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The Swiss Army Knives of Academia: Evaluating the Impact of University-Based Research Centers

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“The world has problems, but universities have departments”
(Brewer 1999)

Abstract

University-based research centers today form an integral part of the global research landscape. Due to their versatility, they have become a popular instrument of strategic research policy over the past few decades. At the same time, the growing demand for accountability has moved research centers along with universities into the focus of evaluation and impact assessment. The most widely used evaluation approaches in the university context, however, fall short in the case of inter- and transdisciplinary research centers as they do not adequately take into account some of their characteristic features. In view of the current academic reward system, which stresses disciplinary productivity, this shortcoming has far-reaching implications for the reputation of inter- and transdisciplinary research and the willingness of individual researchers to engage in corresponding research centers.

Against this background, this dissertation aims to contribute to a better understanding of research centers, their impact potential, and the methodological challenges associated with their evaluation. Conceived as a cumulative dissertation, three journal articles constitute the main body of the work. The case study is a research center in the field of sustainability science, the Competence Center Environment and Sustainability (CCES) of the ETH Domain in Switzerland. The dissertation is largely based on archival data from the research center under scrutiny, bibliometric data, and expert interviews. The quantitative data were analyzed, inter alia, within the framework of a quasi-experimental research design. Statistical analyses were carried out using different methods, including multiple regression, multi-level analysis, and growth curve modeling.

The dissertation comes to the conclusion that a comprehensive evaluation of research centers requires methodological triangulation. While quantitative evaluation approaches can shed light on key aspects, their results have to be interpreted in a wider context, including qualitative evidence. Research centers can contribute to a cultural change in the academic reward system by mobilizing a critical mass of researchers. Finally, the dissertation provides empirical evidence suggesting that engagement in research centers does not have a negative impact on the research productivity of individuals and their groups. On the basis of its main findings, the dissertation discusses recommendations that aim at improving evaluation practice in the context of inter- and transdisciplinary research centers and beyond.

Zusammenfassung

Universitäre Forschungszentren bilden heute einen integralen Bestandteil der internationalen Forschungslandschaft. Ihre vielseitigen Einsatzmöglichkeiten haben sie im Laufe vergangener Jahrzehnte zu beliebten Instrumenten strategischer Wissenschaftspolitik gemacht. Gleichzeitig rücken durch die wachsende Rechenschaftspflicht öffentlich finanzierter Universitäten auch Forschungszentren in den Fokus von Evaluation und Wirkungsmessung. Doch die im universitären Kontext weit verbreiteten Evaluationsansätze greifen bei inter- und transdisziplinären Forschungszentren zu kurz, weil diese einige ihrer Merkmale nicht adäquat berücksichtigen. Dieser Umstand hat in Anbetracht des gegenwärtigen akademischen Belohnungssystems, welches sich hauptsächlich auf die disziplinäre wissenschaftliche Produktivität konzentriert, weitreichende Implikationen für das Ansehen inter- und transdisziplinärer Forschung und die Bereitschaft einzelner Wissenschaftlerinnen und Wissenschaftler sich in entsprechenden Forschungszentren einzubringen.

Die vorliegende Dissertation zielt vor dem Hintergrund dieser Herausforderung darauf ab einen Beitrag zum besseren Verständnis von Forschungszentren, ihrer Wirkungen und den methodologischen Herausforderungen ihrer Evaluation zu leisten. Konzipiert als kumulative Disseration bilden drei wissenschaftliche Zeitschriftenartikel den Hauptteil der Arbeit. Als Fallstudie dient ein Forschungszentrum aus dem Bereich der Nachhaltigkeitswissenschaft, das Competence Center Environment and Sustainability (CCES) des ETH-Bereichs in der Schweiz. Die Arbeit beruht in erster Linie auf Archivdaten des Forschungszentrums, bibliometrischen Daten und Experteninterviews. Die quantitativen Daten wurden unter anderem im Rahmen eines quasi-experimentellen Forschungsdesigns ausgewertet. Statistische Analysen der Daten erfolgten zum Beispiel mit Hilfe multipler Regression, Mehrebenenanalyse und Wachstumskurvenmodellierung.

Die Dissertation kommt zu dem Ergebnis, dass die umfassende Evaluation von Forschungszentren einer methodologischen Triangulation bedarf. Während quantitative Evaluationsansätze wichtige Teilaspekte beleuchten können, müssen ihre Ergebnisse in einem breiteren Kontext betrachtet werden, was auch die Anwendung qualitativer Ansätze impliziert. Forschungszentren können zu einem Kulturwandel im akademischen Belohnungssystem beitragen indem sie eine kritische Masse an Wissenschaftlerinnen und Wissenschaftlern mobilisieren. Schliesslich bringt die Dissertation empirische Evidenzen dafür hervor, dass sich die Beteiligung in Forschungszentren nicht negativ auf die wissenschaftliche Produktivität einzelner Wissenschaftlerinnen und Wissenschaftler oder die ihrer Forschungsgruppen auswirkt. Auf Grundlage der Befunde werden Empfehlungen formuliert und diskutiert, die der Evaluationpraxis im Kontext inter- und transdisziplinärer Forschungszentren und darüber hinaus dienlich sein sollen.

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Küsnacht, im November 2019
Omar Kassab

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List of abbreviations

AB	Advisory Board
BAFU	Swiss Federal Office for the Environment
BIC	Bayesian Information Criterion
CAS	Chinese Academy of Sciences
CCEM	Competence Center Energy and Mobility (ETH Domain)
CCES	Competence Center Environment and Sustainability (ETH Domain)
CCMX	Competence Center for Materials Science and Technology (ETH Domain)
CHF	Swiss Francs
CIHR	Canadian Institutes of Health Research
CNR	Consiglio Nazionale delle Ricerche (Italy)
CNRS	Centre National de la Recherche Scientifique (France)
CV	Curriculum Vitae
CWTS	Centre for Science and Technology Studies (Leiden University)
DFG	Deutsche Forschungsgemeinschaft
DOI	Digital Object Identifier
Eawag	Swiss Federal Institute of Aquatic Science and Technology
EPFL	École Polytechnique Fédérale de Lausanne (Switzerland)
ERC	Engineering Research Centers (United States)
ETH	Swiss Federal Institute of Technology Zurich
EWS	Early Warning System
EXC	Exzellenzcluster
FAN	Fachleute Naturgefahren
FTE	fulltime equivalent
GEE	generalized estimated equation
ICE	individual causal effects
INSA	Indian National Science Academy
MCS	mean citation score
MINT	Science, technology, engineering, and mathematics
MNCS	mean normalized citation score
NCCBI	National Competence Center in Biomedical Imaging (Switzerland)
NCCR	National Centres of Competence in Research (Switzerland)

