultados obtidos nos processos de investigação académica.

Termos chave: impacto da investigação; investigação académica; impacto societal; instituições de ensino superior

Abstract

In general, models of operation and funding of universities has undergone intense changes over the last decade, caused by the demand for a new organizational mission, which includes the production of socio-economic impact. This transformation has been intensified by the adoption of a research impact-based agenda, which has been operationalized in different ways around the globe.

Despite the raising importance attributed to the "societal impact" that should result from academic research activities, the definition of this concept, as well as the assessment approaches and models to assess it, are subject to discussion and shrouded in controversy among academics, university managers and policymakers.

Considering this situation and the challenges of the impact-based research agenda, this study proposed the development of a conceptual framework for research impact which can address some of the current problems and then contribute to the promotion of research impact produced by higher education and research institutions.

Given this objective, a first phase of research was conducted which allowed to deepen the existing knowledge about the implementation challenges of the impact-based agenda, as well as, to unveil a common set of beliefs and values shared by the academic community, which regardless of the research context, may come into tension with policies and other instruments of impact promotion. The obtained results also validated the need and interest in developing a framework for impact focused on the analysis of the academic research process.

Thus, in a second phase of the investigation, the conditions (resources) that could have a positive effect on the production of different types of impacts, referred to as impact conditions, were analyzed. The eight categories of impact conditions here obtained, which were dived into three different categories, served as the basis for the development of a process-based conceptual framework for the impact of academic research.

This framework, together with the impact assessment tool here proposed can be used by management teams of higher education institutions and research organizations to assess the current performance of the organization in what respects to research impact, as well as, to support

the definitions an implementation of strategies that can take the organization towards and increased production of research impact.

The results obtained in this study may also produce effects on research impact assessment policies and procedures, as well as, contribute to a better involvement of the academic community in these topics and therefore increase the efficacy and efficiency of the impact produced by the results obtained in the academic research activities.

Keywords: research impact; academic research; societal impact; higher education institutions

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List of Abbreviations

EC – European Commission

EU – European Union

H2020 – Horizon 2020 European Commission Research Framework Programme

HEI(s) – Higher Education Institution(s)

HERI - Higher Education and Research Institution

IP – Intellectual Property

NSF – National Science Foundation

QH – Quadruple Helix

RAE - Research Assessment Exercise

REF – Research Excellence Framework

RIA – Research Impact Assessment

RRI – Responsible Research and Innovation

TT – Technology Transfer

TTO – Technology Transfer officer

UK – United Kingdom

UoA – Unit of Assessment

USA – United States of America

1 INTRODUCTION

> "Impact also suffers from a standard misconception. We tend to shy away from this word. We do not want to appear to have a utilitarian vision for science. We fear being characterized as philistines, who fail to see that science is a good in itself. Again, I fear we are falling into false dichotomies. [...] So, we can have a culture that, on the one hand, promotes the measurement of the impact of research, while on the other hand, understanding, intellectually, that not all research will have a concrete and immediate impact. I hope that in the next Framework Programme we can have a more sophisticated approach to this issue of impact. We can do more to capture and measure different kinds of outputs – including the unexpected ones. Because sometimes results that we don't think have impact can have a huge impact in other disciplines. We have to work on cross-impact between disciplines. We have an obligation and an incentive to be much better at understanding and communicating the impact of what we do. Not only to ministers of finance, but to the general public!"
>
> Carlos Moedas, European Officer for Research, Science and Innovation, 10 October 2016

1.1 Background and aim

The dynamics and role of Higher Education Institutions (HEIs) have been evolving over time to adapt the needs and characteristics of societies in which they operate. Regardless changes and adaptations, the importance of HEIs in modern societies, is unquestionable, specially to the social-economic development of knowledge-based societies. Hence, it is then impossible to dissociate social advances and contexts with the work performed by HEIs, both in terms of educational activities, as well as, in what regards its other main core activity of research. Therefore, studying and contributing for the reflection about the positioning and contribution of HEIs in current societies, goes hand in hand with the reflection about our social, economic, cultural and technological present contexts and intended future settings, which are topics of extreme relevance.

Following the proposal of a third mission to Universities, mainly discussed during the last decade, where the performance of social, enterprise and innovative activities, were added to the other previously existing missions of providing education and producing knowledge through research activities (Zomer & Benneworth, 2011), there are now new expected roles and responsibilities attributed to HEIs. This new mission introduced changes in the paradigm of knowledge production which was extended from an uninterested form of research driven by the autonomy of scientists and their host institutions (known as 'Mode 1') to a practical-oriented, transdisciplinary knowledge, targeted to societal needs or market interests (‘Mode 2’) (Gibbons *et al*., 1994).

Although some authors, as is the case of Mercelis, Galvez-Behar and Guagnini, (2017), argue that this mode of knowledge production is in fact not new, defending that the market value of science, as well as its importance for economic and political powers, have been felt in societies and research institutions along the last centuries, the pressure that this organizations feel nowadays to produce and focus more on innovation and impact, is unquestionable.

The debates about public research policies have been shaped by the so-called research impact-based agenda, which guides research and its outputs towards societal needs and focus on the positive changes that research is capable to produce outside the borders of research institutions, i.e. effects that go beyond the “simple” production of knowledge. This impact-based research agenda (hereinafter referred simply as “impact-based agenda”, for convenience purposes) has been adopted worldwide, especially in countries and regions where research and development (R&D) activities are considered to be strategic for the regional economic development and, therefore, receive heavy public investments.

The most known example, which pioneered the implementation of clear measures to the promotion of an impact-based agenda, took place at the United Kingdom (UK), where the production of research impact was analyzed and used as metric to evaluate the performance of national HEIs (Research Councils UK, 2011). In this assessment exercise, performed for the first and only time in 2014, the term “research impact” was defined by the Research Councils of the UK, as a positive effect created outside the boarders of the academic organizations (Research Councils UK, 2014a). For coherency purposes, this general definition, better described in section 2.2.1, will be also applied to the use of the term “research impact” made along this thesis.

Besides this exercise to assess the performance of HEIs in the UK, which consequently determined research funding accordingly, other movements towards the production of research impact, have been felt, specially within the research funding policies and instruments across different countries and regions. Even before 2014, European Commission (EC) introduced the term Responsible Research and Innovation (RRI) in their research funding strategic documents (Italian Presidency of the Council European Union, 2014) and reinforced the importance attributed to the production of societal impact by research activities candidate to receive European funding (European Parliament and the Council of European Union, 2013). The same happened in other geographies, such as the United States of America (USA), where the term “broader impacts” have been used with the same meaning as the previous described “research impact”, and is being guiding the National Science Foundation (NSF) in their decisions for attribution of research funding (National Science Foundation, 2017).

Within this new context, universities are under increased pressure to improve their engagement with communities (Miller, Mcadam, & Mcadam, 2016) and focus on innovation and societal impact as the outcome of a responsible research and innovation strategy (Owen, Stilgoe, & Macnaghten, 2012).

As a result of this new agenda for research, changes have been produced on the expected roles of academic researchers, who have now to pursuit research activities that lead to impact, as well as, be able to demonstrate the impacts previously created or to be created by their research activities.

Several studies, especially conducted in the UK, have been revealing that academic researchers assume not to be comfortable with their new expected roles and are generally concerned about the perverse effects this research agenda might have in academic research activities and, more broadly, in academic organizations (Colley, 2014; Gillies, 2014; Detourbe, 2016; Evans, 2016; Chubb, & Watermeyer, 2017; Freedman, 2017; Head, 2017; MacDonald, 2017; Smith, & Stewart, 2017; Angulo-Tuesta, Santos, & Iturri, 2018).

Consequently, there is an identified tension between the impact-based agenda and the academic community, and this tension is in need of attention, as mentioned by De Jong, Smit and Van Drooge (2016) when referring to the importance of finding a consensus between policymakers and academic researchers in what refers to societal impact of research.

Considering that impact and the “Measured University” debate are not considered to go away any time soon (Mitchell, 2019), this thesis aims to contribute to smooth actual challenges of the impact-based agenda for research, more specifically to the development of the Research Impact Assessment (RIA) field, through the proposal of evaluation indicators and the development of a new research impact framework.

1.2 Objectives

Therefore, and taking into consideration the contribution made by RIA approaches currently in place to the existing tensions and controversy about the impact-based agenda (Stevie Upton, Vallance, & Goddard, 2014), the objective of this study is to propose a new conceptual RI framework which can be used by managers of Higher Education and Research Institutions (HERIs) for the promotion of research impact, internally.

Contrarily to the majority of existing RIA frameworks, which analyze and measure impact by looking at different types of impacts produced, hereinafter referred to as "outcomes-based RIA frameworks" (further described and presented in chapter 3), this study aims to develop a process-based RI framework, which can be used to the development of RIA instruments, as well as to potentially produce positive changes on the ways how the impact-based agenda is being implemented in practice. This change on RIA focus, from outputs to the process of research activity, was in fact already supported by some authors, such as Upton, Vallance and Goddard (2014).

Through a novel approach to research impact, that starts by better understanding existing tensions between academic community (more specifically those working within the fields of sciences and engineering) and the impact-based agenda, this thesis aims to unveil the resources needed during the research process to produce impact, here called as "research impact conditions" or "impact enablers", based on which a new process-based research impact framework can be developed.

In summary, by adopting a user-centered approach to both (understand the associated problems and suggest possible solutions), this research intends to present guidelines on how to deal with and to maximize research impact at HERIs, through an approach that intends to avoid or reduce the confronts between the impact-based agenda and the academics' beliefs and values. The results of this study can also inform policymakers to design and propose more efficient and effective policies and instruments within the research impact-based agenda.

1.3 Research questions and methodological approach

To accomplish the previous described objectives, this study proposes a bottom-up approach, based on an interpretivist approach and qualitative methodology, where the following research questions are addressed along this thesis:

Research Question 1

To what extent can the use of a outcomes-based research impact assessment approach (compared to a process-based approach) be related with the existing tensions between academic community and the research impact agenda?

Practical applications of existing process-based research impact assessments frameworks are very limited, as well is the research about tensions between the academic community and the decisions of policymakers to promote research impact.
In order to advance the knowledge about the advantages of a process-based RIA approach and support the development of a process-based RIA approach to act upon existing challenges of the impact-based agenda, the following sub-research questions will be answered in this thesis:

Research Question 1.1

What are the characteristics of the impact-based agenda and existing frameworks and models to assess research impact?

This thesis shall explore, through an extensive literature review, all aspects related to the impact-based agenda, including research impact definitions, impact related policies and other practices in place, as well as, existing frameworks and models to assess research impact.

Research Question 1.2

What are the perceptions of academic community towards the research impact-based agenda?

Existing studies about the tensions between academic community and the research impact agenda are very limited to specific geographies and therefore to specific research contexts. Therefore, to confirm the need to develop a process-based research impact framework, it is necessary to expand the existing studies to other geographies, as well as, to create a general picture about academic community values and beliefs that are in tension with the impact-based agenda. A qualitative study shall be conducted to better understand the perceptions of the academic community towards the policies and practices related to research impact, as well as to understand the motivations of academic researchers to produce impact.

Research Question 2

What can be the characteristics of a process-based conceptual framework to research impact at HEIs?

Following the main aim of this thesis which is the development of a conceptual framework to research impact, the following sub-research questions will be addressed:

Research Question 2.1

What are the enabling conditions for the production of research impact?

To develop a process-based framework, it is necessary to unveil the conditions of the research process that can enable the production of impact. This thesis will use available sources of information, which consist in documents reporting research impact results or giving advice to its production (namely research impact case-studies and innovation standards, respectively), together with information collected through interviews made to academic researchers, about incentives, enablers, as well as existing barriers to the production of research impact.

Research Question 2.2

How to model the impact enabling conditions within the academic context?

After the identification of impact conditions, it will be necessary to study the application of each concept and its possible performance indicators for the specific case of the academic context, which can allow the development of instrument assessments that apply the RI framework to Higher Education Institutions. This study will be based on a literature review together with the application of focus groups to validate the critical review of the collected information.

1.4 Structure of this thesis

According to the previous described aims for this thesis and the short description of the methodological approach applied to each research question, this thesis has been organized into 8 chapters which follow the structure described in figure 1.

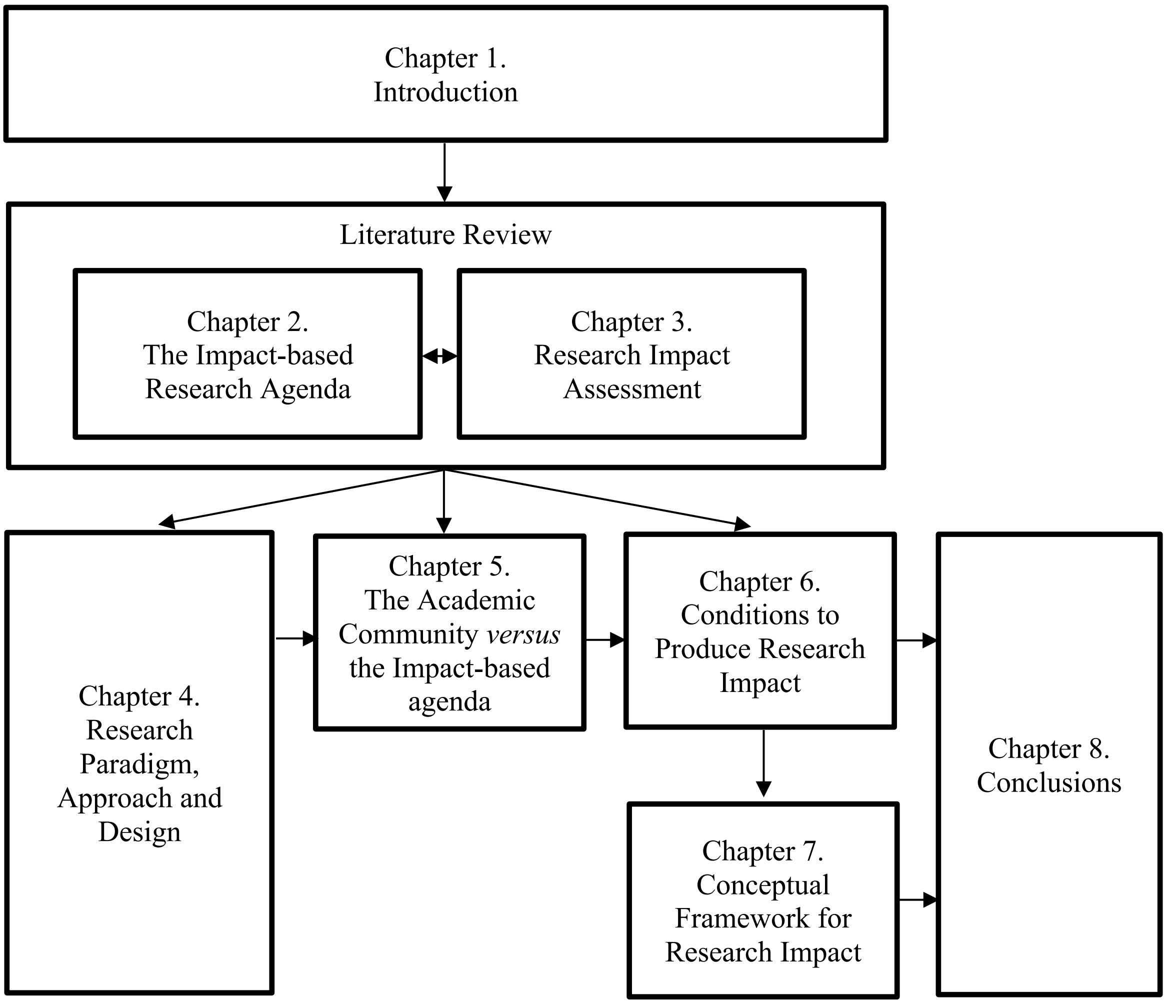

Figure 1 – Thesis Struture

Chapter 1 introduces the background of this study by explaining the importance of research impact, and more specifically the impact-based agenda that is affecting academic research activities and, more generally the entire system of HERIs. This chapter also introduces the aim of this thesis and the research questions to be addressed, as well as includes a short description of the methodological approach to be used in each of the research questions and sub-questions. Moving forward, chapters 2 and 3 contain a literature review of the complete outlook of the impact-based agenda, including definitions for research impact, the most common formats how the agenda is being enacted into practice, as well as, research impact assessment approaches, frameworks and models. Besides defining the research context and presenting a critical analysis on the literature review on RI assessment, chapter 3 also address research question 1, more specifically the sub-research question 1.1.

Chapter 4 describes the research paradigm, approach and design, including the research methodology and research methods to be used in each section of this study and necessary to address each research question previously described.

Chapter 5 details the qualitative study performed to better understand the existing tensions between academic community and the impact-based agenda, and to justify the importance and need of developing a new research impact framework, more specifically with a process-based approach. In this chapter the answers for sub-research question 1.2 can be find, and more generally, conclusions to the research question 1 can be drawn.

Chapter 6 describes the first part of the RI conceptual framework development, where the enabling condition to produce research impact, are studied. This chapter initiates the work on research question number 2, more specifically on sub-research question 2.1. To address this sub-research question, chapter 6 presents the analysis made to impact case studies, innovation standards and the perceptions of academic researchers about the enablers and obstacles to the production of impact. All results of the previous described studies, together with the literature review present in chapter 3, are used to the conclusions proposed in chapter 6 (according to the illustration presented below, here present for clarification purposes).

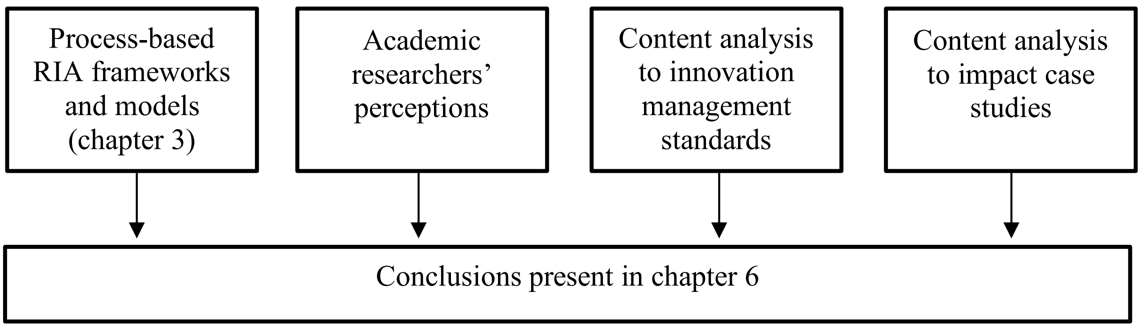

Figure 2 - Inputs to conclusions presented in chapter 6

Chapter 7 presents the second and bigger part of the conceptual framework development, which ends up naming this chapter. In this section, the concepts resulting from the studies performed in chapter 6, are analyzed within the academic context. This analyzes include the proposal of possible performance indicators which can be used to assess each research impact condition that is part of the conceptual framework here developed. This chapter addresses the sub-research question 2.2, and together with chapter 6 contributes to answer research question number 2.

Lastly, chapter 8 presents a thesis overview and discusses the main conclusions and contributions of this thesis, its theoretical and practical implications, as well as, propose recommendations for future research and development. This chapter summarize and analyze the conclusions of chapters 5, 6 and 7, where the main contribution of this thesis lies on.

2 THE IMPACT-BASED RESEARCH AGENDA

2.1 Changing societal role of HEI and the importance of research impact

Society and science have had, along the history, an intertwined pathway where impacts from one another shape a complex system towards, what is expected to be, evolution and progress. In this symbiotic relationship, changes in society have assuming a crucial role in transforming scientific practices and therefore affecting scientific production institutions, as academia (Pestre, 2003).

Changes in models of scientific knowledge production have been affected, and also producing effects, in the evolution of relationship between societal organizations that have been directly involved with the process of putting the scientific knowledge into use. The relationship between these institutions, that include academia, industry and the state, have been evolving along time, in what is defined, from the perspective of the scientific knowledge production, as different phases in the organization of science (Mirowski, 2011, 2012). These different stages were defined by the author Mirowsi (2011) as 'temporally specific 'regimes' of economic and social organization, intertwined with changes in the ecology of the sciences themselves'.

In 'Mode 2' of knowledge production, which at the beginning of 21st century was considered the dominant model in Western societies (Pestre, 2003), societal needs and market interests were in the base of processes involving knowledge production (Nowotny, Scott, & Gibbons, 2001). Unlike the previous dominant 'Mode 1' defined by an uninterest form of research, 'Mode 2' is based and motivated by the application of knowledge, and involves transdisciplinarity in a first response to a need of social accountability and quality control (Gibbons *et al*., 1994; see also Nowotny, Scott, & Gibbons, 2001; Nowotny *et al*., 2003). This knowledge production system requires a very dynamic and efficient relationship between the previous mentioned institutions that act upon the application of knowledge and which were, together, considered necessary to the creation of value through innovation and part of a very known regional level innovation ecosystem, represented by the Triple Helix (TH) model (Etzkowitz & Leydesdorff, 1995).

Due to the specificities of certain contexts, TH model of innovation, was then expanded, from the triangulation of academia, industry and government, to a bigger number of helices (Leydesdorff, 2012), with special emphasis given to the Quadruple Helix (QH) innovation concept first discussed by Leydesdorff and Etzkowitz (2003) and supported by several authors

(Afonso, Monteiro, & Thompson, 2012; Carayannis & Campbell, 2009; Kolehmainen *et al.*, 2016). In the QH innovation concept, the forth helix represents "the public" or "civil society" (Leydesdorff & Etzkowitz, 2003), accompanying the 'Mode 3' of knowledge production (Carayannis & Campbell, 2006), which "captures the notion of an innovative community" (Schoonmaker & Carayannis, 2013, p. 558).

All these changes stress the need to rethink science and adapt the models of knowledge production to the current societal contexts (Nowotny, Scott, & Gibbons, 2001), and end up affecting Higher Education Institutions (HEIs), as main contributors to knowledge production through scientific research. HEIs are then asked to fulfill a third mission, that goes beyond education and basic research, and includes now the realization of socio-economic and innovative activities (Zomer & Benneworth, 2011).

In line with "Mode 3" and the QH model, and reinforced by the attested inefficiency of academic current used models and practices to enact innovation promoted by HEIs (Fletcher & Bourne, 2012; Livesey, Finbarr, Minshall, & Moultrie, 2006; Natsheh, Gbadegeshin, Rimpiläinen, Imamovic-Tokalic, & Zambrano, 2015), which are creating tensions between researchers and businesses, science and commerce; and the greater good and market iterations (Daniel & Klein, 2014); universities are being asked to rethink their model (Miller *et al.*, 2016), and to reinforce their focus on the production of knowledge that could benefit societies through the creation of societal impacts.

From the last decade of the 20th century, civil society in general is becoming more demanding in what regards to documenting, describing or publicizing the benefits that science is creating for society (Martin, 2011). In response to this need to understand and demonstrate, to the general public, the benefits of research that is being funded (Feller, 2017), was created a movement towards what is now known as "the impact agenda", where academic research activities are oriented by the principles and goals of research impact creation[1].

In this impact agenda, the concept of research impact gained a new dressing, going from the most traditional internal impact produced at academia and attributed by peers, known and hereinafter referred as academic impacts, to a broader and more complete version of this concept

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[1] Along this thesis the term "academic research impact creation" is employed as reference to the benefits created through the application of results generated by scientific research activities taking place at HEIs.

that includes impacts generated outside academia (also known as non-academic impacts), which can be perceived and also evaluated by stakeholders outside academia. Following this, the scope of research evaluations became also broader (Mostert, Ellenbroek, Meijer, van Ark, & Klasen, 2010), including what is considered a much more complete approach than using only metrics of academic impacts, such as the number of publications and citations (Bornmann & Marx, 2014).

Feeling the pressure to justify public investments made in research (Wiek, Talwar, O'Shea, & Robinson, 2014), governmental initiatives of HEIs and research funding, marked a turning point to an increased awareness and concern about this broader format of research impact. Due to the importance of governmental funding to HEIs and research activities, it is now impossible for academic researchers and universities to avoid considering research impact if they intend to remain competitive (Chowdhury, Koya, & Philipson, 2016).

Research impact then assumes a prominent place of importance within the academic context and is especially relevant for HEIs that have been working towards a research-oriented positioning, which are from hereinafter referred as Higher Education and Research Institutions (HERIs).

2.2 Research Impact Definition

2.2.1 The perspective of policymakers

In 2006 Australia led the global movement of research impact assessment and was responsible for the first global attempt to comprehensively capture the socio-economic impact of research across all disciplines through the development of the Research Quality Framework (RQF). RQF proposed a case study approach where researchers were asked to evidence the economic, societal, environmental, and cultural impact of their research within broad categories (Penfield, Baker, Scoble, & Wykes, 2014). Although part of this framework was implemented in the Australian Research Network, this exercise was never extended or replicated due to a change in the Australian government which took place in 2007 (Penfield *et al*., 2014).

However, this same case study approach and the metrics used to capture impact generated by research activities, inspired the United Kingdom, that adapted the Australian framework to perform a national research assessment exercise to evaluate HEIs performance and fund them accordingly. The UK's Research Excellence Framework (REF) took place in 2014 and was the first national research assessment exercise where research impact, defined as “an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia” (Research Councils UK, 2014a), was evaluated. From REF’s definition of impact were excluded “impacts on research or the advancement of academic knowledge within the higher education sector (whether in the UK or internationally)” and “impacts on students, teaching or other activities within the submitting HEI” (Research Councils UK, 2011). However, previous mentioned impacts on students or teaching activities, can be included in cases where “they extend significantly beyond the submitting HEI” (Research Councils UK, 2011).

In the REF exercise, a panel of experts (including people from and outside academia), analyzed case studies submitted by HEIs, searching for benefits created in one or more areas of culture, the economy, the environment, health, public policy and services, quality of life, or society, whether locally, regionally, nationally or internationally (Research Councils UK, 2012). Different panels of evaluation were created in REF to assess different research fields, and possible types of impacts created by each field were also identified by the Research Councils of UK in order to facilitate the work of the evaluators (Research Councils UK, 2012).

More recently, Australia has revived the debate about research impact and ended up implementing an assessment of impact produced by HEI, performed in 2018-2019. In this approach to impact assessment, Australia was considered to use interesting innovations compared with the REF exercise, including a differentiation between research engagement and research impact, where the first stands for interaction between researchers and research end-users, and the second represents the contribution research makes to the economy, society and environment (Williams & Grant, 2018).

By its turn the European Commission (EC) integrated the term “societal impact” in the philosophy used to design its research funding framework programs (European Commission, 2011). Societal impact, defined by the combination of (a) social (b) cultural (c) environmental and (d) economic benefits (Bornmann, 2013), is very much used in the European context, having even derived in a funding line itself called “societal challenges” (European Commission, 2013), which uses a challenge-based approach to generate research-based solutions to seven different identified topics. This funding program makes part of the last European Framework Programme for Research and Innovation – Horizon 2020 (H2020); which covers the period from 2014 to 2020, and where researchers applying for the majority of available funding types, need to describe and justify the expected future impacts of their research proposals (European Commission, 2011). Considering this, along with "excellence" and "quality and efficiency to implementation", impact is also used as a third criteria to evaluate H2020 research funding applications (European Commission, 2017).

In the United States (US), a country where there is great focus and investment on research, the presence of the impact agenda is also greatly felt. The US National Science Foundation (NSF), also assess the future possible research impact that can be generated by a research project that applies for funding (National Science Foundation, 2017) societal impacts are also being increasingly assessed and emphasized by reviewers of NSF's grant applications (Holbrook & Frodeman, 2011).

As it will be seen in section 2.3, the impact agenda has been used for different purposes in different parts of the world. Despite this, the definition given to the concept of research impact by policymakers and organizations responsible for policies' implementation, follows the main terms and guidelines that were previously presented.

2.2.2 The perspective of the academic community

Beyond policymakers, also members from the academic community have been discussing the research impact concept definition and presenting their perceptions and opinions about the impact agenda that affects academic research activities and HERIs.

Most of existing scientific literature about research impact discusses the definition of this concept within a specific field of research, where also specific types of impacts are mainly expected. This suggests, as some authors also clearly support, that the definition for research impact is highly dependent on the research field in study and confirms the vision of Research Councils in the UK, that separated different fields of research and respective types of impacts for the REF assessment exercise.

Studies existing in the literature naturally reflect the regional or local research policy context and the implemented impact agenda-based practices and instruments. Therefore, the majority of academic studies about research impact are from the UK, where REF is creating major effects among the scientists of UK's HEIs.

Within the few academic studies proposing general definitions for research impact, it is found the article by Terama *et al*. (2016), where it is proposed a division of research impact into six classes, which include education, public engagement, environmental and energy solutions, enterprise, policy and clinical uses (Terama *et al*., 2016). More recently, Darby (2017) ignite the discussion of a "forgotten" type of impact consisting on the "(…) "simple" contribute of knowledge through the existence of a space for reflection". This goes out of the common spectrum of expected and evaluated types of impact, where research is judged by its economic and social benefits (Gunn & Mintrom, 2017) and suggests the existence of a relation between the academic and non-academic types of research impact, by acknowledging that academic impacts can precede those created beyond academia.

Great interest about research impact and the possible representations that can be assumed by this concept exist within the field of healthcare and health related services. This may probably happen due to the easier association between these fields of research and the creation of social impacts, which are considered an important requirement to healthcare areas and defined by Abma *et al.* (2017), as "an effect on society, culture, quality of life, community services, or public policy beyond academia". Research impact in the fields of public health, health services and primary care is considered to occur when "research generates benefits (health, economic, cultural) in addition to building the academic knowledge base" (Greenhalgh, Raftery, Hanney, & Glover, 2016).

In the scientific literature, it is also possible to find studies discussing the forms that research impact can assume in other fields of research. Economic return, impact on society, and combinations made between economics and environment, health and economics, public policy and environment, and finally between environment and preserving options for the future, can be generated by research results in the field of Agriculture (Gaunand *et al.*, 2015); impact on policy it is considered to be generated by education(al) research (Lingard, 2013) and research in the field of economics (Doraisami & Millmow, 2016); and impacts in a more conceptual form or through an indirect pathway, can arise from research in sociology and criminology (Cherney & McGee, 2011), mathematics (Meagher & Martin, 2017) and political sciences (Head, 2017).

The definition of research impact is far from being either a static or a consensual concept, and greatly depends on the perspectives of those who are defining it. As stated by Terrama *et al.* (2016), research impact does not only vary from discipline to discipline, as it has been differently interpreted among researchers and institutions that are creating their own interpretations of impact not necessarily following the views presented by policymakers. For example, in the field of political sciences there was found some discomfort in relation to the multiple existing accountabilities of impact to diverse audiences as well as supported that funders and other research stakeholders have a narrowed definition of value (Head, 2017).

Since research impact produces effects beyond academia, not only the researchers but also the receivers of research results, should be taken into consideration when it's time to define what impact is. This vision is supported by Bainbridge *et al.* (2015), who studied the impact in the specific context of Australian health research.

Despite the differences in interpretations, it is already known that researchers are motivated to produce their terms of research impact, meaning "making a contribution to scientific/academic knowledge", "intellectual curiosity or personal interest in the subject" and "engaging in interesting or exciting work" (Stevie Upton *et al.*, 2014). A very similar finding was presented in the field of library and information studies, where the pursuit of knowledge, per se, was found to be the strongest motivation behind the research activity (Roberts, Madden, & Corrall, 2013).

Table 1 presents the main studies found in the literature where the concept research impact is defined or generically discussed, and which collectively helped to define the perspectives of the academic community in what regards to the definition of the term "research impact".

Table 1 – Main peer reviewed studies about defining research impact

Reference	**Research field**	**Main findings / contribution**
(Evely *et al.*, 2010)	Environmental research	Authors discuss the absence of a clear definition and classification for cross-disciplinary research that despite being increasing does not show much depth on integrating disciplinary methods and does not have much impact on participants outside of academia.
(Bunn & Sworn, 2011)	Healthcare research	The authors assume that systematic reviews have been a key input to produce impact in the area of healthcare, despite the existent concern that the impact produced in the policy sphere it is not yet optimized. The authors suggest strategies such as active dissemination and knowledge transfer to maximize the impact of systematic reviews in the healthcare policy ecosystem.
(Cherney & McGee, 2011)	Social sciences	Academic sociologists and criminologists see the use of their research in a conceptual form.
(Lingard, 2013)	Education	In this study the author showed that educational research affects policy in multiple ways and varying timeframes, where academic research has typically long-term applications and commissioned research present shorter-term impacts.

Reference	Research field	Main findings / contribution
(Roberts *et al.*, 2013)	Library and information studies.	Found that the strongest motivations to academic researchers conduct their activity are the contribution to practice in the field, expression of professional identity, personal enjoyment and the pursuit of knowledge. This study also maps the ways of connecting research with practice and presents recommendations for strengthening this relationship in the library and information field.
(Stevie Upton *et al.*, 2014)	Generic	The most important factors of personal motivations for pursuing research impact were found to be ‘making a contribution to scientific/academic knowledge’ and ‘intellectual curiosity or personal interest in the subject’. Another identified motivating factor was “engaging in interesting or exciting work”. Also, the most cited requirement for, and frequently barrier to, knowledge exchange was time.
(Bainbridge *et al.*, 2015)	Health	Impact should be accounted by a balance between the interpretation of the giver (researcher) and the receiver (user).
(Gaunand *et al.*, 2015)	Agriculture	Although the economic dimension is the more frequent type of impact on society, the Public research organization analyzed has also other kinds of impact that appear mainly in combination, being economics and environment, health and economics, public policy and environment, and environment and preserving options for the future, the most frequent combinations.
(Greenhalgh & Fahy, 2015)	Public Health, Health Services and Primary Care	The authors found that there are mainly direct and short-term impacts one step removed from patient outcomes, what is contrary to the published evidence on research impact where impact occurs indirectly through non-linear mechanisms.
(Jarman & Bryan, 2015)	Anthropology	Evidences on how anthropology researchers successfully demonstrate the impact of their work in the public sphere.
(Doraisami & Millmow, 2016)	Economics	The authors found that the majority of articles studied (from a specific renowned journal in the area of economics) are not connected with local policy issues and they assume that a possible explanation can be the existence of a great number of top researchers who did not obtained their doctorates in the local context.
(Terama *et al.*, 2016)	Generic	Through the analysis of impact case studies and respective evaluations in the UK’s REF, authors found that institutions have developed different interpretations of impact that vary from discipline to discipline and between institutions, and also diverge from the funding guidelines. It was also found a positive correlation between impact score and research quality score.
(Gibson & Hazelkorn, 2017)	Arts and humanities	Definition of public benefit while still having economic impact in the fields of arts and humanities.
(Head, 2017)	Political science	The author found different definitions of value among diverse audiences, like funders and other research stakeholders. Despite the direct influence of political sciences research, the author advocates a greater contribute through and indirect pathway, that in his view have been underestimated.
(R. Thomas & Ormerod, 2017)	Tourism Management	Correlation of academic impact metrics with non-academic impact, specifically in policy.

2.3 Impact-based research agenda in practice

Despite the first proposal made in Australia to use research impact as a metric of evaluation of HEIs, it was with the Research Excellence Framework (REF) exercise, performed in 2014 by the United Kingdom, that the term research impact gained an imponent place in the table of debate within HEIs and among academic researchers.

REF is the new system for assessing the quality of research in higher education institutions in the UK, and replaces the Research Assessment Exercise (RAE), last conducted in 2008. This HEIs exercise was conducted jointly by the Higher Education Funding Council for England (HEFCE), the Scottish Funding Council (SFC), the Higher Education Funding Council for Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DEL), together refereed to Research Councils of UK. REF exercise evaluated research outputs, impact and research environment, in order to assess HEIs and inform future research funding. The weigh that impact had among these three elements of assessment will increase from 20% in 2014 to 25% in the next assessment exercise that will take place in 2021 (Research Councils UK, 2019), what increases even more the importance and future debate of this thematic among the academic sector, and highlights the emphasis attributed by policymakers to knowledge exchange (Williams & Grant, 2018).

After the implementation of REF, Australia came back to the game, and announced the development of a national engagement and impact assessment, which was done through the publication of the National Innovation and Science Agenda on December 2015 (Department of the Prime Minister and Cabinet, 2015). This Agenda derived into a pilot exercise to assess impact, which took place in 2017 (Australian Research Council, 2017), and the further implementation of the engagement and impact assessment exercise, which started in 2018 (Australian Research Council, 2019).

The last European Union's Research and Innovation Programme - H2020; is also a great example of the concerns and focus on impact and the maximization of societal returns on investment in research. This is very clear through the analysis of the three priorities of this Framework Programme that consist in having excellent science, industrial leadership and societal challenges (European Parliament and the Council of European Union, 2013), together with the adoption of a Responsible Research and Innovation (RRI) approach (Italian Presiency of the Council European Union, 2014).

This new impact focus and approach used by research funding agencies has being felt in many other parts of the glob beyond Europe and Australia. In 2015, Justin Trudeau as Prime Minister of Canada addressed mandate letters to the Minister of Science and the Minister of Innovation, Science and Economic Development, where clearly states the importance of investing in research that will return benefits for the Canadians in general, through a "balance between fundamental research to support new discoveries and the commercialization of ideas", and the intention of using research results to inform governmental decisions (Trudeau, 2015a, 2015b). Also, in the United States research impact or as it is there referred to "broader impacts", is one of the two major criteria used by NSF to their funding programs and decisions (National Science Foundation, 2017).

Research impact is being assessed by governments, funding agencies and research organizations, to evaluate the success of programs, policies or investments to therefore support future strategies and provide accountability to funders. Besides the previous mentioned regional contexts where research impact is representing an important position within strategies and policies related with research and innovation, also many other governments and research funding organizations, have been assessing and monitoring impact of previous and on-going programs to provide accountability of investments made and also prepare, justify and strengthen future strategies and instruments to research funding. Examples of this exist in the European Union assessment and monitoring of research and innovation programmes (European Commission, 2019a); in the United Kingdom to the monitoring to the funding attributed by the REF exercise (UK Research and Innovation, 2019); in Spain where Research impact assessment is performed in the context of health science programmes; in the United States through the monitoring of societal impacts produced by research funded by National Science Foundation (National Science Foundation, 2017) or the case of the US Department of Energy's Office of Energy Efficiency and Renewal Energy that performed studies to evaluate the returns of their research portfolios (Gallagher *et al*. 2012, Link *et al*. 2015); in the Netherlands through the research assessment protocol implemented by the Association of Universities in the Netherlands – through a joint collaboration that developed a protocol to assess research in the Netherlands, (Association of Universities in the Netherlands (VSNU), the Netherlands Organisation for Scientific Research (NWO), 2014); in Australia where it was developed an impact model to be applied in different research fields (Commonwealth Scientific and Industrial Research Organisation, 2019); in France, the French National Agricultural Research Institute also measured the socio-economic impacts of public sector agricultural research (Joly *et al*., 2015 ; Graunrand 2015); in Canada, among others.

2.4 Challenges of the impact-based research agenda

The analysis of manuscripts referenced in table 2 paints a very clear picture of the existent controversy around the thematic of research impact, where different perspectives from different stakeholders, ranging from academics, university administrators, policymakers, business related people and other research users, must be considered. This controversy also caused by academic emotional dissonances in response to an impact agenda (Chubb, Watermeyer, & Wakeling, 2017), is demanding the collaboration and involvement of the different stakeholders in defining and assessing research impact, with especial interest in the alignment between researchers and policymakers (Ion, 2012; Lightowler & Knight, 2013; Watts, 2016; Meagher & Martin, 2017; Angulo-Tuesta & Pacheco Santos, & Iturri, 2018).

The subjectivity in defining and assessing what is societal impact is a great cause of existing controversy around academic research impact. Societal impacts are by nature a very subjective matter insofar as it is necessary to judge about its positive or negative effects on society (Penfield *et al*., 2014; Gunn & Mintrom, 2017). Therefore, also methods to assess these types of impacts, further described in chapter 3, preferably use qualitative tools (Gunn & Mintrom, 2017), contrary to the most traditional and less subjective quantitative methods used to measure academic types of impacts (Claire Donovan, 2011). Other challenges in assessing research impact, include the exaggerated focus on short-term impacts and automated approaches to assess research impact are considered alarming (Greenhalgh, Raftery, *et al.*, 2016), the possible effect of current assessment methods on the devaluation of 'blue skies' research and reduction of the pure and creative quest for knowledge to the detriment of direct economic impacts (Buxton, 2011; Penfield *et al.*, 2014) and the difficulty and the inappropriate of research impact metrics to assess institutions (Dixon & Hood, 2016). In the review made by Penfield *et al.* (2014), there is also reference to other challenges in research impact assessment, defined as the "time lag" which refers to the time difference between the realization of research and its impact, the "developmental nature of impact" which , the "attribution" – difficulty to relate one or more research outputs with a specific impact, and knowledge creep – absorption of knowledge over time.

Gunn and Mintrom (2017) argue that, since research activities and their impacts can be very difficult to predict, a direct command and control from government or funding agencies in general, is not really suitable nor would it be effective. This kind of policies could restring the academic freedom of academic research (Colley, 2014) and force a neoliberal status quo of the academic work (Rhodes, Wright, & Pullen, 2018).

If on the one hand academics want to have a more democratic, inclusive, independent, ethical and impactful research system (Colley, 2014; Bergman, Delevan, Miake-Lye, Rubenstein, & Ganz, 2017), on the other hand there is a resistance to have their research defined in policy terms (Detourbe, 2016; Rhodes *et al.*, 2018). And since public funding is still fundamental to the majority of academic researcher, what happens is that when asked for demonstrations of future impacts, researchers not only struggle with this task (Watermeyer, 2012), but also exaggerate and work out their impact claims on research funding applications, for funding success purposes only (Chubb & Watermeyer, 2017).

This pressure applied by the need to capture public funding and the importance that impact is now having in research funding instruments, raises also ethics, equality and justice related concerns. These concerns are especially important in the fields of healthcare and social sciences, where it is defended the importance of focusing on creating good rather than in responding to the demands of policies or higher education guidelines (Blazek *et al*., 2015; Evans, 2016; Rolfe, 2016; Freedman, 2017; MacDonald, 2017).

Another important aspect, mentioned in the literature is that, academic organizations, there is a recognition of lacking incentives and rewards, generally from academic organizations, which could make a great difference and contribute to better align academic researchers with the impact agenda (Ballabeni, Boggio, & Hemenway, 2014; Bergman *et al.*, 2017; Missingham, 2016).

Table 2 presents findings and the contributions of main scientific per reviewed literature, where the challenges of the impact agenda are identified and discussed, which complements the critical analysis previously presented.

Table 2 - Main peer reviewed studies presenting and discussing tensions and challenges of the impact agenda

Reference	Research field	Main findings / contribution
(Buxton, 2011)	Generic	The author concludes that impact indicators used by research funders are poor predictors of the broader impact that may eventually arise.