NCE	Networks of Centres of Excellence (Canada)
NIH	National Institutes of Health (United States)
NPM	New Public Management
NSERC	Natural Sciences and Engineering Research Council (Canada)
NSF	National Science Foundation (United States)
OA	Open Access
POA	public outreach activity
PSI	Paul Scherrer Institute (Switzerland)
QA	Quality Assurance
REF	Research Excellence Framework (United Kingdom)
SB	Steering Board
SCNAT	Swiss Academy of Sciences
SDG	United Nation's Sustainable Development Goal
SEM	structural equation model
S-ENETH	ETH Zurich School Domain of Earth, Environment and Natural Resources
SNF	Swiss National Science Foundation
SSHRC	Social Sciences and Humanities Research Council (Canada)
STC	Science Technology Centers (United States)
STHC	Scientific and Technical Human Capital
STI	science, technology, and innovation
TD	transdisciplinary / transdisciplinarity
UK	United Kingdom
UKRI	United Kingdom Research Councils
UMR	Unité Mixte de Recherche (France)
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research

Chapter 1

Introduction

For much of the 19th and 20th centuries, the Humboldtian model of higher education was considered a blueprint for universities all around the world (Schwinges 2001, Krull 2005). The most widely known cornerstone and intellectual rationale of the model lies in the primacy and strong interdependence of research and teaching (Nybom 2003). While research and teaching still represent the university's core missions until today, they long ceased to constitute their only raison d'être. Labeled as diverse as Mode 2 knowledge production (Gibbons et al. 1994, Nowotny et al. 2003), academic capitalism (Slaughter and Leslie 1997), or Triple Helix of university-industry-government relations (Etzkowitz and Leydesdorff 2000), paradigmatic shifts in research policy and other relevant domains have substantively transformed the traditional university system over the past few decades (Cozzens et al. 1990, Ziman 2000, Thune et al. 2016). Some of these transformations include the call on the "entrepreneurial university" to drive growth-inducing innovation (Clark 1998, Etzkowitz et al. 2000, D'Este and Perkmann 2011), or the mandate to develop solutions to grand societal challenges (Barth et al. 2007, Waas et al. 2010, Stock and Burton 2011, SDSN 2017, Kuhlmann and Rip 2018, Bohunovsky et al. 2019, Schwan 2019). In fact, the emergence of inter- and transdisciplinary research priorities like climate change, future mobility, or food security has not only challenged the traditional disciplinary organization of the university (Brewer 1999, Becher and Trowler 2001, Neumann 2003, Mutz et al. 2015, Turner et al. 2015), but it has also prompted a trend in the way universities provide education, moving towards more problem-based approaches (Wiek et al. 2011, O'Byrne et al. 2015). Another transformative momentum started out from the introduction of market-based reforms, subsumed under the concepts of New Public Management (NPM) or Quality Assurance (QA), which since the 1980s have given rise to competition and accountability, which is particularly the case in publicly funded universities (Alexander 2000, Salter and Tapper 2000, Ferlie et al. 2008, Bleiklie et al. 2011, Johnson et al. 2014). While universities and researchers formerly worked in an unconditionally supported "ivory tower" environment, they are today more than ever under pressure to disclose how their research contributes to the welfare of society to garner political support and further funding (Puschmann 2014, Thune et al. 2016).

University-based research centers[1] are among the most prominent instruments used today to absorb the plethora of expectations placed on the traditional university system (Stahler and Tash 1994, Turpin 1997, Bozeman and Boardman 2003, Bishop et al. 2014). While not all of the following would qualify as "university-based" in the sense of this dissertation, some of the best known research centers include the *National Centres of Competence in Research* (NCCR) of the Swiss National Science Foundation (SNF) in Switzerland, the *Exzellenzcluster* (EXC) of the Deutsche Forschungsgemeinschaft (DFG) in Germany, the *Unité Mixte de Recherche* (UMR) of the Centre National de la Recherche Scientifique (CNRS) in France, the *Istituti di ricerca* of the Consiglio Nazionale delle Ricerche (CNR) in Italy, the *Research Centers and Programmes* of the Research Councils (UKRI) in the United Kingdom, the *Engineering Research Centers* (ERC) and *Science Technology Centers* (STC) of the National Science Foundation (NSF), the *Research Centers* of the National Institutes of Health (NIH) in the United States, or the *Networks of Centres of Excellence* (NCE), a joint initiative of the Social Sciences and Humanities Research Council (SSHRC), the Natural Sciences and Engineering Research Council (NSERC), and the Canadian Institutes of Health Research (CIHR) in Canada. The Chinese Academy of Sciences (CAS) and the Indian National Science Academy (INSA) also use research centers as strategic tools, illustrating their diffusion beyond the European and Anglo-Saxon context.

It is foremost their versatility that has made research centers a widely utilized instrument in the university context: In contrast to the disciplinary structure of departments[2], research centers enable interactions between researchers from a whole array of backgrounds to conduct interdisciplinary research collaboratively (Lin and Bozeman 2006, Boardman and Corley 2008). They also expose researchers to diverse networks that generate extracurricular learning opportunities with benefits regardless of their educational level (Bunton and Mallon 2006, Youtie and Corley 2011), for example, by equipping researchers with the capacity to interact in teams and complex systems (O'Byrne et al. 2015). And finally, research centers foster different horizontal and vertical channels that facilitate transdisciplinary processes and dialog with stakeholders from industry, politics, public administration, as well as the general public (Rivers and Gray 2013, Smith et al. 2016), thus enabling universities and researchers to also live up to their "third mission"[3] (Laredo 2007, Montesinos et al. 2008, Schneidewind 2016).

[1] As the title suggests, this dissertation focuses on "university-based" research centers, acknowledging their use beyond the university context, such as in industry or the health care sector. To improve the readability, however, they will be referred to as "research centers" hereafter and throughout the dissertation.
[2] While not all universities would use "department" as a term to describe their organizational structure, it will be used throughout the dissertation to encompass all kinds of academic organizational units along disciplinary lines.
[3] With research and teaching constituting the first and second mission of universities, respectively, third mission (or third stream) activities refer to "the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments" (Molas-Gallart et al. 2002).

Aim of this dissertation: Evaluating the impact of research centers

There is little doubt about the systemic relevance that research centers had and have for the transformation of the global research landscape (Geiger 1990, Bishop et al. 2014). There is also broad agreement on their potential (Feller et al. 2002, Youtie and Corley 2011, Ávila-Robinson and Sengoku 2017). However, if there was one weak spot in view of a constantly mounting public accountability, it would be their evaluation. As Woelert and Millar (2013) succinctly explain, there is a "significant mismatch between the discourse of interdisciplinarity and associated conceptions of knowledge on the one hand, and current, relatively inflexible (…) evaluation practices on the other". Indicative of this phenomenon, a meta-study of NIH research center evaluations (Madrillon 2010) and extensive background research on websites of research funding organizations and research centers across the globe has shown that research centers are in the vast majority of cases subject to reporting schemes and evaluation practices as they are prevalent in institutional assessment contexts. More concretely, research center participants and managements either compile annual reportings to disclose information on the scientific and non-scientific outputs, or they are subject to expert review, or a combination of both (SWIR 2015, CNRS 2016, IEKE 2016).