Reference	Research field	Main findings / contribution
(Claire Donovan, 2011)	Generic	The author argued that impact is an important evidence to increase research support in all fields and should have a meaning broader than economic returns, despite the differences among disciplines. The author demonstrated that metrics-only approaches to impact assessment are behind the times and pointed out the lack of engagement between research evaluation specialists and the broader academic community, and a lack of consultation between policymakers and the research evaluation community.
(Lightowler & Knight, 2013)	Social sciences and humanities	This study identified a tension between the research impact agenda and the value placed on knowledge brokerage, due specially to funding models, short-term contracts, and posts combining knowledge brokerage with other functions.
(Shortall, 2013)	Generic	The article concludes that the idea of impact' and use-value' is extremely complex and depends on the policy context of knowledge power struggles, and on how policymakers want to view the world.
(Colley, 2014)	Educational research	This paper critics the current view on the impact agenda, defending that alternative perspectives are needed, specially not to put academic freedom in question.
(Gillies, 2014)	Educational research	This study "acknowledges the risk to academic integrity and objectivity of such overtly political behavior but argues that remaining outside the political sphere simply guarantees minimal research impact".
(Penfield *et al.*, 2014)	Generic	Authors concluded that impact assessments, mainly in public promoted exercises: - are highly dependent from the ability of researchers to write a persuasive text; - could benefit from increasingly use the mixed-method case study approach; - should make a distinction between applied research and basic research with higher potential to create long-term impacts.
(Dallyn, Marinetto, Cederstrom, & Cederström, 2015)	Generic	Authors present a view where the academic public intellectual - an 'independent spirit' that fearlessly challenges unjust power; refers to a temperament, "which is *in* but not *of* the academic profession", and this academic should "aspire to go beyond academic institutional norms and requirements" to achieve research impact.
(Khazragui & Hudson, 2015)	Generic	In this study, despite the authors recognition of the REF's merit when assessing impact through case studies analysis, they defend that these narratives are still not enough and do not solve issues regarding timeframe and spatial differences, suggesting that universities need to continue collecting data to facilitate improved analyses in the future.
(Russell & Lewis, 2015)	Anthropology	The authors used an impact case study to demonstrate that some forms of impact generated in the anthropological research, namely the multiple impacts of collaborative and participatory research in anthropology, are not considered in the exercise of impact evaluation proposed in U. K.' s Research.

Reference	Research field	Main findings / contribution
(Detourbe, 2016)	Generic	The author argues that research funding policies are defining research and influencing academic research practices in the long run.
(Dixon & Hood, 2016)	Generic	The authors recommended changes on the research impact metrics to be able to separate metrics by institutions, as well as a further stabilization of the metrics.
(Evans, 2016)	Young caregiving	The author calls the attention to the growing pressures on academics to demonstrate impact may have in an ethic of care in university settings, as well as in the 'field'.
(Greenhalgh, Jackson, Shaw, & Janamian, 2016)	Health services	In this study authors defend that "impact metrics must reflect the dynamic nature and complex interdependencies of health research systems and address processes as well as outcomes".
(Kellard, Sliwa, & Śliwa, 2016)	Business and Management	Authors alert to the important problem of separation from impact with engagement that may be caused by the current research impact assessment metrics.
(Missingham, 2016)	Generic	The study found that business organizations value trusted timely, relevant research. Accessibility and peer-reviewed research outputs are highly valued, but little used. Barriers to use of the research include availability (material not openly accessible), discoverability (ranking on search engines) and knowledge by trusted mediators and connectivity (presentation as part of a cohort of scholarly knowledge). Barriers for researchers include lack of rewards and recognition for research outputs.
(Rolfe, 2016)	Nursing	The author defends a return of nursing research focus to the demands of nursing practice and patient care and focus on the good it develops rather than simply responding to the demands of higher education employers.
(Watts, 2016)	Hydrology	In this study, the author acknowledged the importance of interface organizations to research impact and proposes that research impact in hydrology can be increased when researchers better engage in future anticipation and link research goals with these future needs and trends, as well as, by better align interests and connect researchers with decision makers.
(Bergman *et al.*, 2017)	Healthcare	Authors suggest that there should be a better alignment between academic incentives with contributions to the health care organization and a formal recognition of operational impacts of research, while maintaining some flexibility and independence of the research process.
(Chubb, & Watermeyer, 2017)	Generic	This study found that academics protest against the ways how impact is asked to be demonstrated in advance, while at the same time they are complicit with the system and end up exaggerating their impact claims for the sake of research funding.
(Darby, 2017)	Generic	The author defends an impact agenda that encourage researches that, more than only commercialize or legislate, help to "develop societal capacities for values- based decision-making, collaboration and iterative responsiveness to evolving challenges" and contributes by creating space for reflection.

Reference	Research field	Main findings / contribution
(Freedman, 2017)	Media studies	This paper unveils existing tensions between the job descriptions of media studies academics and the impact conversation, suggesting that "academics should refuse the false binary between "scholarly" and "political" activity to pursue a "committed" approach to their work".
(Gunn & Mintrom, 2017)	Generic	The authors defend an assessment made through the analysis of detailed case studies, rather than quantitative indicators of innovation; in a hindsight analysis; with non-academics involved in the evaluation process. Authors also suggested to evaluate only field of research that are likely to produce non-academic impacts, and nudge researchers with main preoccupation about the societal impacts of their work.
(MacDonald, 2017)	Social sciences	The author unveiled both negative potential of the impact agenda, such as the distortion of research priorities and lead to overstatement of "real world" effects, and the positive potential, such as to provide institutional space for work towards social justice.
(Smith & Stewart, 2017)	Social sciences	Authors defend that social policy academics should join the debate and assessment of research impact in order to decrease the existing controversy.
(Angulo-Tuesta, Pacheco Santos, & Iturri, 2018)	Health	The authors pointed out to a need of aligning policymakers and researchers in what regards to the definition of impact in the health sector.
(Rhodes *et al.*, 2018)	Generic	The authors argue that research impact, contrarily to academic activism, performs a policing function which, despite its own rhetoric, is arranged as an attempt to ensure that "academic work maintains a neoliberal status quo by actually having no real political impact".

3 RESEARCH IMPACT ASSESSMENT

In order to guarantee the accountability of financial resources invested in academic research (Wiek *et al*., 2014), the field of research impact assessment have been flourishing in recent years. This has been the main motivation behind the impact debate, which is definitely here to stay and will continue to promote new advancements in the field of research impact assessment. However, other motivations to assess impact of impact include also the need to achieve different purposes considered as strategic to academic institutions, such as giving an overview of the institution's performance and to understand the mechanisms to impact, so it is possible to maximize results (Penfield *et al*., 2014).

Research Impact Assessment (RIA) is defined by the International School of RIA, as a "growing field of practice that is interested in science and innovation, research ecosystems and the effective management and administration of research funding" (The International School of Research Impact Assessment, 2019).

Despite the recent considerable growing in the field of RIA, the practice of measuring the success of research activities, are far from being completely new. In previous approaches, still applied in present days to evaluate the success of research and researchers, has been using metrics related to the immediate research results, such as number of publications, citations (among many other bibliometrics data), number and amount of research funding, and sometimes even patents, spin-offs and other indicators more related with the creation of innovation. However, the use of these metrics started to be considered insufficient to make a complete and rigorous analysis of the impact produced by research activities (Bornmann & Marx, 2014), and therefore other RIA frameworks, models and criteria started to arise in order to go along with the recent transformations in research policies and practices caused by the research impact-based agenda. This revolution and development of the RIA field brought new approaches and techniques to assess impact which attempt to respond to a more holistic approach and interpretation of the research impact concept.

RIA methods are essentially used by public research funding and other research policy-related organizations, HEIs and research institutions (Joly & Matt, 2017). These organizations have different goals to the application and use of RIA methods, which can range from assessing the impact of research projects, the impact of a research funding program or programs, to evaluate the performance of HEIs or researchers themselves. Therefore, considering the aim of the RIA exercise, as well as, the research characteristics of the research field (as it will be following mentioned), different RIA methods and specific adaptations have been applied, (especially during the present decade), to justify and showcase accountability of investments made in research activities.

3.1 Approaches to Research Impact Assessment

Research Impact Assessment (RIA) strategies can vary a lot according with the main goal of the assessment exercise, the research field in study and the profile of the entity who is performing the assessment. In general terms there are two approaches to research impact. By one hand there is the prospective approach, also called *ex-ante* rationale, and in the other end the retrospective assessment of research impact, also called *ex-post* rationale, used depending on the contexts and purpose of the assessment (Feller, 2017).

To assess research impact, different frameworks have been developed or adapted to fit different purposes of evaluation or to become more accurate for specific fields of research. As previously mentioned, the definition of impact is highly dependent on who is defining it and on the research field of application. Therefore, also different methods of evaluation were developed, mainly depending on the aim to which impact needs to be measured, the specificities of the research field that is going to be assessed, and the definition of impact that serves as basis to decision makers who are developing or applying the framework.

In both, *ex-ante* and *ex-post* rationales, there can be found two different types of impact assessment frameworks and models, which vary depending on the nature of the impact metrics that are applied, namely metrics related with the outcomes produced by the research activities, here named as outcome-based RIA methods, and others based that use metric related to the characteristics of the research process, here named process-based RIA methods.

Regardless the type of approach used to RIA, and also the nature of evaluation metrics used, both qualitative and quantitative methods are being used. Quantitative methods are mainly applied to the assessment of economic impacts (Ruegg & Feller, 2003). These methods serve assessment methodologies where the main focus is to analyze the return on investment made in research, which is mainly used by research funding organizations that are searching to track research budget in a specific area (Greenhalgh, *et al.*, 2016). However, qualitative methods are in fact the favorite approach for broader societal impacts, where more complex information, in terms of subjectivity, needs to be analyzed. The most used qualitative method is in fact the case study (Feller, 2017; Mitchell, 2019), and the development of case studies can be found in the base of the previous mentioned UK's REF exercise and the Australian ERA. The advantages of using case studies include the articulation of a story that can bring surprising elements to the surface which could not be took in consideration in the case of a pre-defined taxonomy (King's College London and Digital Science, 2015).

In order to provide a richer picture about the inherent complexity of research impacts, a great number of existing proposals to RIA are now proposing a combination of both quantitative and qualitative methods (Joly & Matt, 2017). Therefore, different criteria and procedures, varying from self-evaluation to evaluation by experts, are being applied to the many different existing and currently under development frameworks and models, that will be discussed in the next section.

3.2 Research Impact Assessment Frameworks and Models

The large number of existing assessment frameworks, in addition to declare that there is not a one-size-fits-all procedure, also reflect the importance that research impact has in and to academia and research related organizations.

In this section there are described the existing and also under development frameworks and models developed to assess impact, whether they are generic or specific for a research field, and whether they are based in the outcomes produced by the research activity or metrics of the research process. This description includes references to the philosophy behind the development of each framework or model, its procedure, when applicable, the type of criteria used for measurements as well as, some advantages and disadvantages.

3.2.1 Outcomes-based research impact assessment methods

The majority of existing RIA frameworks and models with cases of practical application, can be categorized as outcomes based.

Economic metrics, such as rates of return and cost savings, are used in economic models developed to assess research impact. These models are the most known example of assessment exclusively based in quantitative methods, where the focus is the understanding of economic value generated by the research activities. This exclusive focus on quantifiable types of impacts, is in fact one problem of the economic models to assess research impact, considering that this restriction can be very limiting for a complete and more accurate analysis of the impact produced by research, which can certainly go beyond the economic types of impact. Another negative aspect of the economic models is the variability of the results obtained when applying this exercise to the same research activity or context but in different time lags between the research activity and the evaluation exercise.

To expand the type of impacts being measured and provide a more complete picture of the research impact produced, it was created the Payback Framework (Buxton & Hanney, 1996; Donovan & Hanney, 2011), which is specific for the field of health and medical research and the most used framework to assess impact of research within this field (Greenhalgh, *et al.,* 2016*)*. The Payback Framework incorporates metrics related with both academic outputs and wider societal benefits, what consisted in an essential advancement to the previous use of metrics more focused on academic types of impact, such as the number of publications and citations, and therefore proposed the assessment of more and broader types of impact produced by research activities. In this framework, research is conceptualized into a seven stages process that goes from inputs to impact (Donovan & Hanney, 2011). The paybacks assessed are classified into five categories, namely knowledge (where metrics such as publications, and that are related with the advancement of knowledge are captured), benefits to policy, benefits for future research (which include training activities of future researchers), benefits for health and health systems, and finally also broader economic benefits (which include the creation of commercial spin-outs, among other criteria). This framework and the assessment exercise here used, is a great example of a mix-method approach, considering that both qualitative, through researchers' interviews, as well as quantitative information, through the analysis of documentation to verify the impact claimed by the researchers. The assessment exercise using this framework, which has several cases of application by far, besides being very specific for the field of health, it is also very labor intensive as it can be understood by the previous described methods here used. This framework is also adapted to study a specific research project and not applicable in cases of assessment of a body of research with different projects.

Different adaptations to this framework also to the field of health research, have been developed. This is the case of the Canadian Academy of the Health Sciences Framework (Canadian Academy of Health Sciences, 2019), which makes small adaptations to the five categories of impact, by including social benefits to the previous category of economic benefits only, and where there are provided several metrics and measures to assess each criteria, which therefore makes it a very labor intensive exercise, as well.

Still within the health sciences fields of research, there is the Research Impact Framework, which is the second most used framework (Greenhalgh, *et al.,* 2016*)*., and consists in a self-assessment tool that helps researchers to identify research impacts without the intervention of experts or research impact assessment specialists. This is a very much informal exercise that has a checklist of impacts, designed to promote reflection and discussion, and include research related impacts, policy and practice impacts, service impacts and societal impacts.

Other attempt of expanding and complementing economic approaches to impact, is presented in the Social Return on Investment (SROI) framework, where monetary values are used as a representation of how benefits are impacting different types of stakeholders (The SROI Network, 2012). This framework suggests applying six steps, that use quantitative but also qualitative methods, to calculate the return on investment, where investments are subtracted from benefits generated. The authors of this framework, that are composed by a consortium of organizations in the UK, advocate that the results obtained are much more than a value, but rather are "a story about change". It is important to take into consideration that this framework is not specifically developed for the research activity, but instead more directed to be applied in organizational contexts, more specifically to company type organizations.

A similar approach to measure impact created by research activities within the fields of social sciences is proposed by Morton (2015) and was named the "Research Contribution Framework". In this framework the perspective of different stakeholders is also used to create the impact story, but it is designed in a way that only allows the assessment of past research projects, i.e., can be only applied in retrospective and not for prospective analysis.

For the research field in business and management, there is also a recently proposed framework that includes the opinions of the stakeholders involved, in what respects to six previous identified parameters. These parameters are associated with areas where impacts produced by the fields of business and management can be felt (Phillips, Moutinho, & Godinho, 2018). By doing so, the authors are looking at specific places where business and management research is typically showcasing their outcomes and where impact can then be produced.

This upfront identification of parameters where impact must be identified can in fact limit the analysis of impact that is being produced by this type of frameworks, by disregard other possible impacts generated in no so typical places or formats. This assessment style, where clues to the identification of impacts are being given upfront, is even more detailed and specific in the Translational Science Benefits Model (TSBM), where an assessment exercise for the fields of Clinical and Translational Sciences, is proposed (Luke *et al.*, 2018). Considering the analysis of previous case studies within these research fields, the authors of TSBM, present 30 indicators that can reflect benefits generated by the research activities, which then serve as a guide for the assessment analysis.

In table 3 it is possible to find a more detailed description on the functioning and sector of application of each framework and model, which were find by the author of this thesis as important references to make a representation of the main existing outcomes-based impact assessment approaches.

Table 3 - Outcomes-based research impact assessment frameworks and models

Reference	**Field of research**	**Name of the Framework / Model**	**Main components and criteria**
(Buxton & Hanney, 1996, see also C. Donovan & Hanney, 2011)	Health	The Payback Framework	The Payback Framework includes a logical model representation of the research process and a set of categories to classify the paybacks of research. This framework has been adapted by other authors that propose assessment models within the health research fields.
(The SROI Network, 2012)	Generic	Social Return on Investment Framework	This framework proposes an analysis of social returns, which follows six stages, as it is following described: 1) Identification of key stakeholders; 2) Design an impact map (together with the stakeholders) with obtained or possible outcomes to be generated, showing the relationships between inputs, outputs and outcomes; 3) Search for data that can be used in the evaluation of each outcome; 4) Establishment of what is or not impact, through analyzing previous evidences and eliminating those changes that would have happened anyway or are a result of other factors; 5) Calculation of the SROI, by summing all positive benefits, subtracting negatives and comparing the result to the investment; 6) Reporting, using and embedding, by sharing findings with stakeholders and responding to them, embedding good outcomes processes and verification of the report.

Reference	Field of research	Name of the Framework / Model	Main components and criteria
(Morton, 2015)	Social sciences	Research Contribution Framework	The process for applying RFC is 1) to conduct contextual analysis: 2) to develop a logic model for the unit of assessment identified by the participants (project, programme or center); 3) assess assumptions and risks; 4) identify possible evidence and evidence gaps and 5) assess a research contribution story or report based on the work, building upon the basic pathway to impact (which includes research uptake, research use and research impact). This assessment exercise starts by building a framework for the specific case which is done by the use of a set of questions made to the stakeholders involved in the research process.
(Luke *et al.*, 2018)	Clinical and Trans-lational Sciences	Translational Science Benefits Model (TSBM)	This framework was created with the aim of supporting institutional assessment of clinical and translational research impacts beyond academia, and proposes 30 indicators that reflect benefits, divided in four categories, namely: clinical and medical; community and public health; economic; and policy and legislative benefits.
(Phillips, Moutinho, & Godinho, 2018)	Business and manage-ment	AR2I - Academic Rigour and Relevant Index	This index proposes six parameters to evaluate research in the business and management fields, which include the significance of the contribution, academic scholarly intelligence, relevance to business systems, perceived content by society and citizens, implications and recommendations, citations and impact factor. Each one of these parameters are assessed by three different stakeholder groups, composed by business practitioners, society and academics.

3.2.2 Process-based research impact assessment methods

More recently, research impact assessment frameworks and models went deep on the understanding and analysis of societal relevance of impacts and are proposing the evaluations of relationships, interactions and interdependencies with other elements of the research ecosystem, focusing then on process-related aspects of the research activities. Here lies the first advancement to solve the challenge of attribution *versus* contribution, considering that types of impacts such as relationships assume now a central role as a factor that can contribute to other impacts that research may achieve in the future.

Examples of this are the societal impact assessment models, initially proposed by Spaapen and Sylvain (1990) and subsequently refined by the Royal Netherlands Academy of Arts and

(Greenhalgh *et al.*, 2016), where researchers and other stakeholders involved, are asked to analyze their relationships, interactions and interdependencies with other elements of the research ecosystem, which include policymakers, practitioners, industry, and other possible research users or interested parts.

The first developed model based on the societal impact assessment approach was the Sci-Quest model, described as the 4th generation approach to impact, and where it is required a detailed assessment of the research program in context and the development of bespoken metrics, both qualitative and quantitative, to assess interactions, output and outcomes (Greenhalgh *et al*., 2016).

After Sci-Quest it was developed the SIAMPI, which stands for Social Impact Assessment Methods of Productive Interactions of Productive Interactions. This assessment exercise is made through a self-evaluation, performed by a research team, where researchers give their opinions about the relationships, interactions and interdependencies that link the team to other elements of the research ecosystem. SIAMPI is a mixed-method case study approach to map three categories of productive interactions, which include "direct or personal contacts; indirect interactions through texts or artefacts; and financial interactions through money or 'in kind' contributions" (Spaapen & Van Drooge, 2011). Despite being vey labor intensive, this framework is also very subjective, since all results are highly dependable on researchers' opinions. However, the great advantage of this framework is the possibility to develop the method adapted to the assessment and each specific research field. The possibility to apply the framework to different fields of research, is also the case of other models that use the networks and relationships as the main focus of impact assessment, as it will be following presented.

Another method which follows this approach of connections and interactions was developed by Kok & Schuit (2012), and was named the Contribution Mapping. This is also a method developed to be applied in the field of health research and uses in depth case studies to analyze the network of actors present in the research process which is here divided into three phases, namely formulation, production and extension (Kok & Schuit, 2012). This case studies analysis is made through interviews to researchers and other stakeholders including potential key-users. This triangulation of results is then analyzed and validated with relevant stakeholders. Just like other previously mentioned models, and despite the triangulation made through the combination of different perspectives of those directly or indirectly involved in the research project, the contribution mapping is also subject to some subjectivity. Still with limited empirical demonstrated work, this assessment model focus on accounting how the network of actors and artifacts shifts and stabilizes (or not) (Greenhalgh *et al.*, 2016), and can therefore be applied to other research fields, beyond the health sciences, to which it was originally developed.

In health research fields, other frameworks with more limited application have also been developed to assess impact following this approach of focusing on relationships and networks, such is the case of SPIRIT Action Framework which puts emphasis on engagement and capacity building activities on organizations (Redman *et al.*, 2015), and the Participatory research impact model (Cacari-Stone, Wallerstein, Garcia, & Minkler, 2014), which analyze the partnerships between the academic community and the policy-making process.

More recently it was proposed a research assessment framework that analyzes the process of research, and shed light into potential enablers of impact production (D'Este, Ramos-Vielba, Woolley, & Amara, 2018). This framework has the great advantage of being generic and therefore possible to be applied to different research fields and providing a much more complete overview of impact potential, that goes beyond the productive interactions' studies in the previous mentioned SIAMPI framework.

Just like what was previously done for the development of table 3, table 4 presents a summary of existing process-based RIA frameworks and models, including some very recently proposed and with very limited or no practical applications, at the moment. The selection of frameworks and methods included in tables 3 and 4 intend to give a general perspective on the RIA approaches, their modes of application and criteria used to perform the research assessment, as well as to complement the presented critical analysis about RIA.

Table 4 - Process-based research impact assessment frameworks and models

Reference	**Field of research**	**Name of the Framework / Model**	**Main components and criteria**
(Spaapen & Van Drooge, 2011)	Generic	Social Impact Assessment Methods of Productive Interactions of Productive Interactions (SIAMPI)	This framework focus on the analysis of productive interactions, which can be created between researchers and other stakeholders. The productive interactions in analysis were categorized in three types, including direct or personal interactions; indirect interactions and financial interactions.

Reference	Field of research	Name of the Framework / Model	Main components and criteria
(Kok & Schuit, 2012)	Health	Contribution Mapping	In this assessment model, it is designed a map of the research process with three phases of the process research, which includes research formulation, production and knowledge extension. In this map there are identified the main actors, activities and alignment efforts which took place in a research project. In the category of actors there are identified all those involved in the research process but also potential key users. To design this map, it is used information collected through interviews with the researchers involved in the process, as well as, with other stakeholders including potential users. After a first analysis about the alignment efforts, the results are shared in order to receive feedback and validation.
(Cacari-Stone, Wallerstein, Garcia, & Minkler, 2014)	Health	Participatory Research Impact Model	Through the application of a great variety of research methods, such as interviews, focus groups, document and data review, and participant observation, this model studies the links between its components, which include contexts, community-based participatory research processes, policy strategies and outcomes.
(Nunamaker, Twyman, Giboney, & Briggs, 2017)	Information Systems	Systematic High-Impact Research (SHIR) model	This model is a systematic approach to support the conduction of high-impact research in the fields of information systems. In this approach, the authors propose the analysis of four main elements that are considered essential to solve societal challenges, which consist in academic partnerships, practitioner partnerships, research centers, and outreach activities.
(Redman *et al.*, 2015)	Healthcare	SPIRIT Action Framework	Through a literature search and interviews with policymakers, the authors identified main factors likely to influence the use of research in policy.
(D'Este, Ramos-Vielba, Woolley, & Amara, 2018)	Generic	Analytical and operational framework to scientific and societal impacts	This framework proposes the assessment of impact, following the analyses of three types of factors that influence the generation of scientific and societal impacts. These factors are: 1) key characteristics of individual researchers – which include motivations for research and KT, their attitude toward a scientific research agenda in cooperation with nonacademic actors, diverse set of skills and intellectual capital (organizational, social and human capital) and professional trajectory (things as formal education and international mobility); 2) a set of organizational factors - which include supportive climate, interdisciplinarity, infrastructure facilities and barriers and obstacles; 3) a set of process-context preconditions – which include variety of stakeholders, modes of

			interaction (breadth and depth of the interactions, formal or informal, among others) and bi-directional learning.

3.3 The future of Research Impact Assessment

Definitions and assessment tools for research impact have a primarily focus on impact results tending to search for "tangible" profs of positive effects generated by specific research projects. However, especially due to the existing controversies involving aspects such as the attribution of an impact to a specific research project or the time lag that should be considered between the research and its impact, mechanisms for impact have more recently been also considered to develop research impact assessment models.

Through the analysis of tables 3 and 4, it is possible to say that assessment methods have been mainly developed for specific research fields, where health and medical research were found to be top priorities. This conclusion also follows the analysis of the literature review made in chapter 2, where it was demonstrated the segmented study of impact definitions per field of research.

Despite the existence of different models and frameworks to assess impact, consensus is far from being reached and there are a lot of authors analyzing and criticizing these methods, as well as proposing new approaches or basic principles for future assessment models. Examples of these critics, including the lack of important parameters or the use of inappropriate ones, in the fields of social work research, social sciences (Shortt, Pearce, Mitchell, & Smith, 2016), and biomedical research (Ovseiko *et al.*, 2016). In fact, the diversity of impacts (Feller, 2017) and its context-specificities (Mitchell, 2019), are seen as great challenges to the development of a more holistic, complete and accurate impact assessment exercise.

Adam *et al.* (2018), points to 5 methodological challenges in RIA, which, beyond the previously mentioned challenges in finding appropriate units of assessment, include also time lags, attribution and contribution, marginal differences (distinction between high and low impacts) and transaction costs (ensure that the benefits outweigh costs). To overcome these challenges, the authors proposed ten guidelines that, regardless of the research field, should be taken into consideration when developing practical impact assessment strategies, namely: "(1) context, (2) purpose, (3) stakeholders' needs, (4) stakeholder engagement, (5) conceptual frameworks, (6) methods and data sources, (7) indicators and metrics, (8) ethics and conflicts of interest, (9) communication, and (10) community of practice" (Adam, *et al.*, 2018).

Existing RIA tools are been considered poor and incomplete, since they are capturing impact in different points of the research process, including the research creation, dissemination of findings, research use and potential benefits (De Jong, Barker, Cox, Sveinsdottir, & Van Den Besselaar, 2014), fail to be generic and easy to implement (Joly & Matt, 2017), as well as incorporate long-term impacts (Buxton, 2011), which can change over time, whether positively or negatively (Brewer, 2011).

At this point, and in general terms, existing methods to RIA are considered to "fail to capture the soul of academic labor, which may result in demoralization" (Sutton, 2017). This, together with the previously identified challenges is resulting in a need to develop new research impact assessment methods. Also, the increasing complexity of grand challenges (Amanatidou, Cunningham, Gök, & Garefi, 2014), is requiring RIA methods that better represent of relationships between research, innovation and society (Joly & Matt, 2017).

Following this, process-based methods are recognized as the future trend to the field of research impact assessment. More specifically, there is a search for the development of process-based RIA methods with generic applications (to different research fields), and which are based in the conditions of the research process that can enable the production of impact, such as it is presented in the "analytical and operational framework to scientific and societal impacts", proposed by D'Este, Ramos-Vielba, Woolley and Amara (2018).

A confirmation of this recent and future trend are the numerous studies (made by academic researchers but also policymakers and other practitioners of the RIA research field) about enablers and barriers to impact. These studies conclude about research process-related important aspects, which were corelated with the production of impact. These aspects, here named as impact conditions, include mainly collaboration and teamwork related factors, and have been extensively studied for different fields of research, in recent years.

An important type of engagement where barriers and misalignments were found (Missingham, 2016; Bergman *et al.*, 2017) is the collaboration between university and industry or business organizations, which is strongly correlated with the production of research impacts (Holt, Goulding, & Akintoye, 2016; Karmakar, 2014; Shetty, Naarayanan, & Sundaram, 2017).

Also, engagement and co-creational practices with practitioners, innovation users and citizens is mentioned as a critical issue, present in a communication by European Commission about the maximization of research impact (European Commission, 2019b), and appearing also in studies from a great variety of research areas, such as healthcare (Wooding *et al.*, 2014; Greenhalgh, Jackson, *et al.*, 2016; Bergman *et al.*, 2017), participatory research (Abma *et al.*, 2017), policy research (Jackson & Crabtree, 2014), event management (Coghlan, Sparks, Liu, & Winlaw, 2017), social sciences (Cherney, Head, Povey, Boreham, & Ferguson, 2015), computer science (Dong, Johnson, Yang, & Chawla, 2015), and Business and Management (Kellard *et al., 2016)*.

In addition to the previously mentioned collaboration with external stakeholders, also inside academia there are practices of collaboration found to be related with the generation of research impact, namely the multi and interdisciplinary work, vastly mentioned in the literature (Evely *et al*., 2010; Lyall & Fletcher, 2013; Wooding *et al.*, 2014; Blazek *et al*., 2015; Holt *et al*., 2016; Darby, 2017; Meagher & Martin, 2017; Ozanne *et al.*, 2017). Despite the effort made by the European Commission to value this aspect, especially reflected in their last research and innovation program, this is not being taken into consideration in RIA exercises, such is the case of UK's REF (Russell & Lewis, 2015). In addition, there are clear guidance or best practices on how to effectively create and manage multi and interdisciplinary teams of researchers, for the benefit of research projects and its potential impact.

In short, RIA state of the art and existing literature are pointing to the need to develop new RIA approaches that focus on allowing a better understanding of research impact mechanisms (Joly *et al.*, 2015), and solutions considered to be simple, easy to be understood and used by non-impact experts, comparable and possible to be suited across different projects and disciplines (Mitchell, 2019). To do so, and besides the previously mentioned recommendations given by Adam *et al.* (2018) to the development of new RIA methods, academics also highlight the importance of strategies to the active dissemination of research results, (Bunn & Sworn, 2011; Schnitzler, Davies, Ross, & Harris, 2016; Smith *et al*., 2017), the introduction of 'nudges' given to researchers that could raise their interest and awareness about the societal impacts of their work and the already mentioned change in focus from impact as a product to a process (Baim-Lance & Vindrola-Padros, 2015).

4 RESEARCH PARADIGM, APPROACH AND DESIGN

Considering the aim of this research and taking into consideration the literature review described in the previous two chapters, it was designed the research process following represented in figure 2.

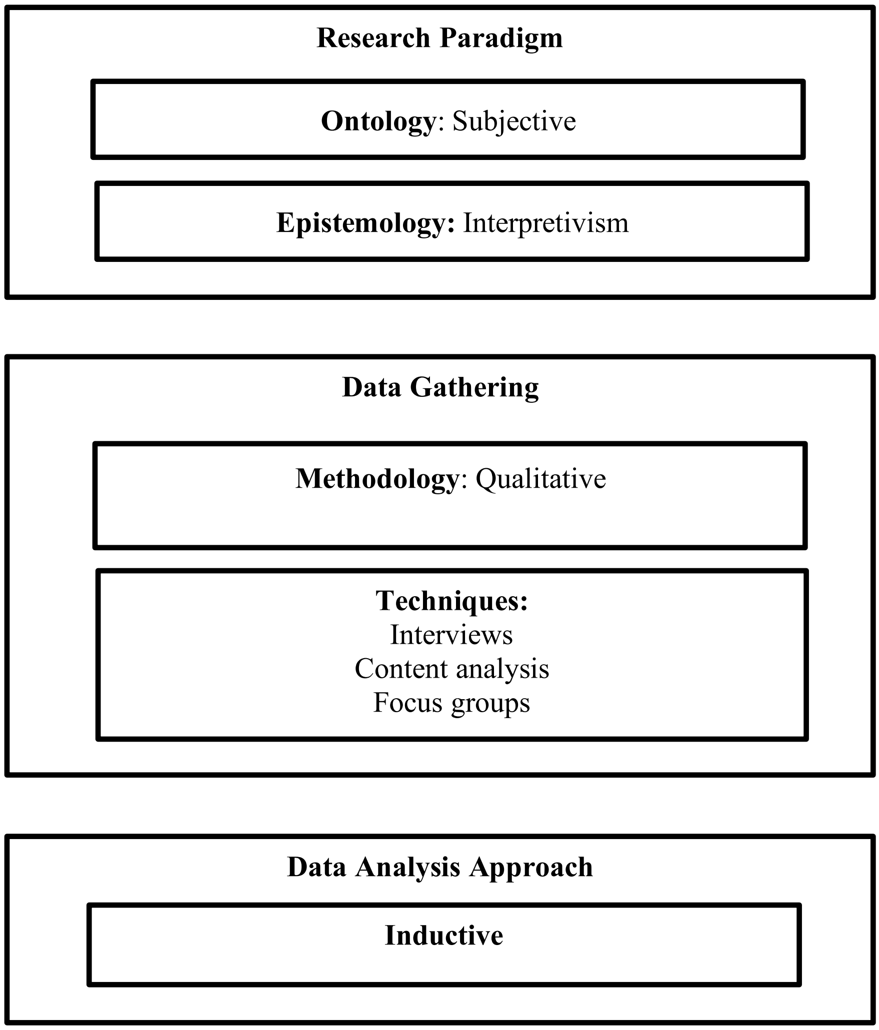

Figure 3 - Methods map
adapted from (MacIntosh & O'Gorman, 2015)

4.1 Research Paradigm

4.1.1 Research ontology and epistemology

Following the general objectives described in chapter 1, this thesis will collect different perspectives and insights to expand existing understanding about research impact, especially in regions where this knowledge is not being explored (as it is the case of regions outside the UK and Australia), to confirm the development need of a new process-based research impact assessment framework. Considering this, together with the inevitable use of the researcher's past professional experience during the development of the research impact framework here proposed, this thesis follows an ontology based on the subjectivism rather than objectivism. In the ontology position of subjectivism, the study of being or reality is shaped by the perceptions of all those involved in the research, as opposed to the objectivistic ontology where an external reality more independent from social actors. As described by (MacIntosh & O'Gorman, 2015), these perceptions can be affected by many variables such as behaviours, attitudes, experiences and interpretation of both the observer and the observed.

The relationship between the researcher and the reality, as well as, the way how this research developed valid knowledge (Carson, Gilmore, Perry, & Gronhaug, 2001) – its epistemology; is more close to an interpretivist philosophy which is the natural tendency of a research that uses a subjective ontology, and is described by MacIntosh & O'Gorman (2015), as "a paradigm focused on meaning(s) that tries to understand what is happening, look at the totally of each situation, develop ideas through induction from the data, uses multiple methods to establish different views of phenomena and investigate small samples in depth over time" (MacIntosh & O'Gorman, 2015, p. 60).

By applying this approach, the research work will take into account the context of the phenomenon under investigation, the contextual understanding and interpretation of the collected data and the nature and depth of the researchers' involvement (MacIntosh & O'Gorman, 2015). Broadly speaking, interpretivism allows the focus to be fixed on understanding what is happening in a given context rather than just measuring it (Klein & Myers, 1999; Patton, 1990), or as explained by Easterby-Smith, Thorpe, Jackson, & Jaspersen, (2018), the focus is placed on meanings, instead of facts as it is done in the positivist approach.

Table 5 – Key profile of positivist *versus* interpretivist epistemology
adapted from (Easterby-Smith *et al.*, 2018)

		Positivist	Interpretivist
Researcher	Involvement	Independent	As an involved to what is observed
	Focus	On facts	On meanings
Research Paradigm and approach	Approach	Hypothesis and first formulate to be then tested, in a deductive approach to data analysis	Development of theory / findings through induction where there is a first collection of data
	Research through	Should demonstrate causality	Is looking for increase the understanding of the situation
Research design	Unit of Analysis	Should be reduced to simple terms	Look to the complexity and the "big picture" of the situation
	Concepts	Should be operationalized to allow measurement	Should capture different perceptions of those involved
	Generalization Through	Statistical probability	Theoretical abstraction
	Sampling	Random selection of a large sample	Selection of small sample of cases for specific reason that can be investigated over time

As already mentioned, in an interpretivist philosophy, and regardless the level of intervention, there is an involvement of the researcher in the understanding and interpretation of the context and results, what contrasts with the positivism in which the researcher remains independent and it is assumed that his personal beliefs and experiences will not influence or affect the results. Although there is actually an involvement of the researcher, the aim placed in an empathetic understanding made available by the interpretivist epistemology, also allows a detachment or usage of researcher' established assumptions about academic community and context derived from the author professional experience and involvement in academia.

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4.1.2 Research methodology

A study expressing a subjective ontology with an interpretivist approach tends to be aligned with a qualitative research methodology, since it aims to understand phenomena and gain insight, in opposition to the quantitative research where the purpose is to explain, predict and/or control phenomena. Qualitative research it is interpretive, ethnographic and is looking to describe rather than to quantify as is the case of the quantitative research (Wilkinson, 2000).

Table 6 – Quantitative *versus* qualitative methodology
adapted from (Greener, 2008)

Quantitative	**Qualitative**
Numbers	Words
Point of view of researcher	Point of view of participants
Theory testing	Theory development
Structured research process	Unstructured research process
Generalization	Contextual understanding
Behaviour	Meaning

4.2 Research approach

The research approach questions how the arguments are built, or in other words, presents the storyline behind the research process that has its starting point in the phenomenon. More specifically, the research approach positions the theory – which can be a scheme or system of ideas or statements; a statement of general laws, principles, or causes of something known or observed (Gill & Johnson, 2010); in the research process. This positioning can therefore range from a place where theory drives research - in the deductive approach; to theory being the outcome of the research – in the inductive approach (Bryman & Bell, 2011).

Considering all the previous choices made in the research paradigm, together with the emphasis and nature of the research, considered by Saunders, Lewis, & Thornhill, (2009) as the most important criteria to decide upon the research approach, this thesis followed an inductive approach where the data collection precedes and supports the theory development. In contrast with deductive approach in which at first a theoretical methodology and hypothesis are formulated to only then design a research strategy that will enable to test it (Saunders *et al*., 2009; MacIntosh & O'Gorman, 2015), and inductive approach starts with the observations to only then propose any kind of theory (Goddard & Melville, 2001).

An inductive approach, often referred to as theory-development or theory-building process, commences with the research design followed by the data collection and data analysis that will further support the presentation of a theory, in a pathway that seeks to establish generalizations about the phenomenon under research. It is then important to note that, as mentioned by Saunders, Lewis, & Thornhill (2009), this approach does not neglect or reject by any means existing theory, but instead uses the data collected to identify patterns and relationships and therefore build a theory. This approach, through its philosophy of learning from experience, also allows more freedom to change the direction of the study after its beginning, what it seems adequate for research topics more ambiguous, complex and less explored (Djamba & Neuman, 2002).

4.3 Research design

Research design consists on the framework for collection and analysis of data (Bryman & Bell, 2011), and presents the choices made to connect research questions to the data obtained, its interpretation and conclusions. Therefore, this section describes and explain the methods used throughout this thesis, and substantiate each choice based on the objectives and characteristics of the research question, as well as the previous described research approach.

4.3.1 Research methods overview

The previous choice of a qualitative methodology was here taken into consideration to choose qualitative methods that better apply to each specific purpose. Figure 4 makes a graphical representation of each research phase, divided in the two research phases composed by an initial study to support and base the development of the research impact framework and the actual development of the conceptual framework, where there are indicated the object or topic under study through each method applied.

For the actual development of the conceptual framework, and as it was already briefly mentioned in chapter 1, different methods and objects of study were used in order to better support and inform results and allow triangulation – where two or more independent sources of data or data collection methods are used to corroborate research findings (Draper, 2008).

The reasoning that justifies the application of each chosen research method in each specific research question is provided in table 7, and in-depth analysis of each method application in this thesis is presented in the following sub-sections.

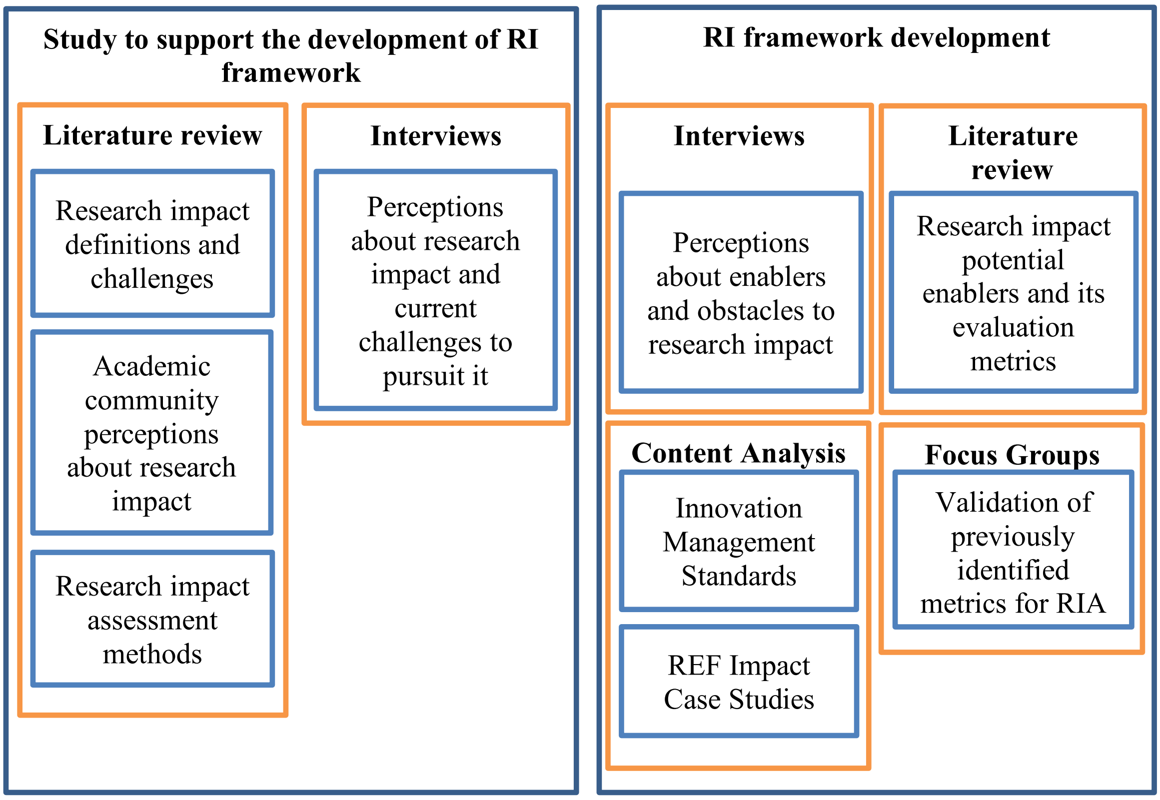

Figure 4 – Research methods overview

Table 7 - Research methods definition and rational of application in the specific research questions

Research Question	Sub- Research Question	Research method	Definition of the research method that justifies its application for the question purposes
To what extent can the use of a outcomes-based research impact assessment approach (compared to a process-based approach) be related with the existing tensions between academic community and the research impact agenda?	What are the characteristics of the impact-based agenda and existing frameworks and models to assess research impact?	Literature review	Review and critical analysis of existing literature which informs about existing knowledge and studies previously performed in this same study field.
	What are the perceptions of academic community towards the research impact-based agenda?	Semi-structured Interviews	Research in which information is obtained by asking respondents' questions directly, allowing the research to interpret and conclude about participants viewpoints and perceptions about a topic.

Research Question	Sub- Research Question	Research method	Definition of the research method that justifies its application for the question purposes
What can be the characteristics of a process-based conceptual framework to research impact at HEIs?	What are the enabling conditions for the production of research impact?	Literature review	Review and critical analysis of existing literature which informs about existing approaches to impact assessment frameworks, which can unveil viewpoints of interest for the research question.
		Semi-structured Interviews	Research in which information is obtained by asking respondents' questions directly, allowing the complementation of previous obtained results, by adding the perceptions of the academic community.
		Content Analysis	Determine the presence of certain words or concepts within texts or sets of texts. Researchers quantify and analyze the presence, meanings and relationships of such words and concepts, then make inferences about the messages within the texts.
	How to model the impact enabling conditions within the academic context?	Literature review	Review and critical analysis of existing literature which informs about possible performance indicators for each research impact conditions previously identified.
		Focus group	Study the perceptions of a group with specific knowledge and experience about the academic context, and validates the previous identified performance indicators

4.3.2 Interviews

Considering the research paradigm of this thesis, where there was given room for the exploration of meanings, and the involvement of the researcher in the understanding and interpretation of the context and results, semi-structured interviews were the format chosen to conduct interviews. In this format there is a script which serves as a question guide to the interview, but it is given space and opportunity to he interviewee to take the questions to the level he/she wants and even to conduct the conversation to other related topics of his/her interest (Greener, 2008)

Following the interpretivist approach where the concept is to capture the perceptions of those involved, semi-structured interviews place the focus on the interviewee, not the interviewer (Greener, 2008). This can sometimes be challenging to the researcher, that has to master time management during the interview, respect the silent moments, pay attention to non-verbal communication, and find a balance between moments of divergence and convergence around the topic in focus. A professional interviewer is genuinely interested in the interviewee's perspective and so will allow conversation to follow new directions suggested by the interviewee, even if that same directions appear later on the interview script (Greener, 2008)

In the design process of interviews that collected data to both research questions a) and b), as described in table number 6, a first pilot study was developed, which included the preparation of a script, the chosen of an initial sample and the consequent interview test. A pilot study helps the researcher to fine tune the data collection strategy, in both the content and the applied procedures Yin (2003: 79).

As it can be seen by the previous choice made to choose the interviewees of the pilot study, the target sample of the interviews performed included two main groups. The first group are the academic researchers who are the main actors in the process of research impact and were selected based on their previous experience with research impact outcomes or outputs, such as involvement in start-ups, patenting and/or licensing activities, and other types of research valorization activities. The second group consists on what is here referred as Interface Agents, which include transfer officers, entrepreneurship programs directors, staff for academic funding support and Deans in the areas of Research or Innovation related topics. The choice of including these two different groups intends to add different perspectives about research impact and then to develop a broader picture of the perceptions and opinions of the academic community.

Considering previously presented critical analysis of the existing literature about research impact where it is seen a segmentation of definitions, types of outputs and approaches to impact among different research fields, this thesis focus and explored the case of science and engineering fields of research. This choice avoids the comparation of results that could not be comparable, as the same time as it aligns with the background, professional experience and interests of the researcher.

In order to better define the chosen research fields for the development of the case presented in this thesis, it was considered the segmentation made by the United Kingdom's Research Assessment Exercise (REF), which created different panels to assess the different research fields, namely: Medicine, Health and Life Sciences; Physical sciences, engineering and Mathematics; Social Sciences; and Arts and Humanities (Research Councils UK, 2012). This thesis then focused attention in the panel named Physical sciences, Engineering and Mathematics, which for clarification purposes, includes the fields of Earth systems and environmental sciences, Chemistry, Physics, Mathematical sciences, Computer sciences and informatics, and Engineering (Research Councils UK, 2012).

Therefore, all academic researchers interviewed work in the fields of science and engineering, with different years of research and in different career levels (including postdocs), and interface agents work at or have close relationships with HERIs or research groups in these same fields of research.

Despite the focus of this thesis in the study and development of a theoretical framework for this specific research field, there is a conviction that further explained results and presented conclusions can be generalized to the other fields of research, as well.

The interview guide was designed to cover all topics and perception that wanted to be collected, unveiled and understood, and questions were written by taking into consideration the inclusion of descriptive and structural questions, as well as contrast questions which were used to increase the reliability of the (Spradley, 1976).

In the preparation phase and especially during the interview it is important to keep in mind the advice given by Saunders, Lewis, & Thornhill (2009) in respect to the competencies of the interviewer, which include the use of appropriate language, the ability to questioning but also to listening, the regular test and summarizing understanding, the creation of an opening to the interview, to be able to recognize and deal with difficult participants and data recording. It was also considered the facilitating prompts to further and deeper discussion, suggested by (Greener, 2008) that included simple phrases such as “can you tell me more about that?”; “That’s an interesting point, I hadn’t thought of that, so what exactly do you mean by…”, “I’m not sure I have fully understood, can you explain that a little further… or give me an example?”

Right after the interview take place it is also important to take immediate contextual notes, where there are referenced the personal impressions of the interviewer about the outcome, highlights or surprises, notes about the interviewee’s non-verbal communication and other specific comments (Greener, 2008).

Each interview was recorded using a digital support and then transcribed for further analysis, as it will be described next.

It was used an inductive qualitative approach to analyze the data (Glaser & Strauss, 1967; Strauss & Corbin, 1990; Miles & Huberman, 1994), informed by the researcher focus on beliefs about the role and mission of academics and academic research while remaining open to emerging ideas. The orientation to data collection and analysis was therefore exploratory and the analysis consisted of multiple readings of the interview transcripts.

In the first stage of analysis the transcripts were marked up twice. The first set of markings highlighted key terms of interest in the research, which were previously mentioned in the existing literature as associated concepts to define research impact, obstacles and enablers of the production of impact.

Although this first phase followed an approach that could be better considered as deductive, in the second phase of the analysis, the transcript was analyzed by using a more explorative mindset where a clear perception and viewpoints of the interviewee were searched and captured.

This second phase assured that analysis was in fact avoiding preconceived ideas about the possible results.

From this two-phase analysis of the transcripts, it was prepared a summary of each interviewee results that allowed the comparison between interviewees, as well as, the conversion of each code to themes and sub-themes. Then, references to more frequent themes and sub-themes, as well as references that were coded as results for questions that I was looking for, namely definitions for research impact, perceived obstacles and enablers, were placed in a separate sheet to allow better comparison and analysis of results.

Throughout this thesis all respondents are anonymized and referred to by a code. This code attributes a fictional name for each interviewee (without changing his/her gender) and indicates the group to which he/ / she belongs to, between academic researcher an interface agent.

4.3.3 Content Analysis

To perform content analysis on the documents selected to unveil the needed conditions to generate impact (described in chapter 6), it was also used an inductive approach, consistent with the general research approach. This content analysis was performed by applying the 5 steps of the protocol described by (Glaser, B., & Strauss, 1967; Miles & Huberman, 1994). This protocol was implemented as follows:

1) All materials were first read to ascertain the general meaning (Silverman, 2000) and to decide on areas of focus within the documents;

2) Then it followed a search for keywords that were considered by the researcher as having some connection with conditions (activities and processes) to produce research impact;
3) Every part of the text in which keywords appeared was analyzed, and units of analysis were codified by the formation of new categories in order to classify the most important meanings embedded in the text. Whenever possible, the categories were titled using words identical to those in the text, in order to remain as close as possible to the textual materials. An interactive process (Easterby-Smith *et al*., 2018), was followed to ensure that categories were used in an identical manner;
4) Final analysis and interpretation

4.3.4 Focus group

In order to validate the assessment instrument developed to apply the Research Impact Framework here developed, in a way that can better represent the reality of the academic ecosystem and its peculiarities, it was used the focus group method.

This research method is different from the interviews in the way that supports the debate and confronting of opinions of the participants, helping to construct a rational that goes beyond each individual perception (DeMarrais & Lapan, 2004). Focus groups are considered to be useful in cases where the researcher aims to design a survey instrument (DeMarrais & Lapan, 2004), which is not very different from the format of the present RI assessment instrument that is here being validated through the use of this technique.

To validate the identified metrics to assess each research impact enabling conditions, it were created different small groups, constituted by 3 to 5 participants, divided according with the profile of the academic community members, namely full professors, associated and assistant professors, postdocs and junior researchers, members from the school's management team and interface Agents.

5 THE ACADEMIC COMMUNITY *VERSUS* THE IMPACT-BASED AGENDA

As it can be concluded by the analysis of the literature review chapters (2 and 3), studies about research impact are very much concentrated in the UK and Australia, where the research impact topics have been mostly developed, whether in research as in practice. In order to complement these existing studies and search for a possible generalization (not geographic and political context dependent) for the reasons that are causing the tensions between academics and the impact agenda, this research studied two other countries with different research contexts, namely USA and Portugal. The choice of these countries was made for convenience reasons (related to the easiest assess to the academic community), and also considering that both countries have considerable percentages of public research investment. As it will be seen in chapter 6, Portugal is also very developed in terms of innovation management standards, which are used as data for the development of the conceptual research impact framework, considering that innovation is a predecessor of research impact.

To explore the role of academic researchers' and the broader academic community values and beliefs in their resistance (sometimes implicit) to the way how impact-based research is being enacted into practice, it was designed a qualitative study, based on interviews, which is following presented.

Semi-structured interviews were conducted with 40 different members from the academic community between 2017 and 2018 at research intensive universities located in USA and Portugal. Themes were drawn inductively from the data.

To form an empirically grounded understanding of how academics understand what is considered an impact-driven research, in particular how they perceive impact-driven research as part of their occupational mandate and how much this is supported by institutional practices of universities, we engaged in a qualitative, interview-based study. This study includes 24 semi-structured interviews with academic researchers plus 6 PhD students and 10 interviews with academic interface agents, both acting in different geographic regions, making a total of 40 interviews, lasting 45-60 minutes.

Interviews with academic researchers aim to explore the interviewees' perceptions of societal impact (e.g. How do they define societal impact? Do they see societal impact as something important in their research work?) and examine research practices (e.g. how they come up with research questions? how they go about funding?). We asked informants to provide rich descriptions of their research practices and their academic career (What motivated them to become an academic? Why were their successful in their careers? What is evaluated by their institutions?). We aim through these interviews to raise the understanding about what is or should be considered as research impact in the perspective of the academic community, as well as, unveil potential barriers and opportunities to do it.

Figures 5 and 6 make a representation of the different characteristics of each group of interviewees, among the two sampled groups of academic researchers and interface agents, as mentioned in chapter 4. Indeed, an occupational mandate is not only internal but also external and we believed that interface agents would provide us with good insights on the occupational mandate of academic researchers – the one currently enacted by academic researchers and possibly the one associated with impact-based research.

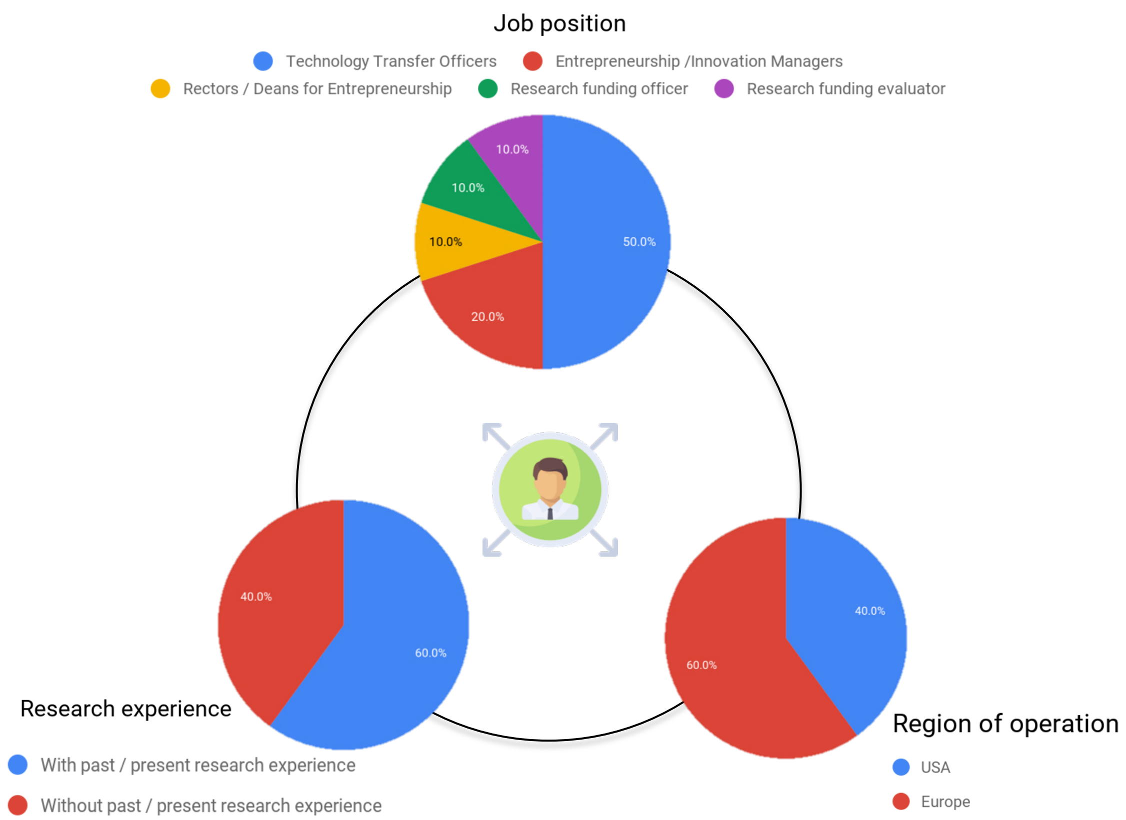

Figure 5 - Characterization of interface agents in terms of job position, geographic region of operation and past/present research experience in the fields of science and engineering

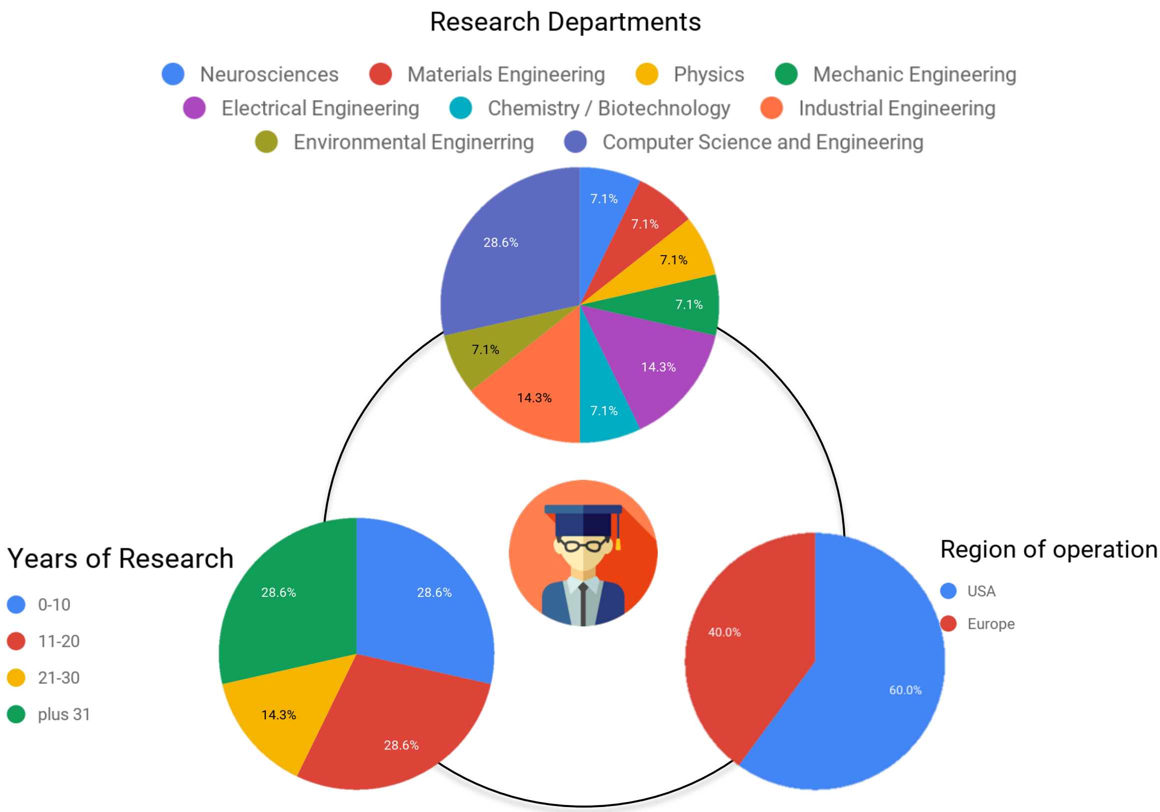

Figure 6 - Characterization of academic researchers in terms of years and field of research, as well as geographic region of operation

5.1 Definition of and motivation to research impact

To unveil the general perceptions of academic community about how research impact is being promoted and rewarded, we will first analyze how do they define research impact and the meaning of it in their daily academic activities.

Impact is, in general terms, perceived as a positive change in people lives, such is represented in the definition of impact gave by an interface agent: *"I think that's just the number of lives that are touched is a positive way."* Richard, Technology Transfer Officer. Or by other words from an academic researcher who held also responsibilities as interface agent: *"Is very simple. To make people's lives more livable and better."* Philip, interface agent.

This perception of research impact is in fact, very close to the definition given by policymakers who defined impact as a positive result produced outside or beyond academia. But more than having found alignment in the general definition of impact, this study also showed consensus among academic community regarding the importance of generating research impact, which is seen as a shared aspiration of researchers and an understandable mission of universities. The creation of research impact seems to give researchers a higher purpose and a sense of career, as it is illustrated by the following quote: 'For me it only makes sense if I'm able to create societal and economic impact. Not so much to publish papers and other things like this' Eudora, academic researcher

Academic community is not only supportive of an impact-driven strategy, as also recognizes impact as a personal motivation to perform research, whether this impact is seen in the form of knowledge creation, or more practical results that have a direct contribution, as it can be seen in the answer of an Interface Agent when questioned about financial rewards being a primary motivation to create impact:

> *"No, I mean they're very focused first and foremost on keeping their labs going so keeping the funding flowing to their graduate students and making sure that they have interesting projects to work on, and then I think .... seeing an impact, whether it's in the literature, in their field or if it's, you know, in terms of deployment of a technology. I think, in that order that's what really matters to them."* Richard, interface agent

5.2 Tensions with the impact-based agenda

Even though the academic community care with the production impact and have a general definition of impact that matches what governments and research funding organizations are also looking for, i.e. the production of positive effects beyond academia, they have the perception that there are some challenges in the way how impact is being promoted in practice and the effects this will have in the future of research activities.

Both groups interviewed, recognized a lack of skills among academic researchers that might be hindering them to perceive and generate value from research, such illustrated by the following quote by an academic researcher: *"We are not educated to the value perception' Jack.*

These value creation skills, and its development early on, is seen as a crucial need to 'raise awareness about societal impact (...) or collaborative research", as said by Christopher, an academic researcher.

Thus, there is a perception that academic researchers lack skills to detect and evaluate opportunities to generate impact, but also other types of skills that were considered to be essential to promote research impact, such as teamwork or, more specifically collaborative work skills, such illustrated by the following quote: *"I don't think researchers work well together with other departments (....). departments tend to be silos and even within the silos, the researchers within the department tend not to work well."* David, associated Professor

This last quote also stresses the importance of having an organizational culture and structure that promotes the development of personal and interpersonal skills essential to achieve research impact. Highlighted points elated with academic researchers' competences were found to be always interconnected with organizational structure and culture, pointing out the lack of incentives to develop or even put into practice those necessary competences to achieve research impact.

Through the analysis of the results of this study, it is possible to unveil several examples of what academic community perceive as obstacles to impact created by the organizational stance and culture of universities around the world. One of this is that time to explore potential projects with impact is not prioritized by academic researchers, since it is not recognized as a priority given by the organization, as well as, nothing that will extremely affect their career and position within the university.

When immersed in so many bureaucracy and different activities including teaching, fundraising and team management, there is not enough time to deeply engage with questions, societal or knowledge problems, to connect with others in order to identify opportunities for research and impact production.

The translation of research to society and planning of future impact is something considered to be more challenging for the general profile of an academic researcher. Even those who opt for a more applied field of research, which has been privileged by research funding policies, still feel not having the right organizational incentives and culture to help them in the pursuit impact.

What then happens is that academic researchers in senior levels of career end up feeling freer to search for impact, since they are no longer in the run to achieve one more indicator to career's progress or to become accepted in the community, as it is the case of junior researchers. *"as a junior faculty member, what I had to do was get published out there, get recognized for making contributions, make it possible so… a tenure decision depends on a bunch of people write very positive strong letters."* Alexander, associated Professor

However, when researchers reach a higher position in their careers, they do not feel so much pressure to reach indicators seen as essential to career promotion, such as publications, and are then free to pursuit their own interests and deep motivations to contribute to society, regardless the final output it may be produce. But this is not true for the majority of academic researchers, that must guarantee their positions at academia, and impact is seen as a fortunate and random result of the research activities they bet on. For example, David, an academic researcher, stated that *"So, we have this issue, that tenure track lack motivation to do startups and patents"*, and this lack of incentives also highlighted by many researchers and interface agents interviewed, could lead to a necessary choice between social good and career progression, such illustrated by the following quotes:

> *"But if your success is social good you may not reach that point because you stopped at the point which was valued by the community around, like papers or funding"* Peter, academic researcher

> *"I think bibliometrics have a big predacious effect on research. Because people work toward that goal, because they are evaluated in that way and know that is the way how to advance in career. So, the goals are conditioned by the way how the evaluation is made."* Derek, associate Professor

> *"Here are no incentives for value creation. The incentives in University are towards publications, and it is very rare to have someone in the team who want to be entrepreneurs or knows how to do it. He was not trained to become an entrepreneur, he doesn't want to..."* Jack, full Professor

> *"And unfortunately, you know, I am measured not by those things but mostly by my research publication, my research output and my teaching. And so those things don't necessarily have to involve any of the entrepreneurial and innovation things, and as a*

result, there is really no good incentive for our faculty to do this. I'm just doing it because I think it's important and because that I hear that my students need it and I think it's important to teach these skills to our students". Claire, academic researcher

This lack of incentives in the academic system brings to the surface a discussion about how to measure impact and which metrics to use, as it can be also seen in the previous transcribed quotes.

If the current metrics do not seem to guide researchers towards impact creation, so what type of metrics could do that instead? This seems not to have an easy answer, since all academic community members interviewed considered impact a very difficult thing to measure, as following stated:

"Do we need to have a metric? I think that we want to measure things that are not measurable and that's a problem. Creativity and...in a technological area that are minor things that can have a major impact. And the reverse can be also true." Derek – associate Professor

"I think that (metrics to promote impact) are still based in numbers rather than in technology transfer or societal impact. Maybe a change from quantity to quality is important, but then the problem is how do we measure the quality. But maybe the services we make to companies... but that is not the scientific part, because many times what companies need is more technological than scientific. And science is more long term than short term." Jeffery, academic researcher

In fact, not only Universities but the general strategy of research funding and support is based in the same metrics, incentives and forms of assessment. And academic researchers not only consider that they do not have time to pursuit impact, as well as the notion of time is different between the metrics in place and the "real" time needed to generate impact. Therefore, impact was considered not only difficult to measure but also a time demanding result, that may be putted at risk by the current assessment models, as suggested by a European Interface agent who is responsible for supporting researchers in fundraising activities who said: "*you're detracting research for the sake of products and services in the market in a short period of time*." Eleanor, interface agent.

This feeling of "detracting" or "perverting research" ends up leading us to reflect on issues related with the mission of universities and the reason of its existence in today's society.

"*So, all this strategy of our university with the publications and impact, increased the number of publications but it turned them more irrelevant."* Jack, full Professor

What came naturally from the conversations was a confirmation that, most of the times, solutions for great societal problems or needs end up coming from outside of university. But, academic community do believe that University is the place where a deep understanding about the functioning, the why and the fundamentals, takes place, and this is considered to be absolutely needed knowledge to allow the existence of innovations outside universities.

> *"I think there is a difficulty in defining university. Great inventions were made by studying classics. And is here where university should act. Fertilize old ideas to our contemporaneity. We do not need to be in the front line to produce quotidian research… which is research for survival. Like our Paleolithic ancestors, they didn't need universities to learn how to make fire. The necessity gives birth to processes of discovery and creation. And this happens in society."* Andrew, assistant Professor

So, the impact-based agenda and the reflections about research impact directs attention to a fundamental reflection about universities' mission. And mission or motivation appears to be a much more profound, immaterial and intrinsic issue than the nature of metrics used to assess and to "force" impact (such as papers, patents, amount of research funding, etc), what seems to be the cause of some existing tensions.

While the route to impact was instrumentalized through a major survival aspect to academic research, which is funding: *"Funding is oxygen to researchers. You can change whatever you want in academia by giving or taking out funding from researchers" Sean, Entrepreneurship support;* funding, as well as the fundraising activity, seems not be currently aligned with the mission, the goals, the motivations and the occupational mandate of academic researchers.

> *"Doing research is fascinating, it's fantastic, but you have also to apply for money"* Christopher, academic researcher

This analysis unveils a tension between what researchers consider the core of their main occupational mandate, knowledge production, and their need to be free to explore unexplored avenues of knowledge, and another key activity – fundraising, which by definition, limits topics, and creates expected outputs and other requirements that need to be met in order to win these competitive games of governmental research grants.

Since research funding and metrics to career progression are being used to enact the strategy of an impact-based agenda to research, and impact seems to be more aligned with a deep motivation of academic researchers, intrinsic to their occupational mandate, these metrics are generally being perceived as limiting. This strategy is not only limiting researchers and the potential impact they can create as they are being possibly limiting the whole organization and the existence of a cohesive academic community, as it is reflected in the statement made by an academic researcher

> *"Metrics have that function, to supposedly fix quantitative parameters in the assumption that those individuals do not have a motivation… Interior, personal, to do what they are doing. The only recognized motivation is the career progression. What makes me sad in the metric is this profound disbelief in the human nature. (…) Another thing that I don't like in metrics is the disbelief in the values of a community, because metrics are individualization processes. And humanity is an effort to build communities more and more functional. (…). So, knowledge creation is intrinsically connected with the reorganization of communities and their values."*
> Andrew, assistant Professor

This individualization process created by metrics that evaluate impact, seems to separate the academic community what ends up naturally to reducing the potential impact it can creates, as previously mentioned in the aspect of lack of communication and collaboration between academic researchers.

<u>Academic researchers' occupational mandate is grounded in the pursuit of knowledge</u>

Insights from our analysis suggest that academic researchers' occupational mandate influence the type of research that academic researchers choose (by free will and considering they have all needed resources) to engage with.

Currently strategies in place to promote research impact are being perceived as being privileging short-term results in a very practical problem-solving approach, which was not found to be in line with the typical occupational mandate of academic researchers. This perception ends up creating tensions with researchers' occupational mandate, which is much more in line with the idea of pursuing knowledge regardless of its short or long-term possible use and application.

Academic research activity was defined as knowledge production, rather than a problem-solving activity which is even described by some as a source of distraction, such as it was by Paul, and academic researcher when he said: '"o be a very good researcher you can't be distracted with industry problems." This quote, unveils a deep assumption about what is knowledge and where it comes from, or in this case where it does not come from: "true" scientific knowledge is by definition distinguished from industry problems and in a way, emergent problems from the industry might be solved but they won't produce scientific knowledge. Paul contrasts the occupational mandate of scientists and their jurisdiction, with "people who are just focused on industry problems".

Knowing about industry problems and solving them may not be the central role of academic researchers. Their research may and should be motivated by industry or societal problems, and as we previously seen this type of contribution is something that researchers care about, but their occupational mandate is not specifically focused on solving industry problems, but instead in producing knowledge that can contribute to industry and societal problems. Finding solutions for societal or industry problems may or not happen within academia, but the production of general knowledge useful to solve these challenges is something that academics identify as their role and responsibility.

There is a general concern among academic community about the effects that the impact-based agenda is having in the fundamental research that must take place at academia, since they perceive that research supported by this agenda is much closer to applied research type or a problem-solving approach. This perception is then seen as harmful to academics' occupational mandate and to the perceived role that universities should play in society.

Regardless the identification of academics with fundamental research or the pure pursuit of knowledge that ground their occupational mandate, most academics and interface agents here interviewed, supported a balanced universities approach, where both, more fundamental as well as more applied or problem-solving oriented research, should take place, as said by an interface agent responsible for research funding support: "Universities should do a lot of fundamental research. We should bet in what we are really good doing. But we should support fundamental research as well as applied research". Eleanor – interface agent. This balanced view of the university mission and strategy does not necessarily erase the belief that the approach to research should be focused on the production of knowledge, respecting academic occupational mandate or, as described by an interface agent respecting '(…) what we are really good doing'. In fact, this view exists due to the recognition of the importance of applied research or problem-solving approaches to drive knowledge forward in the sense that generates questions that must be answered by fundamental research, as claimed by an academic researcher:

> (…). But not only does it drive technology forward, but it also pushes basic science forward, because you hit that technological barrier and then you realize that you need to understand some basic science, so it drives to basic science research agenda to actually understand the science to solve the problem.

Both forms of research need to co-exist to generate impact, and this perception is clearly a result obtained in this study. In other words, knowledge creation and the research process are precedent activities and essential conditions for impact and value creation, as stated by Carl, a technology transfer officer, who said: 'I think university should have fundamental research to bring this basis to more applied research'.

<u>Knowledge production is an activity potentially generator of impact</u>

Not only the combination between both types of research was considered essential to the mission of universities, but also each type, independently, was considered as a potential impact generator activity itself. Even though within different timelines, this study unveils the belief of academic community regarding the potential that both types of research have to impact creation, such as reflected in the comment of Jeffrey, an academic researcher, while describing his definition of research impact: "I think there is the direct impact in value creation, as well as the impact of basic research in the future, and the problem is to find a balance between them".

Most than believing that universities should have both types of research, academic community recognizes the importance of this balanced strategy to achieve research impact. Therefore, there is a clear concern about the potential negative effects of the strategies in place to enact the impact-based agenda, which are being turning fundamental research into the poor relative, such as illustrates the following opinion of an academic researcher: *"I think it [fundamental research] is under fire, in trouble, not being appreciated in this country. And that's a problem."* Alexander, associated Professor.

In the majority of interviews, it was notorious this notion of fundamental research as an essential activity of universities, as well as, a way how to search for research impact. In this line, Douglas, an academic researcher, described the importance of fundamental research as a forgotten source of impact produced by academia, when he said: “At universities we’re losing that notion that we should understand broader phenomena and there is where we should look for impact”.

This differentiation between different types of knowledge emerged with an associated difference of status between researchers doing pure research and those doing applied research, which is supported by the metrics for research funding, career promotion and the reward system. Consequently, academic researchers perceive a conditioning that again moves them away from a “free” research, which sometimes is subliminally associated with the right way how to produce impact from academic research, as shown in the following examples:

> *“Because with the press to publish should I risk in a new area or should I use a buzzword? So, all this strategy of our university with the publications and impact, increased the number of publications but it turned them more* irrelevant.” Jack, full Professor

> *“Another aspect is that there is an excessive publication rhythm. We can only vote if we have a specific number of publications, so we end up choosing comfortable areas of publication. We have a primitive fear of exclusion, so we end up publishing. There is a discussion about publishing or perish but what we forget about is that we can also perish by publishing.”* Andrew, assistant Professor

Academic researchers and research activity should be free

The feeling of lack of freedom in research it is a very present issue among the academic community, when discussing research impact policies enacted by governmental funding and universities incentives or rules. This feeling of lack of freedom imposed by research funding instruments it is a general concern of the academic community, regardless the professional level of researchers and their geography.

In fact, freedom of thought and exploration of new discovery avenues was often invoked when debating the risk of betting into a more problem-solving research strategy, which is the perception created by the impact-based agenda currently in place. These fears are well illustrated through the following examples:

- ‘I do believe that there needs to be an increase of government funding on proposals, so that universities can be free (…)’ William, PhD student.

- 'There should always be a space to explore fundamental research. We cannot stop researching the wing flapping of a fly just because there is no interest in that' Julie, interface agent

While both, academic researchers and interface agents, agreed that impact-based research should be supported, they stressed that it should not be at the expense of the free pursuit of knowledge and academics' creativity and freedom.

Figure 7 summarizes the values and beliefs, shared among the academic community interviewed. That were found to be in tension with their perceptions about the impact-based agenda, and can be, consequently, the cause for the perceived obstacles in the pathway to impact.

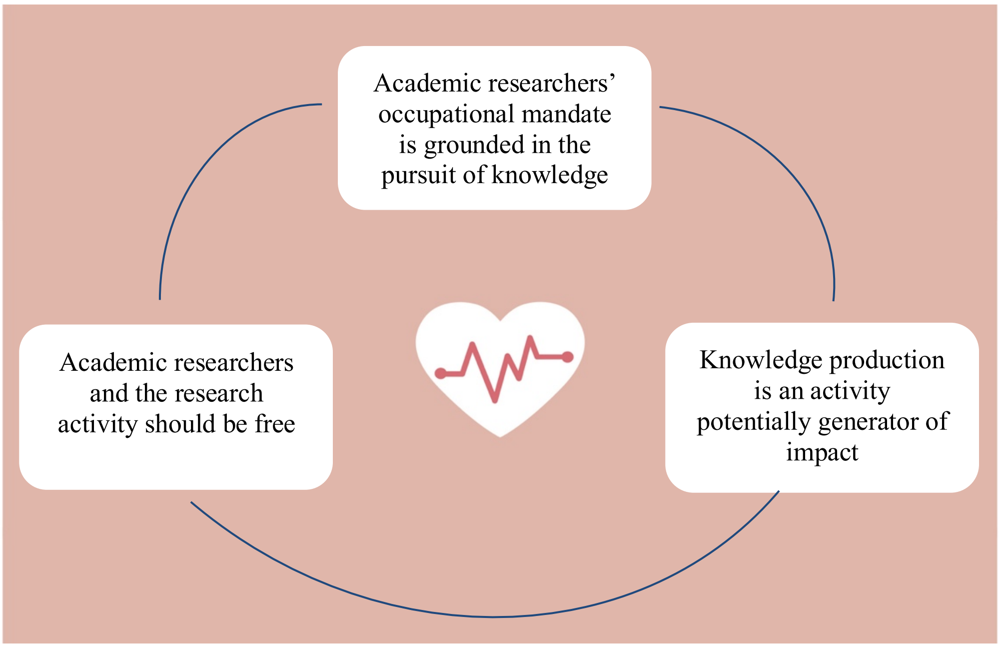

Figure 7 - Academic community's shared values and beliefs found to be in tension with their perceptions about the impact-based agenda

Besides expanding the previous work on the role of academic researchers' perceptions towards the impact-based agenda, this study presents an additional contribution made by the identification of a set of shared beliefs and values among the academic community that were considered as the root causes for the existing tensions.

These results can also be valuable and should also be taken into consideration when designing effective strategies to promote research impact. Therefore, to promote impact we should not forget that academic researchers' occupational mandate is grounded in the pursuit of knowledge, regardless its timeframe of future impact. While advancing knowledge, the academic community consider to be advancing society and promoting positive benefits to it, whether the impact becomes real in a short or long-term timeframe. Also, related with this time-frame aspect, academic community believes that all types of research are potentially able to produce impact. So, not only more applied research but also fundamental research should take place at universities and should be seen as a potential source of future impact generation.

A final aspect that was brought up by these interviews with the academic community, was the shared value of research and researchers' freedom which is considered to be at risk with the strategies implemented in the sequence of the impact-based agenda. This aspect of research freedom was seen as an essential condition to achieve impact, and can also be related with the previous studied vocational profession of an academic researcher that decides to pursuit this professional activity more as a "calling" than as an "employment", as it was verified by (Anderson, Ronning, Devries, & Martinson, 2010), in their study about the norms of science used by academic scientists in their work.

All the previous identified values and beliefs shared among the academic community working across different regions can be easily respected and integrated through the use of a process-based approach to research impact, where the research process specificities and intervenient are analyzed. The same is not true for cases when research impact is measured by an approach based in outputs or outcomes, where very specific results of the research activity are expected to be produced.

6 RESEARCH IMPACT ENABLING CONDITIONS

Considering previous findings about the reasons behind the existing tensions between the academic community and the impact-based research agenda, and having now a more clear understanding about the importance that process-based approaches to assess research impact might have to smooth those tensions (which provided answers to research question 1), this research section intends to focus attention on possible enabling research process-related conditions for research impact at Higher Education and Research Institutions.

To discover what conditions may positively affect the pathway towards research impact, there were pursuit different research strategies and analyzed different research objects. To start with, it is important to use the information about existing process-based research impact assessment models and frameworks, previously presented in chapter 3.

As seen in chapter 3, different engagement practices, including collaboration with industry and with potential research users, are considered to be important conditions to the generation of research impact. Together with this, also the proposed guidelines to the development of future research impact assessment instruments, proposed by Adam, *et al*. (2018), implicitly suggest possible conditions to generate impact, which were found in the following analysis:

- Guideline 3: stakeholders' needs - the importance of the knowledge about stakeholders' needs;
- Guideline 4: stakeholders' engagement – which reinforces the importance to identify and collaborate with other stakeholders;
- Guideline 9: communication – where it is shed light to the importance of communication to the research impact process;
- Guideline 10: community of practice – which reinforces the importance of engagement with research users (also supported by Cacari-Stone, Wallerstein, Garcia, & Minkler, (2014)).

To complement previous information, it was performed a qualitative study based in interviews that serves to unveil enablers and obstacles to research impact based on previous experiences of academic researchers, which is described in sub-section 1 of the present chapter.

After having this first picture about the possible impact conditions, it was performed a content analysis to the existing documentation that could be used to unveil other impact conditions. These documents are the innovation management standards, which were used due to the fact that innovation is considered precede impact (further described in section 2 of the present chapter), and the impact cases studies developed for the UK's REF exercise in 2014 (further described in section 3 of the present chapter).

6.1 Academic community experiences

To start unveiling possible enabling conditions to produce research impact, and complement existing knowledge of the literature, as well as inform the content analysis that will be following performed, it will be firstly studied the opinions of those who perform research activities or are very closely related with this type of activities at HERIs. The opinions of the academic community in relation to the necessary conditions to achieve impact, was given taking into consideration the definition of impact that is presented by the results of the qualitative study described in chapter 5. Therefore, it was conducted a series of interviews with academic researchers who had achieved outputs that are related with the future production of research impact, such as for example the creation of university' spin-offs, patents and its licensing to companies, among others. The sample analyzed included 30 academic researchers based in Portugal and in the USA, developing research in the fields of sciences and engineering.

Following the same motives presented for the interviews previously performed and presented in chapter 5, this study included also in the sample of interviewees other members of the academic community beside academic researchers, that included interface agents and academic managers. To do so, 10 interface agents, also working in HEIs operating in the fields of sciences and engineering and based in the two different analyzed geographies (Portugal and the USA).

To achieve the intended results, the interviewees were questioned about examples of what they considered to be research impact achievements, whether they were performed by themselves or others, and then to indicate what conditions were essential during the course of the research process, that guarantee the achievement of those results. In order to complement these results, when the interviewee was an academic researcher, it was also asked if they could point out essential conditions to produce impact that they found to be lacking and consequently reducing their chances to produce impact or any kind of obstacles they feel are on their way to produce research impact.

By coding the transcribed text of the 40 interviews, it was possible to unveil the opinions and perceptions of academic community in what respects to the conditions that must be met to produce research impact.

Collaboration was, as observed in the literature, vastly mentioned by the academic community, which mainly identify it as a lacking condition, especially due to their understanding of the need to establish long-lasting and trusty relationships to effectively increase the chances of impact. In this collaboration topic it was here possible to identify specific categories or types of collaborations, namely collaboration with industry/companies, collaboration with governmental bodies / agencies, collaboration with other HERIs, where it was specially mentioned the importance of multidisciplinary research teams to create more potential impact from research, and finally also some less frequent but also present mentions to the importance of collaboration with civil society (traduced in local communities or potential consumers or users of a scientific knowledge or result).

In general terms, collaboration was a very highlighted aspect to potentiate research impact, as it is demonstrated by the following quote from an academic researcher:

> "*I think that a researcher is not able to create impact by himself. He needs other people and to work in a network*" Eudora, associate Professor

When talking about collaboration with industry, an academic researcher also said the following:

> "*(…) So, I think that part is extremely important. We could not do it on our own*". Mark, associate Professor

Despite the importance attributed to collaboration for the production of impact, some struggles are also generally felt among academic researchers, who mentioned a lack of alignment and sometimes also communication between HERIs and non-academic organizations, as it is illustrated in the quotes transcribed below.

> *"I think is that they do not know each other. Companies do not know the potential of universities and universities do not know about the problems of companies."* Derek, associate Professor

> "*The industry is also key, and sometimes they are not open to that (…) because connections with the university are established with a cost and it takes time. And what happens is that industry don't want to pay and don't understand the time it takes*." Jeffery, assistant Professor

As previously mentioned, academic community also identified collaborations with other researchers, especially from other scientific areas, as a very welcome condition to increase their chances of impact production. As said by an academic researcher: "*We have a big problem which is the physical distance of the faculties, the business, the science and social humanities. We should work together to create value.*" Jack, full Professor

This aspect of collaborations was perceived as a main obstacle to generate research impact, due to the natural difficulties of researchers and the research process to the establishment of partnerships, as illustrated by the quotes from academic researchers, transcribed below.

> "*I don't think researchers work well together from other departments. (...) departments tend to be silos and even within the silos the researchers within the department tend to not work well outside the norm, like they work at a group. Like, there is a cybersecurity group like they're all tight, they're all working together really well. But then they do not cross and talk to somebody else in another department even within the same department, I'm guessing they kind of do their own things. Some of them do, but… I think if they saw opportunities, they probably would do it, because ultimately the goal is to get research grants.*" David, industry Professor
>
> "*what I feel is that is very difficult to work with people from different areas. Because we have different languages. We are not able to communicate. And we need to work on this to create impact*". Eudora, associate Professor

Collaboration with the civil society was a less frequently mentioned issue, but also present in the results of this study, more often expressed indirectly through the aspect of science communication skills to non-academic audiences, but also in a more direct approach, as it is presented in the testimonial of an academic researcher, following presented.

> "*I think that universities are a bit lost. Universities lived most of the times in an Ivory Tower, what disconnected the university from fundamental aspects of society. So, universities have been most times alienated from fundamental aspects and movements of society (...) great thinkers are marginal to universities. If you see most of the times people who give great contributions and revolutionize new visions, are not inside academia.*" Andrew, assistant Professor

It is important to notice that in all types of previously mentioned collaborative practices, that are two aspects that must conditionate the establishment and results obtained by these collaborations, namely the teamwork skills and behaviors of academic researchers, as well as the existence, access and profile of the different types of organizations previously mentioned. Considering the type of organizations mentioned as important partners for collaboration with HERIs and researchers in the pursuit of impact, these organizations are here collectively named as the Quadruple Helix (QH) innovation ecosystem. This naming follows the quadruple helix framework and its components, described in chapter 2.