As this dissertation will argue, this widely applied "standard" evaluation approach falls short of capturing some of the defining characteristics of research centers. This deficit can involve profound consequences, particularly, in view of the current reward system in academia: Today the most decisive criterion for a successful career in research is a researcher's productivity, generally assessed as the absolute number of scientific publications. However, those who commit to engaging in the complex fabric of a research center will potentially encounter opportunity costs to the disadvantage of their productivity and thus of their career prospect, mainly evoked by differing languages, norms and expectations, perceived statuses, or disciplinary parochialism (Brewer 1999, Robinson 2008, Whitmer et al. 2010, van Rijnsoever and Hessels 2011, Garner et al. 2013, Brown et al. 2015, Turner et al. 2015, Bozeman and Youtie 2017, Haider et al. 2018). Even the strongest proponents of inter- and transdisciplinarity note that respective collaborations are "highly labor intensive; often conflict-prone; and require substantial preparation, practice, and trust among team members to ensure a modicum of success" (Stokols et al. 2008b). Consequently, even the most intrinsically motivated researchers would rather refrain from engaging in research centers against the inadequate recognition that the generated outputs would allegedly gain in light of the current academic system and its performance metrics (Wiek et al. 2014). This "incentive incongruity" (Su 2014) will continue to undermine the willingness of researchers to engaging in inter- and

transdisciplinary research centers as opposed to disciplinary contexts, despite the general consensus over the immediacy of the issues that they generally address.

Summarizing the above, there is an urgent need for evaluation approaches capable of providing valid evidence on the impact of inter- and transdisciplinary research centers. On the basis of an in-depth case study of a research center from the field of sustainability science, this dissertation is guided by the following research question: *How can research centers be adequately evaluated?* Conceived as a cumulative dissertation, the work at hand is divided into three consecutive parts (see Figure 1): Part I, covering chapters 2 and 3, lays the groundwork. It introduces the main concepts and challenges related to research center evaluation, delves into the relevant scholary discourses, and describes the case under scrutiny. Part II, covering chapter 4, constitutes the main body of the dissertation. It comprises three paper-based contributions (journal articles[4]). Part III, covering chapters 5 to 8, synthesizes the dissertation's findings and discusses them in a broader context.

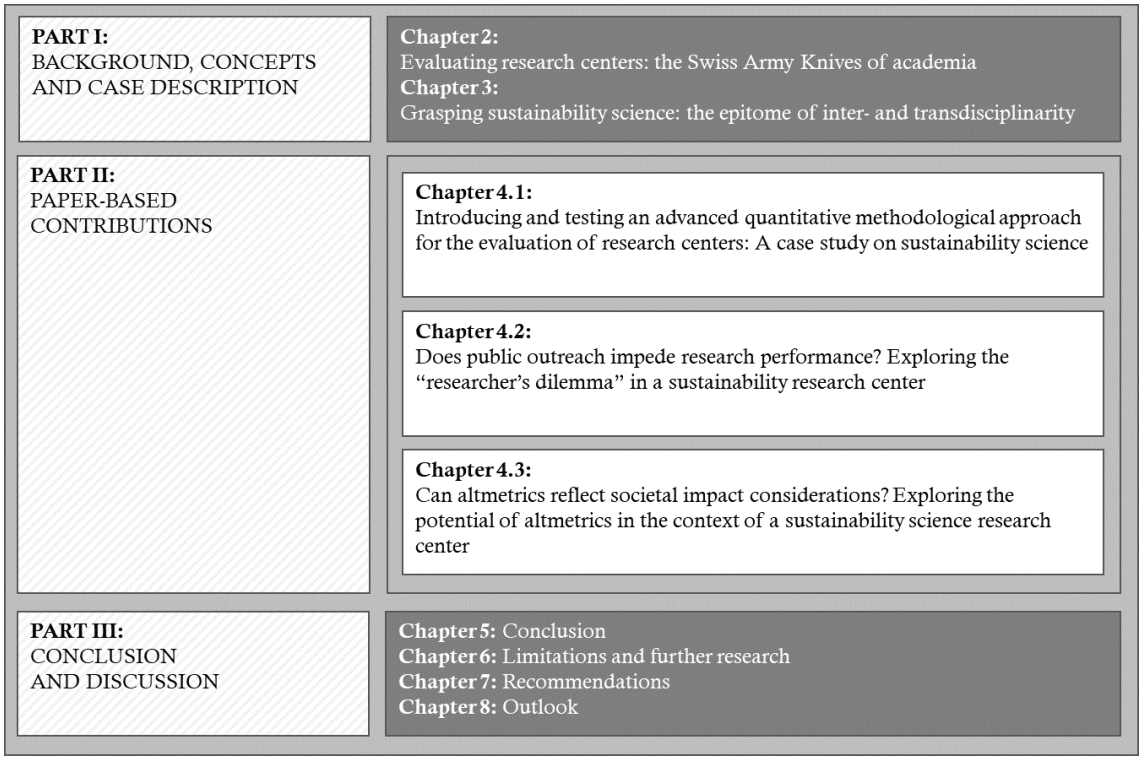

Figure 1. Structure of the dissertation

[4] At the time the dissertation was submitted, the paper-based contributions had different publication statuses. For reasons of readability, however, all three are referred to as "articles" throughout the dissertation.

PART I

BACKGROUND, CONCEPTS AND CASE DESCRIPTION

Chapter 2

Evaluating research centers: the Swiss Army Knives of academia

This chapter describes why and how evaluation has become increasingly important in the context of publicly funded universities and which challenges the evaluation of research centers poses in view of prevalent institutional evaluation approaches. Another basis is laid by introducing the concept of the logic model, a widely utilized tool to reduce complexity in evaluation practice.

2.1 Public sector reforms and the implications for university governance and evaluation

The practice of evaluation has undoubtedly asserted its position in many domains of life (Stockmann and Meyer 2014, Stufflebeam and Coryn 2014). The phenomenon is particularly evident in the public sector, where the gradual introduction of the market-oriented NPM governance model has been challenging the status quo since the 1980s (Hood 1995, Ferlie et al. 1996). Originating in the UK during the Thatcher era, the movement has prevailed in almost all Western economies, as numerous national studies show (Rieder and Lehmann 2002, Frølich 2005, De Boer et al. 2007, Meyer 2007, Schubert 2008). Ferlie et al. (2008) summarize that NPM "seeks to produce a smaller, more efficient and more results orientated public sector. It is influenced by ideas (…) which stress incentives and performance".

Even though public administrations are very different from universities in the way they operate, the introduction of NPM has had a number of implications for universities as well, including a substantive increase in autonomy, adoption of corporate management forms, the strengthening of internal management level competencies, the improvement of internal information and control options, and the stronger provision of competition and incentive elements, by increasing the competitiveness in the allocation of research funds, or by shifting from input to output control (Schubert 2008, Rytmeister 2009).