As mentioned, to the effective establishment and performance of research collaboration it is important to have both a good and functioning QH innovation ecosystem, and also academic researchers with skills and behaviors that allow them to work collaboratively, which is a practice very much connected with the production of research impact, as illustrated by the following quote by an academic researcher: "*I have always done a lot of collaborative research, because I like to stretch out what we do and find other applications for it. and having I think diversity perspective on the research also helps develop new ideas. So, for me it's just my ...the way I work, and I like to be collaborative and I like interacting with other groups and getting other perspectives. I think it makes the science better to get diversity, in terms of perspectives and opinions and even diversity of people. And I think it lets us do that science that we do*" Claire, Associate Professor

In several examples previously presented about the importance of collaboration to the production of impact, is also possible to spot aspects related with communication skills, or in most cases, the lack of the needed communication skills among different stakeholders involved in these collaborations.

Science communication skills were vastly mentioned as a necessary skill that must be mastered by academic researchers, which could leverage opportunities of valorization of their research results or even other research opportunities more directed to the application of scientific knowledge in solving a specific problem / need.

Communication skills were valued by the academic community as an essential skill that could potentiate the impact of their research. These skills included both cases of science communication directed to academic audiences, where it is possible to potentiate the development of future research, collaborations with other academic researchers, and also enable the production of impact on governmental policies; as well as science communication to non-academic audiences, that can typically leverage partnerships with the industrial / corporate environment, governmental bodies and also the civil society. Both types of science communication and its importance to research impact, are also illustrated in the examples previously presented about the importance of collaboration and collaborative skills, but they were also specifically enforced along the conversations with most academic researchers interviewed, that stated things like "*Researchers should be able to communicate science*." Eudora, Associate Professor and "*(...) in a personal level we should develop personalities that have the core competences to interact and to know how to communicate*" Cristopher, industry Professor

Despite seen science communication as a basic skill that researchers must master, this skill is still also perceived as a main challenge to researchers, since references to science communication were also made in cases where researchers were illustrating their main challenges or blocks to research impact. One example of this are references made to the lack of university training and development of science communication skills among university students, which therefore ends up being a lacking skill in future generation of professionals and researchers. This lack of science communication training of university level students is seen in the example below, which was given by an academic researcher.

> "*and I've heard that also from future employers when they want to employ students, they say: 'You raised excellent engineers, they know everything about computer science, but they lack communication skills'. And that's weird. They say communication skills are as important as technical skills"* Cristopher, industry Professor

Besides science communication skills, other type of competences and behaviors was also identified through this study as an enabling condition for researchers who want to turn their research activities and outputs into impact. These skills and behaviors were coded into a theme named research valorization skills, and cover aspects related with the identification of needs, problems and opportunities, as it was stated by an academic researcher that said "The understanding about the problem it was decisive in this whole process", while talking about a specific research project and the impact produced. This theme includes also the knowledge about how to exploit these value creation opportunities, through the performance of research activities, which includes the entrepreneurial behavior or entrepreneurial competences together with knowledge in what refers to technology transfer and technology valorization.

There is a perception shared among academic researchers and interface agents that academic researchers must master or, at least, have some basic skills of entrepreneurship, technology transfer and valorization related aspects, which can allow them to detect possible opportunities to impact, topics for research, applications of their research to different fields, and also to facilitate the identification, engagement and establishment of partnerships not only with other researchers in different but complementary fields of research, as well as, with other entities, either public or private organizations. This was a vision shared by interface agents, as it would be more easily expected, but also by the majority of academic researchers interviewed, as it is illustrated by the example below.

In respect with the entrepreneurial and technology transfer / valorization skills there are some academic researchers, that while recognizing the importance of these behaviors and knowledge among the academic researchers' community, also defend that there should exist a specialized and dedicated staff or in place collaborations with third parties or individuals more specialized in these issues that could support academic researchers. In this approach academic researchers ask for more institutional support in providing this assistance and also in creating conditions that propitiate this type of activities.

> "*I mean to be a very good researcher you can't be distracted with industry problems, but there's people who are just focused on industry problems let them be the ones that come to you and say: you know this is what we need to do*" Paul, industry Professor

> "*I think they (the researchers) should not be involved in these forms of impact. They should contribute, with more technical skills, but I have no doubt that it should be people with other skills, 100% dedicated to this issue. (...) We need to have more support to write patents, to have tech transfer experts (...) more commitment from the university towards value creation, as for example helping in the process of startup creation*" Eudora, Associate Professor

This idea of having more institutional support to communicate and connect with external entities was mentioned as a missing piece in the creation of value out of research activities, such as the following quote by an academic researcher: "interface agents that can bring the problem of companies to the universities and present the potential of universities to companies." Derek, associate Professor

But the organizational support that was perceived as essential to achieve research impact was not limited to the existence of structures, procedures and staff, but also related with the management practices and consequent organizational culture, aspects that were especially identified when interviewees were describing existing barriers to research impact.

One of these aspects is the evaluation metrics used in academia to evaluate their staff which serve as the basis for career progression, which are not perceived as enablers to generate research impact but are instead seen as barriers to researchers dedicate and focus on impact. As said by the words of an academic researcher, "*But if your success is social good you may not reach that point because you stopped at the point which was valued by the community around, like publications or funding. (…) But if there is a culture that appreciates and values it, you will see it happening more and more*" Peter associate Professor.

This same opinion is also seen in places where patents and other technology transfer / valorization outputs are used as metrics to evaluate academic researchers, but the culture of academic types of impact is still predominant, as it can be seen in the following opinion given by an academic researcher. "*Performance metrics are oriented in a management vision, but we do not have a culture or infrastructures to do that. But I think that progression in the academic career should not even be done through metrics of patents or startups but by measuring impact in advancing knowledge further. Citations are definitely not impact*". Douglas, assistant Professor

Here, it is seen not only a confirmation about the previous mentioned occupational mandate grounded in the production of knowledge, but also an inadequacy of metrics used to evaluate researchers, (whether used internally in researchers' host organizations, national or regional exercises of the performance of HERIs, or in research funding evaluation panels), in regard with the goal of achieving research impact.

Not only directly the metrics used to evaluate researchers, but other types of policies and incentives that could be put in place by academic organizations, were found to be preventing research impact. Among these cases we can found in fact organizational incentives or policies that promote other identified research impact conditions, such as collaboration with external entities or among researchers (1), a risk-friendly environment (2), having time of being creative by reducing the bureaucratic burden, and an environment that promotes a good and close relationship between researchers and students, especially with PhD students. In short, academic community assigns academic institutions the responsibility of promoting and incentivizing research impact by putting in place internal policies and other instruments that could promote research impact conditions.

(1) "*So, they say: "if I work with this mechanical engineer, we join forces and we can do this". They will do it. I think they just tend to get… I think that the grant process, what they're asking for tends to be focused. so, the N.S.F. would have to open up to the next level saying we want you to solve this problem. and this problem is an umbrella. So, I think it's going to come*

from the top down. And once they do that, I think that everybody will do it" David, academic researcher

(2) "*And the third thing is at the university we can risk and fail. In companies we cannot*." Jack, full Professor

The importance of PhD students was many times referenced in different examples of research impact given by the interviewees, not only as members of research groups and research activities (3) but also as promoters of value creation activities that drove impact.

(3) "in terms of impact of the pure research I think that students are crucial, the PhD students, because the research group is a pyramid where professors have PhD students that supervise master students and so on." Jeffery, assistant Professor

Not only due to a lack of professional opportunities, as mentioned by many of the interviewees (4), but also because of a genuine interest in creating some kind of impact, as referenced by some interface agents, younger generations can in fact lead to a future change in the occupational mandate of academic researchers and affect the academic stance and culture, what makes them an interesting "piece" of this unique ecosystem.

And the effect of students and younger researchers, as the Postdocs, is already felt in academia, once they are connecting faculty members with impact-based activities, such as the example of many academic researchers interviewed who co-founded companies together with their students or who were motivated by them to start working on applications for their research, such as it was mentioned by Philip, an interface agent: *"So, what we found is that the group that is most willing to look at something that comes out of a basic science lab and explore whether this can be used for something new are the postdocs"*.

It was also found that academic researchers' role as educators ends up connecting some faculty with impact-based activities, as for example David, an academic researcher who, when talking about commercialization, patents and startups, stated: "*I look at that as an opportunity for students, I think it's tremendous*". The educators' role also creates a sort of accountability feeling that faculty must have this kind of impact-based experiences to use that knowledge together with the fundamental knowledge, at the classroom: "*There's a delicate balance…I walk in the classroom with rigorous theory and application. You have to have both, and one or the other is not good enough*" Cristopher, Industry Professor.

(4) "*But I would not go so much with the professors, but more with the students. The students are the key. Students of any level. most of the companies created here, were created by PhD students who don't have job opportunities*" Jack, full Professor

Interestingly, one topic that was considered of importance to research impact and that emerged from conversations about the duties of researchers' host organizations, end up also being an issue to consider within the previously mentioned teamwork skills of researchers, since researchers themselves also have the responsibility to integrate and develop effective relationships with younger researchers, such is the case of PhD students.

Finally, there was one theme that unambiguously emerged from the analysis of the results of this study which refers to the existence and access to research funding.
When questioned about the conditions that must be in place to allow the potential generation of impact from research activities and / or the obstacles to impact, members of the academic community made different references to research funding and its importance to the existence of research activities that naturally precede research impact. Research funding is, as it was defined by an interface agent, "oxygen" for researchers, and ultimately determines the research line, topic or direction, as well as conditionate researchers in the choice of their research partners.
"*how we decide to work on it,* a lot of it is dependent on funding so. *Whatever grants I've applied to that I've received funding for is whatever we end up working on, because that's what supplied the funds for my grad students"* Claire, Associate Professor

Besides reinforcing the aspect of influencing freedom of research activities and researchers, that was previously explored in chapter 2, it is here impossible to ignore that members of the academic community attribute great importance to research funding also as an essential condition to the performance of research activities and consequently on its outputs, outcomes and further impacts.

Through this qualitative study performed through interviews to the members of the academic community, it was possible to verify the emergence of different research impact conditions and the reinforcement of others already mentioned by previous works in the literature, referenced in the previous section.

At this point of the research where a greater number of research impact enabling conditions are identified, it is now proposed to divide them into three different categories or contexts. These categories are composed by the individual context, where the identified researchers' skills and behaviors make part, the organizational context, which includes aspects related to the researchers' host institution, such as organizational support structures, staff and procedures, and by the external research context, that includes aspects related with the existence of entities and procedures that are not controlled by the academic organizations neither by academic researchers themselves.

Tables 8, 9 and 10 show the research impact conditions unveiled by the study presented in this section, within the three contexts in which they were categorized.

Table 8 - Enabling research impact conditions within the individual context

Dimension	**Individual Context**							
Category	Science Communication		Research valorization			Teamwork / Collaboration		
Research Impact Condition	Science communi-cation skills to non-academic audiences	Science communi-cation skills to academic audiences	Entrepre-neurial skills and behaviors	Technology transfer skills and behaviors	Identification of research and research valorization opportunities	Teamwork and work dynamics within the research group, especially with junior researchers	Collaborative practices with academic researchers in different research fields	Collaborative practices with members from non-academic organizations

Table 9 - Enabling research impact conditions within the organizational context

Dimension	**Organizational Context**			
Category	Support structures, staff and procedures	Management practices	Organizational culture	
Research Impact Condition	Organizational support to entrepreneurship, IP and TT related issues	Researchers' evaluation metrics	Policies and incentives to research impact conditions (creativity, collaboration, etc)	Risk-taking environment

Table 10 - Enabling research impact conditions within the external research context

Dimension	**External Research Context**	
Category	Research policy	QH innovation ecosystem
Research Impact Condition	Existence, access and profile of research funding	Existence and collaboration with business, government, universities and the civil society

6.2 Benchmark with Innovation Management Standards

Despite the focus of this research on the academic environment, more specifically on the research activities performed at academia, this research work searched for external possible sources of inspiration that could be indicative of important conditions that should be considered or assured to support research impact generation.

Considering that innovation precedes impact, and innovation is a very advanced field of knowledge, whether scientifically or in terms of practices, documents about standardized practices of innovation, where there are made considerations and recommendations about pathways and conditions to innovation, were considered as useful resources to serve as research objects to find conditions to produce research impact.

Therefore, Innovation Standards were seen as a reliable resource to use, considering that these documents are generated by a collaboration effort of experts in the fields, providing as described by the International Organization of Standardization "documents that provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose." (ISO, 2018).

Another interesting aspect of analyzing standards is that these documents intend to create common understanding, and therefore could be considered to avoid the most important obstacles to innovation, and consequently possible obstacles to research impact, consisting in cultural and organizational issues (De Casanove, Morel, & Negny, 2017). In sum, standards in innovation management presented a perfect alignment with the general aim of this research.

Portugal was one of the first countries to propose, in 2007, a standard about managing Research, Development and Innovation, named NP 4457, which stands for the Portuguese Norm number 4457. In 2008 a European Technical Committee (CEN/TC) number 389 was created to study and further produce the European Norm number 16555 (EN 16555) about Innovation Management, which presents a more systematic approach to innovation in organizations, which then served as base to the development of other innovation management standards in different countries, such as UK, France, Germany, Brazil, Mexico and China (De Casanove *et al.*, 2017).

Currently, it is also in place an international effort aiming to create a series of International Standards on Innovation Management - ISO 50500 series (ISO, 2018), that will provide international harmonization on innovation management relates issues. At this moment, there is only one published document about the International Standard of Innovation series 505000, which is consists in a draft form – ISO/DIS 50503, voted and approved May 31st of 2018, and where tools that can be used to identify, select and align partners to create innovation, are presented.

Therefore, it was performed a content analysis to the documents of the previously mentioned Portuguese and European Standards, as well as, to the available documents produced for the underdevelopment International Standards on innovation management. The results and critical review of this content-analysis are following presented.

Pro-collaboration environment and culture

In terms of collaboration, the European Norm 16555, refers to the importance of an open environment, where collaboration is clearly encouraged and also possibly rewarded, such as illustrated in the following parts of text extracted from pages 11 and 12 of the document CEN / TS 16555:

> "The Innovation Management System should incorporate a strategic approach to human resources. The human resource policy should –(…); - implement job design that allows variation, challenges and open interactions; - encourage open interaction, trust, diversity and tolerance; - provide procedures for employee contracts ensuring appropriate incentives for innovation; - encourage participation and representation in the innovation process of persons in the organization when appropriate; - allow persons access to relevant information from management"

> "The organization should define a policy for internal and external collaboration. Collaboration within the organization should be fostered so that ideas and knowledge can be shared across different persons, groups and units by:
> - disseminating challenges and stimuli for ideas and problem solving;
> - encouraging persons and groups (with a diversity of perspectives) to collaborate to develop ideas and share knowledge (…)"

Stakeholders' engagement (including identification, selection and alignment)

The Portuguese Norm - NP 4457, advises to perform an identification of possible stakeholders that could have interest in the topic in analysis, such as it can be find on page 4

> "The organization should establish a process to manage the technological, market and organizational interfaces of the innovation process, that assures the transfer and circulation of knowledge between the organizational innovative activity and its environment.
> To do so, the organization should:
> a) analyze the external environment to identify the players with whom it is interacting or should be interacting to the exchange of information considered necessary by the organization, as well as to the identification of opportunities and threats. This analysis

should cover the micro surrounding of the organization in what is considered as relevant: suppliers, consultants, partners, distributors, clients and competitors. It should cover also the macro surrounding, such as educational system, scientific and technological system, informational infrastructure, regulators, funders and sectorial systems."

Regardless the current and future final content of ISO/DIS 50503 - the only currently available document about the International Standard of Innovation, still in its draft form; it is possible to conclude that identification, selection and alignment of stakeholders are important activities to perform in order to achieve innovation.

Achieve a shared understanding or an alignment between stakeholders it is also a common topic among innovation recommendations, such it is described in the transcribed section of the document ISO/DIS 50503 (page 7), bellow:

> "Before organizations formalize a legally binding agreement, it is important to ensure a shared understanding of the purposed opportunity for innovation and the partnership. To do so a number of factors to develop a common understanding should be addressed in order to increase the innovation partnership's likelihood of success."

To align involved stakeholders, it is important to know their needs, such as described on page 7 of CEN / TS 16555.

> "Understanding the needs and expectations of interested parties – Interested parties are divided into those external to the organisation (e.g. partners, suppliers, distributor, research organisations, customers and users, public authorities, etc) and those within it (e.g. employees, top management departments, shareholders, etc). Interested parties need to be involved and consulted to identify theirs needs and expectations which may be explicit or implicit. In particular, it is important for the organization to understand the needs of customers as well as users and their unmet and unarticulated needs."

<u>Identification of opportunities</u>

Collaboration appears also in the analyzed documents, as a source to identify opportunities to innovation, such as can be found on page 12 of CEN / TS 16555 and also on page 11 of NP 4457, transcribed bellow:

“Collaboration and networking with external organizations can help identify ideas, customers need, knowledge and partners, to help with both problem-solving and exploitation of ideas. Opportunities may be identified by:

- actively listening and adopting ideas from customers, suppliers and other parties;
- joining knowledge transfer network, professional bodies and trade associations;
- collaborating with or commissioning universities and innovation support services to assist with idea generation and development”

“The organization should identify the necessary management activities for R&D+I process, namely:

a) Management and coordination of projects’ portfolio
b) Identification and analysis of problems and opportunities

Communication

Dissemination of knowledge was identified in the analyzed documents as an important activity to enable and manage innovation.

CEN / TS 16555 (page 11)

“The human resource policy should – foster creativity, learning and dissemination of knowledge”

“(…) what to communicate, when, to whom and by whom, the provision of communication channels and the intended feedback”.

NP 4457 (page 11)

“4.43 – Communication

The organization should assure the establishment of appropriate communication to internal and external communication.

NP 4457 (page 4) - “Identify the elements from the organization that assure or can assure the communication flows and information exchange with the identified players.”

Table 10 summarizes results obtained from studying existing innovation standards, which, as previously mentioned, can help in the identification of basilar conditions important to produce innovation and then also potentially influencing the consequent research impact. In order to connect the results here obtained with those obtained and categorized in previous sections of this chapter, table 10 also indicates the categories and sub-categories of each identified conditions, according to the previous categorization performed. As showed in table 11, results obtained in this section reinforce the importance of some conditions already unveiled in the studies presented in previous sections, namely by presenting findings that are similar or comparable to those belonging to sub-categories of science communication, research valorization, organizational culture and QH innovation ecosystem.

Table 11 - Enabling research impact conditions from the analysis of innovation standards

Dimension	**Individual Context**		**Organizational Context**		**External Research Context**
Category	Science Communicat ion	Research valorization	Organizational culture		QH innovation ecosystem
Research Impact Condition	Communicat ion	Identification of opportunities	Pro-collaboration environment	Promotion of creativity	Collaboration
CEN / TS 16555	YES	YES	YES	YES	YES
NP 4457	YES	NO	NO	NO	YES
ISO/DIS 50503	NO	NO	NO	NO	YES

6.3 Impact Case-studies' Analysis

Aiming to detect all possible activities and processes that can unveil necessary conditions to achieve research impact, it was performed a search about available information regarding research projects considered to be good case studies of research impact.

This search delivered a main result, which were the public impact case studies submitted by Universities in the UK to the national research assessment exercise performed in 2014. Thus, the documentation from the impact case studies, was analyzed using the same content analysis method applied in the previous analysis of innovation management standards.

In the research assessment exercise, performed by the UK in 2014, impact produced in the period of 2008 to 2013, defined as 'An effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life beyond academia', was assessed through the analysis of case studies, therefore evaluated in a scale of 1 to 4 by a panel of evaluators composed by academics and also research users from outside academia (Research Councils UK, 2014a).

All 6.637 impact case studies submitted to the REF by Universities in the UK, were turned publicly available, through the REF's website (Research Councils UK, 2014b), but since we are searching for good examples of research impact, it was important to select from the entire list of impact case studies submitted, those with higher scores. Considering that it is not possible to access information about the score attributed by the evaluators to each case study, it was used the available information about the University that better performed in terms of impact, per Unit of Assessment. These results were made available in a scale of 0 to 100, where for example a University with impact score of 100 in a specific Unit of Assessment, has had all its impact case studies from that Unit of Assessment rated 4 (Research Councils UK, 2012).

Considering that this research focuses attentions in the fields of sciences and engineering, the related units of assessment included in the panel B of evaluation, were used to identify the better scored universities, and consequently constitute the impact case studies to be here analyzed. Panel B includes the units of assessment identified by REF as number 7 - Earth Systems and Environmental Sciences; nº 8 - Chemistry; nº 9 – Physics; nº 10 - Mathematical Sciences; nº 11 - Computer Science and Informatics; nº 12 - Aeronautical, Mechanical, Chemical and Manufacturing Engineering; nº 13 - Electrical and Electronic Engineering, Metallurgy and Materials; nº 14 - Civil and Construction Engineering; and nº 15 - General Engineering.

Therefore, through the REF results available online, it was produced the table 11, presented below, that identifies the Higher Education Institution ranked first and second per unit of assessment, and its corresponding scores (Research Councils UK, 2014b).

Table 12 – Best ranked institutions in the units of assessment included in panel B of UK's REF exercise

Unit of Assessment Number (from Panel B)	**Unit of assessment name**	**Rank of best scored HEIs**	**Institution Name**	**Percentage of the submission meeting the standard for:**				
				4*	3*	2*	1*	Uncla-ssified
7	Earth Systems and Environmental Sciences	1st place	University of East Anglia	77,1	22,9	0	0	0
		2nd place	Newcastle University	73,3	26,7	0	0	0

Unit of Assessment Number (from Panel B)	Unit of assessment name	Rank of best scored HEIs	Institution Name	Percentage of the submission meeting the standard for:				
				4*	3*	2*	1*	Uncla-ssified
8	Chemistry	1st place	University of Durham	76	24	0	0	0
		2nd place	University of Cambridge	65,7	34,3	0	0	0
9	Physics	1st place	University of Manchester	82,9	17,1	0	0	0
		2nd place	University of Strathclyde	80	20	0	0	0
10	Mathematical Sciences	1st place	University of Oxford	87,5	12,5	0	0	0
		2nd place	Royal Holloway, University of London	80	20	0	0	0
11	Computer Science and Informatics	1st place	Newcastle University	90	10	0	0	0
		2nd place	University of Cambridge	86,7	13,3	0	0	0
12	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1st place	Imperial College London	75,6	20	2,2	2,2	0
		2nd place	University of Birmingham	70	30	0	0	0
13	Electrical and Electronic Engineering, Metallurgy and Materials	1st place	Imperial College London	100	0	0	0	0
		2nd place	University of Oxford	90	10	0	0	0
14	Civil and Construction Engineering	1st place	Cardiff University	100	0	0	0	0
		2nd place	Imperial College London	65,7	34,3	0	0	0
15	General Engineering	1st place	University of Oxford	84	12	4	0	0
		2nd place	King's College London	80	20	0	0	0

The number of impact case studies submitted in the respective unit of assessment by the higher education institutions ranked in first and second place, as well as the types of impact created, are identified in the table 13.

Table 13 – Number of cases studies submitted, and types of impact generated by the cases studies best scored in panel B of UK's REF exercise

Unit of Assessment Number (from Panel B)	Unit of assessment name	Rank of best scored HEIs	Institution Name	Number of case studies submitted	Type(s) of impact
7	Earth Systems and Environmental Sciences	1st place	University of East Anglia	7	Environmental (7)
		2nd place	Newcastle University	3	Technological (2) Environmental (1)
8	Chemistry	1st place	University of Durham	5	Technological (5)
		2nd place	University of Cambridge	5	Technological (3) Societal (1) Environmental (1)
9	Physics	1st place	University of Manchester	7	Technological (4) Societal (3)
		2nd place	University of Strathclyde	4	Technological (4)
10	Mathematical Sciences	1st place	University of Oxford	13	Health (1) Technological (6) Societal (2) Economic (4)
10	Mathematical Sciences	2nd place	Royal Holloway, University of London	2	Technological (2)
11	Computer Science and Informatics	1st place	Newcastle University	4	Technological (4)
		2nd place	University of Cambridge	6	Political (1) Technological (4) Economic (1)
12	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1st place	Imperial College London	18	Technological (13) Economic (4) Political (1)
		2nd place	University of Birmingham	3	Technological (3)
13	Electrical and Electronic Engineering, Metallurgy and Materials	1st place	Imperial College London	10	Technological (8) Political (2)
		2nd place	University of Oxford	2	Technological (2)
14	Civil and Construction Engineering	1st place	Cardiff University	2	Environmental (2)
		2nd place	Imperial College London	7	Technological (2) Economic (3) Environmental (2)
15	General Engineering	1st place	University of Oxford	5	Technological (5)
		2nd place	King's College London	5	Technological (5)

All 108 case studies selected were submitted to content analysis, were submitted to content analysis to produce the results that will be following presented and analyzed. Detailed results, with transcription of selected text that inducted the achievement of such result, can be found in Appendix B.

To perform this study all 108 case studies selected were submitted to text analysis, and by using previous professional experience, the author, induced the present conditions that facilitated or enabled that specific route to impact.

The majority of information that led to results about possible influences to produce research impact, was found in the section number 4 - "Details of impact" of the text, where it is made a detailed description of routes to impact and the background of research that led to the achieved impact. Although most conclusions were taken from this section, the entire documents were analyzed, and other sections of the impact case studies were also used to produce results. Whenever a part of text used to infer the presence of a specific condition to impact, was not taken from section number four (from where it was extracted the majority of results), the number and title of the respective section it is specifically mentioned in the result's table.

It is also important to highlight that, most of the times, these impact case studies do not directly mention the conditions that were essential to achieve or produce such impacts, and therefore this analysis was an inference made through analyzing the text content. Whether impact case studies made an explicit or implicit reference to essential conditions that were met to produce that impact(s), those parts of the text were extracted and coded by using the name of activity, resource or process used, which therefore names the condition in analysis, and turned available in the result's table of Appendix B. Table of Appendix C summarizes all research impact conditions found in each one of the impact case studies analyzed.

It is also important to mention that other not identified research impact conditions may have had influence in the final result of each analyzed case study but might not been identified due to lack of disclosure of information in the document produced by each HEIs.

To illustrate how the content analysis was performed, some examples are following presented.

'Through advisory work with the Brazilian Ministry of Environment (MMA), Peres has attended numerous conservation planning workshops, (…)' is a quote found in a case study presented to the UoA of Earth Systems and Environmental Sciences, which was coded as collaboration with governmental bodies, the name given to an influence to research impact.

Another example is the presence of science communication skills to non-academic audiences, as an influence to research impact, which was found in the following quote, extracted from a case study presented the same UoA of the previous example: ‘Our research has provided the basis for a science fiction novel’.

Through the analysis of the REF’s impact case studies from universities better evaluated in the impact criteria for each unit of assessment (of panel b) it was observed that communication skills were present in 37 per cent of impact case studies analyzed, also previously identified in the analysis of the innovation standards. In this category of communications skills, it was possible to identify a division between two specific types of communication, namely communication skills to academic audiences, which allow the publication of impactful papers or other type of oral or written science communication routes directed to academics, and, in the other hand, science communication skills specifically targeted to non-academic audiences, such as television programs, public exhibitions, courses and general oral presentations, among others.

In the collaboration category, also previously identified in the study made to the text content of innovation standards, it was here possible to identify more specific types of entities with which the collaboration was established, and in some cases and in some cases also the motives behind the creation of the partnership. With regard to the type of entities with which partnerships were established to create research impact, were found strategic collaborations between HEIs and industry/companies (including start-ups) – present in approximately 48 per cent of the analyzed case studies; collaborations with governmental entities – present in approximately 13 per cent of the analyzed case studies; collaborations with other Higher Education Institutions – present in approximately 4 per cent of the analyzed case studies; and collaborations made directly with the civil society / possible users or local communities – present approximately in 1 per cent of the analyzed case studies. This last type of collaboration made with the civil society or final users, was considerably least found, having been identified in only one of the case studies.

In the cases where collaborations were established with industry/companies it was possible to find examples where these collaborations were made to a) solve a specific problem (whether companies approached academic researchers first hand, or the other way around); b) to use industrial/market knowledge to scale up, prototype and /or apply the research to a real world context; and c) in the specific case of startups, academic researchers collaborate with the company to advise and support them in terms of the technology, science that was being applied to commercialization purposes. It was also seen that collaboration with industry/companies can also take place through direct funding to academic research, or by hiring academic researchers as consultants, to the advisory board of the company or other similar roles.

In the case of collaborations performed between academic research and governmental bodies, the case studies analyzed, indicated that this can happen when there is a specific need or problem to be solved, for example in terms of environment or policies, and most of the times academic researchers are asked to join expert groups and panels, serve as consultants or to write articles and advice that can be further used by the governmental entity.

Still, in respect with collaborations, it is also important to mention that collaborations established with other HERIs, where specially made with academics in different areas of expertise from those existing in the research group that is proposing or leading the research activity.
It is also interesting to note that this type of collaborations between different fields of research, from researchers in the same HERI, were not identified in any case study here analyzed.

In what was here categorized as research's skills, it is possible to find a research impact condition that was named as entrepreneurial behavior/competences and technology transfer/valorization awareness and knowledge, found in the profile of researchers involved in the research activities described. This condition was identified in nearly 31 per cent of the selected REF impact case studies. This type of skills and behaviors was found in cases were the researchers became entrepreneurs and launched or were involved in the creation of a new business to commercialize the products or services that resulted from the research activities, or were directly involved in the commercialization of the research outputs even when this activity was performed by an existing commercial entity.

The identification of influences on research impact, that were produced or related with the organizational context, were also made in this study. In nearly 26 per cent of the analyzed case studies it was identified the existence of organizational support given to aspects of intellectual property, collaboration agreements and other technology transfer issues, which turned to be essential to the success of existing collaborations between the HEIs and other organizations, as well as, to the general production of impact through the creation of a university spin-off.

Through this study of content analysis made to the documents of impact case studies best scored in the panel B of UK's REF exercise, it is also possible to relate impact conditions with specific types of impact generated and fields of research, which can be very useful to adapt the efforts and strategies that must be followed in a specific HEI, attending to their fields of research and strengths, as well as the specific needs of a region that are identified as strategic to promote its development.

Within the sample of 108 REF impact case studies analyzed, were present different types of impact generated, namely environmental, technological, economic, societal, political and impacts on health. The impact case studies reporting technological types of research impact accounted for 66,67 per cent of the total case studies analyzed, representing the most present type of impact reported in the analyzed sample of documents. The other mentioned types of impact were reported in a range of 0,93 per cent to 12 per cent from the total of cases analyzed, which is a small percentage of cases and therefore this sample was not considered representative to validate conclusions about the relation between types of impacts and the underlying conditions that influence the creation of that impacts.

The summary about the number of impact types referenced in the sample of REF's impact case studies, here analyzed, is presented in table 14.

Table 14 - Number of REF impact case studies analyzed per types of impact

Type of research impact	Environ-mental	Techno-logical	Economic	Societal	Political	Health
Number of case studies analyzed	13	72	12	6	4	1
Average percentage of case studies from the total sample	12,04	66,67	11,11	5,56	3,70	0,93

Table 15 represent the percentage of case studies where each research impact condition was found, per type of impact. This data can allow conclusions about the needed conditions that can influence the creation of a specific type of research impact.

From the analysis of this table it is possible to state that when it is necessary to generate technological types of research impact, it is very important to promote and develop the business regional context, as well as to foster relationships and collaborations between HEIs and this kind of entities, whether regionally or internationally located. To do so, HERIs as well as governments, can have an active role in the promotion of this research impact condition, which can be done through the establishment of new incentives, policies and other types of instruments that affect the establishment of a strong business context in specific fields of activity, as well as, to promote the connections and relations between HERIs and this type of organizations.

Also promoting entrepreneurial and technology valorization skills, as well as given organizational support to this type of activities, were conditions considered to be important for the generation of technological types of impact.

As previously mentioned, we do not consider that the sample of impact case studies analyzed which report other types of impact to draw any kind of conclusions. However, considering the results presented in table 15, it is possible to state that, overall, science communication skills to non-academic audiences, as well as the existence of collaboration between HEIs and industries and companies, are consensual conditions that must be present regardless the type of impact that is intended to be achieved.

Table 15 - Relation between the presence of research impact conditions with each type of impact generated

Research Impact Conditions		Environ-mental	Techno-logical	Eco-nomic	Societal	Political	Health
Indivi-dual Context	Science communication skills to academic audiences	7,69%	5,56%	8,33%	0%	25%	0%
	Science communication skills to non-academic audiences	69,23%	16,67%	25%	83,33%	75%	100%
	Entrepreneurial and technology transfer / valorization skills	0%	40,28%	25%	0%	25%	0%
Organi-zational Context	Organizational support to entrepreneurship, IP and TT related issues	0%	33,33%	25%	0%	25%	0%

Research Impact Conditions		Environ-mental	Techno-logical	Eco-nomic	Societal	Political	Health
Research Context	Collaboration with industries / companies	38,46%	50%	66,67%	16,67%	50%	0%
	Collaboration with governmental entities	38,46 %	6,94%	8,33%	0%	50%	100%
	Collaboration with other HEIs	7,69%	4,17%	0%	0%	0%	0%
	Collaboration with civil society / users or local communities	7,69%	0%	0%	0%	0%	0%

Leveraging from the categorization made in previously obtained results, the results obtained from the analysis of case studies best scored in the exercise of REF, are following presented in table 16.

Table 16 – Research impact enabling conditions resulted from the analysis of REF's impact case studies

Dimension	Individual Context							Organiza-tional Context	External Research Context
Category	Science Communica-tion		Research valorization			Teamwork and Collaboration		Support structure, staff and procedures	QH innovation ecosystem
Research Impact Condition	Science Communication skills to non-academic audiences	Science Communication skills to academic audiences	Entrepreneurial skills and behaviours	Technology Transfer skills and behaviours	Identification of research valorization opportunities	Collaborative practices with academic researchers in different research fields	Collaborative practices with members from non-academic organizations	Organizational support to entrepreneurship, IP andTT related issues	Existence and collaboration with business, government, universities and civil society

Table 17 summarizes all results obtained in all different studies described in this section. From the analysis of this table it is possible to identify which research impact conditions were supported by which specific study here performed (marked in green color) and which ones were missing (marked in red color).

Table 17 – Summary of all research impact enabling conditions

			RIA frameworks, models and existing literature	Innovation Management Standards	Academic community perceptions and opinions	Impact Case studies
Individual Context	Science Communication	Science communication skills to non-academic audiences				
		Science communication skills to academic audiences				
	Research valorization	Entrepreneurial skills and behaviors				
		Technology transfer skills and behaviors				
		Identification of research and research valorization opportunities				
	Teamwork and Collaboration	Teamwork and work dynamics within the research group, especially with junior researchers				
		Collaborative practices with academic researchers in different research fields				
		Collaborative practices with members from non-academic organizations				
Organiza. tional Context	Support structures, staff and procedures	Organizational support to entrepreneurship, IP and TT related issues				
	Management practices	Researchers' evaluation metrics				
	Organizational culture	Policies and incentives to research impact conditions (creativity, collaboration, etc)				
		Risk-taking environment				
External Research Context	Research policy	Existence, access and profile of research funding				
	QH innovation ecosystem	Existence and collaboration with business, government, universities and the civil society				

7 CONCEPTUAL RESEARCH IMPACT CONDITIONS FRAMEWORK

Following the definition of a framework, which consists in a way how to represent possible variables that affect a topic of interest, which doesn't necessarily provide relationships between them (Ostrom, 2007), this chapter aims to introduce the development of the conceptual framework for enabling conditions to produce research impact at HEIs.

The conceptual framework here proposed has been built using the literature review on research impact assessment, interviews made to the academic community and content analysis of existing impact case studies and innovation standards, described and analyzed in the previous section.

In this section it will be presented the development of a framework, that uses and applies the results obtained in the studies previously presented in chapter 6., as well as the development of an assessment method for the developed framework. This framework, and its respective application through an assessment instrument, intends to support Higher Education and Research Organizations to understand their current position in terms of conditions necessary to ignite research impact, and also looks forward to serve as a supporting tool to the decision making process of university manager who can now be more capacitated to strategize and position the organization toward the production of research impact.

It is important to note that the conceptual framework here presented structure and organize the results of research impact conditions obtained with the available data and the application of the research methods described in chapter 6. Therefore, future studies and exercises about research impact can bring more information about research impact conditions to complement the framework here developed and presented.

This Framework has been developed based on the academic literature collected and presented in sections n.3 and 6.1, together with the results collected in the study performed and presented along the chapter number 6 where it is also taken into consideration the inputs from various members of the academic community.
Its purpose is to support and influence the promotion of research impact at academia and further, potentially, influence research policies and the development and application of new impact assessment methods.

The following figure consists on a graphical representation of the dimensions where impact conditions were found to take place. In this graphical representation it is possible to observe that impact conditions were placed in three dimensions, that represent the individual level, in this case the academic researcher, the organizational level – the HERI (its practices and organizational culture), and the external research environment, here named as the research context that include other organizations, whether private or public, with whom HERI can interact and collaborate, and the effect of their practices, attitudes and policies. Considering the relationship between these three dimensions, the graphical representation of figure 7 represents the relation between them, where the individual dimension is placed inside the organizational dimension which is, in its turn, also placed inside the dimension of external environment which interact and influence the other two.

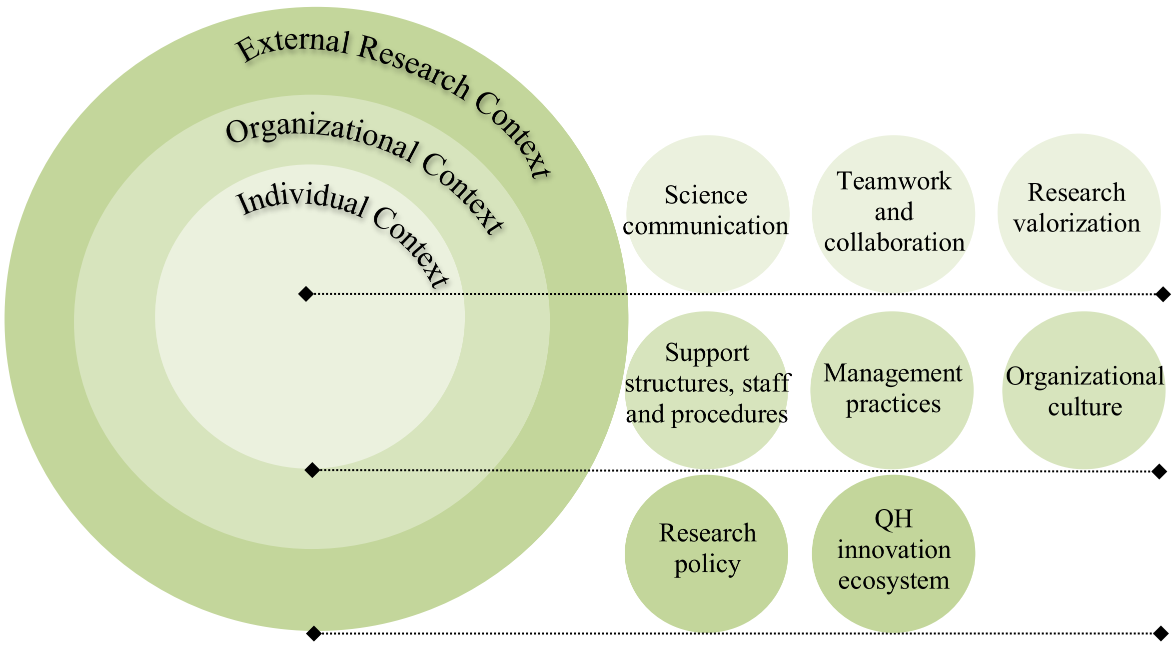

Figure 8 – Framework of enabling conditions for research impact

7.1 Framework Dimensions

This section aims to introduce all dimensions (i.e. contexts) chosen to make part of the research impact framework here developed.

In the research process used to identify research impact conditions, described in chapter number 6, were first identified patterns and opinions about the necessary conditions to generate research impact (here called research impact conditions), to only then, while the research progressed and more results were obtained, group and categorize them. The previously mentioned composing units, here named research impact conditions are very specific processes, activities or abilities that were found to have some positive influence in the production of research impact. However, with the purpose of developing a conceptual framework of research impact, these composing units were considered to be very specific and narrowed to be analyzed and to constitute, in this context, the framework components themselves. Therefore, the previously defined sub-categories, which represented groups or types of research impact conditions were considered better suited elements to constitute the components of this framework.

These research impact types / groups were also previously categorized in the contexts where the conditions take place or by whom (type of individuals or entities) they can be promoted or developed. This categorization is here used to define the dimensions of the present framework, what helps to better identify who is related with the implementation or development of that group of research impact conditions.

Summing up, categories and research impact types/groups identified in previous results, described in chapter 6, were used to define the dimensions and components of the present framework, respectively. Therefore, three research impact dimensions, and eight components characterize the research impact framework, as following described.

As mentioned in the beginning of the present chapter, it is important not to forget that additional research impact conditions in each dimension may be, in the future, added to complement the framework here developed and presented.

Research context is the name here given to describe external influences on academic research activities. These external influences were found to be existing organizations, research-related instruments and policies, as well as research practices, that can influence the academic research activity, and therefore have some direct or indirect effects on the research outputs and its future impacts. Within this framework dimension, there are two components that constitute types of research impact conditions that are promoted by or related with activities or organizations external to the academic institution in study, what composes the external environment that directly or indirectly affects the research activities that take place at one specific academic organization. One of these two framework components, named quadruple helix innovation ecosystem, represents the members and dynamics between the quadrangulation of those institutions that make part of the regional innovation ecosystem, namely university, business, government and the civil society. The other framework component which was previously identified as a group of impact conditions regarding aspects about research funding, is here expanded and renamed to research policies and instruments, to include not only research funding related conditions but also the general political external context that produce effects in the research activities performed in the academia.

An inner and second dimension represents the organizational context where the research activities take place, i.e. the HERIs in study. In here it is possible to find three framework components that were the three previously identified groups of research impact conditions that are related and can be powered by the academic institution, namely the organizational support structures, staff and procedures, organizational management staff and practices, and other aspects not included in the previous two groups and that make part or affect the organizational culture.

A final dimension named the individual context, was created in this framework, attending to the fact that different results obtained during the study of impact conditions to generate research impact were identified at the individual level of the researcher. This dimension includes all research impact conditions that are related with the main actor of the research activity which is the academic researchers. In here we have three components that represent groups of attitudes, behaviors and skills of the researcher, related with the fields of science communication, research valorization and teamwork / collaboration.

7.2 Framework Components

The concepts representing each framework component identified by this research, were submitted to a search in the existing academic literature and other information sources, in order to fundament its definition and scope of usage in the context of HEIRs, and when possible within the specific context of the academic research itself.

Searches in scientific literature databases were performed having in mind the main objectives of 1) allowing the analysis of the context in which each concept is being used, studied and the connection it has with other terms in the general context of academia; 2) allowing the understanding of typologies and definitions given to each concept term; and 3) collect information about references and new proposals of performance indicators that can be used to assess each indicator. Having these goals in mind, it was used the Scopus database due to its transversal profile more willing to touch and have information from frontier areas that cross multiple knowledges as it is the case of academic research impact.

To perform the bibliographic search, search phrases were written in a way that included the term or keyword given to each framework component, through the application of different possible synonymous, together with the context in which the application of the term is being searched, i.e. the dimension where it belongs and gains meaning. This second part of the search phrases limits the scope of application / study of that main concept and guarantee that the right meaning is being given to the main concept in analysis

Considering this rational to come up with the search phrases, the database was interrogated with the eight search phrases, which are described in Appendix D.

In order to serve both purposes of focusing on the application and use of each concept within the context of each framework dimension and giving a general overview of the existing view points and studies about the topic, it was made the choice to make a search in the title only for the keywords related with the framework components, and a more broad search, including the title, abstract and keywords, for the terms and synonymous that represent the framework dimensions. This means that in the case of the individual context, the terms related with the academic researcher were searched in a broader area of the documents, and in the case of the organizational context the same happened for the terms related with the research activity.

This strategy was not adopted for the searches performed in the documents related with the framework components of the external research context, considering the extensive number of results that needed to be narrowed down in order to be possible to analyze the results. Due to this, the searches performed for the framework components within the external research context were done within the existence of the terms in the field of the title only. This search strategy was followed after interrogating the database with the chosen keywords but searching its presence in a bigger number of document sections, namely in the title, together with the abstract and keywords. By comparing the general results of this inquire with those that focused only on the presence of the keywords in the title section, it was possible to conclude that the later are a good and fair representation of the existing studies in the topic. This broader search and analysis of respective results was also useful to brainstorm possible synonyms for the terms and its use in the specific context of this research.

When looking to search phrases number one and two, it is possible to see that the research context dimension was traduced as "academic research", fitting the main components of collaboration and research policy in the context of the academic research activity.
Components within the organizational level dimension were searched within the scope of the type of activities in focus in this study, which are the research activities. To avoid losing information, different synonymous to this same term were applied.
In its turn, searches related with the components belonging to the individual level dimension, needed to reflect this individual framing, which in this case is related to the academic researcher. To represent the individual dimension and frame the research in this context, different synonymous of the word researcher were used, including investigator and scientist. Additionally, and in order to place the search in the academic context it was necessary to use also keywords related with the academic organization.

Table number 18 shows the number of results in each of the eight search phrases used to interrogate the Scopus database.

Table 18 – Number of results per application of each search phrase in Scopus database

Nº of search phrase	Dimension	Concept main focus	Nº results
1	External Research Context	Collaboration	289
2		Research Policy	368
3	Organizational Context	Organizational culture	113
4		Organizational support	101
5		Organizational management	251
6	Individual Context	Science Communication	339
7		Teamwork	199
8		Research valorization	167

Results of each search were then exported to a CSV (excel) format and therefore used as sources to create a network visualization through the software tool VOSviewer.

The creation of the network map, based on bibliographic data, facilitates two of the search goals of analyzing the context in which each concept is being used when applied to the academic research activity and understand the definition given to each framework component.

In the network visualization of VOS viewer, (version used - 1.6.10) the size each keywork used in the document is represented by a circle, and the size of the circle is proportional to the number of times each keyword appears in the results of the search. Keywords are also connected by lines what represent the existing links of the keywords used in the documents and are represented in different colors depending on the cluster to which the item belongs (done automatically by the software) (van Eck & Waltman, 2019).

For the number of occurrences of a term in a document it was chosen the number that represented the presence of the term in an average of 2% of total results, which varied between 3 to 7 occurrences. It was also used the Full counting option which means that to each keyword was attributed the same weight (van Eck & Waltman, 2019).

The results of the analysis performed to each framework component it will be following presented, starting by the components that belong to the external research dimension, then analyzing the components of the organizational dimension and finalizing with the analysis of the framework components that make part of the individual dimension.

Within the external research context, this analysis starts with the framework component of collaboration which is extensively studied in the academic context, whether for educational purposes, where collaborative experiences can leverage the learning outcome of university level studies, as well as for academic research activities, as it is the focus of this research.

It is interesting to note the raising interest, along the years, in collaboration within the academic research context. This result obtained from the literature review exercise here described, can also go along the more recent focus and interest on innovation and impact produced by academic organizations, which is verified by the correlation between these two topics, signaled in figure 9.

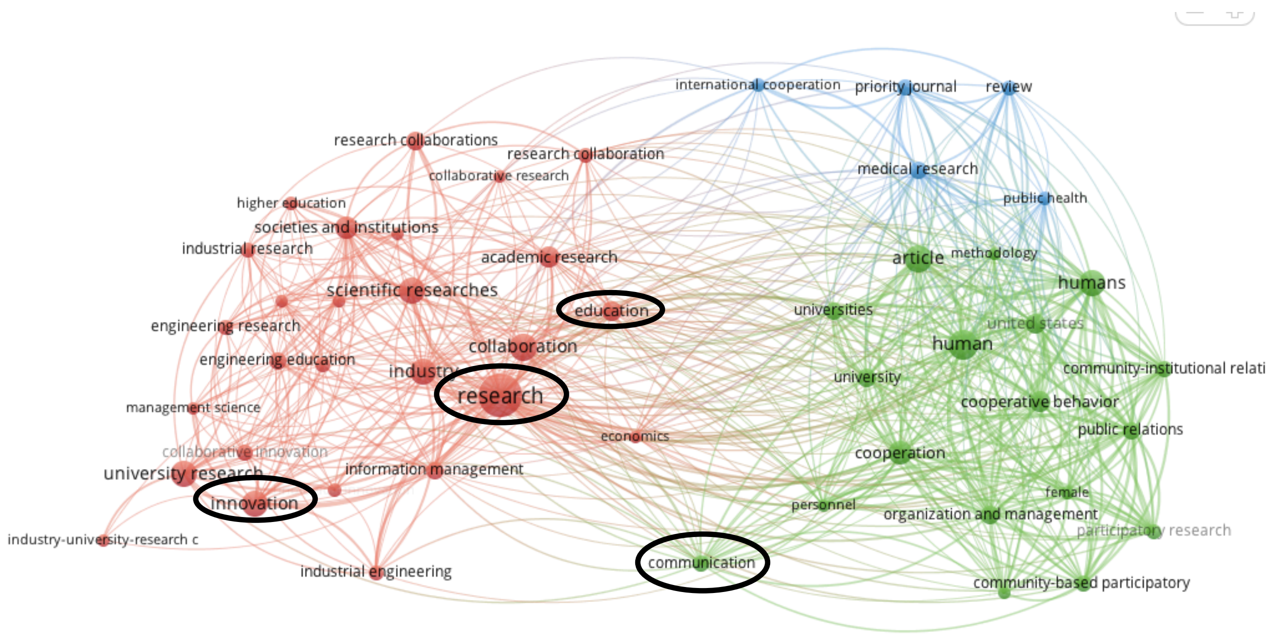

Figure 9 – Keywords map of results obtained in literature search about collaboration

For academic research purposes, collaboration is seen as an important and must have practice, as it is indicated by many studied that resulted from this literature review. Collaboration between academia and other organizations, whether also academic or not, has been extensively studied and found to be positively correlated with the impact obtained inside academia, more specifically through bibliometric indicators, such as publication (Mamun & Rahman, 2015; Wang, Hu, Li, Li, & Li, 2015).

Besides the presence of studies about collaboration practices with the impact produced inside academia, it is also possible to find studies that enhance or purpose a better understanding on how collaboration affect impact outside academia, regardless the followed pathway. Here, most of the studies are related with the specific type of collaboration between academia and industry, highlighting the importance of this relationship to academic research activities and academic researchers.

Ranging from studies about the impact of academia-industry collaborative practices in specific fields of research, to more broad and general studies or contexts (Wang & Zhang, 2014), the importance of academia-industry collaboration seems to be unquestionable.

Academic studies here analyzed cover not only the previously mentioned academia-industry type of collaboration, but also the relations between academia or academic members and governmental entities or even the triad academia-industry-government within the so called triple helix ecosystem of innovation (Li, Yao, Xi, & Guo, 2018), which includes the relationship between the triad university-industry-government.

In line with what is now being called the quadruple helix of innovation, which adds the civil society to the previous triad of stakeholders, there were also found studies about the collaboration between academia and the civil society (Parsons, Fisher, & Nalau, 2016), some of them proposing the exploration of participatory and co-designed research processes.

It is relevant to note that studies about collaboration in the academic context, not only cover the practices, mechanisms and policies to establish partnerships among different institutions and researchers, which, but do also touch other fields that were here identified as other framework components, such as communication and organizational culture.

Therefore, collaboration is also affected by the HERIs policies and practices, as well as by the researcher's attitudes, such as their openness to collaborate and other competences to maintain and create successful collaborations. These aspects will be further discussed in the respective sections that present the framework components that fall inside the organizational and individual dimensions, respectively.

The existence of this extensive body of literature about collaboration in the academic research process also corroborate the perceived importance of this aspect to the valorization of research activities at academia, such as was also proposed by the research impact policies mentioned in section 2.3. As it can be seen in section 2.3, research impact policies privilege partnerships among HERIs, which is, in some cases, a mandatory condition to receive governmental research funding.

In general terms, collaboration is seen by the existing literature as a driving force to accelerate research, create innovation and valuable research outcomes, and promote growth nationally or regionally.

Most common studied types of collaboration include, collaborations between academia and industry, academia and government, and between the triad academia-government-industry.

Studies in the literature about collaboration make also reference to policies and incentives to collaboration which can be led and implemented by the government, the business fabric, or the academic organization themselves. In order to cover all types of policies with effects produced on research process and consequently on the results and impact produced by these activities, it will be following performed the analysis of the results obtained to the search about research policy.

This concept of research policy is identified in this study as a framework component due to the expansion made to the previous found research impact condition of research funding, as previously explained. However, despite the intention to cover other types of policies affecting the research activity, the true is that the prominent number of studies within this field are related with research funding aspects, as it is shown by the keywords map of figure 10.

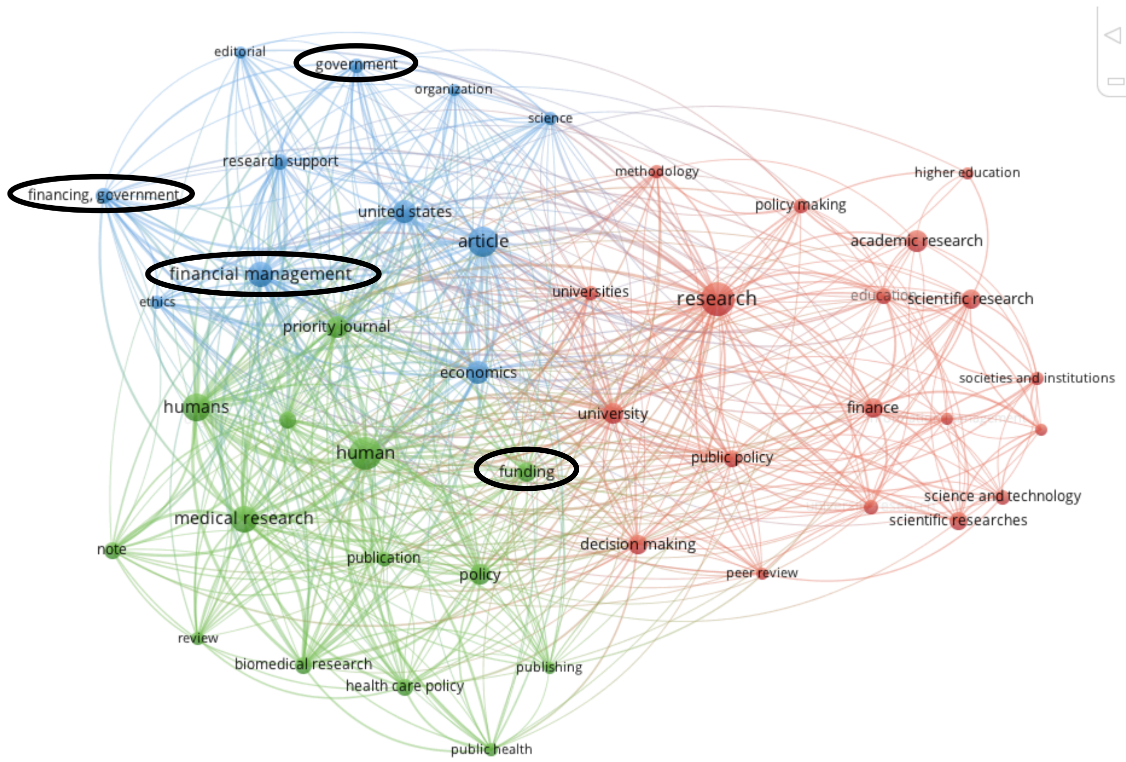

Figure 10 – Keywords map of results obtained in literature search about research policy

Funding for research activities, ranging from basic to more applied research, proof-of concepts, scale up among other activities related with the research process and its outputs valorization, was a recurrent theme extracted from the interviews with the academic community (see section 6.3), and these topics are also focus of interest of studies found in the literature (Yin, Liang, & Zhi, 2018).

Beyond the different objectives and purposes of the funding, also different funding sources are identified in the studies here analyzed, including the widely used public funding, the industrial and corporate funding, military funding, but also less traditional formats of research funding, such as crowdfunding (Belitski, Aginskaja, & Marozau, 2019; Sauermann, Franzoni, & Shafi, 2019). The importance of junior researchers within the funding scenario is also an aspect highlighted by the literature, not only in what regards to less traditional formats of research funding, as the previously mentioned crowdfunding, as well as due to the important role played by PhD students in the research process and the production of innovation through these activities (Boulos, 2016).

Research funding has also direct links with other components that make part of this research impact framework, such as collaboration and organizational culture, all of them intertwined and interlinked as policy instruments that directly affect the research activity performed at HERIs. Policies of incentive to collaboration and networks can be very much found embedded in public funding instruments (European Commission, 2019b; Teirlinck & Spithoven, 2015), and this powerful combination of policies end up shaping the direction and nature of research, and consequently its outcomes and impacts (Bégin-Caouette, Schmidt, & Field, 2017). Besides there is not a direct mention and relationship between research funding with research impact, it is clear the influence that it can have on public engagement, collaboration and the type and focus of the research activity, which are all conditions that, as been previously discussed, can affect the generation of research impact.

Research funding, as well as other research policy instruments, does not necessarily have a direct relationship with the generation of impact, but they can definitely determine the possibility and likelihood of its creation, by the impact that it produces on the academic research activity itself.

As it was found in studies related with framework components that, in this study, fall within the external research context dimension, the organizational set and proprieties are also conditions to take into consideration while designing and implementing strategies that can enhance and promote innovation and impact.

At the organizational dimension, different research impact conditions originated the creation of three framework components, namely the organizational support, to include the structures, staff and other practices that give support to academic researchers to produce and achieve research impact; the organizational management variable, which represent management staff and practices, and finally the organizational culture; which is created in result of previously practices and decisions and, it is here proposed as a separated component to complement the other two components of this dimension, since there are other aspects, not previously accounted, that can define the collective values, beliefs and principles of the members of an organization. In this last component of organizational culture, it will be possible to include and analyze aspects that can take longer to produce and effect on. The academic culture is the deepest level of essential beliefs that are shared by the members of a community (Pedraja-Rejas, Araneda-Guirriman, & Rodríguez-Ponce, 2018).

The organizational support found in the literature was much close to examples of leadership and management support and other types of support that academics can have determined by the organizational culture, rather than specific examples of support structures and/or staff that can facilitate the work of academics in their pursuit for research impact. This conclusion is supported by the main keywords of the results of this search, mapped in image 11.

Despite not bringing results to conclude about organizational support structures and staff of importance to research impact, existing studies highlighted the importance of organizational culture as a support system to improve staff organizational citizenship behavior, important to create organizational commitment and job satisfaction and productivity. By its turn, organizational commitment and job satisfaction were previously related in the literature with aspects such as organizational ethics, emotional intelligence, job characteristics, workplace friendship and financial rewards.

Leadership practices and behaviors are also a topic touched by the results of the search here performed to the organizational support related studies, since they were considered by some studies as influences that can be used to improve staff organizational citizenship behavior.

In summary it is very clear that the existing literature about organizational support is dedicated to aspects included in the other two framework components that fall into the dimension of the organizational context, and that will be further analyzed, namely organizational management and the whole aspects of the organizational culture. However, it is important to note that these results also validate the importance of the other framework components as important organizational aspects that have influence on the support of academics to the pursuit of success in their academic research activities.

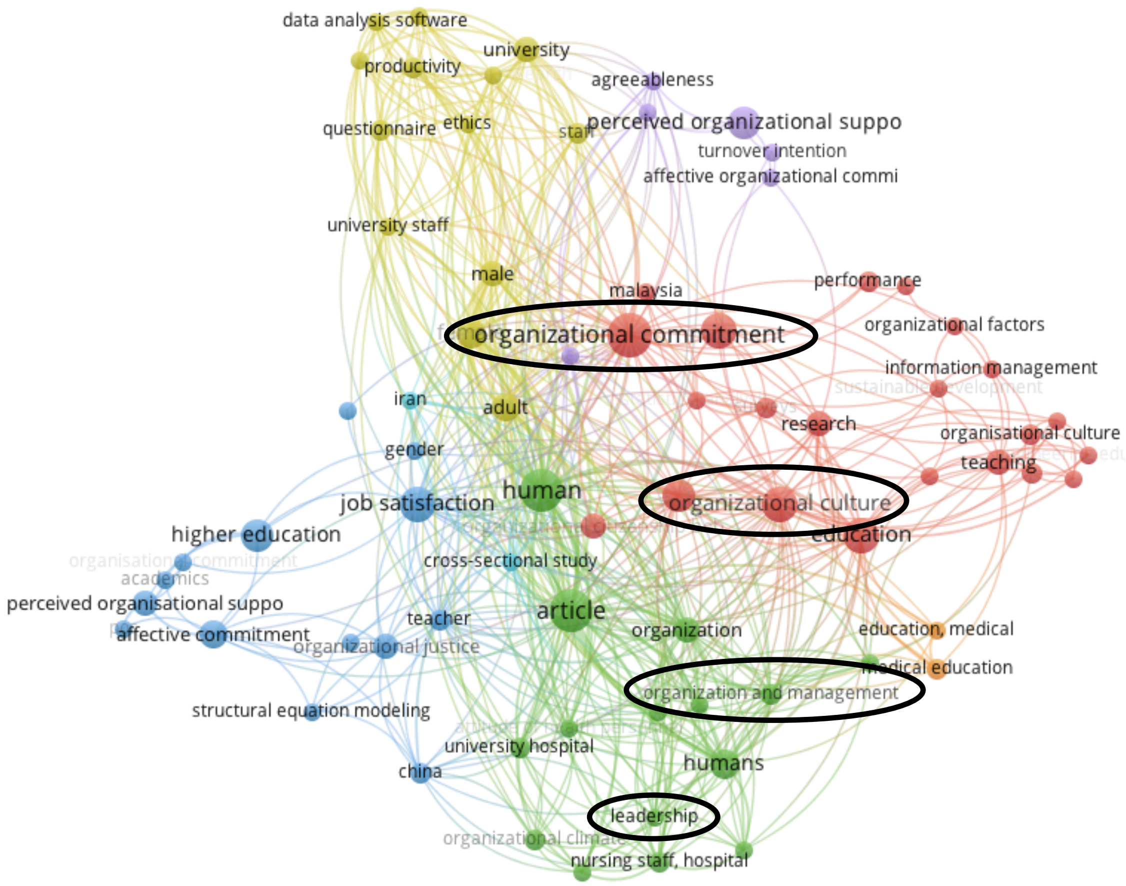

Figure 11 – Keywords map of results obtained in literature search about organizational support

As mentioned before organizational management and leadership play an important role in the promotion of job satisfaction, productivity and innovation, having then the potential to influence also the potential of research impact production. The role of the management team of a university and other academic staff that occupies leadership positions can influence behaviors, attitudes and practices towards an intended organizational culture and new organizational mission. Leadership and management are not easy tasks in a "common" organization, but there is a shared opinion agreeing that these tasks become even more difficult when taking place at academic institutions, like illustrates the following quote "managing academics is like herding cats: difficult and ultimately pointless" (McCormarck *et al.*, 2014).

Despite the difficulties of managing and leading academic institutions, these tasks are of paramount importance when there is the intention to imprint new behaviors and attitudes among academics and lead them towards knowledge sharing practices, specially through the promotion of organizational trust. By knowing the impact that organizational climate and culture has on knowledge management, and the consequent importance of knowledge management for the organizational performance (Iqbal, Latif, Marimon, Sahibzada, & Hussain, 2019; Ngoc-Tan & Gregar, 2019), it is important to take these aspects into consideration when designing strategies to take the organization into a specific direction where the attitudes and behaviors of the staff member are important to shape, as it is the case of research impact production. This is even more important, for this specific case of research impact, when it is known the existence of a relationship between knowledge management and organizational innovation (Sadeghi Boroujerdi, Hasani, & Delshab, 2019).

Just like resulted from the previous search about organizational support, the search in the literature for studies related with organizational management, also returned studies where management and leadership are extremely related with knowledge management and organizational culture, as it is demonstrated by the map of results' keywords, present in image 12.

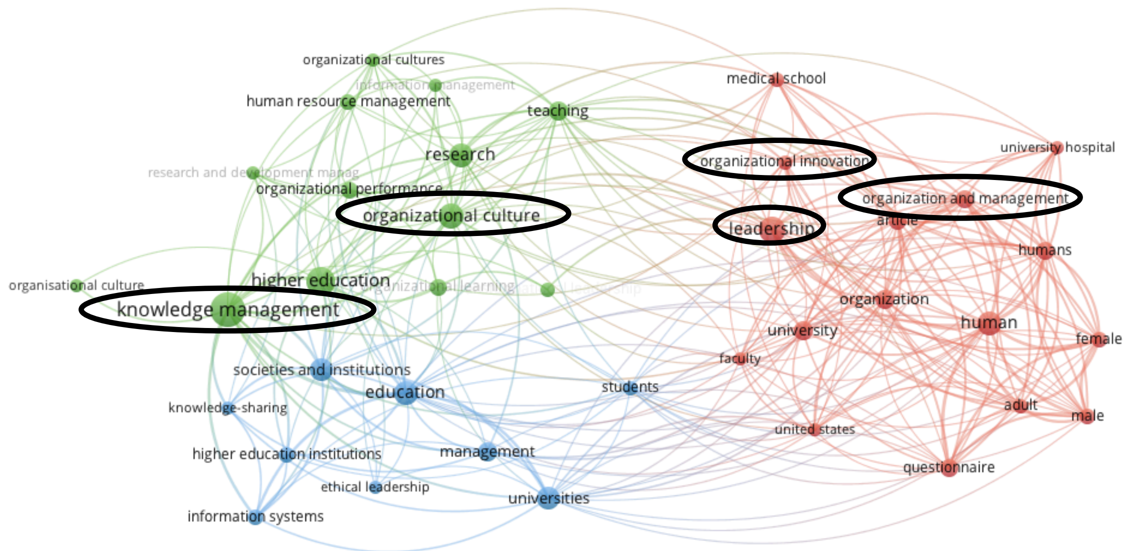

Figure 12 – Keywords map of results obtained in literature search about organizational management

This attested the previous comment about the existing connectiveness between the three framework components that were categorized in the dimension of the organizational context. Leadership and management are in fact very important and known influencing factors of the organizational culture and of the previous mentioned organizational citizenship behavior and performance, which can be enhanced by self-efficacy, openness to innovation, effective communication and the adoption of a friendly and fair policy by academic leaders (Adewale, Ghavifekr, & Megat Daud, 2018) .

Leadership behaviors among academics, whether they have a management position or not, can in fact have a tremendous effect on different aspects of relevance to HERIs, such as publications, research grants, the reputation of the institution, among others, and this type of behaviors are in turn very much related and impacted by the institutional resources, organizational climate and communication (Uslu & Welch, 2018).

Beyond the existence of specific support structures and staff to the attainment of research impact, and the influence of the organizational management team, other aspects, such as human relations and internal organizational policies, also define the organizational culture that can approximate or move away an institution from promoting and creating research impact. The concept of organizational culture refers to how things are done within an organization (Deal & Kennedy, 1982) is considered to have a high influence on the performance of an organization, and off course academic institutions are no exception.

As previously mentioned, organizational culture of academic institutions affects knowledge management processes (Vanti & Sanz-Casado, 2016; Chen, 2017; Chidambaranathan & Swarooprani, 2017; Prabhakar, Reddy, Savinkina, Gantasala, & Ankireddy, 2018), transformational leadership (Al Issa, 2019; Tohidian & Rahimian, 2019), as well as job satisfaction and commitment among faculty members (Azizollah, Abolghasem, & Mohammad Amin, 2015; Chipunza & Malo, 2017; Joshi, Sareen, Mishra, Chaturvedi, & Hussain, 2017; Penner, Pan, Petersen, Kaski, & Fortunato, 2013).

Organizational culture of higher education institutions has been already assessed and documented in several existing studies in the literature, which mostly use the competing values framework by Cameron and Quinn, where there are four types of organizational culture, named Clan, Adhocracy, Hierarchy and Market.

From these four organizational culture types, the market is the one that is considered to be closer to an organizational environment ruled and producer of innovation, what can be important to the entrepreneurial university and the mission of creating value to society through innovation and research impact. The influence of organizational culture on the promotion of entrepreneurship and innovation within a higher education institution is the focus of some existing studies (Ganji, Ebrahimpour, Zahed, & Khalegkhah, 2013; Sart, 2014), what is therefore an indication of potential interest of organizational culture for the promotion of academic research impact.

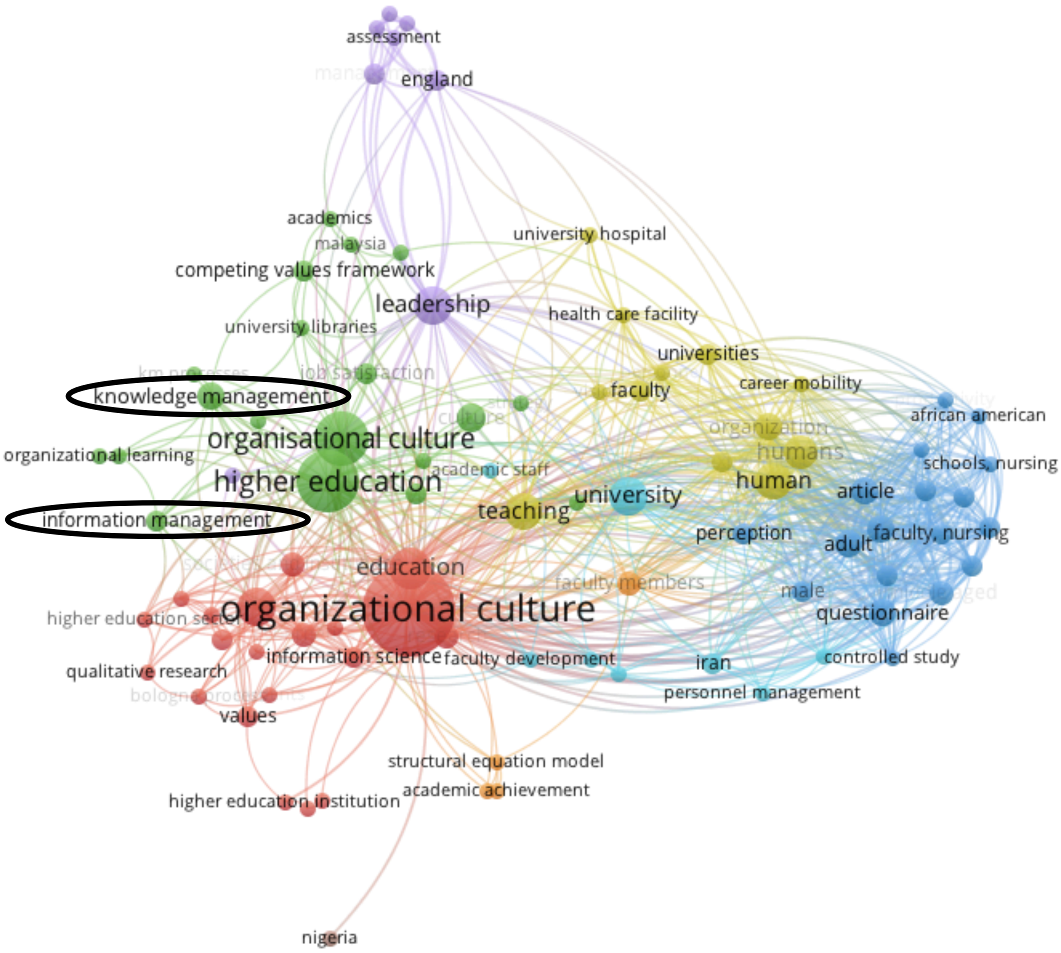

Figure 13 – Keywords map of results obtained in literature search about organizational culture

Within the individual level dimension of the framework to impact, it is possible to find components related to researcher's attitudes and skills. The concept of attitude here used is based on the definition given by the psychology field, which refers to a set of emotions, beliefs, and behaviors toward a particular object, person, thing or event.

Considering the central role of science communication for research activities, it was not surprising to find a great number of studies about this topic. Within the academic research context, science communication is mainly used to communicate research results to peers and scientific community, through publications, as well as to reach the general public and achieve public engagement, which can be done through media or outreach activities.

However, it is worth of note that the majority of studies found are related with science communication to non-academic audiences (Suldovsky, McGreavy, & Lindenfeld, 2017), and identify the challenges of these type of activities, as well as reflect the importance of developing these skills for innovation purposes, as well as for a responsible research and innovation (RRI) strategy (Suldovsky *et al*., 2017). Therefore, it is here found a relation between science communication and public policy, mainly related with research funding where innovation and the use of RRI strategies have becoming of more importance. Some studies found in this search also confirm the importance of science communication directly to research impact (Fogg-Rogers, Sardo, & Grand, 2015).

Topics related and influenced by science communication, previously mentioned, were identified by the study made to the keywords used in the results of the search performed to this term of science communication, graphically represented in figure 16. In this figure were found and highlighted keywords of public policy, funding, public engagement, public opinion, outreach, media and publication, all of them previously considered.

Many studies found in the literature focus on the study of training and other educational activities to develop science communication skills, which is also confirmed by the representativity of the terms education and teaching in relation with science communication, such is illustrated by figure 15. The bet on science communication skills have been defended and studied as an important ability that must be acquired and developed by students, young researchers and general academic scientists (Baram-Tsabari & Lewenstein, 2017; Hundey *et al*., 2016; Kloepper, 2017; Bankston & McDowell, 2018; Oliveira, Bonatelli, & Pinto, 2019). Studies found in the literature refer different formats of training ranging from courses, workshops or even mentorship.

Many studies that refer to science communication skills analyze its strategic importance to public engagement and outreach, as it can be attested by the analysis of keywords of figure 14, and debate general existing challenges of this task (Pryce, 2018), as well as specific challenges as what refers to communication in the digital era, through social media, portals and others, (Fontaine, Lavallée, Maheu-Cadotte, Bouix-Picasso, & Bourbonnais, 2018; Redfern, Illingworth, & Verran, 2016).

It is interesting to notice that the analysis of studies related with this impact condition are also linked to topics that are for themselves other impact conditions identified in this study. This happens with the condition of organizational culture (France, Cridge, & Fogg-Rogers, 2017), and collaboration between academia and other entities, also cited by studies that focus on science communication skills.

Because of this, the development and optimization of science communication skills is connected with aspects that were also identified to the development of the previous research impact conditions analyzed, such as the development of trust between academics and other organizations and the public in general (Weingart & Guenther, 2016), and the opportunities for innovation and impact produced by partnerships between scientists and non-academic audiences (Pei & Schmidt, 2019).

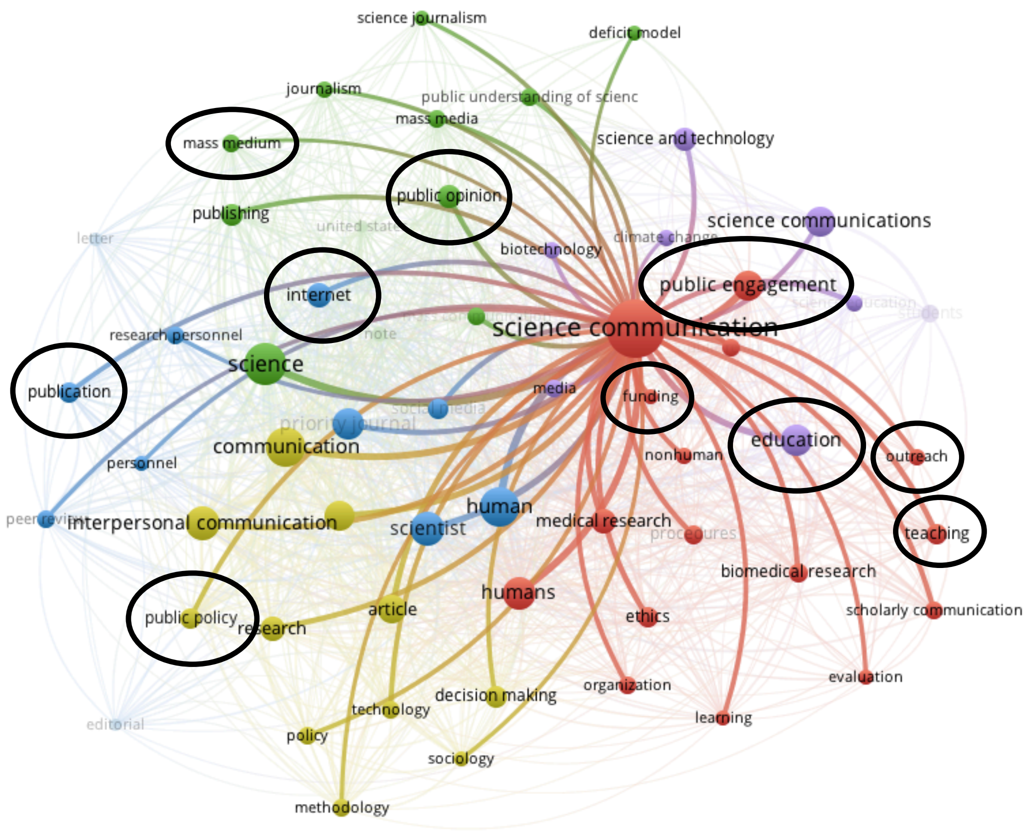

Figure 14 – Keywords map of results obtained in literature search about science communication

Collaborative attitudes and behaviors and teamwork are topics extensively explored within the academic sector, whether for education, and among students, as well as for research purposes, as it can be seen in figure 15, where these two terms are represented by two of the biggest circles, indicating that this terms are very much used as keywords of the results obtained in the search about teamwork and collaborative skills and behaviors.

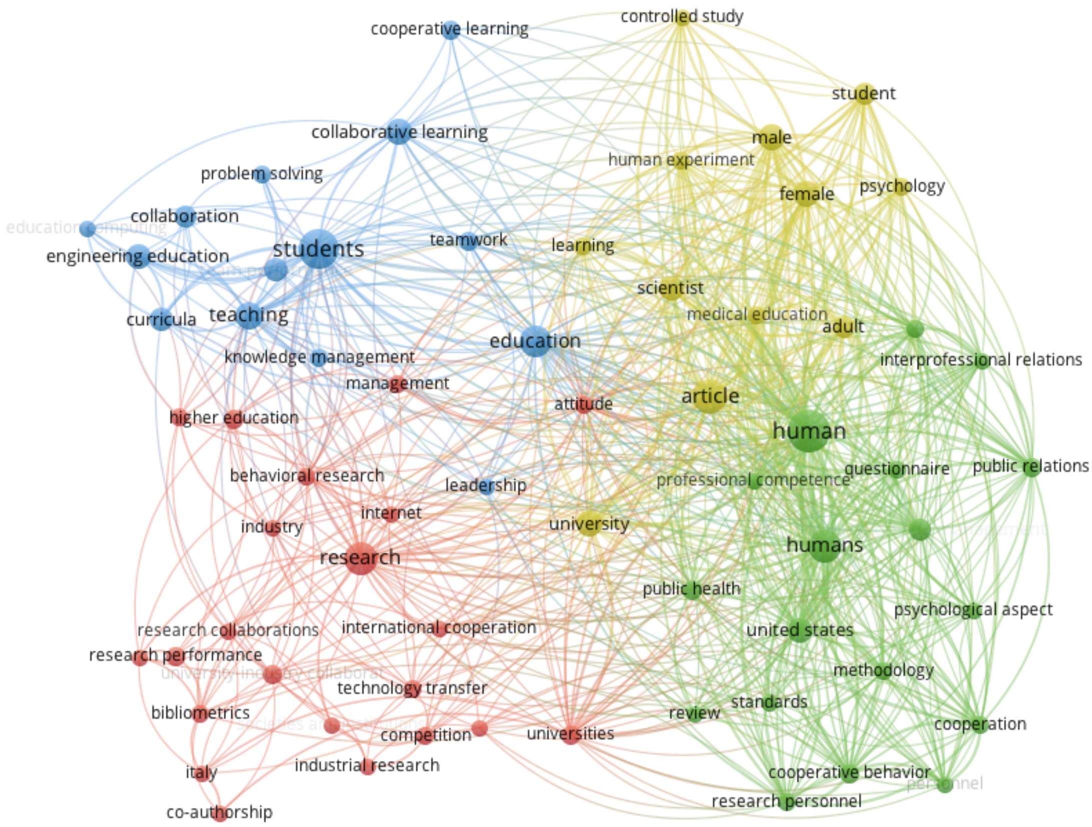

Figure 15 - Keywords map of results obtained in literature search about collaboration and teamwork

When looking closely to the terms that are more closely associated with the keyword research, represented in figure 16 it is possible to identify two main aspects. In one hand, teamwork and collaborative behaviors and skills are related and in this can, can lead to innovation and technology transfer, what confirms the potential relation and importance of teamwork and collaboration skills and behaviors to the generation of research impact. In the other hand it is possible to identify different type of collaborations or collaborative practices in which these skills and behaviors have been studied, namely collaborations between academia and industry, and collaborations at an international level. This ends up reinforcing the importance of these skills and behaviors in the academic community to the establishment of collaborations that can then lead to innovation and research impact, such as was previously identified within the dimension of the external research context. Even acknowledging the existence and importance of mediators for collaborative processes between academia and other institutions, it is still known that academic researchers and their competencies play a very important role in collaborative research and related processes (Ting, Yahya, & Tan, 2019).

Teamwork and collaboration have been also studied as important skills and behaviors of researchers who want to have better research performances, measured by their outputs in terms of scientific publications, that are achieved through co-authorship. To do so, it is then important to develop strong relationships between scientists, at a national but also international level, who are complementary in terms of knowledge and research fields and can take the research to a new level of outreach and impact. Different aspects of the dynamics within a research team, such as the leadership style end up affecting the knowledge management and research performance.

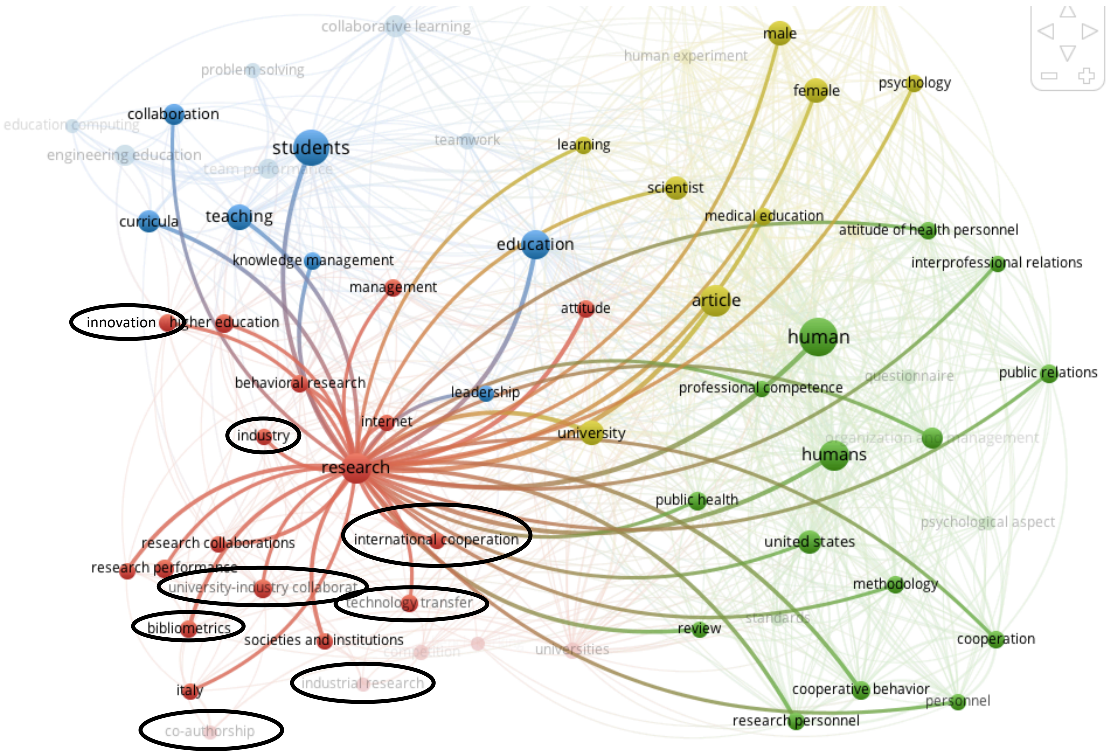

Figure 16 - Keywords map of results obtained in literature search about collaboration and teamwork

The framework component named as “Research valorization skills”, represent the ability of researchers to identify research valorization opportunities and engage in them, whether they are activities of research collaboration, knowledge transfer or entrepreneurial activities.