The very tension between autonomy and performance control has confronted universities with questions many of which have been answered with strategic adjustments in university governance (Salter and Tapper 2000, Ferlie et al. 2009, Paradeise et al. 2009). With further pressure stemming from the global competition for the brightest minds, renowned grants,

excellence awards or positions in global university rankings, more and more universities established in-house evaluation offices or units for institutional research, controlling, and quality assurance (Bornmann et al. 2006, Kim 2008, Bleiklie et al. 2011, Agasisti et al. 2019). An immediate consequence of this new governance model is the emergence of additional, mostly administrative routines and duties on various levels of the university (García-Gallego et al. 2015). Cozzens and Turpin (2000) specify that the evaluation environment is "tightening through the introduction of regular monitoring and assessment systems, fed by more systematic reporting on the activities of academic researchers through new information systems". Somewhat unpopular yet widely applied in practice, it is today part of every researcher's job description to regularly report on a variety of "objective" achievements related to research and other activities, classically covering the number of publications, but also details on courses taught, students supervised, academic and other expert mandates, acquired funding and grants, collaboration networks, secondary occupations, or public outreach activities. In other words, a large part of institutional evaluation practice has evolved into "highly sophisticated benchmarking procedures involving ever-growing numbers of quality criteria and performance standards, as well as immense systems for counting almost everything" (Coryn et al. 2007). Reported outputs are then aggregated at the level of the department or the entire institution to serve as a basis for strategic decisionmaking by the university management and other executive bodies (Dixon and Coy 2007, Parker 2013). Quantitative assessments are often complemented by qualitative evaluation procedures in the form of expert panels or other types of peer review. Largely considered the "standard" institutional evaluation approach in the context of higher education (Gibbons and Georghiou 1987, Alexander 2000, Geuna and Martin 2003, Schröder et al. 2014, Gallo and Glisson 2018), the "one-size-fits-all" approach entails a few yet decisive shortcomings when it comes to the evaluation of research centers.

2.2 Research centers and the challenges of their evaluation

Research centers have played a strategic role in the reorientation of the university system worldwide (Turpin 1997, Santoro and Gopalakrishnan 2001, Feller et al. 2002, Slaughter et al. 2002, Boardman and Corley 2008, Gaughan and Ponomariov 2008). One of the main reasons contributing to their systemic relevance is the fact that research centers differ from classical university departments in many respects. The difference becomes clear against the definition proposed by Bozeman and Boardman (2014), who see the *research center* as:

> *An entity within a university that exists chiefly to serve a research mission, has participants from more than one department, more than one discipline and has multiple functions including not only research but also education and outreach.*

As much as research centers differ from university departments, their evaluation also raises unique challenges that the current institutional evaluation standard does not account for adequately. By means of discussing additional conceptual features of research centers, these challenges are explored in more detail below:

(1) *Interdisciplinarity of research teams:* Over the past few decades, the global university landscape has witnessed a rapid increase of research centers where problems "could not sensibly be attributed to any particular discipline" (Mittelstrass 2011) or became too complex for a single discipline to manage (Stokols et al. 2008a, Su 2014). While the interdisciplinary character of research centers is probably their major strength and defining characteristic, it also poses one of the biggest challenges to evaluation. Research centers, by definition, bring together researchers from different disciplines whose publication culture and behavior (i.e., computer scientists primarily publish conference proceedings and historians tend to write monographs) differ greatly from one another, making a fair comparative evaluation of their research outputs somewhat tricky, if not impossible. Focusing merely on the quantitative output invites comparisons of "apples and oranges", which in interdisciplinary teams will disadvantage at least one of the involved parties. Even if the expert review makes a more in-depth analysis of research outputs and research centers possible, it fails as soon as the disciplinary composition of the expert group is incongruent with the disciplines represented in the research center. In other words, there will hardly be any individual experts with a "proper understanding of those methodologies and conceptions that are borrowed from another disciplinary context" (Woelert and Millar 2013), let alone of the interdisciplinary totality (Wickson et al. 2006, Pohl et al. 2011).

(2) *Transdisciplinarity and public engagement:* Research centers stand out for their capacity to foster diverse channels for dialog with stakeholders from the private sector, politics, public administration, as well as the general public (Rivers and Gray 2013, Smith et al. 2016). Through the engagement with extra-academic stakeholders, research centers can facilitate the consolidation of transdisciplinary networks, the development of applied solutions to societally relevant problems, and the public dissemination of knowledge (Ponomariov and Boardman 2010, Spaapen and Van Drooge 2011, Jahn et al. 2012). There is a widespread belief, however, that transdisciplinary engagement and the commitment in public outreach comes at the cost of individual research productivity, thus representing an impediment to the career in academia (van Rijnsoever and Hessels 2011, Lang et al. 2012). While it is true that reporting and evaluation schemes increasingly provide the possibility to disclose such engagement, as prominently exemplified in the forthcoming UK's 2021 Research Excellence Framework (REF 2019), the 'hard currency' in many research fields, and

evaluation practices for that matter, remains the disciplinary peer-reviewed journal publication (Haider et al. 2018). And even if experts may recognize these efforts in their evaluation, the assessment of societal added value resulting from transdisciplinary research activity or public outreach is hardly possible by review panels composed of researchers only (Porter and Rossini 1985, Nightingale and Scott 2007).

(3) *Broader impact potential:* Funding decisions are increasingly tied to "broader impact" considerations (Holbrook 2010, Lok 2010), including, for example, the prospect of "increased incomes, better health, cleaner environment, enhancement of social and cultural values, and any other benefit that could be an objective of public policy" (Jaffe 2015). Especially in the context of publicly funded research, proposals therefore commonly include sections that outline strategies for achieving impact beyond academia (Martin 2011, Thune et al. 2016). In the case of research centers, which per definition tackle societally relevant issues like climate change, food security or sustainable mobility, demonstrating societal impact is particularly crucial. However, while it is relatively straightforward to assess the broader impact by disclosing the number of extra-academic stakeholders involved in transdisciplinary processes or public outreach activities, it is a major methodological challenge to identify the societal impact research on the basis of research outputs alone. In view of the broader impact potential associated with research centers, this incapacity of existing evaluation approaches is particularly disadvantageous.

(4) *Temporary lifespan:* Research centers can vary enormously across a multitude of dimensions, such as their institutional and disciplinary composition, collaboration opportunities, or quite distinctively, their operative lifespan (Rogers et al. 2012, Rivers and Gray 2013, Sabharwal and Hu 2013, Bishop et al. 2014, Smith et al. 2016, Corley et al. 2017). Other than departments, research centers may be designed to operate for a limited period of time only. Accordingly, while a researcher remains member of a department, the affiliation with the research center is temporary by definition. In contrast to departments, research centers are typically evaluated at the end of their lifetime. The number of researchers that were involved over the entire lifespan is a commonly assessed criterion, as it allows drawing conclusions about productivity and network formation, among other things. However, the fact that not all researchers begin and end their affiliation with the research center in parallel, but rather in a staggered manner, has consequences for such an assessment and the evaluation more generally.

(5) *Participation intensity:* Related to their temporary character is the phenomenon that research centers almost never constitute the main institutional affiliation of researchers. Rather, researchers become partially involved in addition to their primary affiliation, at times

causing a certain "role strain" (Boardman and Bozeman 2007). Even if this aspect (at least theoretically) can be accounted for in an expert review, it is hardly accounted for when assessing the quantitative output. For example, a researcher who only has a few hours per month available to work at the research center due to other commitments will most likely not be able to be as productive in the research center context as someone involved three full days a week. The same holds true for capacity-building, the "ability to enhance individual and organizational capacities to produce knowledge or to apply it in technology" (Cañibano and Bozeman 2009) and other contexts. Whether and to what degree these capacities are enhanced largely depends on the temporal involvement and exposure of the participant to the research center setting. This very evaluation challenge is additionally complicated by the fact that research centers may be "physical" entities with staff and fixed offices (Ikenberry and Friedman 1972), or only "virtual" in the sense of existing mostly on paper (Stahler and Tash 1994).

(6) *Diversity of funding sources:* The funding scheme of research centers exemplifies the trend as inspired by the NPM governance model in the university context, shifting from directly allocated "institutional" funding to the more competitive "program funding" (or: project funding), indirectly granted by university managements, research funding organizations, or other entities (OECD 2003, Lepori 2006, Horta et al. 2008). Often times the funding scheme is characterized by the requirement to diversify the funding sources, through "matching" funds from third-parties such as industry or public administration (Sinnewe et al. 2016). The process of writing proposals and obtaining actual funding, however, is associated to significant efforts on the part of the researchers, which can delay the research process significantly. Moreover, the more different sources the research funding ultimately comes from, the more implications will this have in terms of reporting duties, with every sponsor requiring a different level of detail, aspect or even language of disclosure (Lange 2007). Even though the acquisition of additional funding is overall credited by experts, and researchers explicitly mention successfully obtained grants in their academic CVs and on their personal websites, this issue is rarely, if at all, adequately accounted for in the practice of quantitative research center evaluation.

The above discussion has shown that research centers are designed to perform a multitude of functions, making the metaphor of the "Swiss Army Knife" particularly fitting. At the same time, however, the discussion has highlighted a versatility that implies a certain degree of complexity and a broad range of impacts to be assessed. For scholars and practicioners wishing to understand research centers comprehensively, this can be overwhelming at first. In what

follows, therefore, the dissertation draws from the logic model concept, a tool developed to help simplifying complex processes and systems.

2.3 Capturing complexities of research centers with logic models

Logic models have their origin in program evaluation. It is therefore worthwhile looking at research centers through the "program" lens since this allows benefitting from a rich body of literature. Royse et al. (2016) define programs as an "organized collection of activities designed to reach certain objectives". This definition comes close to what Stockmann and Meyer (2014) define as the "instrumental" view on programs. They juxtapose an "organizational" view on programs, which captures the reality of a research center more accurately. Programs, according to the organizational view, are understood as units equipped with material and human resources that are embedded in an organization (see also Stockmann and Meyer 2014, McLaughlin and Jordan 2015). This organization, in the case of research centers, would be the university. Patton (1990) coined an apt definition for program evaluation, aligned to which a research center evaluation can be specified as a systematic collection of information about the context, resources, processes, outputs and impacts to make judgements about the research center, its effectiveness, and inform decisionmaking (see also Carew and Wickson 2010).

For breaking down procedural complexities, logic models have been used in the practice of program evaluation since the 1960s. Logic models "can provide a valuable tool for clarifying how various goals will be assessed and for assisting evaluations in distinguishing between outputs and outcomes" (Madrillon 2010). By developing an underlying theory of change[5] (Rogers 2008, Funnell and Rogers 2011), logic models – sometimes referred to by the somewhat more intuitive name of "results chain" (Gertler et al. 2011) – are used for "pictorially depicting the chain of components representing processes and conditions between the initial inputs of an intervention and the outcomes" (Kneale et al. 2015). While most logic models are not inordinately complex and often include simplifying assumptions, "they have the advantage of imposing a certain discipline in causal thinking" (Kellogg Foundation 2001, Bozeman and Boardman 2014) about different steps leading to the prospective impact.

[5] Gertler et al. (2011) define theory of change as a "description of how an intervention is supposed to deliver the desired results. It describes the causal logic of how and why a particular project, program, or policy will reach its intended outcomes. A theory of change is a key underpinning of any impact evaluation, given the cause-and-effect focus of the research. As one of the first steps in the evaluation design, a theory of change can help specify the research questions."

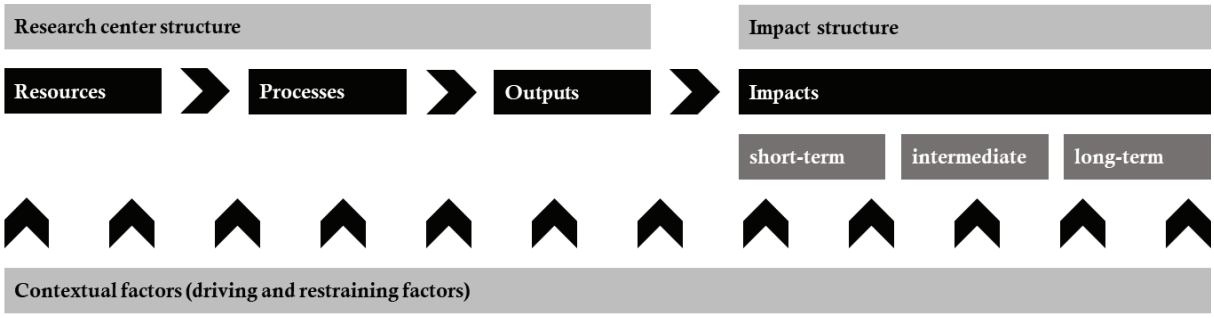

Figure 2. Basic logic model, adapted from McLaughlin and Jordan (2015).

As illustrated in Figure 2, the basic logic model consists of three structural parts. Applied to the context of research centers, the three parts are defined as follows, (1) research center structure, (2) impact structure, and (3) contextual factors:

(1) *Research center structure:* On this side, the elements of the logic model are resources, processes, and outputs: *Resources* are human and financial means as well as other inputs required to support the research center, such as research infrastructure, or an existing partnership network. Information on the type and level of the problem addressed by the research center can also be an essential resource for the research center. *Processes* are the action steps necessary to produce research center outputs. *Outputs*, in turn, are the products, goods, and services provided by and in favor of the research center's participants. The research center structure is mostly under the control of the research center management and the participants, as these elements are determined during the starting phase and modified as experience is gained during operation (McLaughlin and Jordan 2015).

(2) *Impact structure:* Research centers typically have multiple, sequential impacts, collectively called the impact structure. First, there are *short-term impacts*, the changes or benefits most closely associated with or caused by the research center's outputs. Second are the *intermediate impacts*, which are expected to result from the short-term impacts. *Long-term impacts* then follow from the changes or benefits accrued through the intermediate impacts (McLaughlin and Jordan 2015). It is important to note that the examination should be concerned both with direct and indirect, but also with intended and unintended impacts, especially as the latter tend to be systematically disregarded in a "tunnel view" (Stockmann and Meyer 2014).

(3) *Contextual factors:* Critical features of the logic model are the factors, which are not under the research center's control but may influence its success either positively or negatively. Such factors include, for example, the reward system in academia, or the availability of other funding sources.