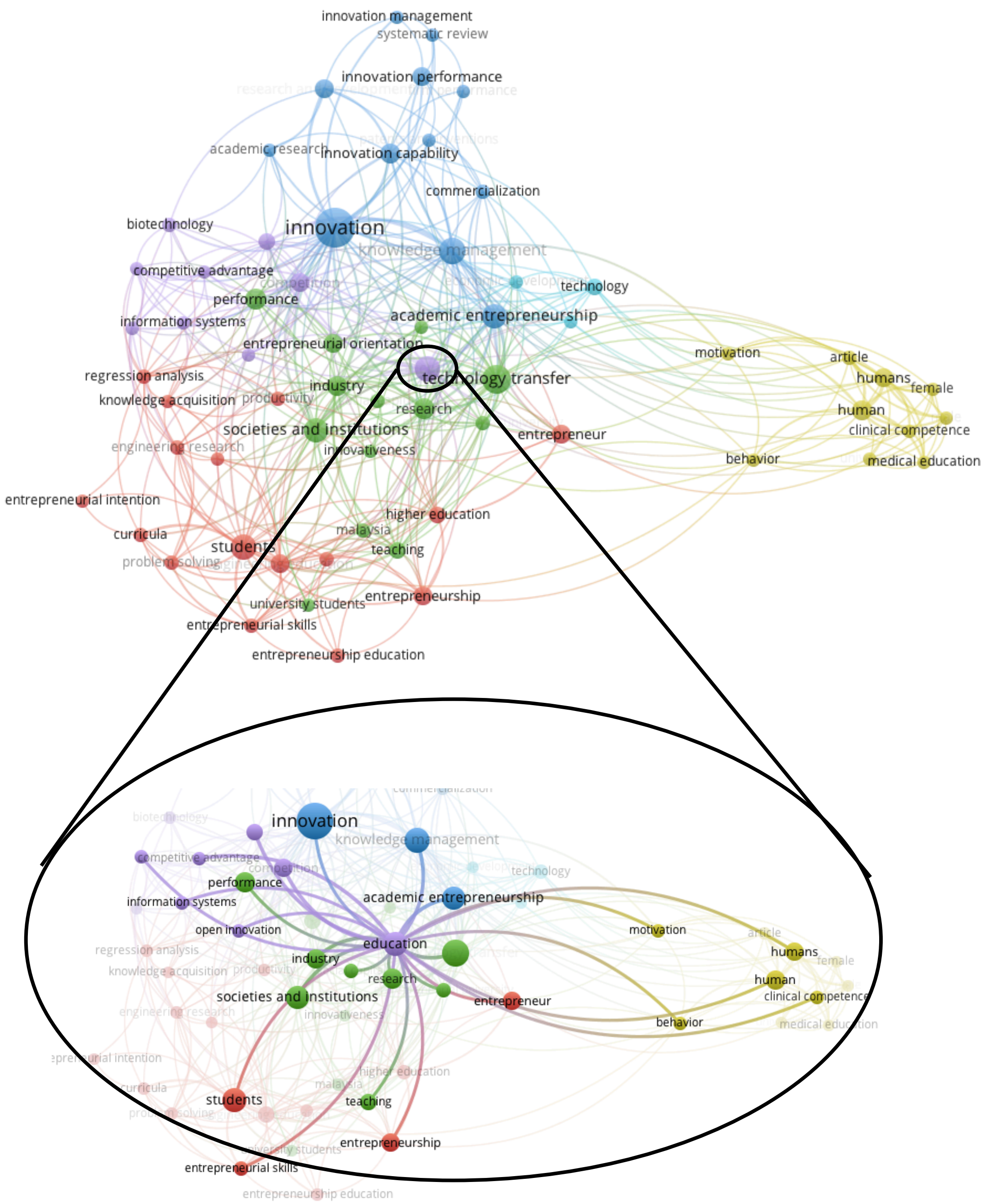

Figure 17- Keywords map of results obtained in literature search about research valorization

Through a first look at the keywords map, in figure 17, made using the results of the literature search, it is possible to, as happened in the previous skills and behaviors analyzed, conclude about the importance of these skills in the academic context, whether for students and/or for educational purposes (as it is suggested in the amplified part of the image), and for academic researchers and professors.

Studies about research valorization skills, which comprise those fields mainly signaled by the keywords of the results of this search (figure 15), namely innovation, technology transfer and academic entrepreneurship, were motivated by the importance of these skills to collaboration, mainly the extensive studied field of university-industry collaborations (Kobarg, Stumpf-Wollersheim, & Welpe, 2018).

Besides their own motivation, which play an important role to the development of researchers' innovation capabilities, as seen in the effect that "mission motivation" has to the advancement of the of societal role of universities (Iorio, Labory, & Rentocchini, 2017), also the country culture (Del Giudice, Nicotra, Romano, & Schillaci, 2017) and organizational culture (Loon, Udin, Hassan, Bakar, & Hanaysha, 2017), were found to imprint some influence in the entrepreneurial attitude and performance of academic researchers.

The literature about this topic identify and describe the profile of the researcher which performs better in terms of skills related with innovation, named the Pasteur Scientist (Baba, Shichijo, & Sedita, 2009). With this knowledge about the profile and characteristics of the "Pasteur scientist" it will be possible to have more detailed information to inform the how can we detect innovative behaviors and develop mechanisms to improve these competences.

7.3 Assessment instrument

In order to propose a first assessment instrument which could be used to assess the performance of HEIRs in terms of the enabling conditions to research impact, this chapter presents possible performance indicators to evaluate each one of the impact conditions. In order to find and propose performance indicators for each component of the framework, the results of previous searches in scientific literature databases complemented with other studies (not necessarily scientific literature), were used, analyzed and complemented with the authors knowledge of the academic context. These performance indicators can serve as a reference system to design an assessment instrument to evaluate how well each organization is performing in relation to each specific condition.

Considering that existing metrics of evaluation for each impact condition are not specifically design to the academic context, the list of possible performance indicators for each research impact conditions was therefore discussed and validated within different focus groups constituted by members of the academic community. The focus groups were organized and held at the NOVA Science and Technology School, and the groups were divided by the type of profile of participants. Participants profiles included 1) full Professors; 2) associated and assistant Professors; 3) Pos-docs and junior Researchers; 4) Members of the school's management team, and 5) Interface agents (which follow the same profile described in chapter 5). The participants of each focus group discussed the relevance of each performance indicator proposed and suggested other indicators that could be used within the academic context to assess the enabling condition in study.

7.3.1 Performance indicators

Starting now with the research impact enabling conditions within the individual dimension, more specifically in what regards the science communication skill and behavior, it was possible to find in the literature different studies about the value of training and education activities for the development of this skill (Mercer-Mapstone & Kuchel, 2017). These studies then indicate that training and education activities, for both types of science communication highlighted in this research, namely communication to academic and non-academic audiences, can be a metric to assess the current ability of academic researchers to communicate science effectively, and therefore contribute to the increase the chances of research impact creation.

Also, the theory of planned behavior explains that a person's intention to engage in a specific behavior can in fact determine the engagement in that behavior. Due to this knowledge it would be important to include in each one of the three behaviours here presented as research impact conditions, performance indicators that measure the intention and interest of researchers in assuming that behavior and developing each skill.

Within the research valorization condition, there is a behaviour which is in fact related with this willingness of academic researchers to engage in this type of activities. This is called the pro-social behaviour and analysis the importance that societal impact has as a motivation for research activities (Iorio *et al*., 2017).

Similarly to what was the result of possible performance indicators to measure communication skills and behaviors, it was also here identified that participating in educational activities where innovation skills are taught is a first good indicator about the potential ability of researchers to identify and exploit innovation opportunities (Meissner & Shmatko, 2018).

As it is clear through the research work described in chapter 6, entrepreneurial behaviors and skills are one important type of a research valorization skill, since many academic researchers or members of the research team, end up creating impact through setting-up a company or identifying entrepreneurial opportunities which can be pursuit by others to exploit commercially the research results.

The book "New skills for entrepreneurial researchers" describe all skills researchers need to increase their chances to identify and exploit, by themselves, the results of their research.

Through literature analysis it is possible to identify different studies that make proposals to measure the entrepreneurial behavior of researchers, such as the Entrepreneurial Competency Framework, the Vitae Researcher Development Framework, as well as the use of the concepts of individual entrepreneurial orientation (IEO) and individual market orientation concept (IMO), measured with i-MARKOR (Felgueira & Rodrigues, 2012).

It is also suggested in the literature, that researchers that are exposed to diversified past professional experiences outside academia, and specially working in collaboration with entrepreneurial colleagues, also influences the entrepreneurial intentions, which is (Moog, Werner, Houweling, & Backes-Gellner, 2015).

Considering the importance of exposing researchers to environments and collaborations with people with behaviors and skills related with research valorization, may have to influence this type of behaviors and the promotion of this skills, I defend that also other types of activities that doesn't necessarily require researchers to work mainly in non-academic organizations, may be important to measure. Examples of this can be the participation in events where other stakeholders are present, such as those that have been referenced as the innovation stakeholders, within the quadruple helix innovation framework.

The creation of this relationships and networks can therefore lead to the establishment of collaborations, whether in formal or informal formats, that constitute other enabling condition to research impact.
When studying existing literature about topics of collaboration within the academic sector, it is possible to find studies and suggested metrics to assess collaborative behaviors and skills, as well as practices that must be established among the research and innovation stakeholders, which produce effects to the research context dimension of the framework here developed.

In terms of behaviors and skills, it is important to measure all types of different profiles of collaborators previously identified in the research about research impact enabling conditions, described in chapter 6, such as collaboration between academic researchers and industry / business, governmental organizations and the civil society. The existence of these types of collaboration can demonstrate the collaborative behavior and skills of the researcher which confirm their interest and capabilities to establish collaborations with different types of stakeholders, important to the innovation process, which can therefore contribute to the creation of impact.

Beyond the importance of collaborations with other stakeholders, also the establishment of collaborative work with peers from academia is considered of extreme importance to increase the chances of research impact production. It is important though that these collaborations can somehow add value to the field(s) of knowledge mastered by a researcher or a research group. In other words, it is relevant to identify disciplinary and interdisciplinary research collaborations, which can be complementary and by doing so, contribute to increase impact produced by the research process (Goring *et al.*, 2014; Woolley, Sánchez-Barrioluengo, & Marceau, 2015). Besides interdisciplinarity and transdiciplinarity, also forming a group of researchers in different age ranges (Krapf, 2015), establishing informal *versus* formal collaborations with other researchers (Olmos-Penuela, Molas-Gallart, & Castro-Martinez, 2014), and the level of physical proximity with collaborators (Kabo, Cotton-Nessler, Hwang, Levenstein, & Owen-Smith, 2014; Claudel, Massaro, Santi, Murray, & Ratti, 2017), can contribute to the success of partnerships, and therefore to the impact to be produced in the future

To find this partnerships, researchers need to rely in their network of contacts, but they can also use existing tools, mainly online, which can facilitate in the search for meaningful collaborators (Asiwal, Suresh, & Reddy, 2016; Du, Liu, & Yu, 2018) and also contribute to the remote collaborative work.

In what refers to collaboration as the practice between academic institutions and other organizations, it is once again important to analyse the possibility to establish collaborations with each type of stakeholder present in the quadruple helix framework of innovation. Considering that we are now looking to collaboration as an enabling condition within the research context, it is then necessary to evaluate the existence of each type of stakeholders' profile, as well as their accessibility (Odei, 2018), adequacy, organization size (El Hadidi & Kirby, 2017; Garousi, Felderer, Fernandes, Pfahl, & Mäntylä, 2017; Lin, 2017; Malviya & Malviya, 2018) and the duration of the collaboration (Kanso & Monette, 2014).

For the specific case of collaborative work academic research, it can also be important to have collaborators outside academia, interested in basic research, which is a great core part of academic research (Wu, Siswanto, & Arifin, 2018). All previous mentioned characteristics are factors which can influence the establishment and the success of the collaboration.

The existence and profile of the organizations or individual stakeholders with whom it will be possible to establish collaboration it is of unquestionable importance, but having access or creating opportunities to meet, discuss ideas and work in collaboration, are also determinant for the promotion and implementation of those possible collaborations (Bindels, Baur, Cox, Heujing, & Abma, 2014; Kaye, Cabrera, Smith, Houser, & Krolikowski, 2015; Parsons *et al.*, 2016; Bhullar, Nangia, & Batish, 2017).

In order to have a successful collaboration, it is important that during the preparation phase, all parties consider potential challenges that are identified as factors that affect collaboration processes among these different stakeholders of the quadruple helix innovation framework, which include collaboration agreements, Intellectual Property issues, among others (Rose, Marshall, & Surber, 2015; Garousi *et al.*, 2017; Thomas, Vieira, & Balestrin, 2017).

When looking at factors that can enhance or constrain the establishment of collaborations among the stakeholders of the quadruple helix of innovation, it is also frequent to find references to the local or regional context in terms of policies which can promote or hinder collaboration (Gillies, 2014; Tseng, Huang, & Chen, 2018).

Besides collaboration policies, other factors of the regional context, such as innovation policies or availability of research funding, have great influence on the research process, as it was identified in chapter 6. Therefore, to completely access the research context, it is also important to evaluate the availability and suitability of research funding from different possible organizations, ranging from public to private funding. This funding resources, must also include direct funding for PhD students, which are considered important research team members, especially for the purposes of innovation and impact creation (Hallonsten & Hugander, 2014).

The characteristics and availability of research funding sources must also cover the complete range of research stages / types, that include what is more defined as “blue ocean” research where completely new research lines and concepts are explored, basic research, applied research and proof-of concept.

Besides the research funding instruments and policies, there are other policies of the research context that can also have great impact in the research activities and their future success. In general terms policies that promote innovation and incentive research impact among academic community, can understandably stimulate or hinder research impact.

Sometimes, the power to change the culture and incentivize research impact, can also belong to the academic institutions themselves, as it was seen in chapter 6, which identified different conditions to research impact within the organizational context.
Management practices and implemented decisions related with support staff and structures, will influence changes in the organizational culture, which can therefore be adapted to incentivize innovation and impact.

The leadership practices of the management team (Adewale *et al*., 2018; Bello, Ahmad, & Yusof, 2018), and the policies and incentives that they promote and implement at the institutional level (Zhang & Wang, 2017; Muriithi, Horner, Pemberton, & Wao, 2018), can influence behaviors, openness and the effectiveness of research impact activities.

Management team members of academic organizations can also introduce and implement initiatives that promote other enabling conditions to research impact, such as collaboration. Therefore, the promotion of events or encounter between the stakeholders of the quadruple helix of innovation and incentives given to research impact behaviors, such as for example having researchers’ metrics of evaluation, are also top-down initiatives that will influence other enabling conditions, whether within the organizational but even in the individual context. These initiatives and instruments can in fact follow a general strategy and vision of HERIs as a main producer of research impact, that will therefore culminate in enacting policies, establishing procedures and creating new instruments, which clearly impact the organizational culture and can have a positive or a negative influence the academic community.

As it was the result of the research performed and described in chapter 6, there are a group of structures and dedicated staff, which was generally named as support structures and staff, which can make smooth research impact processes and therefore positively contribute to it. Research impact case studies previously analyzed identified structures and staff in the fields of entrepreneurship, intellectual property and technology transfer, which were complemented with support to science communication and research funding activities, resulted from the interviews with the academic community, also reported in the same chapter. Following this, it is important to evaluate the existence and performance of these structures and staff, in order to verify the current situation of each HERI in terms of its organizational support structures and staff.

As previously mentioned, all current strategies and implemented activities, instruments and structures, can influence organizational cultural changes to an environment more conducive to innovation and research impact. Considering that there are no studies that specifically evaluate the organizational culture which favor academic research impact, the performance indicators here proposed were found in studies where specific characteristics of the organizational culture are related with innovative behaviors, capabilities and performance. Most of the indicators were found in the very known organizational culture assessment instrument (OCAI), where characteristics that define organizations with the profile of market quadrant of OCAI model, where organizational conditions favor the production of innovation and to be innovation oriented. These characteristics include dynamic entrepreneurial and risk-taking environments, the general commitment with innovation and development, the profile of trying new things and taking paths less travelled, as well as, having an organizational leadership and management with an entrepreneurial and innovative profile (Cameron & Quinn, 2006).

OCAI model is also very much used to assess organizational culture within the academic context (Tomilin, Fadeeva, Tomilin, & Kluyev, 2018), and this is the reason why it was decided to directly use the questions of OCAI that represent the market profile, in the assessment instrument here proposed.

To add to the previous known factors that positively influence organizational culture in the direction of innovation production, also promoting and environment collaborative friendly and where creativity is valued, were also indicators suggested by the academic community during the interviews, mentioned in chapter 6, where enabling conditions to research impact were analyzed.

Considering the results obtained in this section, it was developed the following assessment instrument, which proposes the following performance indicators to measure each enabling condition for research impact.

Table 19 – Research impact assessment instrument

Researcher experience, skills and behaviors	
A.	Level of experience with scientific publications or science communication to non-academic audiences
	Level of comfort in situations of oral science communication to non-academic audiences
	Level of science communication education / training orientated to academic audiences
	Level of science communication education / training orientated to non-academic audiences
B.	Level of pro-social behavior – do you take societal impact into consideration and use it as a motivation for your research activities?
	Level of education / training in research valorization and innovation activities
	Level of participation in events with the industry, governmental entities and the civil society
C.	Level of collaboration with academic researchers from the same department / research center
	Level of collaboration with academic researchers from other departments / research centers within your faculty
	Level of collaboration with academic researchers from complementary research fields
	Level of collaboration with academic researchers from completely different research fields
	Level of collaboration with academic researchers from other academic institutions
	Level of collaboration with industrial / business entities
	Level of collaboration with governmental entities
	Level of involvement of possible final users in your research process
	Level of informal collaborations with other researchers
	Level of collaboration with researchers in a different age range
	Level of physical proximity with your main research collaborators
	Access to online interfaces to find research collaborators
	Access to collaborative communication and working tools
Organizational Context	
D.	The organization provides good support to the aspects of intellectual property and technology transfer (e.g. collaboration agreements support)
	The organization provides good support to entrepreneurial activities
	The organization provides good support to science communication activities
	The organization provides good support to research funding activities
E.	The management team of the institution has a clear strategy to promote innovation and research impact
	The organization has policies and/ or metrics to encourage collaborations with external entities for research purposes
	The organization has clear established collaboration practices (e.g. collaboration agreements)
	The institution has researchers' evaluation metrics that recognize non-academic research outputs (e.g. patents, collaboration agreements with industry, etc)

	The organization promotes, with a regular frequency, events and /or incentives collaborations among research groups / departments
	The organization promotes, with a regular frequency, events with industry and governmental entities
	The organization promotes, with a regular frequency, events with the civil society
F.	The organization has a pro-collaboration environment
	Creativity and time to be creative are promoted and incentivized in your organization
	The organization is a very dynamic entrepreneurial place. People are willing to stick their necks out and take risks
	The glue that holds the organization together is commitment to innovation and development. There is an emphasis on being on the cutting edge
	The organization emphasizes acquiring new resources and creating new challenges. Trying new things and prospecting for opportunities are valued
	The leadership in the organization is generally considered to exemplify entrepreneurship, innovating, or risk taking
	The management style in the organization is characterized by individual risk-taking, innovation, freedom, and uniqueness
External Research Context	
G.	There is enough access to governmental research funding
	There is enough access to private research funding
	There is research funding within your research area
	There is funding for different types / stages of research (i.e. basic research, applied research, proof-of-concept research, etc)
	There is enough funding for PhD students
	There is research funding to conduct explorative research lines
	There are strong local/regional policies to promote and incentive innovation and research impact
H.	There is access to academic – practitioners encounters (e.g. industrial conferences or brokerage events)
	There are local firms with enough size and innovation activities to enter in collaboration with
	There is access to business and industrial partners in your research fields
	There are long-term trusty relationships with industrial partners
	There are strong local/regional policies to promote and incentive collaboration among QH stakeholders
	There are opportunities to meet, co-create and co-design research with the civil society
	The industrial and governmental ecosystem is involved with or interested in basic research activities
	During collaborations with external organizations, parties consider all challenges early on and proactively work together to reach mutual agreement in important issues (e.g. Intellectual Property aspects, licensing, etc)

7.3.2 Performance Indicators Validation

To validate all performance indicators, both found in the literature and suggested by the researcher, more specifically its adequacy to the academic context, different focus groups with members from the academic community were organized.

During these focus groups it was made a presentation of all performance indicators that were found as possible metrics to assess each research impact conditions. One at a time, possible performance indicators for each research impact conditions were discussed, very specifically in what regards its applicability to the academic context. The participants of the focus groups were also asked to suggest other possible performance indicators which could be used to assess each specific research impact condition.

The groups were constituted by 3 to 5 participants in order to allow everyone to share his/her experience and took about 60 to 90 minutes. As mentioned in the introduction of the present chapter, as well as in the chapter 4 presenting research methods, groups were created according with the profile of the academic community members, namely full Professors, associated and assistant Professors, Postdocs and junior researchers, members from the School's management team and Interface Agents.

The presentation of the research impact conditions, and its possible performance indicators started from those belonging to the individual context, passing by the organizational context and ending with the conditions that make part of the external research context.

Overall comments asked for more quantitative metrics and also to increase the specificity of existing metrics in order to not only bring more clarity about the sometimes not easily defined research impact conditions, but also to help respondents to make a self-assessment more accurately. One example of this specificity request can be illustrated by the expansion of criteria used to assess past experience with science communication to non-academic audiences, to include more specific examples such as interviews to the press, social media posts, communications made to high school level students, oral elevator-pitch to potential research or corporate investors, among others. Besides giving as much examples as possible within this category, it was also suggested to include a quantification of the indicators, considering that an experience of someone who did an activity once or twice can be considered very different from an academic research who had performed that same activity several times.

Participants in the focus group of management team members, full Professors and also associated and assistant Professors, suggested to give specific examples of science communication activities and asked for a quantification about the number of occurrences for each metric used to assess science communication to non-academic audiences, as for example the average number of interviews given to the press. The same suggestion was made about science communication skills to academic audiences, where for example it was suggested to quantify the number of participations in conferences to academics.

Some participants of the focus groups, mainly Professors argued that the performance indicators that ask researchers to indicate their level of comfort with some activity, as for example communicating science, are too subjective, and so that metrics should be replaced by others or should be used with proper care to avoid inaccurate conclusions.

When questioned about the performance indicators suggested to evaluate teamwork, interface agents and associated and assistant Professors suggested the inclusion of a metric to evaluate past collaborative experience with members from non-governmental organizations, as well as the inclusion of an indicator to evaluate the past experience of respondents, themselves, working in different types of organizations, which was considered a factor that can influence researchers ability to connect with a specific type of non-academics (whether from industry, government or NGOs), as well as, the existence of an established network in which they can leverage to start developing partnerships and institutional connections. In terms of professional past experiences, Postdocs and junior Researchers, also suggested to question about research mobility experiences or even so experiences in other HERIs or research centers.

Regarding the issue of quantification for the evaluation of teamwork, an assistant Professor suggested: "you must ask researchers the number of their collaborations, for example if they had collaborated with industry less than 5 times, between 5 and 10 times, or more than 10 times". This suggestion of quantification, regardless the performance indicator in which it is applied, increases the objectivity but should take into consideration the years of professional experience of respondents, in order to be fair and robust.

Another very interesting suggestion that came from the group of Associated and assistant Professors was to question respondents about the duration of the collaboration, since they consider that teamwork skills can be strengthen and results can be higher in cases where there is a long and trusty relationship established, compared with a collaboration that happened only once.

One participant of the group of full Professors mentioned also that the national or international profile of the organization with which collaboration is being established, could also be an indicator of a higher or lower level of teamwork and network ability, and should therefore be also assessed.

While discussing performance indicators to assess research valorization skills, interface agents suggested also the inclusion of an indicator to evaluate past experience with patents, development of products and services. In this research impact condition, participants of focus groups generally expressed their concerns with the subjectivity of the metrics.

While interface agents didn't agree with the presence of the metric "Level of experience in the participation of events with industry, governmental entities and the civil society" as an indicator of research valorization skills, arguing that it would make more sense having this assessment metric in the science communication skills to non-academic audiences, participants of the group of assistant and associated Professors suggested that more specific examples of this events must be given, such as "participation in brokerage events or business and technology fairs as the Web Summit". The same was suggested for the training / education activities where participants suggested to exemplify those types of activities or divide the category among possible types of education/training that help improving researchers skills to research valorization, such as training in entrepreneurship-related topics or education/training in intellectual property and technology transfer related subjects. Another suggestion was to include prizes won by academics in business idea competitions, prizes sponsored by companies, distinctions made by governmental entities, among others.

Mainly in regard with the research impact conditions that make part of the individual context, which refers to experiences, skills and abilities, academic members that participated in the focus groups, shared their concern with the subjectivity of these metrics, and suggested the inclusion of more objective performance indicators and increased objectivity in those that are already being proposed.

In order to also increase objectivity, one participant from the group of assistant and associated Professors suggested that this self-assessment of researchers skills and behaviors were also complemented by an assessment made by non-academics, such as members from companies or others with whom the researchers have past or present collaboration projects, whether in the field of research or others, such as in educational activities. The other participants of the same focus group agreed with the given suggestion, as well as other academic community members that were therefore questioned about it.

In the dimension of organizational context, mainly groups constituted by academic researchers in different career levels, pointed out to a great number of metrics mainly related with organizational structures, but also with management practices, that they feel to be affecting the potential of their research to create impact or consider as important organizational aspects to improve the likelihood to achieve research impact. Among these it is included better research funding, science communication and legal support, as well as adequate physical infrastructures, as facilities and equipment to perform research.

Interface agents also agreed that the existence of adequate physical infrastructures are organizational conditions essential to the production of good quality research and consequently research impact, and also added that it is also important to assess the ability of academic organizations to negotiate and partner with suppliers of equipment and other materials needed for the research activity. In terms of support structures and staff, participants of the groups composed by Professors, agreed that these must be decentralized in the organization, in order to become more efficient and effective services, as well as, be adapted to the needs and specificities of different research fields. Therefore, these academic members believe that the proposed assessment tool should also verify the characteristics of these support structures, such as the number of structures, number of staff working there, number of academics that the structure serves, and if the structures are a central service or are decentralized among departments or research centers.

This same decentralization was considered important in terms of management practices and strategy, where all participants of the focus groups agreed that it is important to see the management team not only as the main managers of the faculty or the university, but also including other roles as the head of the department and the principal investigator or leader of the research group. All these management layers were considered important due to the impact people allocated to these roles and their management practices can have in the performance of academic researchers and their research activities.

Other types of incentives and recognition of researchers that could be promoted and implemented by HEIs were also mentioned by participants of the interface agents group, which proposed the inclusion of assessment of existing incentives and other types of professional recognition of academics that participate in boards of companies, research funding assessment exercises, consultancy projects, and other type of activities that occur in collaboration and direct contact with non-academic entities.

The profile of the management team was also considered very strategic to promote the right incentives and strategies to pursuit research impact. Postdocs and junior Researchers, who participated in the focus group, believe that assessing past professional experience of the management team can also produce effects in the overall assessment of research impact conditions. When referring to past experience, participants of the focus group mentioned examples as past research impact experience and also their personal skills and abilities that relate with research impact, as those that make part of the conditions in the individual context.

Another suggestion made by participants of the same focus group, as well as the interface agents, was to question about the existence and implementation of a clear strategy that facilitates research to produce the intended impacts. In here the interface agents reinforced the importance of having a clear research strategy, as a starting point.

Groups composed by Professors in different career levels, as well as the interface agents, mentioned the importance of the academic institutional reputation and the power of the brand in the market, and the consequent position of the institution in different contexts, whether in the academic, industrial or government contexts, as well as in the perception of the general society.

Following the decentralization approach, postdocs suggested to include metrics that evaluate the dynamics among researchers of the same research groups, such as group meetings, group retreats or other connection and teambuilding activities.

To evaluate conditions of the external research context, that include funding and the existence of member of the quadruple helix of innovation, participants of the different focus groups also suggested the expansion and specification of the metrics proposed. For the funding performance indicators, interface agents suggested to expand the existing types of funding, for the context in which they are coming from, namely national, regional or international level, as well as the existence of funding for research infrastructures and other essentials to perform the research activities. Another suggestion, made also by interface agents and PhD students and Postdocs, was that researchers have an opportunity to self-assess their knowledge about existing funding opportunities, because they can indicate that there is not enough research funding but, in fact, they would preferer indicating that they do not consider having sufficient knowledge about existing opportunities.

To assess the community that makes part of the quadruple helix, participants of the focus group composed by members of the management team, proposed to include the existence of national or regional policies that are promoting collaboration among the different members of the quadruple helix innovation ecosystem.

Participants of the focus groups (PhD and junior researchers, and Management Team), also proposed the inclusion of metrics related to policies to promote and incentive innovation, research impact, as well as collaboration and all other conditions considered strategic to produce impact. The management team referred the importance of influence of local policies in the organization and also the opposite, e.g. the influence of the organization in the public policies.

It was also suggested by PhD and Postdocs, Interface agents, to check if there is an alignment between the fields of academic research and fields of operation of the existing industry, as well as governmental strategies for regional development. The existence of this alignment can in fact better position all stakeholders to perform better in terms of impact.

Attending to the previous obtained results, the research impact assessment instrument was reformulated and improved for a final version, presented in the following table. This table includes also possible instructions to be given to respondents of this assessment instruments, when evaluating this survey in a Lickert scale of 1 to 7, also proposed by the participants of the focus groups.

Table 20 – Research impact assessment instrument reviewed

Researcher experience, skills and behaviors Instructions: Classify your experience, skills and behaviors, using a scale from 1 (very rare) to 7 (extremely frequent). Use 0 as a non-applicable level in cases where you do not have any experience in the matter.	
A.	Level of experience in science communication to the press
	Level of experience in science communication via social media
	Level of experience in science communication to high school level students or other educational institutions
	Level of experience in oral elevator-pitch to investors
	General level of experience in science communication to non-academic audiences
	Level of comfort in situations of oral science communication to non-academic audiences – use with proper care to avoid inaccurate results
	Level of science communication education / training orientated to academic audiences
	Level of science communication education / training orientated to non-academic audiences
B.	Level of pro-social behavior – do you take societal impact into consideration and use it as a motivation for your research activities?
	Level of education / training in research valorization and innovation activities (e.g. entrepreneurship, intellectual property, technology transfer, etc)
	Level of past experience with patents, development of products and services
	Level of participation in events with the industry, governmental entities and the civil society (e.g. brokerage events, market fairs, etc)
C.	Past working experience in business organizations
	Past working experience in other national academic institutions
	Past working experience in other international academic institutions
	Past working experience in governmental organizations
	Past working experience in non-governmental organizations
	Level of collaboration with academic researchers from the same department / research center

	Level of collaboration with academic researchers from other departments / research centers within your faculty
	Level of collaboration with academic researchers from complementary research fields
	Level of collaboration with academic researchers from completely different research fields
	Level of collaboration with academic researchers from other national academic institutions
	Level of collaboration with academic researchers from other international academic institutions
	Level of collaboration with national industrial / business entities
	Level of collaboration with international industrial / business entities
	Level of collaboration with national governmental entities
	Level of collaboration with international governmental entities
	Level of collaboration with national non-governmental organizations
	Level of collaboration with international non-governmental organizations
	Level of involvement of possible final users in your research process
	Level of informal collaborations with other researchers
	Level of collaboration with researchers in a different age range
	Level of physical proximity with your main research collaborators
	Access to online interfaces to find research collaborators
	Access to collaborative communication and working tools
Organizational Context Instructions: Classify your opinions about the structures, practices and strategies of your host academic institution, using a scale from 1 (disagree) to 7 (fully agree). Use 0 as a non-applicable level in cases where the organization does not present the issue in analysis.	
D.	The organization provides good support to the aspects of intellectual property and technology transfer (e.g. collaboration agreements support)
	The organization provides good support to entrepreneurial activities
	The organization provides good support to science communication activities
	The organization provides good support to research funding activities
	The organization provides adequate facilities, equipment and material for the research activities
	The organization provides support to a good negotiation with suppliers of equipment and other materials needed to perform research activities
	The previous support given to different activities is enough for the number of researchers and appropriate to each research field
E.	The management team of your academic institution has a clear strategy to promote innovation and research impact
	The head of your department has a clear strategy that promotes innovation and research impact
	The head of your research group has a clear strategy that promotes innovation and research impact
	The organization has policies and/ or metrics to encourage collaborations with external entities for research purposes
	The organization has policies and/ or metrics to encourage collaborations with external entities not for research purposes (e.g. participation in boards of companies, research funding assessment exercises, etc)
	The organization has clear established collaboration practices (e.g. collaboration agreements)
	The organization has researchers' evaluation metrics that recognize non-academic research outputs (e.g. patents, collaboration agreements with industry, etc)
	The organization promotes, with a regular frequency, events and /or incentives collaborations among research groups / departments
	The organization promotes, with a regular frequency, events with industry and governmental entities
	The organization promotes, with a regular frequency, events with the civil society
F.	The organization as a strong brand and reputation in the market, within the academic context
	The organization as a strong brand and reputation in the market, within the non-academic context

	The organization has a pro-collaboration environment
	Creativity and time to be creative are promoted and incentivized in your organization
	The organization is a very dynamic entrepreneurial place. People are willing to stick their necks out and take risks
	The glue that holds the organization together is commitment to innovation and development. There is an emphasis on being on the cutting edge
	The organization emphasizes acquiring new resources and creating new challenges. Trying new things and prospecting for opportunities are valued
	The leadership in the organization is generally considered to exemplify entrepreneurship, innovating, or risk taking
	The management style in the organization is characterized by individual risk-taking, innovation, freedom, and uniqueness
	You have good team dynamics within your research group (e.g. frequent group meetings, group retreats, etc)
External Research Context Instructions: Classify your opinions about the external context that affects the research activities, using a scale from 1 (poor) to 7 (excellent). Use 0 as a non-applicable level in cases where you don't know, or the external context does not present the issue in analysis.	
G.	There is enough access to governmental research funding
	There is enough access to private research funding
	There is research funding within your research area
	There is funding for different types / stages of research (i.e. basic research, applied research, proof-of-concept research, etc)
	There is enough funding for PhD students
	There is enough funding for research infrastructures and other essentials to perform research activities
	There is research funding to conduct explorative research lines
	There are strong local/regional policies to promote and incentive innovation and research impact
	There are local policies and/or initiatives to promote the alignment of academic research with the fields market of operation of local business and governmental organizations
H.	There are strong local/regional policies promoting collaboration with non-academic organizations
	There is access to academic – practitioners encounters (e.g. industrial conferences or brokerage events)
	There are local firms with enough size and innovation activities to enter in collaboration with
	There is access to business and industrial partners in your research fields
	There are long-term trusty relationships with industrial partners
	There are strong local/regional policies to promote and incentive collaboration among QH stakeholders
	There are opportunities to meet, co-create and co-design research with the civil society
	The industrial and governmental ecosystem is involved with or interested in basic research activities
	During collaborations with external organizations, parties consider all challenges early on and proactively work together to reach mutual agreement in important issues (e.g. Intellectual Property aspects, licensing, etc)

This assessment instrument must be used and responded by academic researchers and academia managers, as well as other stakeholders of the research process, such as staff from industry and government that collaborated with the HERIs in study, or even by the civil society engaged in research processes. By doing this it will be possible to have a more complete picture of the current performance of HERIs in enabling research impact, as well as, to decrease the impact of the subjectivity profile of indicators.

8 CONCLUSIONS

8.1 Thesis overview

This thesis aimed to identify new avenues for assessing research impact, more specifically by developing a new process-based research impact assessment framework, based on a deeper understanding about the reasons of the failing impact-based agenda, studied from the perspective of the academic community.

Thus, this research started by an in-depth analysis of the impact-based agenda, including definitions of research impact, assessment methods and frameworks, as well as, existing practices and policies to enact this research agenda. After this analysis, performed by an extensive literature review, it was performed a qualitative study that aimed to complement previous existing studies and validate the main objective of this study, which consisted in the development of a process-based research impact framework.

Through this qualitative study it was possible to better understand the academic community in what regards to research impact and the impact-based agenda, more specifically in regions where this analysis was not previously conducted. This change in geography allowed the comparation of the obtained results with those obtained in the previously studied regions (UK and Australia), and therefore contribute with a generalization of the academic community perspective about the research impact agenda, which is not context dependent.

Leveraging from a better understanding on the common beliefs and values shared by the academic community, which are causing the existing tensions with the impact agenda, it was possible to move on to the next research phase that consisted on the development of a conceptual framework to academic research impact. Considering the objective of developing an impact assessment framework focused and based on the research process *versus* the generated outcomes, this phase of research started by studying and unveiling the enabling conditions that could benefit academic research projects for the purpose of impact creation.

In order to identify all possible enabling conditions for the promotion and production of academic research impact, were used different research methods, including a literature review to existing process-based RIA frameworks and models, interviews with academic researchers that unveiled the obstacles and enablers of their experiences with research impact creation, and a content-analysis performed to innovation standards and impact cases studies documentation available from the UK's REF exercise.

After the identification and categorization of different possible research impact conditions, it was developed the conceptual framework that defined each component for the specific purpose of application within the academic context, and by doing so, also proposed possible performance indicators that could be used to measure each one of them. This study about the performance indicators and the assessment instrument that could be designed with them, was validated, in terms of its adequacy to the academic context, by a group of members of the academic community located in a Portuguese university.

8.2 Main contribution

This study increased our understanding on a great number of aspects related with the academic research impact and the impact agenda, especially from the perspective of the academic community. The research complemented existing studies, about the existence of tensions between the academic community and the research impact agenda, that were previously performed in the UK and Australia. Considering the influence that different regional research political contexts imprint in the opinions and perceptions of the academic community, this study not only offers a more consolidated view about the common values and beliefs that are in tension with the impact agenda regardless the research context, as well as contributes to increase the effectiveness of future strategies to promote and assess impact that find alignment with this information.

Thus, by analyzing the resulting framework of common values and beliefs that are causing the tensions with the impact agenda, it is possible to avoid creating tensions with future strategies to promote or assess research impact within HERIs. The first aspect that it is important to take into consideration is that academic researchers' occupational mandate, i.e., the way how do they perceive their profession, is effectively grounded in the pursuit of knowledge, whether this knowledge will create few or many, short or long-term impacts. A related aspect is that academic community perceives this pursuit for knowledge and knowledge production as an activity that it is, *per se*, a way how to look for impact. This happens considering that knowledge is the raw material that will be used to produce research impact, what reflects the importance that production of new knowledge has for the academic community and how they perceive this as a central piece of the impact creation process. A third and very important unveiled belief shared by the academic community is the value attributed to the researchers' freedom of choice about the topic and other aspects of their research activities. This belief was found to be in tension with the current focus on the outcomes and impact that will be generated by research activities, embedded in the different existing strategies to promote and assess impact. Existing impact promotion strategies are therefore seen as freedom-taking and cause of huge lateral damages related with the hindrance generated to the advancement of knowledge, since the potential of production of certain types of knowledge can become extremely conditionate.

These conclusions informed the answer to the research question number 1 addressed by this thesis, which were searching to understand if a process-based research impact assessment could be a better approach to reduce existing tensions between academic community and the research impact agenda.

With a deeper knowledge about academic community shared values and beliefs and the confirmation that a research impact approach based in the research process it was indeed a good way forward, the second phase of the research searched for enabling conditions that can be corelated with the production of research impact, here named research impact conditions (or simply impact conditions), where were found eight different types. These eight different types of impact conditions were then categorized in three different contexts, namely the individual context that is related with the individuals that perform research, i.e. the researchers, the organizational context, that regards to the organization where the research takes place or the researchers' host organization, and the external research context, which represents the external surroundings of the academic organization.

The individual context includes three types of conditions that are essentially skills, abilities and behaviors of the academic researchers that were found to have some influence with the production of research impact, namely related to science communication, teamwork and collaboration, as well as research valorization. Within the organizational context, three different types of impact conditions were identified. These conditions that HERIs can model and develop to increase the likelihood of impact production from research activities are related to management practices, specific support structures, staff and procedures, and generic organizational culture related aspects. Finally, in what concerns with the external research context, findings of this research identified the research funding and policy related context, together with the relationships among the members of the quadruple helix innovation ecosystem, are important aspects to consider when working on research impact.

A conceptual framework to research impact was built upon the results of enabling impact conditions found in this study and developed through the identification of the specificities of the use and application of the framework components within the academic context. By studying the possible application of the framework components within the academic context, together with the possible performance indicators that can be used to assess each framework component, it was also possible to present a first proposal to an assessment instrument that can be used by HERIs to assess their performance regarding research impact. In this second phase was then addressed the research question number 2 and its sub-research questions.

In conclusion, it is important to mention that although the study performed in present study has focused on the areas of science and engineering, its conclusions and the contribution of the study can be generalized and applied to other areas of knowledge and research.

8.3 Theoretical and practical implications

The main results of the first phase of research can serve as basilar principles to the development of new approaches to academic research impact and its assessment, that can include, but do not limit to, proposals of new policies in the field of academic research, assessment instruments and other types of incentives to the production of impact within the academic context.

The research impact framework and the assessment instrument developed in this study can be used by HERIs and also by the government to assess the performance of a specific organization in terms of the conditions that can enable research impact. By measuring the current performance in each of the research impact conditions identified in this study, managers of HERIs and academic researchers themselves can take action towards the development and improvement of those conditions where the institution performed worse.

The results of the assessment exercise can also be used to draw some conclusions about possible measures that local or regional governments can put in place, in order to develop the local research context and its conditions that are affecting the academic research activity and consequently the generated impacts. The research impact framework here proposed can also be applied in different time frames and thus allow an analysis of the progression of results over time.

Considering the challenges of existing RIA methods, presented in chapter 3, the framework here proposed also answers the need of addressing the complete research process, by studying the inputs, research processes and outputs, necessary to create the future outcomes that will therefore generate impacts. By taking the focus out of the outputs or types of impacts that each research activity can produce, and in the enabling conditions to research impact, it will be possible to promote impact without creating tensions between policymakers and the general academic community, as it is happening with the policies and instruments currently in place.

Beyond all practical applications previously mentioned, the results and conclusions of this study will also contribute to the advancement of the very young filed of research in research impact and research impact assessment.

9 Recommendations for future research and development

The future application of the research impact assessment instrument in different HERIs and different political contexts is essential, not only to the validation of the developed framework and assessment instrument, as well as, to possibly identify weighing patterns that better fit each context and contribute to a better and more accurate assessment exercise. Therefore, it is recommended the application of the research impact framework and assessment instrument in as much HERIs as possible, and the consequent correlation between the obtained results and the impact-related policies in place in that specific political and organizational context.

It is important to recognize that this study has some limitations, mainly in the geographic context specificity of the available data used in chapter 6 for the identification of the impact conditions. The impact case studies documentation used to unveil research impact conditions is not only limited to the UK, but it is not geographically consonant with the other information used in the same chapter, namely the interviews with academic researchers that took place in regions outside the UK. Following this limitation of available information, it would be recommended to complement this study with the use of results from future assessment exercises, namely the next REF in the UK and the ongoing exercise in Australia. Indeed, impact studies developed in Australia can be extremely useful for this study considering that this assessment exercise focus mainly on the institution's mechanisms to promote or enable impact (Williams & Grant, 2018), which will therefore have a more direct contribution to the understanding of the enabling conditions of impact within the research process. Also, following this same research approach, and in order to validate the generic application of the research impact framework here developed, it could be important to replicate the methodology applied in this study to other scientific fields, beyond sciences and engineering.

As future research it is also advised to study strategies to be implemented in order to improve each research impact condition here identified, and consequently the performance of the HERIs. These strategies can also serve as motivations to academic researchers to take part in studies about research impact, what contributes to the operationalization of the proposed framework.