Chapter 3

Grasping sustainability science: the epitome of inter- and transdisciplinarity

Having laid out the definitional foundations for research centers, the challenges related to their evaluation, and an approach to depict their complex logic and impact structure, this chapter forms another building block in approaching the main body of the dissertation. It outlines the scholarly discourse on inter- and transdisciplinarity, and discusses the field of sustainability science as a prime example of the latter. The chapter also provides a detailed description of the case under scrutiny, the Competence Center Environment and Sustainability (CCES) of the ETH Domain, as well as the data sources and methods used in the dissertation.

3.1 Getting inter- and transdisciplinarity right

It goes without saying that disciplinary research approaches have had a considerable influence on the organizational arrangement of the modern university system as well as on the development of the scientific method (Neumann 2003). Disciplines not only provide scientists with "frames of reference, methodological approaches, topics of study, theoretical canons, and technologies", but also with "shared concepts and language, accreditation to practitioners within their fields (i.e., recognition of competence by others within the shared institution) and, importantly, the epistemological and ontological security that is required to progress science without constantly having to question the nature of science itself" (Stock and Burton 2011). With the advent of inter- and transdisciplinary research priorities, however, the university in its disciplinary organization no longer provided the optimal institutional setup to tackle these issues, or as Brewer (1999) pithily coined it: "The world has problems, but universities have departments".

Not only since the discourse about the paradigmatic transformations in the higher education system was sparked, but all the more since then, a broad and so far still inconclusive scholarly debate has been held about notions, characteristics and conceptual distinctions of inter- and transdisciplinarity (Klein 1990, Rosenfield 1992, Mittelstrass 1993, Kötter et al. 1999, Nowotny et al. 2001). A very good example to illustrate the intricacy of the discussion is Weingart's narrative of the "paradox", which criticizes that "interdisciplinarity (or

transdisciplinarity and similar derivatives) is proclaimed, demanded, hailed, and written into funding programs, but at the same time specialization in science goes on unhampered, reflected in the continuous complaint about it" (Weingart and Stehr 2000). A similarly pessimistic, almost satirical perspective is that of Becher and Trowler (2001), who utilize the anthropological metaphor of "tribes" to describe a disciplinary isolation: "Men of the sociology tribe rarely visit the land of the physicists and have little idea what they do over there. If the sociologists were to step into the building occupied by the English department, they would encounter the cold stares if not the slingshots of the hostile natives (…). The disciplines exist as separate estates, with distinctive subcultures". Put simply, while some would refer to inter- and transdisciplinarity as a "politically useful label" (Woelert and Millar 2013) rather than as a research mode in its own right, others are no less critical, but much more optimistic with regard to the actual attainability (Kueffer et al. 2012, Stauffacher et al. 2012, Pohl et al. 2017). Pohl advances a telling summary of the polarized discourse about ideas and definitions of inter- and transdisciplinarity, which he finds "relatively ironic for a community of scholars who sees the openness to other viewpoints as the fundamental prerequisite for doing [inter- and] transdisciplinarity" (Pohl 2010).

In order to understand the concept of interdisciplinarity, it is useful to contrast it with the concept of multidisciplinarity (Mitchell 2005). Jantsch (1972) and Rosenfield (1992) speak of multidisciplinarity when researchers "work in parallel or sequentially from disciplinary-specific bases to address common problems". Stock and Burton (2011), who position multi-, inter-, and transdisciplinarity on a continuum or "hierarchy in terms of extent of integration and holism", see multidisciplinarity as "the least integrated form of integrated research", or how Petts et al. (2008) frame it, the disciplines "co-exist" in a context. In line with the hierarchical classification, interdisciplinarity can be understood as the next degree following multidisciplinarity, because interdisciplinary research encourages the researchers to overcome their disciplinary boundaries to potentially enable the examination of existing knowledge and methods from the perspective of another discipline (Kutílek and Nielsen 2007), and in turn, to develop new integrative knowledge (Tress et al. 2005). Building on this notion, *interdisciplinarity* is defined in the framework of this dissertation, following Tress et al. (2006), as follows:

> *Bringing together "several unrelated academic disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory and solve a common research goal".*

While multidisciplinarity and interdisciplinarity can be easily distinguished by the degree of "integration", the next integration step towards transdisciplinarity raises new conceptual

questions. In a comparative analysis of circulating definitions of transdisciplinarity, Pohl (2010) identifies patterns that lead him to a classification along three concepts: According to the first concept, research becomes transdisciplinary by "transcending and integrating disciplinary paradigms in order to address socially (as opposed to academically) relevant issues". This first concept, in fact, comes close to the above definition of interdisciplinarity. The distinct difference becomes clear with the second concept, which is characterized by the inclusion of extra-academic stakeholders into the research process, or as Lawrence says, "transdisciplinarity implies a fusion of disciplinary knowledge with the know-how of lay-people" (Lawrence 2004). The third concept starts from the first one and adds "the search for a unity of knowledge" in the sense of a disciplinary convergence towards a new common perspective rather than reorganizing existing approaches, however, without the involvement of extra-academic stakeholders.

From the viewpoint of a research center, the third concept is overly ambitious because the temporary lifespan and the different intensity of participation will hardly allow such a degree of conflation to be achieved. The first concept, on the other hand, falls short because it does not involve extra-academic stakeholders, a defining criterion of research centers. Therefore, the second concept and the following definition of *transdisciplinarity* are suitable for the purpose of this dissertation, drawing from Lang et al. (2012):

> *"Transdisciplinarity is a reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge".*

The scholarly debate about inter- and transdisciplinarity is very much interwoven with the field of sustainability science, or as Mobjörk (2010) writes: "transdisciplinary research is particularly required in relation to future-orientated issues that include a notion of the common good, such as sustainable development". According to Stock and Burton (2011), "nowhere has this push for integrated research (…) been more important than in the field of sustainability science", which they go on to describe as "inherently transdisciplinary". Since the research center acting as a case study for this dissertation addresses sustainability-related questions, the concepts of sustainability and sustainability science will be introduced and defined in what follows.

3.2 Sustainability and sustainability science

Sustainability is probably one of most prominent buzzwords of the past thirty years. And yet, in view of the inflationary use, there is hardly any consensus on what truly qualifies it as a concept (Kajikawa 2008, Spangenberg 2011). Even though the normative definition from "Our Common Future" (UN 1987) – commonly known as the "Brundtland Report" definition ("development that meets the needs of the present without compromising the ability of future generations to meet their own needs") – enjoys international approval on the political level, there are voices discrediting it as being rather loose, or too human centered (Shahadu 2016).

With the "2030 Agenda for Sustainable Development", the international community has lifted the global sustainability discourse to a new level. Ratified by all 193 member states of the United Nations in a historic act on 25 September 2015, it forms an international consensus including 17 overarching Sustainable Development Goals (SDGs), 169 sub goals, and imperatives for concrete action to achieve sustainable development on the global scale. In the fourth year of their existence, the SDGs have already achieved a global impact in that governments, businesses, and other organizations use them as an inspiration to align their strategies and formulate own goals. Numerous universities worldwide have likewise taken the SDGs as a guideline for adaptation and thematic focusing, stemming from the belief that universities are well positioned to address the SDGs and develop corresponding solutions (SDSN 2017, Bohunovsky et al. 2019). Among researchers, there is an increasing consensus that universities have not just the opportunity, but also an obligation to contribute to solving the major sustainability challenges facing humanity (Yarime et al. 2012, Schwan 2019).