By further developing the research impact approach and assessment instrument that were proposed in this study, it will be possible to take the field of research impact forward and inspire the development of new and more effective strategies to promote and assess impact within the academic sector. The work previously suggested for future research can also open up new avenues for scientific research within these topics (research impact and RIA), which are still in an initial stage of development. Maybe in some years we can be no longer discussing impact, but instead a more consensual and effective concept to demonstrate the value of academic research activities.

In conclusion, it is important to mention that the objective this thesis have sought to achieve it is not an end, but rather an incentive for future research to achieve a better and broader understanding of the value that can be generated through research activities taking place at HERIs.

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10 APPENDIXES

<u>Appendix A</u>

Interview Guide to Academic Researchers

Present myself and present the research context and goals

Ask permission to record

I would like to ask your permission for record the audio of our conversation just to allow me to recall your insights later.

Check background Information:

- Department / University
- Field of research / or research lines?
- Professional position?
- Years of research career
- Previous professional experiences (especially in industry or governmental environments)
- Do you have patents or any kind of IPR?
- Do you have start-up experience?

<u>Questions:</u>

● Impact is kind of a buzzword now inside academia, especially in the academic research activities. What in your eyes is the definition of impact?

● Can you give some examples of impact generated from your research activity?

● What other types of impact can be generated from the academic research activity? Can you give some examples of research projects (made by others) that in your opinion created impact?

● Based on the examples you just mentioned, I'm wondering if there are external conditions, not only dependent on you and your motivations, that can affect or are strictly needed for impact to be achieved.

In case the answer includes the involvement of other stakeholders:

● I noticed that you referred not only physical or infrastructural conditions, but also conditions related with people and human resources. If you could map all those people who are necessary to achieve impact from your academic research activities, how would you draw it?

● What is your strategy to identify these people from research project to research project? Who else is needed to achieve impact? How do you tend to identify those other stakeholders?

In case the answer includes financial aspects:

● How do you go about **funding**? What are your current research funding sources?

● What's your perception about research funding?

● How do you choose your next research project (topic)? How do you tend to identify a scientific question?

● Do you feel motivated to create impact? Why or Why not?

● What could improve your motivation and efficiency to achieve impact?

● What is in your opinion, hindering the achievement of impact?

● In my work I have been exploring the terms of Responsible Research and Innovation & Societal Impact of Research. I would like to know if have you heard about these terms before? What do you think that they may refer to?

● Could a research result achieve economic return and not societal impact?

● Do you consider that Universities should consider performing research better aligned with societal needs?

● Should this alignment be more representative in the University's mission? Why?

Case studies presentation:

I have with me the flyers representing 3 models of possible avenues for research impact. Some are used in academic contexts others don't.

I would ask you to read each flyer and comment on each initiative telling me which one do you feel more inclined to participate, and why?

Would you suggest another model to improve the likelihood of impact creation from academic research activities?

Interview Guide to Interface Agents

Present myself and present the research context and goals

Ask permission to record

I would like to ask your permission for record the audio of our conversation just to allow me to recall your insights later.

Check background Information:

● Professional position

● Responsibilities

Questions

● Impact is kind of a buzzword now inside academia, especially in the academic research activities. What in your eyes is the definition of impact?

● Can you give some examples of impact generated from academic research activities?

● What are the conditions needed to achieve those impacts?

● Based on the examples you just mentioned, I'm wondering if there are external conditions, not only dependent on you and your motivations, that can affect or are strictly needed for impact to be achieved.

In case the answer includes the involvement of other stakeholders:

● I noticed that you referred not only physical or infrastructural conditions, but also conditions related with people and human resources. If you could map all those people who are necessary to achieve impact from your academic research activities, how would you draw it?

● What is your strategy to identify these people from research project to research project? How should researchers identify these other stakeholders?

● Do you think there is a specific profile of faculty who are interested in engaging in impact-based research projects? Can you describe them?

● What moves researchers to be involved in impact-creation research projects?

● What could improve your motivation and efficiency to achieve impact?

● What is in your opinion, hindering the achievement of impact?

● In my work I have been exploring the terms of Responsible Research and Innovation & Societal Impact of Research. I would like to know if have you heard about these terms before? What do you think that they may refer to?

● Could a research result achieve economic return and not societal impact?

● Do you consider that Universities should consider performing research better aligned with societal needs?

● Should this alignment be more representative in the University's mission? Why?

Case studies presentation:

I have with me the flyers representing 3 models of possible avenues for research impact. Some are used in academic contexts others don't.

I would ask you to read each flyer and comment on each initiative, telling me which one you think would be better accepted by the academic community and what could and couldn't work here.

Would you suggest another model to improve the likelihood of impact creation from academic research activities?

Appendix B

Unit of Assess -ment	Unit of assessment name	Rank of best scored HEIs	Institition Name	N. of ICS	Types of impact	ICS n. and title	Text transcriptions	Conditions that influences the productions of research impact
7	Earth Systems and Environmental Sciences	1st place	University of East Anglia	7	Environmental (7)	1446 – Costing the Earth: Influencing Government Policy for Ecosystem Services	**Pathways to Impact #1: via direct advice to Government and via Government Committees**: Since 2009 Bateman has given personal briefings to a variety of senior decision-makers including: The Defra Secretary of State, Oliver Letwin, MP and Minister of State at the Cabinet Office; Ministers from H.M. Treasury, Defra, Foreign Office, UK Trade and Industry, Department for Communities and Local Government, the Department for Transport, the Department of Energy and Climate Change, the Department for International Development and the Department for Business, Innovation and Skills; Members of the House of Lords and House of Commons; various Departmental Permanent Secretaries, Director-Generals, etc. Bateman also gave formal presentations and answered questions at the House of Commons Environment, Food and Rural Affairs Select Committee; also to the Government Chief Scientist, Sir John Beddington; all Government Chief Scientific Advisers and held regular meetings with the Defra Chief Scientist.	Science communication skills to non-academic audiences
							Pathways to Impact #2: through networking, capacity building and wider engagement: CSERGE leads the NERC Valuing Nature Network (http://www.valuing-nature.net) which has over 1,200 business and policy members across 43 countries, and undertakes numerous collaborating studies worldwide. From 2011 it has co-funded 18 studies with the business and **public sectors**, including the joint business/Defra Ecosystem Market Task Force (EMTF). Bateman wrote the EMTF Top Ten Opportunities paper [15] which led directly to their final report recommendations for business opportunities raised through the delivery of ecosystem services [16]. Finally impact through raising awareness of ecosystem service related issues has been generated through more than 50 media interviews including TV appearances for BBC and ITV news, interviews on national and regional radio, and newspaper features in The Telegraph, The Times, The Guardian and others.	Collaboration with industry / companies & Collaboration with governmental bodies
						1447 – Catchment Management Policy and Practice	**In Key researcher involvement of section 2: "Underpinning research":** Research and dissemination activities were carried out in collaboration with colleagues principally at the University of London (SOAS) and CEH Wallingford. **In section: 4. Details of the impact** Policy Input: During the course of the catchment research detailed above we provided policy input through, for example, contributions by Bateman to the UK Foresight *Land Use Futures* project (corroborating source [7]) and advice through representing the RELU Programme's interdisciplinary research on managing land and water use for sustainable catchments to the Office of Science and Technology's review of *River Basin Management Plans* (corroborating source [8]).	Collaboration with other HERIs & Collaboration with governmental bodies
						1448 – Informing Climate Policy with Global Carbon Budgets	The School's work on the world's carbon budget is published annually in the autumn prior to the annual meeting of the Conference of the Parties to the UNFCCC and is also widely disseminated via the media and social media. This effort has achieved impact in three ways: (1) it has informed the wider public of the recent high growth in CO_2 emissions and the sensitivity of the carbon sinks, (2) it has played a key role in strengthening the UK emissions target from 60 to 80% by 2050, (3) it has provided incentive and information to support international climate negotiations The public has been informed widely of the recent trends in CO_2 emissions and sinks from the widespread diffusion of our carbon updates. For example, 1459 media stories were recorded worldwide between 2007 and 2012 [7] and	Science communication skills to non-academic audiences

							since 2011 the news coverage is also diffused through new social media (Facebook and Twitter), e.g. *The Guardian* news item on this was re-tweeted 264 times in 2012. The true coverage will substantially exceed these numbers because of the difficulty of recording foreign-language news articles. The carbon budget is also re-disseminated through the independent organisations CO2now.org and www.rtcc.org. Highlights of our work were presented widely by other influential opinion formers, including Al Gore, HRH Prince of Wales and even Hollywood [8]. Our work was also cited for two of the six reasons to strengthen the target in a letter written by Lord Turner, Chair of the Committee on Climate Change to the UK (…) In support of the International Negotiations, our carbon budget data have been requested by the European Commission, the Minister of the Environment in Germany, congressional advisers in the US, policy advisers in Sweden and the UK, and the Department of Climate Change in Australia [10]. We presented our work in briefings to the Leader of HM Government's Opposition (David Cameron, 2007), to the Prince of Wales's corporate leaders group on climate change (2008), to the Department of Energy and Climate Change (2010, 2012), to the Canadian Ambassador for Climate Change (2011), and to the UNFCCC Subsidiary Body for Scientific and Technological Advice on research and systematic observations (2011). Australian MP and Parliamentary Secretary for Climate Change and Energy Efficiency Mark Dreyfus testified in a radio interview on 3 December 2012 that our carbon budget released that day was being discussed at the UNFCCC Conference of the Party in Doha [11].	
						1449 – Guiding Sustainable Adaptations to the Impacts of Climate Change	UK adaptation policy and regulatory development has been influenced through the codified knowledge of possible future climate impacts and adaptation options developed in the School. Hansard cites links to our work in three White Papers between 2001 and 2005 and three policy briefings from the Parliamentary Office for Science and Technology, one of which was authored by a School secondee to Parliament, have relied heavily upon this work [7]. These findings have been presented through personal briefings to successive Secretaries of State for the Environment (Beckett, 2001-05; Miliband, 2005-07; Benn, 2007-10); to parliamentary select committee inquiries (International Development; Science and Technology; Energy and Climate Change; Environment Audit [e.g.8]); and to devolved administrations in Belfast, Cardiff and Edinburgh.	Science communication skills to academic audiences & Science communication skills to non-academic audiences
							Liss (since 1971) served on the UK's Royal Commission on Environment and Pollution for their 2010 report on *Adapting Institutions to Climate Change*. Warren led Workstream 1 of the AVOID programme funded by the Department of Energy & Climate Change during 2009-2013 to inform UK's mitigation and adaptation strategies. Watkinson was seconded to lead *Living With Environmental Change* from 2008-2013. The School provided a team (led by Hulme) which designed and delivered the UKCIP02 climate scenarios for Defra [9]. The UKCIP02 scenarios have been cited over 1,100 times (half of which are in the period 2008-2013) in academic, policy and applied studies and used by large numbers of public and private sector organisations in their strategic planning and decision-making in the period from 2002-2010.	Collaboration with governmental bodies
						1450 – Global Temperature Data Underpins International Climate Negotiations	(…) This demonstrates that these data are vital for informing decision-makers each year about the current state of world climate. (…) The School's datasets are widely used by many less-developed governments around the world.	Science communication skills to non-academic audiences
							The work of the School – jointly with the Met Office Hadley Centre – in making it possible to quantify and monitor the world's average surface temperature has therefore *directly contributed* to this internationally-agreed climate policy goal.	Collaboration with governmental bodies

						1451 – Halocarbons: Impacts on Ozone Depletion and Global Warming	(…) The Montreal Protocol is an international agreement which was initially adopted in 1987, but is an on-going process by which the Parties are informed of the latest science through international WMO Assessments (hereafter referred to as Assessments) provided by a Scientific Assessment Panel of experts every 4 years, and, based on these, the Parties have agreed Amendments to the Protocol [7]. It is through inclusion of our results in this on-going process of Assessments and Amendments that out research has had most impact (…) In addition to impacting policy on ozone depleting substances through the established international process, we have also reported our research results directly to the UK Government. The Head of the Global Atmosphere Division in the UK Department of the Environment has provided a testimonial to confirm this [10].	Science communication skills to non-academic audiences
						1452 – Management Strategies for Biodiversity Conservation	The School's underpinning research contributed to the UK Government Parliamentary Office of Science & Technology (POST) briefing [9] and has 166ecognize166 international conservation organisations to adopt an evidence-based approach to global conservation interventions and policy (e.g. [10]).	Science communication skills to non-academic audiences
							The Biodiversity Audit Approach, developed in 2010-11, had immediate impact, assisted by knowledge transfer and engagement with Natural England, Defra, Institute of Ecology and Environmental Management, Local Authorities and stakeholders including CLA (Country Land and Business Assocation), National Farmers Union and Wildlife Trusts. (…) Through engagement, local community outreach and participation in governmental and inter-governmental working groups, and adoption of research findings by environmental advocates Peres' research has had demonstrable impacts on global, neotropical and national (Brazilian) forestry and carbon policy, including: (…) (…) Through advisory work with the Brazilian Ministry of Environment (MMA), Peres has attended numerous conservation planning workshops, the impacts of these include defining: (a) a protocol for long-term biodiversity monitoring in Amazonian forest reserves within Programa ARPA [15]), which manages 52Mha of forest within 95 Amazonian protected areas; and (b) biodiversity assessment protocols for Reduced-Impact Logging (RIL; [16]) concessions, upon which large-scale environmental licensing and certification have become conditional	Collaboration with governmental bodies & Collaboration with local communities / civil society
		2nd place	Newcastle University	3	Technological (2) Environmental (1)	21955 – Cost-effective restoration strategies for at risk / damaged coral reefs	Research at Newcastle effectively assessed strategies for coral reef restoration the results of which were worked into a series of international guidelines. The '*Reef Restoration Concepts & Guidelines*' [E1]: Edwards & Gomez 2007) (translated into Indonesian, French and Spanish [**E1**]), rehabilitation manual [E1] (Edwards 2010) and advisory paper [E1] (CRTR 009/2010) have led to measurable changes to the practices of NGOs, coastal managers, and the maritime insurance industry. (..) *Impacts on NGO's* Two thousand print copies of the *Reef Restoration Concepts & Guidelines* have been distributed and over 1000 electronic copies downloaded from the CRTR website (www.gefcoral.org) per year while this was monitored (2008-2009). Additionally 1000 print copies of the *Reef Rehabilitation Manual* were distributed within 4 months of publication. The manual and guidelines have been requested by and sent to practitioners in at least 66 different countries. Newcastle has received feedback from the users that the guidance has been used on at least 26 reef restoration projects in 19 different countries on every continent except Antarctica [E2]. *Impacts on ecological consultancies*	Science communication skills to non-academic audiences

							The guidelines constitute "scientific best practice in the consideration and planning of proposing coral transplantation as a mitigation measure related to IFC PS6 [International Finance Corporation- World Bank – Performance Standard 6] and biodiversity offsetting" [E4].	
						21954 – Risk reduction in petroleum systems and pore pressure prediction	A Geoscience Fellow and highly respected pore pressure expert at ConocoPhillips [E4] states: *the basic research of GeoPoP has……improved our drilling efficiencies by avoiding pressure related problems which can run into tens of millions of dollars per event and in some cases can increase the risk of a release of high pressure fluids at the sur* BG's Technical Authority on Petroleum Systems states that the Newcastle research has impacted that process and points out that the methodology is widely accepted by the industry in that it has been coded into standard, basin-scale fluid flow simulation software: *"A key paper published by the Newcastle Group (P6)led to widespread awareness of the (mudstone) methodology and soon resulted in it being incorporated into high end Petroleum Systems Modelling software.Thus it became possible to predict pore pressure more accurately ahead of drilling"* [E3]. (…) ConocoPhillips [E4]: **"***Materials that have been generated by GeoPoP and more recently Caprocks have been an exceptional resource for developing our training courses for seal evaluation and overpressure. Publications by Caprocks and GeoPoP workers are now recommended readings for our new Geoscience employees and references for experienced employees.*	Science communication skills to non-academic audiences
						21956 – Improved production from diodegraded heavy oil reservoirs	Evaluation of viscosity gradients in heavy oil reservoirs now forms an important part of production process design in the oil industry with several major oil companies (e.g. Statoil, Woodside, Shell) with a global footprint incorporating these insights into their heavy oil businesses [E1-E4]. One project sponsor specifically highlights how the science developed in the Bacchus project has had a direct influence on the value of a specific field, "*understanding of the reasons for fluid property variability influenced the decision to sell the field to another company and also added significant value (probably in the $10's of millions) to the asset*". (…) The fundamental principles developed from our research and specific models developed have been incorporated into practical software tools developed in-house by oil company sponsors [E2-E4] (…) Permedia, a company that develops and markets basin modelling software [E5] worked closely with Bacchus researchers to couple Permedia's high resolution modelling software with the science base from our oil biodegradation research.	Collaboration with industry / companies
							6. Impact on popular culture Our research has provided the basis for a science fiction novel, "Petroplague" by Amy Rogers [E9] with our research (Jones, et al. Nature 451, 176–180; Section 3, Reference 3, above) one of the sources cited in the technical annex (p. 322).	Science communication skills to non-academic audiences
							In 2006, the research led to the formation of a successful spin out company, Gushor Inc., [E6] which provides services to the heavy oil industry.	Entrepreneurial and technology transfer skills
8	Chemistry	1st place	University of Durham	5	Technological (5)	1175 – Structural science – equipment and software for industry	Research at Durham aimed at developing an open-flow cryostat capable of cooling below liquid nitrogen temperatures [1] was performed as part of an EPSRC-funded project in collaboration with Oxford Cryosystems (OC). OC is an Oxfordshire based company which employs 20 staff and has an annual turnover of £3–£3.5M. The prototype was completed in 1998 and the commercial version was launched by OC as the HeliX at the IUCr Congress in Glasgow, 1999. IP for the Helix is owned by OC who have sold around 20 units in the 2008-2013 period to academic institutions and central facilities globally [Im1].	Collaboration with industry / companies
							The jEdit interface he developed and distributes for "power-use" of the software is used by many academic and industrial groups, and Durham has trained in excess of 500 people in its use at predominantly industrial workshops worldwide (USA, Germany, Italy, UK, Australia).	Science communication

								skills to non-academic audiences
							Many of these innovations are now incorporated in the commercial version of Topas [Im4], which has a list price around £10K. Sales figures for Topas are commercially sensitive information that Bruker cannot release. Many licenses have been sold and that their distribution would be approximately 50:50 between industry and academia.	Organizational support to entrepreneurship and TT related issues
						1776 – Elemental fluorine for fine chemical manufacture	In 1992 BNFL established a spin-out company, BNFL Fluorochemicals Ltd, later F2 Chemicals Ltd, to develop new markets in the fine chemicals sector using their expertise in the production and handling of F2 developed from nuclear power generation applications. The company also provided funds for building and equipping a new, purpose-built research laboratory for handling F2 within the Chemistry Department and RDC subsequently became a non-executive Director of the company. In the period from January 2008 to July 2013, multi-tonne quantities of F-ketoester 1 were manufactured by F2 Chemicals Ltd [Im2] as the exclusive supplier for Pfizer using Durham direct fluorination chemistry [2]. (…) In order to further develop the use of Durham F2 chemistry for fine chemical manufacture, a Durham University spin-out company, Brock Fine Chemicals Ltd [Im7], was established in April 2011 by Graham Sandford with assistance and legal expertise from Durham Business Innovation Services (DBIS). Multi-channel continuous flow microreactor techniques developed at Durham [3] were patented by Durham University [Im9] and a world-wide exclusive license negotiated by the University (DBIS) and granted to the Asahi Glass Co., Japan for a significant fee and a subsequent royalty stream. This acquisition formed a core part of the IP knowledge base in flow reactor technology at Asahi Glass.	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
						11777 – Lanthanide complexes in analysis and diagnosis	Following the first publications on emissive lanthanide complexes in the late 1990s, several companies independently contacted the Durham chemists and began to support research in Durham.	Collaboration with industry / companies
							In 2007/8, Molecular Devices marketed an assay [Im1] for high throughput screening of kinase inhibitors using a nanoparticle labelled with a Tb complex developed in Durham [6], a five-figure deal was agreed with the University, and it was protected by a primary patent (US Patent 7,517,701, 3 named Durham inventors) [Im1]. (…) A Durham University spin-out company Fscan Ltd [Im2] (company number 6550089), was set up in 2009 to examine the use of various anions as screening biomarkers using responsive luminescent probes.	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
							International publicity in 2009 [Im5] for the citrate test for prostate cancer raised significant public & commercial awareness. The story was carried by Reuters and reported in over 50 countries and in at least 30 magazines and papers (e.g. as a front-page lead in the Daily Express; page 3 of the Sun; also in the Hindu in India). Live interviews were given on 5 radio stations in the UK and Eire and it was covered in Channel 4 News and on the BBC web site.	Science communication skills to non-academic audiences
						11778 – Super-rpellent surfaces by plasmachemical functionalizatio n	To exploit this technology Badyal and Dr Luke Ward (a former PhD student) founded the IP-ownership company Surface Innovations Ltd. In 2001 [Im1]. Durham University agreed to assign non-industrially sponsored intellectual property developed within the Badyal group to the company in return for an equity stake.	Organizational support to entrepreneurship and TT related issues &

								Entrepreneurial and technology transfer skills
						11779 – Chemical and Materials Technoogies for cell biology	Durham University spin-out company, Reinnervate Limited [Im1] (UK Company 04468747), was established in 2002 by Pryzborski with the aid of the Durham Business & Innovation Services team as a vehicle to commercialise technology in the bioscience sector and, specifically, to develop enabling technology to improve the growth and function of cultured cells stemming from Durham research in the porous polymer scaffold [3,6] and synthetic retinoid fields [1]. (…) The stable synthetic retinoids for predictable stem cell differentiation designed, 169ecognize169a and described in [1] were patented by DU in 2006 (WO2008025965 "Retinoid compounds and their use", Przyborski, Whiting and Marder) and the IP rights assigned to Reinnervate.	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
		2nd place	University of Cambridge	5	Technological (3) Societal (1) Environmental (1)	31942 – Impact on international measures to control ozone-depleting substances and their replacements	The World Meteorological Organisation (WMO) has published 7 *Scientific Assessment of Ozone Depletion* reports since 1987. The most recent in 2010 (published spring 2011), contains over 35 citations to underpinning research performed in the Department of Chemistry. On the evidence of their ongoing research contributions, the group led by Pyle was asked to contribute scientific evidence to all the WMO assessments.	Science communication skills to non-academic audiences
							Pyle was also a lead author in the special report for the UNEP/WMO Intergovernmental Panel on Climate Change (IPCC) on "Safeguarding the Ozone layer and the Global Climate System" in 2005.2 (….) Pyle continues to provide informal, independent advice to industries producing and using halocarbons	Science communication skills to non-academic audiences
						20084 – Chem4word	The Chem4Word research collaboration was unique at the time, with software development happening both within Microsoft and the University of Cambridge, and it provided a model for future collaborations between Microsoft Research and academic institutions worldwide.	Collaboration with industry / companies
						20083 – structure-guided and fragment-based drug discovery	On the basis of high resolution by X-ray crystallographic structures of fragments that bound to protein targets carried out in the Blundell and Abell laboratories, a spinout company, Astex Technology Ltd, was created in 1999 (Company No. 03751674, incorporated 14/4/1999).	Entrepreneurial and technology transfer skills
						20087 – liquid assisted grinding	A search of US Issued patents referring to methods for co-crystallisation reveals a number of patents that reference the use of LAG and the Jones Group in their methodology indicating that the technique has been adopted across a number of Pharmaceutical industries.	Science communication skills to non-academic audiences
						20089 – enabling methods for cleaner chemical synthesis	Ley has had direct input into Cyclofluidic as a member of its Scientific Advisory Board.	Collaboration with industry / companies
							Similarly, in collaboration with Mettler Toledo, Ley's flow chemistry techniques have driven the need for improved in-line analysis, which has resulted in further commercial products for flow IR monitoring being introduced to the market	Collaboration with industry / companies
							In 2005, Steven Ley set up the spin-out company Reaxa to exploit work on the nickel, palladium, platinum and osmium encapsulated reagents EnCat, and QuadraPure reaction clean-up scavengers	Entrepreneurial and technology transfer skills
9	Physics	1st place	University of	7	Technological (4)	28173 – Public Engagement with the	Public engagement with our research has led to impacts on the economy and on society, culture and creativity. We have stimulated public interest in science and engineering and inspired thousands of schoolchildren by including our research in their education programmes. We achieve this impact through a strategic approach to developing a high	Science communication

			Manchester		Societal (3)	research of Jordell Bank	national and international media profile combined with a purpose-built facility at Jodrell Bank to welcome visitors and engage them directly with the actual research going on at the site. This engagement with live science and active researchers at a working observatory is a key element in our delivering impact. Another key element of our approach is that the engagement programme is directed by designated members of staff – currently Prof. Tim O'Brien (1999-date; Associate Director Jodrell Bank Observatory) and Dr Teresa Anderson (2006-date; Director of Jodrell Bank Discovery Centre) and, until 2007, Prof. Ian Morison (retired 2010). (…) popular feature of our outreach programme is "The Jodcast", a twice-monthly podcast which has been produced since Jan 2006 by a team primarily composed of research students. The show features news, interviews with our researchers and others, and audience Q&A	skills to non-academic audiences
						28174 – the impact of the production and 170ecognize170 ation170 of graphene	Note : In this case study it is not possible to unveil any kind of condition to the creation of impact since it only mentions the potential impact and use of the characterization of graphene by the industry and policy makers.	-
						28175 – Public & media impacts arising from particle physics research at Manchester	Brian Cox's success in communicating science to a broad audience is underpinned by his credentials as a leading researcher, and by the research of the particle physics group in Manchester. He set out to convey the excitement of particle-physics research, through the broadcast media, contributing significantly to public interest in, and understanding of, the search for the Higgs boson, and has gone on to 170ecognize170 many other areas of science. His deep understanding of much of the material he presents makes him an authoritative voice, and his specific expertise in particle physics regularly informs his media work. With Jeff Forshaw, his writing on popular science books adds to the reach of the impact. (…) *Taking science broadcasting to a new level* Building on his background in particle physics, the success of "Big Bang Machine" led rapidly to three further Horizon programmes: "What on Earth is wrong with gravity?", "What time is it?" and "Can we make a star on Earth?". The success of these programmes was the trigger for the "Wonders of the Solar System" five-programme mini-series. Audience figures for the series were extremely high and persistent, averaging over 3 million per programme, and regularly featuring in the top 3 BBC2 programmes of the week [C]. Wonders of the Solar System won a Peabody Award in the USA for excellence in documentary film making. In 2011 Cox won "Best Presenter" at the Royal Television Society awards for Wonders of the Solar System and at the Broadcasting Press Guild Awards he won the award for best performer in a non-acting role, while Wonders of the Solar System was named best documentary series. (…) Cox also has a long-standing collaboration with Professor Jeff Forshaw. Together they have written two best-selling popular science books, (…).	Science communication skills to non-academic audiences
						28176 – Transfer of laser research and development to spin-out companies, Lynton lasers	Lynton Lasers Ltd and Laser Quantum Ltd are both spin-out companies from the University of Manchester and were formed in each case by former members of the School of Physics and Astronomy.	Organizational support to entrepreneurship and TT related issues &

						ltd and laser quantum ltd.		Entrepreneurial and technology transfer skills
						28177 – CPO software package for designing charged-particle optical systems	Consequently, a spin-off company was formed to make CPO available to manufacturers of scientific instruments and other users of electron optics. This company, called Charged Particle Optics Ltd, was started by two staff from the School of Physics and Astronomy (Read & Bowring).	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
						28178 – The square kilometer array – in 171ecogn, Australia and the UK	Note: In this case study it is not possible to unveil any kind of condition to the creation of impact	-
						28179 – communicating physics through the royal society	The Royal Society's annual Summer Science Exhibition showcases the most exciting cutting-edge science and technology research [A]. It provides a unique opportunity for members of the public to interact with scientists and ask them questions about their work. The Exhibition is the Society's main public event of the year and is open to members of the general public as well as students and teachers, scientists, policymakers and the media [A].	Science communication skills to non-academic audiences
		2nd place	University of Strathclyde	4	Technological (4)	42304 – Creation of a cluster of innovative laser companies in Glasgow serving global markets	This was met by the setting up of a spin-out company, Microlase Optical Systems Ltd, in 1992 by Professor Ferguson and two former graduate students.	Entrepreneurial and technology transfer skills
						42306 – Applications of microwave and mm-wave sources and amplifiers for the defence, security and health sectors	Fundamental research into new sources and amplifiers was conducted by the ABP group, publishing regularly in leading journals, and its potential impact was identified soon after the early work in 1996	Science communication skills to academic audiences
							Companies such as e2v and TMD were involved at an early stage, building prototypes and using them to conduct trials which have changed their thinking and business plans	Collaboration with industry / companies
						42305 – Increased employment and wealth creation from a	The patent was assigned to Cascade Technologies, a company started by Normand in 2003. The transfer of intellectual property developed in the Physics Department to Cascade Technologies has allowed the company to build systems that have been applied to many different gas sensing scenarios. The company has negotiated licence agreements with industry, leading to the application of the technology in a variety of fields	Organizational support to entrepreneurship and TT related issues

						spin out technology company – Cascade technologies		& Entrepreneurial and technology transfer skills
						42303 – Market leading sales of fluorescence spectrometers for multidisciplinary applications	David Birch co-founded IBH and the Photophysics Group in 1977/8, served as IBH Chairman 1977-2003 and is presently Horiba Jobin Yvon IBH Director of Science and Technology. His role, bridging between research, new products and the market, has been crucial to achieving commercial success. The process to impact started by demonstrating new instrument capabilities and applications through publications, which developed the field, attracted the market to related instrument products, and built the brand and reputation of IBH and Horiba.	Entrepreneurial and technology transfer skills
10	Mathematical Sciences	1st place	University of Oxford	13	Health (1) Technological (6) Societal (2) Economic (4)	4905 – computational fluid dynamics: the rolls-royce hydra code for jet engine design	In 2004, Rolls-Royce received from Oxford the first production version of the HYDRA CFD code for testing. In 2006 it was established as the company's compressor design tool, and by 2009 it had become the design tool for multiple businesses across Rolls-Royce – including gas turbines, air and thermal systems, and power generation [E].	Collaboration with industry / companies
						4906 – adjoint sensitivities in computatuinal finance bring orders of magnitude runtime improvements	Affymetrix licensed the source code for both IMPUTE v1 (2009) and v2 (2010) from Oxford University for £250,000 [A].	Organizational support to TT related issues
						20176 – pharmaceutical and biotechnology companies gain economic benefits from novel statistical methods for imputing genotypes	Affymetrix licensed the source code for both IMPUTE v1 (2009) and v2 (2010) from Oxford University for £250,000 [A]. Affymetrix use Impute v2 as a central part of the process of designing both generic and custom-made SNP chips (a chip is a collection of microscopic DNA spots attached to a solid surface). In addition, licences for use of the software, without the source code, worth ~£70,000 in total have been sold to Genentech (2008), GlaxoSmithKline (2008), Biocomputing Platforms Ltd. (2009) and PgxHealth (2010) [A]. IMPUTE has also been used in a study of drug response by Roche via a 2011 consultancy agreement with Marchini.	Organizational support to TT related issues
						20178 – influencing 172ecogn government policy through mathematical	Through collaborations during the period 2005-2012 Maini's role was pivotal in extending the model building to enable further strategies to be considered which accounted for variations in behaviour on a district level [B], and the effects of anti-retroviral therapy [A], in addition to the published work [1]. A member of the NACP III and IV planning teams (and co-author of [1]) reports [C] that "The output of these models were used extensively in finalizing the implementation plans for the country. […] We are grateful to Professor Maini and Dr Rao for their	Collaboration with governmental bodies & Science communication

						modeling of the hiva&aids epidemic in india	continued assistance in guiding these policy decisions and their contribution to enabling scenarios to be assessed and results to be evaluated and help those working in these difficult areas" In addition to presentation directly into the NACP the research work was circulated more widely into Indian AIDS prevention activities [eg D,E]. It was presented at a collaborative meeting between the Indian Clinical Epidemiology Network, a network of academic health care researchers across 135 Medical colleges/Institutions in India, and the Indian Statistical Institute, Kolkata, which was providing technical assistance to NACP. It also formed part of a Capacity Building Workshop on Operations Research in HIV/AIDS for the Northeast States during September 2010. The research was further disseminated through activities of the Postgraduate Institute of Medical Education and Research School of Public Health, first at a Technical meeting in June/July 2009, and then in their School of Public Health Impact Study in June 2010, and also at the Indian Council for Medical Research Institute in Kolkata in December 2009. The direct impact of the research was facilitated by two of the co-authors of [1] who were members of the NACP III planning team. The work formed the cornerstone of documents and presentations produced by this team, including predictions directly from the paper [1], forming a central element of the Strategy and Implementation Plan [A].	skills to non-academic audiences
						20200 – mathematics in the design and manufacture of novel glass products	Between 2002 and 2006, the University of Oxford team (led by Prof. John Ockendon FRS) was a node in the €1.4m EU Research Training Network Mathematics for the Glass Industry: Computing and Analysis (known as MAGICAL) which aimed to promote collaborations between Universities and glass companies across the EU, including Schott AG. Finally, Pilkington (now NSG group) has had a long-standing relationship with the University of Oxford's Mathematical Insitute through Industrial Workshops 173ecognize by the Oxford Centre for Industrial and Applied Mathematics (OCIAM) and was also involved in MAGICAL.	Collaboration with industry / companies & Science communication skills to non-academic audiences
						20248 – driving clinical genetic testing and biotechnology development based on the international hapmap project	The publication of the first phase of the HapMap Project was widely reported in international nonspecialist media including, in the UK, interviews with Donnelly on Newsnight and Radio 4's Today programme [G]. The contribution of the HapMap Project was acknowledged in the House of Lord's report into Genomic Medicine [H] (published in 2009; Donnelly was interviewed as part of the committee enquiries), which in turn has resulted in the founding of the Human Genomics Strategy Group [I], which advises the government and NHS on how genomics can be integrated into a national healthcare programme.	Science communication skills to non-academic audiences
							In "2. Underpinning research": The International HapMap Project was an international collaboration of research institutions from the UK, US, Canada, Japan, China and Nigeria (for details see www.hapmap.org). The project assayed genetic data on a sample of individuals from around the world in order to map the patterns of common genetic variation.	Collaboration with other HERIs
						20286 – development and implementation of mathematical algorithms enhance performance of software	The impact has been achieved through the transfer of software developed by Giles as part of his research. This has gone into libraries developed and maintained by NAG, NVIDIA, and Apache. With NAG and NVIDIA, this came about through long-standing research collaborations and personal contacts. In the case of the Apache Foundation (which develops open source software),the 173ecognize173at asked for Giles' software as a result of reading his papers. NAG and Giles have long-standing connections, including the recent development of a wholly new GPU-based library [B] targeted at the needs of the finance industry.	Collaboration with industry / companies

						libraries on GPUs		
						20291 – risk on / rosk off: from academic research for financial market staple	**In "1. Summary of the impact":** This case study charts the influence of the Risk On / Risk Off (RORO) paradigm, developed in research at the University of Oxford in collaboration with investment bank HSBC. **In "4. Details of the impactFrom research to impact"** The HSBC Foreign Exchange Group were key partners in the development of the underpinning research, three HSBC employees were coauthors, and HSBC coined the phrase RORO.	Collaboration with industry / companies
						20293 – billmonitor: predicting the best mobile phone contract for users	The founder of Optimor discussed the idea of the company with Holmes and Meinshausen, who 174ecogniz that their previous research provided just the insights required for building an accurate algorithm for predicting an individual's future mobile phone usage. He states [B] "The research done by Professor Chris Holmes and Professor Nicolai Meinshausen of the University of Oxford was an essential component which has enabled us to build an accurate algorithm for predicting an individual's future mobile phone usage and we have used this to develop Billmonitor."	Collaboration with industry / companies
							The parent company, Optimor, employs a managing director and four developers. Holmes and Meinshausen were directors of Optimor (Holmes from April 2008 until January 2012 and Meinshausen from April 2008 until September 2011) and continue to act as scientific advisers, and there are three further commercial advisers.	Entrepreneurial and technology transfer skills
						20302 – cycles of time; public engagement with conformal infinity	**In "1. Summary of the impact"** This case study describes public engagement with the University of Oxford's research in Mathematical Physics via the popularization of science through the writings, public lectures and media appearances of Sir Roger Penrose. Published in 2010, Penrose's book Cycles of Time deals directly with the research contributions and has reached broad audiences via books, public lectures, TV appearances, and YouTube postings. The impact has been to engage large numbers of the public with modern theories of the origin of the universe in a mathematically non-trival way. **In "4. Details of the impact"** The impact is on society through public interest and engagement with science and the stimulation of public discourse. The questions of the 'origin of the universe', 'what happened before the big bang?', and 'how space-time might emerge from a more fundamental theory' are some of the most frequently addressed issues in popular science and stimulate wide interest (and controversy). Roger Penrose's writings have opened up new avenues in this debate that have led to much interest outside academia. The beneficiaries since 2008 have been the general public who gain an understanding of current models for the evolution of the universe. (…) The wide impact of these ideas and Penrose's presentational style is evidenced by regular invitations to give distinguished public lectures and to appear on the media the world over	Science communication skills to non-academic audiences
						20329 – R, a free software environment for statistical computing and graphics	Analysis of SubVersion commits – the measurement used to assess which users are updating collaboratively developed software – (http://www.ohloh.net/p/rproject/commits/summary) shows that, from 1999 to 2013, just over 50% per cent were by Ripley and that this rate of contribution has been sustained over the entire period. This phenomenal output constitutes literally millions of lines of code. (…) The software, along with many original insights on its use in applied statistics, are laid out in Modern applied statistics with S-plus (R is an implementation of the S programming language combined with lexical scoping semantics). This classic book, written by Ripley and co-author Venables, was published by Springer in 1994 and now in its 4th edition.	Science communication skills to non-academics and academic audiences

							It has sold over 90,000 copies. It is complemented by more recent 175ecognize175a texts, often aimed at practitioners, such as those in the Springer series `UseR!'.	
						20416 – exploitation of rapid protein structure prediction tools	Pathway to impact pyFREAD has been made accessible through three different routes: · the direct implementation in 2010 of the software by UCB Pharma, who were industrial partners in the research project.	Collaboration with industry / companies
						20446 – finding moonshine: engaging the public through mathematical research	**In "1. Summary of the impact"** By using the progress of his own research over the course of a year as a major narrative theme, in Finding Moonshine Marcus du Sautoy provides the public with unique insight into the content and nature of his mathematical research programme. The success of the book, published in 2008, in conveying the essence of cutting edge research, in elementary terms, attracted the attention of broadcasters and policymakers and provided a platform from which du Sautoy has been able to expand his public engagement activities to reach millions of people through TV, radio, public lectures, social media and interactive projects. His three part documentary The Code stimulated over a million viewers to play Flash games based directly on mathematical concepts. The phenomenal success of his unique brand of engagement in awakening an interest in mathematics, in both young and old, has had a great impact on society.	Science communication skills to non-academic audiences
		2nd place	Royal Holloway, University of London	2	Technological (2)	30193 – Design of a block cipher used in TETRA secure radio	Blackburn, Cid, Martin, McKee, Murphy, Ng and Paterson are current academic staff who have published cryptography papers and/or undertaken cryptographic consultancy within the current REF period.	Science communication skills to non-academics and academic audiences
						30194 – Design of authentication algorithms for GSM phones	In **"1. Summary of the impact"** Cryptographers at Royal Holloway, at the request of GSMA, designed a replacement algorithm (COMP128-2), the example implementation offered by the GSM Association (GSMA) to over 800 Mobile Network Operators (MNO) in over 200 countries. The algorithm is still regarded as robust and it and derivative algorithms are relied upon by enormous numbers of users every day.	Collaboration with industry / companies
11	Computer Science and Informatics	1st place	Newcastle University	4	Technological (4)	21273 – Expansion of the middleware software market	Route to impact: Arjuna Technologies Ltd, whose origin dates back to 1998, is a spin-off company founded by the researchers (Shrivastava, Caughey, Wheater, Little and Ingham) to commercialise the ground-breaking results of the research into middleware technologies (Arjuna system).	Entrepreneurial and technology transfer skills
						21791 – novel computational approach to discover medicines	**In "1. Summary of the impact"** New computational analysis methods have been developed to make drug discovery and toxicological analysis much more efficient. These methods have been patented (UK, EU, US) and are employed in e-Therapeutics Plc, a computational drug discovery spin-off company of the University.	Entrepreneurial and technology transfer skills
						21792 – improved processes for the development of dependable systems	*Adoption of research results by practitioners and educators* Formal methods techniques, mostly inaccessible without expertise, are widely regarded as impractical outside of critical software analysis research [1]. Our novel tools and approach to disseminating formal methods research has influenced industry to adopt and benefit from these techniques and engendered a lively international community of formal methods end-users.	Entrepreneurial and technology transfer skills

						21793 – worldwide adoption of asynchronous circuits and improved business process modeling	**Authors' note:** This case study states the application and impact of a theoretical knowledge developed by this university, that seems to be happen through the normal process of scientific publication of research outputs that were therefore used and applied by the industry in the development of new technologies	Science communication skills to non-academics and academic audiences
		2nd place	University of Cambridge	6	Political (1) Technological (4) Economic (1)	13828 – electronic payment systems	Anderson's team has a high profile not only for research and citations, but also in search engines and conventional media. (…) (the group has advised both the FSA and the European Commission, and has also given evidence to various parliamentary committees) but also globally.	Science communication skills to non-academics and academic audiences & Science communication skills to non-academic audiences
							This led Anderson to propose design changes to the APIs presented by most HSMs. Cryptomathic took a particular interest in this work, hiring Dr Bond as a security architect in 2006. "*One of our latest products, CSG, the Crypto Service Gateway … would not have been built without the great insights that arose from the Anderson group*." [7]	Collaboration with industry / companies
							The Anderson group's research has been at the core of technology developed and commercialized by Cronto Limited, a spin-out company providing authentication systems for online banking. Dr Murdoch is the Chief Security Architect of Cronto in addition to his research role at the Laboratory. Cronto's products are now securing online banking in Chile (Corpbanca), Switzerland (Raiffeisen) and Germany (Commerzbank).	Collaboration with industry / companies
						16707 – Iris recognition	All publicly operational iris recognition systems worldwide deploy, as licensed executables, the Daugman algorithms. Today they are owned by the French conglomerate Safran-Morpho, for whom Daugman serves in a consultancy role as Chief Scientist for Iris Recognition. From 2007 through 2011 they were owned by L1, for whom Daugman served in the same capacity, until L1 was acquired by Safran-Morpho. This pattern of successive corporate acquisitions with Daugman as Chief Scientist extended prior to 2007 with the companies Securimetrics, Iridian, and IriScan (who were the first to commercialise the technology).	Organizational support to TT related issues & Collaboration with industry / companies
						13831 – Real VNC	The research into VNC created the remote access market. RealVNC was founded in 2002 by Professor Hopper and Dr Andy Harter to promote, enhance and commercialize VNC. Today, Hopper is Chairman and Harter is CEO.	Entrepreneurial and technology transfer skills
						13827 – Security economics	Anderson and colleagues have directly influenced the implemented policy of the European Commission. They produced two major reports for the European Network and Information Security Agency (ENISA): the first (2008) on consumer and single-market aspects [6] and the second (2011) on protecting the Internet infrastructure [7] (…) Anderson has directly informed the public policy debate in the UK. He is frequently asked to testify before parliamentary committees and to advise EU policy working groups. For example, he has testified in person at Westminster to the Commons Select Committee on Scientific Advice and Evidence in Emergencies (17 November 2010)(…)	Science communication skills to non-academic audiences & Collaboration with governmental bodies