Sustainability as a concept in the scientific discourse actually goes back to forestry science, in which the German tax accountant and mining administrator Hans Carl von Carlowitz conceptualized it in 1713. In his epochal work *Sylvicultura Oeconomica*, he formulated ideas for the "sustainable use" of the forest, suggesting that the cutting of trees should be limited to the extent that is regrown through planned reforestation projects. While this is still one of the guiding principles of modern forestry, today's understanding of sustainability science goes far beyond the ecosystem of the forest. Sustainability science as it exists today is a relatively new field, which explains the lack of consensus as to what distinguishes it and where its definitional boundaries lie (Shahadu 2016). The most prominent foundations in this discussion were laid by Clark and Dickson (2003), who described sustainability science as "not yet an autonomous field or discipline, but rather a vibrant arena that is bringing together scholarship and practice, global and local perspectives from north and south, and disciplines across the natural and social sciences, engineering, and medicine". Clark (2007) later described sustainability science as "a

field defined by the problems it addresses rather than by the disciplines it employs", which has become a widely quoted minimal definition for sustainability science.

Over the course of the years there have been many different attempts in the literature to sharpen the contours of the field (Rokaya et al. 2017). Among them is the description of sustainability science as an epistemological hybrid, as neither basic nor applied, but rather "use-inspired basic research", which would be assigned to "Pasteur's quadrant" (Stokes 1997, Clark 2007). Spangenberg (2011), in turn, distinguishes two different concepts, which he subsumes under sustainability science. On the one hand, there is the more disciplinary science *for* sustainability, which he understands as an analytical basic science. On the other hand, he sees a transdisciplinary science *of* sustainability, which is characterized by reflexivity and applicability. Hirsch-Hadorn et al. (2006) question the term "sustainability science" altogether and advocate the use of "sustainability research" because they believe that "science" as term would compromise the key role of the "softer" research fields of academia. In addition to these fundamental classifications, a number of scholars have tried to grasp the field through thematic complexes (i.e., fishery, forestry, water, energy, climate change, biodiversity loss, land use change), which they regard as core topics of sustainability science (Kajikawa 2008, Jerneck et al. 2011), or as interlinked (i.e., global, social, and human) systems (Komiyama and Takeuchi 2006). Miller (2013), for example, has developed a thematic classification on the basis of expert interviews.

Not surprisingly, bibliographic and bibliometric approaches are quite prevalent as well. Yarime et al. (2010), Schoolman et al. (2012), and Kajikawa et al. (2014) searched titles and abstracts of journal articles in the *Web of Science* database for keywords using *sustainab** or *sustainability*. Bettencourt and Kaur (2011), Brunn (2014), and Rokaya et al. (2017), in turn, used journals and their classifications to determine the field, and Buter and Van Raan (2013) applied a citation network analysis, starting from a set of highly cited publications in journals that have "sustainability" in their title. The worldwide adoption of the SDGs has also had an impact in this respect, as a study on "Sustainability Science in a Global Landscape" (Elsevier 2015) shows. For their bibliometric study, the authors derived six themes to build the base of their keyword search: dignity, people, prosperity, planet, justice, and partnership.

Irrespective of the heterogeneity of the attempts to define sustainability science, there is a broad consensus in the literature that the emergence of the field has brought about a paradigm shift, even triggering a "third academic revolution"[6] (Yarime et al. 2012). The field is

[6] Etzkowitz and Viale (2010) summarize the development as follows: "The first and second academic revolutions integrated research and then economic and social development as academic missions, changing the nature of the university. The third academic revolution integrates forward and reverse linear models in a programmatic and regulatory

characterized by having "created novel approaches rather than merely borrowing from other disciplines" (Kajikawa et al. 2014). Bettencourt and Kaur (2011) even argue that "there is no example in the history of science of a field that from its beginnings could span such distinct dimensions and achieve at once ambitious and urgent goals of transdisciplinary scientific rigor and tangible socio-economic impact". Against the complexity and urgency of the questions dealt with, many scholars regard sustainability science as the epitome of inter- and transdisciplinarity (Komiyama and Takeuchi 2006). It has therefore become widely accepted what Yarime et al. (2012) have summarized quite aptly, as follows:

> *"The field of sustainability science aims to understand the complex and dynamic interactions between natural and human systems in order to transform and develop these in a sustainable manner. As sustainability problems cut across diverse academic disciplines, ranging from the natural sciences to the social sciences and humanities, interdisciplinarity has become a central idea to the realm of sustainability science. Yet, for addressing complicated, real-world sustainability problems, interdisciplinarity per se does not suffice. Active collaboration with various stakeholders throughout society – transdisciplinarity – must form another critical component of sustainability science."*

Despite the various definitional advances and a growing volume of publications, sustainability science is still far from being an institutionalized field of research. As Yarime et al. (2012) explain, the biggest obstacles include the development and use of concepts and methodologies, the transforming of institutional structures, including incentives and corresponding reward systems, and the development of a coherent set of sustainability competencies and effective pedagogical approaches, the latter of which is particularly challenging against the predominant reality of "disciplinary clustering" (Kajikawa et al. 2007). In fact, it is in the very aspect of education that the challenge of institutionalizing sustainability science becomes evident. Haider et al. (2018) describe that the young generation of early career researchers face a unique challenge, finding themselves in a "dilemma between epistemological agility and methodological groundedness". This means, in one way or another, that the decision to dedicate an entire academic career to sustainability science is also a decision against a disciplinary specialization. Against the background of the vivid discussion in the literature, this dissertation uses a minimal definition for *sustainability science* based on the broadest possible consensus, as suggested by Shahadu (2016):

> *"Sustainability science is focused on practical application of theories, tools and methodologies from different disciplines and bringing together scientists and stakeholders to define important research questions and objectives in dealing with sustainability challenges from local, national and international scales".*

framework, synthesizing knowledge, organization and institutions (…). The university thus becomes an increasingly important platform for societal transformation."

3.3 Case and data description: Competence Center Environment and Sustainability (CCES) of the ETH Domain

The Competence Center Environment and Sustainability (CCES) was founded in 2006 for a period of ten years (until 2016) to facilitate inter- and transdisciplinary research, capacity-building, and public outreach activities within and between the six institutions that constitute the ETH Domain, a union of Swiss federal universities and research institutes. Strategically managed by the ETH Board, the ETH Domain comprises the two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as the four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). CCES was one of four research centers that were founded within the ETH Domain. The themes of the other three centers were: Energy and Mobility (CCEM), Materials Science and Technology (CCMX), and Biomedical Imaging (NCCBI).