							(…) In 2010, Anderson was invited, by the Government Chief Scientific Adviser, to join the Blackett Review of Cybersecurity, which fed into the National Security Strategy [10], which in turn led to the cabinet approving an extra £640m budget for cybersecurity over 2011–5:	
						15513 – Ubisense	Ubisense was founded in 2002, with Professor Hopper as Chairman, to commercialise the location solutions applications of the research.	Entrepreneurial and technology transfer skills
							Within two years it had merged with TenSails LLP, who had been collaborating with Ubisense since its foundation.	Collaboration with industry / companies
						13830 – Xen	In addition to Xen's broad impact, the Cambridge team founded a successful company to exploit the research. In 2005, Pratt, Hand and Fraser co-founded XenSource as a vehicle to provide a robust open source version of Xen. Pratt and Fraser joined XenSource in 2007 on a permanent basis; Hand took sabbatical leave to work at XenSource in 2006/7.	Entrepreneurial and technology transfer skills
12	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1st place	Imperial College London	18	Technological (13) Economic (4) Political (1)	42147 – Standards for the application of materials in industry	**Authors' note:** This case study states the application and impact of a theoretical knowledge developed by this university, that seems to be happen through the normal process of scientific publication of research outputs that were therefore used and applied by policymakers and the industry "The pivotal contribution of our research to UK, US and International Standards and Codes is evident from their direct citations to our research papers. "	Science communication skills to non-academics and academic audiences
						42148 – Commercialisation of guided wave inspection for the detection of corrosion in pipes	In 1999 a spin-out company Guided Ultrasonics Ltd was formed to commercialise the technology under licence from Imperial Innovations, the College technology transfer company. It now employs 7 PhD graduates in NDE topics from Imperial with a total staff of 15 in UK.	Entrepreneurial and technology transfer skills & Organizational support to TT related issues
							Professor Lowe is leading the development of standards, working with standards bodies, in close collaboration with Guided Ultrasonics Ltd and Plant Integrity Ltd. The British Standard [13] explicitly cites [4] above and there are also Italian [14], Japanese [15] and US [16] standards.	Collaboration with governmental bodies & Collaboration with industry / companies
						42149 – Commercialisation of instrumentation for testing and development of lubricants	As well as supporting the Imperial research and attracting substantial funding from industry, the new test methods have also been 177ecognize177atio by a spin-out company, now known as PCS Instruments Ltd, (www.pcs-instruments.com). Over the period 2008-13 (6 yr) it had a turnover of £39.8M (£7.63M in 2012-13), with 80% overseas sales, and now employs five Imperial Tribology PhD graduates, one of whom was recruited since 2008. There are a total of 11 permanent staff in the company. All the manufacturing added value associated with the company is in the UK; thus the company supports a range of subcontractors	Entrepreneurial and technology transfer skills
						42150 – Rolls-Royce University Technology	The Vibration UTC is a strategic partner of Rolls-Royce for the development of a prediction capability for vibration [9]. The research programmes completed by the Vibration UTC are delivered as fundamental investigations of behaviour, processes for prediction, software modules and supporting measurements. By controlling the vibration behaviour the risk of High Cycle Fatigue is dramatically reduced. The delivery of the impact is also assisted by	Collaboration with industry / companies

						centre on vibration	consultancy undertaken by the academic staff and by PhD graduates and postdocs being employed by the company; 10 UTC researchers have joined Rolls-Royce since 1996, including 3 since 2008.	
						42151 – Successful commercialization of advances in computational fluid dynamics	**In "1. Summary of the impact"**: Computational Dynamics Ltd, partnering with adapco and trading as CD-adapco www.cd-adapco.com is the world"s largest independent CFD-focused provider of engineering simulation software, with major products STAR-CD and STAR-CCM+. It was formed by Professor David Gosman and Dr Raad Issa and its turnover has grown more than 30 fold since 1993 and by over 250% since 2008 to currently ~ $190M pa. It employs around 750 staff, of whom roughly 80 are located in the London office.	Entrepreneurial and technology transfer skills
						42152 – Peering into the pore space: digital rock physic to improve oilfield management	iRock Technologies is a start-up company, based in Beijing, that exploits the technology developed at Imperial College. The CEO is Dr Hu Dong, a former researcher in Prof Blunt's research group at Imperial, while Prof Blunt himself is Chief Scientist	Entrepreneurial and technology transfer skills
						42153 – Air rate adjustment to peak air recovery (PAR) to increase mineral production by froth floatation	Anglo American Platinum and Rio Tinto supported financially the Froth and Foam Research Group to increase the understanding of the fundamentals of flotation and the importance of froth in mineral separation. (…) Throughout this research period and development of the PAR methodology, Anglo American Platinum and Rio Tinto were research partners.	Collaboration with industry / companies
						42154 – Full-waveform seismic inversion: improving resolution I oil & gas exploration	Specific impact in particular companies Since 2008, eighteen companies have licensed 3D FWI computer software from Imperial: BG Group, BP, CGG, Chevron, ConocoPhillips, DONG, DUGS, ENI, Hess, Ion-GX, Maersk, Nexen, Rio Tinto, Shell, TGS, TOTAL, Tullow, and Woodside [9].	Organizational support to TT related issues
						42155 – Putting pressure information into sharp focus: the use of deconvolution to boost oilfield reserves	The Imperial algorithm was implemented by BP in 2004 in their well test analysis software product (PIE) which they share with Total. It was subsequently implemented in commercial software packages such as Saphir from Kappa Engineering (2007), Pan-Systems from Weatherford (who purchased the algorithm from Imperial in 2007 and implemented it in 2008), FAST from Fekete (2009). The availability of deconvolution in commercial software made it easier for operators to incorporate it in their well test analysis process.	Organizational support to TT related issues
						42156 – A novel linear gasifier panel design for underground coal gasification	**In "2. Underpinning research":** Contracted by Seamwell International, a private UK natural energy resources company, in 2009 the Group's research on UCG focused on developing new UCG panel designs to ensure that the application of UCG technology can be extended to coalfields with weak roof conditions, such as those experienced in Inner Mongolia and elsewhere in the world. By combining the group's coal mine roof control expertise with extensive geomechanical and thermomechanical modelling, they were able to address the extremely weak roof challenge.	Collaboration with industry / companies

						(UCG) under weak roof rock conditions		
						42157 – Organic solvent nanofiltration – a new paradigm for molecular separations in organic liquids	The research at Imperial College produced membranes at a small pilot scale, and has resulted in patents and patent applications covering the membranes and their means of fabrication. Key among these is UK Patent GB2437519 [8] and the resulting international patent family, which protects the cross linking of polyimide membranes to make them stable in a wide range of organic solvents. Intellectual property on membrane fabrication and applications of the membranes was assigned from Imperial College to Imperial Innovations plc, the technology transfer company set up by Imperial College. Innovations then licensed the findings of the OSN research to an Imperial College spin-out company, Membrane Extraction Technology (MET) Limited. MET's business goal was to develop and commercialise the OSN technology.	Organizational support to TT related issues
						42158 – Process systems enterprise Ltd	**In "1. Summary of the impact":** Research into new process modelling tools and numerical simulation and 179ecognize179at algorithms at Imperial's Centre for Process Systems Engineering (CPSE) has resulted in a powerful new modelling technology. In 1997, a team from (CPSE) established a spin-out company, Process Systems Enterprise Ltd (PSE, www.psenterprise .com), to commercialise this process and energy systems modelling platform – gPROMSTM and to provide associated leading-edge model based services such as the design of new processes and the 179ecognize179at of existing processes. **In "4. Details of the impact":** In 1997, Process Systems Enterprises Limited (PSE) was formed by a team of academics (Macchietto, Pantelides, Perkins, Pistikopoulos, Shah) from the CPSE to meet these challenges, and to ensure the impact of research from the CPSE.	Entrepreneurial and technology transfer skills
							Since 1993 CPSE has operated an industrial consortium. Member companies of this consortium (ranging in number between 8 and 12 over the years, with typical fees of £15,000 per annum) have an opportunity to evaluate software prototypes (under special licences) and provide feedback. This model of prototyping, testing and feedback proved an invaluable part of the 179ecognize179ation179n process. It helped to ensure that once PSE was launched, a software platform that would meet the needs of users was available This combination of basic and industrially-oriented research, together with strong user engagement in the research and development phase, meant that there was a queue of ready customers as soon as the commercial version of the technology was made available. Additionally Professor Costas Pantelides, who was the team leader for the R&D activities, moved from CPSE to PSE Ltd in 2000 where he continues as the Managing Director to date, while retaining a 0.4FTE position in the CPSE. Additional routes through which the impact has taken place include the provision of consultancy services by staff from the Dept to PSE, the recruitment by PSE of PhD students and research associates and the facilitation by PSE of a partnership agreement between ABB and Imperial College.	Collaboration with industry / companies
							At the launch of PSE, the gPROMSTM modelling platform, including modelling language, solution algorithms, results 179ecognize179ati and prototype user interface, comprised an IP package that was licensed to the company by Imperial Innovations, in return for 35% of the equity. The company then worked on improving the usability, developing documentation, business development and incorporating new innovations arising from CPSE. PSE Ltd has so far solely 179ecognize179atio IP arising from the CPSE, and all its revenues can be traced back to the research at the CPSE.	Organizational support to TT related issues

						42159 – Increased safety and efficiency of oil and gas process designs from improved flow assurance	The TMF collaborative programme allows immediate use of the research by the industrial partners. Additional routes through which the impact has taken place include the recruitment of TMF PhD students by TMF sponsors, and the consultancy work carried out by TMF academics on problems that are of specific interest to the sponsors.	Collaboration with industry / companies
						42160 – Advanced thermodynamic modelling for complex fluids	The application of the SAFT-VR approach to industrial problems has occurred primarily through collaborative projects, secondments and consultancies.	Collaboration with industry / companies
							To enable this, the software for the SAFT-VR family of models was licensed in 2009 via Imperial Innovations to Process Systems Enterprise Ltd (PSE), a thriving SME spun out of Imperial in 1997. In 2012, with customers impressed by the accuracy and versatility of the platform, PSE acquired the full rights to the software, which is now marketed as gSAFT [10], [11] and [12].	Organizational support to TT related issues
						42161 – Advanced Sorption instruments for powder characterisation	Surface Measurement Systems Limited (SMS) was formed by Drs. Briscoe and Williams from the Department of Chemical Engineering and in 1994, working in collaboration with Pfizer Research UK, invented a novel gravimetric instrument for water sorption analysis of powders called Dynamic Vapour Sorption (DVS).	Entrepreneurial and technology transfer skills
							The DVS instrumentation approach is closely linked to the IGC research work pioneered by Dr Williams at Imperial College funded by an industrial research contract with Du Pont Fibres. Dr Williams remains the Managing Director of SMS and in 1997-1999 spent 0.5 FTE working with SMS (the balance of FTE in post at Imperial College), promoting the DVS product and working on its 180ecognize180ation180n	Collaboration with industry / companies
						42162 – Introduction of stone deflector in the design of the Airbus A400M Aircraft	**In “2. Underpinning research”:** Having established a reliable model for the initial state of the lofted stone at the start of its projected motion, the next stage of research investigated the subsequent motion of the debris to enable prediction of the severity of any resulting impact on the aircraft. This work was funded directly by Airbus during 2011 and was led by Dr. Emile Greenhalgh with Dr. Nguyenas a postdoctoral researcher.	Collaboration with industry / companies
						42163 – Improving the aerodynamic performance of formula one racing cars	Using the insights from the Nektar code Prof Sherwin carried out work, directly sponsored by the Formula One team McLaren Racing Ltd. (…) Subsequent and more specific studies building on the general findings on passive methods and focusing on Formula One cars was supported by McLaren from 2011-2013. (…) The knowledge has primarily been disseminated through the movement of people into the engineering teams and McLaren have heavily recruited from the research teams involved in the research outlined in section 2.	Collaboration with industry / companies
						42164 – Improving survivability of protective structures through novel design and modelling	Quick-running algorithms developed by Imperial to predict blast effects for operational analysis have been integrated within the Government-developed HIP (Human Injury Prediction) code.	Collaboration with governmental bodies

		2nd place	University of Birmingham	3	Technological (3)	38917 – Enabling the commercial development of market-leading microcapsule-based products by Procter & Gamble using a novel mechanical analysis technology	P&G made the strategic decision to develop a large number of new functional products with microcapsules in 2003, this decision involved Professor Zhibing Zhang who was invited to join a consortium with nine experts in encapsulation and 181ecognize181ation181 from different countries as consultants to the company. (…) Given the critical importance of the micromanipulation data in the development of these products, it is perhaps unsurprising that Professor Zhibing Zhangs group has had 12 research projects, fully funded or co-funded by P&G since 2001. Consultants to the company. (…) Moreover, the impact generated from the above research on P&G's development of new products with perfume microcapsules helped to establish a strategic and long-term partnership between P&G and University of Birmingham in 2010, and contributed significantly as a case study within the School's successful application for a Queen's Anniversary Prize in 2011. A number of patents have been filed based upon the Birmingham fracture strength data.[5.3-5.6]	Collaboration with industry / companies
						38918 – Novel low fat food products leading to improved health and new market share using soft solid microstructures	The findings from research carried out a Birmingham has fed directly into the investment in novel manufacturing processes and new low-fat food products by global companies including Unilever[5.1,5.2], PepsiCo[5.3], and Cargill[5.1,5.4]. Researchers at Birmingham have worked closely with these and other companies in long-term partnerships to maximise the impact from their research findings.	Collaboration with industry / companies
						38916 – Positron emission particle tracking (PEPT) enables a paradifm shift in process design and multi-sclare modelling	Initially funded by the South African Minerals to Metals Research Institute, SAMMRI, the PEPT study provided insights on the influence of key design variables on mill performance and the data was used to test a simulation model	Collaboration with governmental bodies
							PEPT has been used in an investigation of polymer flow and mixing behaviour within industrial twin-screw processes via an EU funded project, called PEPTFlow5.1. This project ran until December 2009 and had a significant impact on the competitiveness of European SMEs throughout the polymer supply chain, 181ecognize higher added value and improved products and services. The project brought together 20 organisations (research groups, equipment manufacturers and industrial users). (…) Procter & Gamble is one of the largest R&D employers' in the North East of England and over the last 10 years have developed a strong relationship with Birmingham University – both with Chemical Engineering and Physics. Through the use of PEPT they have been able to quantify mechanical forces within washing machines, allowing them to understand mass transfer limitations in the laundry washing process. (…) As a measure of the importance of PEPT to its business, Johnson Matthey continue to support PEPT through five projects (three EngD and two PhD). (…)	Collaboration with industry / companies

							IMERYS, the world's largest industrial minerals producer has used the PEPT facility at University of Birmingham for a number of years to develop a better understanding of flow patterns and media behaviour in vertically stirred mills. (…) A project funded by XSTRATA to use PEPT to study the wear in stirred mills used for minerals comminution in platinum mining led to mill designs with improved lining materials in critical regions.	
13	Electrical and Electronic Engineering, Metallurgy and Materials	1st place	Imperial College London	10	Technological (8) Political (2)	42165 – efficient and economical plant management via model predictive control	**Authors' note**: In this case study it is not possible to unveil any kind of condition to the creation of impact.	-
						42166 – Device Applications of 3D Silicon Microstructures	**In "1. Summary of the impact":** The impact of their research has been to: I1) bring the power of mass spectrometry to individual chemists' lab benches and fume hoods, raising their effectiveness and productivity through the launch in 2011 of the world's first commercial desk-top mass spectrometer by Microsaic Systems plc, a start-up company founded by members of the group; (…) create a second start-up company, Nexeon Ltd, to manufacture nanostructured silicon anode materials, resulting in reduced battery size and weight for electric vehicles and portable electronics;	Entrepreneurial and technology transfer skills
							For example, Merck & Co Inc, in collaboration with Microsaic and Imperial College, published the first demonstration of the use of a miniature MS with HPLC [E2].	Collaboration with industry / companies
							Nanostructured silicon anode materials for lithium batteries – The research group's other innovation in microstructured silicon that led to a new company was high capacity anodes for lithium batteries based on "natural" lithography [R4]. (…)As a result the company Nexeon Ltd was established in 2006 [E5]. Between 2009 and 2011 Nexeon attracted over £50M in investment funds, which it has employed to develop and scale up the technology. It is one of the "top three portfolio companies" [E6] of Imperial Innovations plc, which itself has a market cap. Of £256M (6/10/13).	Organizational support to TT related issues
							NASA's Pheonix Mars Mission- The external impact of the group's microengineering research has not only been through 182ecognize182ation182n of its technology. One example is the work of Prof. Tom Pike and colleagues on microstructured substrates for soil analysis [R6], which led to these substrates being included as part of the atomic force microscopy instrument on the 2008 NASA Phoenix mission to Mars [E8,E9].	Collaboration with governmental bodies
						42167 – Ultra-low power electronics for healthcare applications	DNA Electronics (DNAe) is a start-up company founded by Toumazou to exploit the group's breakthrough in semiconductor-based gene sequencing in [R1, R2, R3]. Toumaz is a second start-up; founded to exploit the group's research in ultra-low power techniques for wireless physiological monitoring.	Entrepreneurial and technology transfer skills
							DNAe's sequencing platform technology with its associated patents (US7888015, US 7649358, US7686929, US8114591), all based on the underpinning research [R1-R3], was licensed to Ion Torrent Systems [E2] and Roche in 2010 [E3].	Organizational support to TT related issues
						42168 – Reconfigurable computing for high	Our underpinning research into acceleration of compute-intensive algorithms using FPGA technology has led to its successful commercial exploitation in the start-up company, Maxeler. (…)	Organizational support to TT related issues

						performance applications	Underpinning research by Cheung and Luk also led to several US patents (US6369610, US7543283, US12/747650) assigned to Maxeler on 2 Nov 2012. Moreover, Maxeler US patent US20130139122 A1 cited their work on word-length 183ecognize183at (R5).	
						42169 -Design and 183ecognize183 at methods for power networked impacting industrial strategies and government policies	Influence Government Policies [E1]: The research in [R1] and the results in [R2] form the basis of evidence supplied by Strbac to the House of Common's Energy and Climate Change Committee. This was included in their report to Parliament entitled "The future of Britain's electricity networks" (10th Feb 2010) [E1]. In this report Strbac or his evidence were referenced 38 times.	Science communication skills to academic audiences & Entrepreneurial and technology transfer skills
							Our team's role in advancing Alstom's second generation VSC from a concept (at TRL-1) to key plank of Alstom's strategy at TRL-4 is evidenced by the 3 joint patents (…).	Organizational support to TT related issues
							Imperial's work on 183ecognize design trade-offs in multi-level converters in 1996-2002 [R3], and particularly in the new Alternate Arm Converter 2007-2012 [R4], demonstrated to Alstom how excellent fault management capabilities could be achieved alongside high efficiency and low volume (…) Through the *Vessel* project (2006-2009) [EPSRC EP/E007198/1] and the Bboxx start-up company [E6], Imperial has exploited its expertise in photo-voltaic integration and techno-economic analysis [R6] to promote the "Energy Kiosk" model over conventional grid electrification.	Collaboration with industry / companies
							given the unique modelling capability developed by Imperial College team led by Professor Strbac, in 2011 UK Power Networks and Imperial commenced a joint project. … [to] apply a novel Load Related Expenditure Network Model	Collaboration with governmental bodies
						42170 – Specification of bioglass as a cell stimulating synthetic bone graft and the active agent in Sensodyne repair and protect toothpaste	The Vice President Research & Development at NovaBone Products LLC states: "*…the work conducted by Dr Larry Hench and yourself, in collaboration with Professor Dame Julia Polak, carried out from 1998-2002…, enabled NovaBone Products to provide scientific data to the FDA to support claims of "Osteostimulation" for our products. More specifically, the studies conducted at the Imperial College London were essential to the development and definition of the concept of Osteostimulation which is now understood among orthopaedic surgeons and researchers as the activation of the genes responsible for osteoblast differentiation and proliferation.*	Collaboration with industry / companies
						42171 – Solid oxide fuel celld for high efficiency domestic combined heat and power	The underpinning research led to the invention and patenting of a new class of fuel cell, namely a metal-supported SOFC operating at 500-600ºC [A,B]. The core patent has been granted on a worldwide basis, and further patents have followed.	Organizational support to TT related issues
							The key commercial impact of the invention was the formation of a spin-out company, Ceres Power, in 2001 which has provided continued employment to over 100 people amounting to approximately 600 man years since 2008 (the review period).	Entrepreneurial and technology transfer skills

						42172 – Improved performance of a jet engine through improved materials manufacturing process	A Materials Technologist at Rolls-Royce Plc notes: "*the research collaboratively with Imperial College addressed the mechanism for the formation of stray grains … [and] was instrumental in the design of a novel grain selector that successfully enables the "filtering" of these stray grains and ensuring casting conformance*	Collaboration with industry / companies
						42173 – Influence on UK Government0s nuclear R&D programmes and policy	Grimes" fundamental understanding of nuclear issues (e.g. references 1-3) and his civil nuclear leadership (sources B and C) also resulted in Rolls-Royce placing a University Technology Centre (UTC) in Nuclear Engineering at Imperial, of which he is founding Director.	Collaboration with industry / companies
						42174 – Reductions in emissions and improvements in boiler efficiency at power stations burning coal and biomass	The findings at Imperial College London were then followed with pilot scale trials using the RWE npower 0.5 MW combustion test facility at Tilbury (CTF).	Collaboration with industry / companies
		2nd place	University of Oxford	2	Technological (2)	4909 – Developing the three dimensional atom probe	In "1. Summary of impact" Following a series of patented advances and the formation of a spin-off company (subsequently incorporated into Ametek), research in the UOA has led directly to the sale of 45 Local Electrode Atom Probe (LEAP) instruments since 2008 with a value of $102M. In "2. Underpinning research" Based on the strong IP position developed in the UOA, the company was sold first to Polaron in 2002 and then in 2006 to Imago, now Ametek. Research and development in the UOA has thus led directly to designs critical for the performance of the current market-leading instrument, the Ametek-CAMECA Local Electrode Atom Probe (LEAP). (…) A spin-out company was formed to develop the first commercial versions of the 3DAP, with Smith, Cerezo, Grovenor and Godfrey from the UOA as directors.	Organizational support to TT related issues & Entrepreneurial and technology transfer skills
						19092 – Trace evidence analysis for Orchid Cellmark Erope Ltd	*Cellmark approached Dr Crossley in 2008 seeking collaboration in the analysis of trace evidence, recognizing the Oxford Materials Department's internationally-leading expertise in micro/nano analysis and a research-led forensic analysis track record, backed-up with appropriate equipment dedicated to 184ecognize184a analysis.*	Collaboration with industry / companies
14	Civil and Construction	1st place	Cardiff University	2	Environmental (2)	3663 – Improved flood hydrodynamic,	The impact of the research resulted from the sale and/or application of DIVAST, as illustrated for CH2M HILL (2000), Buro Happold (1999) and the Environment Agency North West (2000). (…)	Collaboration with industry / companies

	Engineering					hazard and water quality model predictions	**Richard Crowder**, Director at CH2M HILL, stated that '*the research undertaken by Cardiff University, and their ongoing technical relationship with CH2M HILL, has made a significant contribution to the capabilities of the ISIS software suite.*	
						3664 – Engineering solutions for high level nuclear waste disposal	Work with SKB, the Swedish Nuclear Fuel and Waste Management Company, for example, was conducted at a specially built Underground Research Laboratory (URL), the Aspoe Rock Laboratory, on the island of Aspoe (http://www.skb.se/default____24417.aspx).	Collaboration with industry / companies
							Posiva, the Finish nuclear waste management company (also part of the EURATOM research programmes), has significantly benefited from Cardiff's unique research.	Collaboration with governmental bodies
		2nd place	Imperial College London	7	Technological (2) Economic (3) Environmental (2)	42180 – Economic impacts of transport investments for appraisal and decision making	In 2005 the UK DfT commissioned him to develop this work to devise a specific approach to WEI estimation that would produce empirical results compatible with existing methods of appraisal. Between 2005 and 2008 the DfT disseminated the results of the Imperial research in a series of high-profile conferences, seminars and workshops aimed at informing civil servants and professional analysts about these new techniques.	Collaboration with governmental bodies
							The research was also adopted by the UK Treasury who in 2006 funed (jointly with DfT) a research annex to their report on 'Transport's role in sustaining the UK's productivity and competitiveness' (The Eddington Report) [2]. The Eddington Report included detailed applications of the WEI approach to appraisal and argued that it provided a superior tool for decisions support than conventional CBA.	Science communication skills to non-academic audiences
						42179 – improved flood risk management through advances in rainfall modelling, experimental evidence, and catchment and urban modelling	**In "1. Summary of the impact":** The impact of our research has been through the creation and application of new methodologies (e.g. AOFD) and software tools (e.g., TSRSim) for the design and analysis of flood management systems in the UK and internationally, via joint projects with consulting engineering companies, and through the influence of our research on national and regional policies towards improved land use management practices (e.g., Glastir, Wales).	Collaboration with industry / companies
						42177 – Improvements to the performance and management of mass transit systems in major cities	Between 2008 and 2013, 98 research projects were defined by industry, completed by Imperial and disseminated to public transport operators worldwide. The global funders and users of the research have included over 70 public transport operators and authorities from 60 cities worldwide, spanning all 6 developed continents. These industry partners have then applied research findings, leading to the significant impacts described here. (…) The key innovation was to establish five industry clubs (consortia), each steered by transport operators and authorities and facilitated by Imperial.	Collaboration with industry / companies
						42178 – Mitigation of geotechnical risk through the development of advanced	ICFEP"s impact on Geotechnical Engineering practice is delivered through direct consulting activities of the staff in the Geotechnics Section and through its strategic partnership with the Geotechnical Consulting Group (GCG) from London, who have adopted ICFEP as their key numerical tool and employ specialists dedicated solely to performing numerical analysis using ICFEP. Indeed, the latter has 185ecognize the reach and practical relevance of the geotechnical numerical research carried out at IC, amounting to approximately 80 projects in the UK and abroad undertaken during the assessment period 2008-2013.	Collaboration with industry / companies

						numerical tools – ICFEP		
						42176 – Modelling extreme waves and their loads on offshore structures	The *CREST* JIP was undertaken from 2007-2010. The technical work was conducted by internationally leading experts and supported by 24 industrial sponsors; the latter including all the major oil companies and numerous regulatory authorities. The only university involved in this work was Imperial College; Swan leading WP2 on nonlinear wave modelling and contributing significantly to WP4 on fluid loading.	Collaboration with industry / companies
						42175 – new design methods from piling research that improve the foundation safety and economy of offshore structures	Critical to the reach and depth of impact was the production of a widely read and used design book [H], developed through engagement with Industrial partners (Amoco, BP, HSE, Shell) and Consultants and published through the ICE's publishers.(…) Additional web-based practical guidance was produced with HSE, who endorsed and funded the work. (…) Examples of effective knowledge transfer include work with, among others, Atkins, BP, Fugro, GCG, Noble Denton, Shell, as noted in our supporting evidence.	Collaboration with industry / companies
							Critical to the reach and depth of impact was the production of a widely read and used design book [H (…) Other steps included the 186ecognize186at of CPD courses and keynotes delivered to over 1000 engineers in 14 countries.	Science communication skills to non-academic audiences
						42181 – Structural use of stainless steel	**In. "2. Underpinning research":** The research has been funded by EPSRC, the European Union and numerous industrial sponsors.	Collaboration with industry / companies
							In the UK National Annex [B] to the stainless steel Eurocode, published in 2009, Imperial research has enabled strength enhancements that arise during the manufacture of cold-formed sections to be harnessed and 186ecogniz in design, leading to more efficient structural solutions. The method is given in Section NA.3 of the National Annex and is based on research reported in [5]. & In. "2. Underpinning research" Many of the published research papers have featured in the most highly cited articles list in top journals.	Science communication skills to non-academic audiences
15	General Engineering	1st place	University of Oxford	5	Technological (5)	4912 – Vital sign monitoring for hospital patients	In 2007, Oxford University licensed the novelty detection algorithms to Oxford BioSignals. (In 2009, Oxford BioSignals became OBS Medical – www.obsmedical.com).	Organizational support to TT related issues
						19994 – Imaging software for cancer diagnosis	Working with colleagues in academia and industry, Brady set up the two spin-out companies to exploit the potential of the research, and he continues to work closely with them (…)	Entrepreneurial and technology transfer skills & Collaboration with other HERIs & Collaboration with industry / companies

						20051 – Efficient, cost-effective membrane filtration	Several companies have now developed processes based on air bubble injection, for which Cui provided the design basis both through publications or direct consultancy.	Collaboration with industry / companies
						20082 – Compact, lightweight compressors for space applications	Modification of the technology to provide the basis for a small engine capable of generating electrical power for deep space and planetary missions. Working with TRW and NASA, the team modified a 6cm3 compressor by increasing the piston and cylinder size to give a swept volume of 21cm3; this device was then used as an expander in a thermo-acoustic Stirling heat engine [9]. (…) This was achieved through close collaboration between Oxford University, TRW and Hymatic (now Honeywell Hymatic, Redditch, UK) which aimed to further develop the compressor after the successful creation of prototype units.	Collaboration with governmental bodies & Collaboration with industry / companies
							Income to the University through a licensing agreement with TRW amounted to £99,640 (gross) between 2008 and the end of 2012 [16].	Organizational support to TT related issues
						20085 – Boujou: soecial effects software for the film industry	Software libraries developed as part of the underpinning research were licensed to 2d3, a company created in 1999 by Vicon (part of the Oxford Metrics Group) to sell Boujou to the film industry. In 2009, Vicon took over direct ownership of Boujou and, to date, has secured £1.37 million in revenue through sales of 654 licences for the software [10],	Organizational support to TT related issues & Entrepreneurial and technology transfer skills
		2nd place	King's College London	5	Techno logical (5)	41233 – MR-guided Cardiovascular catheterization in children	We have worked with Philips Healthcare to develop the concept of a combined MRI and X-ray clinical cardiovascular 187ecognize187ation laboratory (the first research challenge described in section 2) which has led to the CE marking and commercial release of the first such product by Philips Healthcare in 2004 [15].	Collaboration with industry / companies
						41232 – Platform for Image-guided treatment of arrhytmina	**In "1. Summary of the impact":** (…). The Division of Imaging Sciences and Biomedical Engineering at King's College London and Philips Healthcare collaborated to develop a platform for guiding cardiovascular 187ecognize187ation procedures in patients with AF.	Collaboration with industry / companies
						41231 – Robust and accurate 2D-3D image registration	**In "1. Summary of the impact":** A collaborative research project between the Division of Imaging Sciences and Biomedical Engineering, King's College London (KCL) and Philips Healthcare has devised methods to register (i.e. align or match) pre-operative 3D computed tomography (CT) images to intraoperative 2D Xray images, resulting in more accurate and robust registration/alignment measures.	Collaboration with industry / companies
							This system has helped treat over 100 patients at St Thomas' Hospital, London and continues to be in regular clinical use, leading to the formation of a KCL spin-out company, Cydar Ltd [9a], to translate this system into a clinical product.	Entrepreneurial and technology transfer skills
							Two patents (which reference Penney 2011) filed by KCL are pending as International PCT Applications and have been licensed to Cydar Ltd.	Organizational support to TT related issues

						41229 – Simultaneous PET & MRI	Researchers at the Division of Imaging Science & Biomedical Engineering, KCL in collaboration with UCLA, devised and demonstrated, for the first time, the basic concepts of simultaneous PET and MRI, including practical implementations of the technique and demonstrations of applications.	Collaboration with other HERIs
							Thiswork has led to industry collaborations and the development of PET-MR scanners. It has initiated what has become a very large field with considerable commercial and clinical impact. (…) Company-sponsored talks 188ecognize the pioneering work of KCL when discussing the background to their current technology	Collaboration with industry / companies
						41234 – Spatiotemporal undersampling for highly accelerated magnetic resonance imaging	King's College London's k-t method for 3D imaging as described in Kozerke et al. 2004 was patented and subsequently licensed to Philips Healthcare [6].	Organizational support to TT related issues

Appendix C

Unit of Assessment Number (from Panel B)	**Unit of assessment name**	**Types of impact**	**ICS number**	**Type of impact**	**Research impact conditions**
7	Earth Systems and Environmental Sciences	Environmental (7)	1446	Environmental	Science communication skills to non-academic audiences & Collaboration with industry / companies & Collaboration with governmental bodies
			1447	Environmental	Collaboration with other HERIs & Collaboration with governmental bodies
			1448	Environmental	Science communication skills to non-academic audiences
			1449	Environmental	Science communication skills to academic audiences & Science communication skills to non-academic audiences & Collaboration with governmental bodies
			1450	Environmental	Science communication skills to non-academic audiences & Collaboration with governmental bodies
			1451	Environmental	Science communication skills to non-academic audiences
			1452	Environmental	Science communication skills to non-academic audiences & Collaboration with governmental bodies & Collaboration with local communities / civil society
		Technological (2) Environmental (1)	21955	Environmental	Science communication skills to non-academic audiences
			21954	Technological	Science communication skills to non-academic audiences
			21956	Technological	Collaboration with industry / companies & Science communication skills to non-academic audiences & Entrepreneurial and technology transfer skills
8	Chemistry	Technological (5)	1175	Technological	Collaboration with industry / companies & Science communication skills to non-academic audiences & Organizational support to entrepreneurship and TT related issues
			1776	Technological	Organizational support to entrepreneurship & Entrepreneurial and technology transfer skills and TT related issues
			11777	Technological	Collaboration with industry / companies & Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills & Science communication skills to non-academic audiences

			11778	Technological	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
			11779	Technological	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
		Technological (3) Societal (1) Environmental (1)	31942	Environmental	Science communication skills to non-academic audiences & Science communication skills to non-academic audiences
			20084	Societal	Collaboration with industry / companies
			20083	Technological	Entrepreneurial and technology transfer skills
			20087	Technological	Science communication skills to non-academic audiences
			20089	Technological	Collaboration with industry / companies & Entrepreneurial and technology transfer skills
9	Physics	Technological (4) Societal (3)	28173	Societal	Science communication skills to non-academic audiences
			28174	Technological	-
			28175	Societal	Science communication skills to non-academic audiences
			28176	Technological	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
			28177	Technological	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
			28178	Technological	-
			28179	Societal	Science communication skills to non-academic audiences
		Technological (4)	42304	Technological	Entrepreneurial and technology transfer skills
			42306	Technological	Science communication skills to academic audiences & Collaboration with industry / companies
			42305	Technological	Organizational support to entrepreneurship and TT related issues & Entrepreneurial and technology transfer skills
			42303	Technological	Entrepreneurial and technology transfer skills
10	Mathematical Sciences	Health (1) Technological (6) Societal (2) Economic (4)	4905	Technological	Collaboration with industry / companies
			4906	Economic	Organizational support to TT related issues
			20176	Technological	Organizational support to TT related issues
			20178	Health	Collaboration with governmental bodies & Science communication skills to non-academic audiences
			20200	Technological	Collaboration with industry / companies & Science communication skills to non-academic audiences
			20248	Technological	Science communication skills to non-academic audiences & Collaboration with other HERIs
			20286	Economic	Collaboration with industry / companies
			20291	Economic	Collaboration with industry / companies
			20293	Economic	Collaboration with industry / companies & Entrepreneurial and technology transfer skills
			20302	Societal	Science communication skills to non-academic audiences

			20329	Technological	Science communication skills (to both academic and non-academic)
			20416	Technological	Collaboration with industry / companies
			20446	Societal	Science communication skills to non-academic audiences
		Technological (2)	30193	Technological	Science communication skills (to both academic and non-academic)
			30194	Technological	Collaboration with industry / companies
11	Computer Science and Informatics	Technological (4)	21273	Technological	Entrepreneurial and technology transfer skills
			21791	Technological	Entrepreneurial and technology transfer skills
			21792	Technological	Entrepreneurial and technology transfer skills
			21793	Technological	Science communication skills (to both academic and non-academic)
		Political (1) Technological (4) Economic (1)	13828	Economic	Science communication skills (to both academic and non-academic) & Science communication skills to non-academic audiences & Collaboration with industry / companies
			16707	Technological	Organizational support to TT related issues & Collaboration with industry / companies
			13831	Technological	Entrepreneurial and technology transfer skills
			13827	Political	Science communication skills to non-academic audiences & Collaboration with governmental bodies
			15513	Technological	Entrepreneurial and technology transfer skills & Collaboration with industry / companies
			13830	Technological	Entrepreneurial and technology transfer skills
12	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	Technological (13) Economic (4) Political (1)	42147	Political	Science communication skills (to both academic and non-academic)
			42148	Technological	Entrepreneurial and technology transfer skills & Organizational support to TT related issues & Collaboration with governmental bodies & Collaboration with industry / companies
			42149	Technological	Entrepreneurial and technology transfer skills
			42150	Economic	Collaboration with industry / companies
			42151	Economic	Entrepreneurial and technology transfer skills
			42152	Technological	Entrepreneurial and technology transfer skills
			42153	Technological	Collaboration with industry / companies
			42154	Technological	Organizational support to TT related issues
			42155	Economic	Organizational support to TT related issues
			42156	Technological	Collaboration with industry / companies
			42157	Technological	Organizational support to TT related issues
			42158	Economic	Entrepreneurial and technology transfer skills & Collaboration with industry / companies & Organizational support to TT related issues
			42159	Technological	Collaboration with industry / companies
			42160	Technological	Collaboration with industry / companies & Organizational support to TT related issues
			42161	Technological	Entrepreneurial and technology transfer skills & Collaboration with industry / companies
			42162	Technological	Collaboration with industry / companies
			42163	Technological	Collaboration with industry / companies
			42164	Technological	Collaboration with governmental bodies
			38917	Technological	Collaboration with industry / companies

		Technological (3)	38918	Technological	Collaboration with industry / companies
			38916	Technological	Collaboration with governmental bodies & Collaboration with industry / companies
13	Electrical and Electronic Engineering, Metallurgy and Materials	Technological (8) Political (2)	42165	Technological	-
			42166	Technological	Entrepreneurial and technology transfer skills & Collaboration with industry / companies & Organizational support to TT related issues & Collaboration with governmental bodies
			42167	Technological	Entrepreneurial and technology transfer skills & Organizational support to TT related issues
			42168	Technological	Organizational support to TT related issues
			42169	Political	Science communication skills to non-academic audiences & Entrepreneurial and technology transfer skills & Organizational support to TT related issues & Collaboration with industry / companies & Collaboration with governmental bodies
			42170	Technological	Collaboration with industry / companies
			42171	Technological	Entrepreneurial and technology transfer skills & Organizational support to TT related issues
			42172	Technological	Collaboration with industry / companies
			42173	Political	Collaboration with industry / companies
			42174	Technological	Collaboration with industry / companies
		Technological (2)	4909	Technological	Organizational support to TT related issues & Entrepreneurial and technology transfer skills
			19092	Technological	Collaboration with industry / companies
14	Civil and Construction Engineering	Environmental (2)	3663	Environmental	Collaboration with industry / companies
			3664	Environmental	Collaboration with industry / companies & Collaboration with governmental bodies
		Technological (2) Economic (3) Environmental (2)	42180	Economic	Collaboration with governmental bodies & Science communication skills to non-academic audiences
			42179	Environmental	Collaboration with industry / companies
			42177	Economic	Collaboration with industry / companies
			42178	Environmental	Collaboration with industry / companies
			42176	Economic	Collaboration with industry / companies
			42175	Technological	Collaboration with industry / companies & Science communication skills to non-academic audiences
			42181	Technological	Collaboration with industry / companies & Science communication skills to non-academic audiences
15	General Engineering	Technological (5)	4912	Technological	Organizational support to TT related issues
			19994	Technological	Entrepreneurial and technology transfer skills & Collaboration with other HERIs & Collaboration with industry / companies
			20051	Technological	Collaboration with industry / companies
			20082	Technological	Collaboration with governmental bodies & Collaboration with industry / companies

					& Organizational support to TT related issues
			20085	Technological	Organizational support to TT related issues & Entrepreneurial and technology transfer skills
		Technological (5)	41233	Technological	Collaboration with industry / companies
			41232	Technological	Collaboration with industry / companies
			41231	Technological	Collaboration with industry / companies & Organizational support to TT related issues & Entrepreneurial and technology transfer skills
			41229	Technological	Collaboration with other HERIs & Collaboration with industry / companies
			41234	Technological	Organizational support to TT related issues

Appendix D

1) (collabo* OR cooperat* OR partnership*) AND ("academic research" OR "academic R&D" OR "research in academia" OR "research in university" OR "university research" OR "academic R&D" OR "scientific research" OR "higher education research" OR "research in higher education")

2) (polici* OR administration* or fund*) AND ("academic research" OR "academic R&D" OR "research in academia" OR "research in university" OR "university research" OR "academic R&D" OR "scientific research" OR "higher education research" OR "research in higher education")

3) organi* AND culture AND (academ* OR universi* OR facult* OR “higher education*”) AND (research* OR scientific OR "R&D")

4) organi* AND (support OR help OR aid OR assistance OR staff OR procedure*) AND (academ* OR universi* OR facult* OR “higher education*”) AND (research* OR scientific OR "R&D")

5) organi* AND (manag* OR administra* OR direction OR governance OR supervision OR leader*) AND (academ* OR universi* OR facult* OR “higher education*”) AND (research* OR scientific OR "R&D")

6) “science communicat*” AND (performance* OR skill* OR abilit* OR aptitude* OR behavio* OR expertis* OR profici enc* OR attitu* OR capabilit* OR competenc*) AND (researcher* OR scientist* OR investigator*) AND (academ* OR universi* OR facult* OR “higher education*”)

7) (teamwork* OR team OR collaborat* OR cooperat* OR partner*) AND (performance* OR skill* OR abilit* OR aptitude* OR behavio* OR expertis* OR profic ienc* OR attitu* OR capabilit* OR competenc*) AND (researcher* OR scientist* OR investigator*) AND (academ* OR universi* OR facult* OR “higher education*”)

8) (commerciali* OR valori* OR exploit* OR moneti* OR "Knowledge transfer" OR "technology transfer" OR entrepreneur* OR innovat*) AND (performance* OR skill* OR abilit* OR aptitude* OR behavio* OR expertis* OR profic ienc* OR attitu* OR capabilit* OR competenc*) AND (researcher* OR scientist* OR investigator*) AND (academ* OR universi* OR facult* OR “higher education*”)