When discussions were held over which of the six participating institutions could serve as Leading House for CCES, a broad consensus was achieved that ETH Zurich would best qualify for this function. Not only due to the university's long tradition in environmental and sustainability science, but also because of the rich experience it had gained from the ETH Zurich School Domain of Earth, Environment and Natural Resources (S-ENETH) initiative. While the latter was shut down three years after its launch (2005 – 2008), the synergies were an immense advantage for the "problem framing" in the early phase of CCES (Lang et al. 2012, Brandt et al. 2013). The five Education and Research Units (ERU) that defined CCES throughout its existence were primarily drawn from the S-ENETH groundwork. Accordingly, research activities at CCES were clustered along five thematic areas of sustainability science: (1) Climate and Environmental Change, (2) Sustainable Land Use, (3) Food, Environment, and Health, (4) Natural Resources, and (5) Natural Hazards and Risks (see Table 1).

Education and Research Unit / Research platform	Project acronym	Institutional participation					
		ETH Zurich	EPFL	Eawag	PSI	WSL	Empa
CLENCH – Climate and Environmental Change	BigLink	x				x	
	BioChange	x		x		x	
	ClimPol	x	x	x			
	OPTIWARES*	x			x		x
	MAIOLICA*	x	x	x		x	x
FEH – Food, Environment and Health	BactFlow	x	x	x			
	GEDIHAP*	x		x		x	
HazRi – Natural Hazards and Risks	APUNCH	x	x			x	
	COGEAR	x	x				
	EXTREMES	x	x			x	
	TRAMM*	x	x			x	
NatuRe – Natural Resources	ADAPT	x	x	x			
	CARMA	x	x		x		
	GEOTHERM*	x	x		x		
	RECORD*	x	x	x		x	
SuLu – Sustainable Land Use	GeneMig*	x	x	x		x	
	MOUNTLAND*	x	x			x	
Research platform	Swiss Experiment*	x	x	x		x	

Note: CCES operated in two phases, from 2006-2010 (phase 1) and 2011-2016 (phase 2). Projects indicated with an asterisk (*) have received funding for both phases. In total, thus, CCES funded 26 projects (phase 1: 18 projects; phase 2: 8 projects). Fields highlighted in grey indicate the institutional affiliation of the principal investigator.

Table 1. Research projects and institutional affiliation at CCES grouped along thematic clusters.

As defined in its business plan (CCES 2005), CCES was established with the mission to "identify the relevant questions and the appropriate answers to foster the sustainable development of a future society while minimizing the impact on the environment" (CCES 2005). To comprehensively achieve this mission, CCES was designed to operate in three areas of activity: research, capacity-building, and public outreach (see Figure 3).

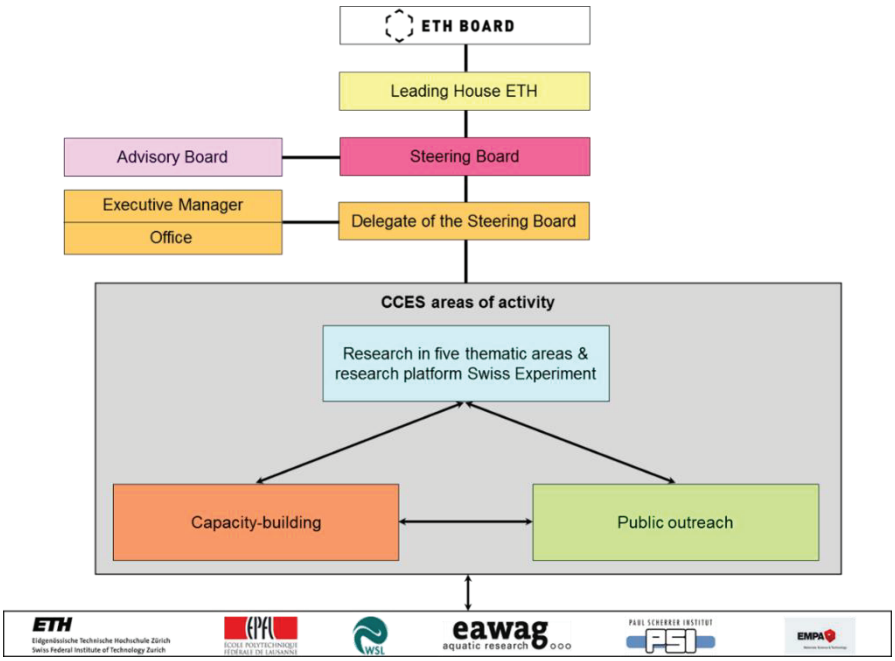

Figure 3. Organizational chart of the Competence Center Environment and Sustainability (CCES) of the ETH Domain[7]

Facts and figures about CCES

Organized along five clusters and 26 projects, more than 800 participants from the six ETH Domain institutions were involved in CCES activities in various roles between 2006 and 2010 (phase 1: 18 projects), and between 2011 and 2016 (phase 2: 8 projects). Around 300 of them were professors and senior researchers, and about 200 were doctoral students and postdocs. Remaining participants include Master students, project engineers, technicians, laboratory, and administrative support staff. Around one fifth of the overall CCES participants were female, while the share was somewhat lower on the level of the project leadership (14 percent). Over the course of two phases, the overall CCES budget provided by the ETH Board was CHF 45 million, two thirds of which were spent during the first phase (CHF 30 million), and one third during the second (CHF 15 million). Funds had to be "matched" at least by an equivalent of institutional in-kind funding and additional external third party funds (i.e., industry, public administration). As a result of this three-fold funding scheme, the overall funding volume added up to around CHF 130 million. As to the research output, CCES participants have reported 1'276 peer-reviewed journal articles, 185 doctoral theses, 417 Master theses and 2'599 abstracts, proceedings, presentations and posters between 2006 and 2016. The educational and capacity-building related output associated with CCES includes 92 doctoral courses, seminars,

[7] Note: Instead of "capacity-building" and "public outreach", CCES originally used the terms "education" and "stakeholder dialog", respectively. For reasons of conceptual consistency throughout the dissertation, the terms were modified in the organizational chart.

summer and winter schools on the topic of environment and sustainability (e.g., CCES Winter School), or the production of teaching materials for high schools. Public outreach activities targeting extra-academic stakeholders and the wider public include several hundred press interviews, public events, or courses held at high schools in Switzerland.[8]

Self-evaluation of CCES

Appendix A of this dissertation contains a peer-reviewed article that was published in *GAIA - Ecological Perspectives for Science and Society* in 2018 (Kassab et al. 2018). The article entitled "Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain" was written by Omar Kassab in collaboration with René P. Schwarzenbach, and Nikolaus Gotsch. Omar Kassab worked at CCES as an Executive Assistant between 2013 and 2015. René P. Schwarzenbach served as Head and Delegate of the CCES Steering Board between 2011 and 2016. Nikolaus Gotsch acted as Executive Manager (part-time) of CCES during its entire operation, between 2006 and 2016. The article thus benefitted from access to all data and insider knowledge about the research center. Due to this perspective, the article can therefore be described as a self-evaluation. The sources on which the article is based are described in Appendix A.

Data sources

Good evaluation practice "gathers systematic evidence on (…) performance and relies on multiple lines of evidence to draw its conclusions" (Cozzens 1997). Depending on the complexity of the object of study (here: the research center) methodological triangulation can prove invaluable for capturing a potentially diverse spectrum of impact. Following Morse (1991), this approach entails the use of different data sources and methods to increase the validity of the results, which will ultimately allow for a comprehensive understanding of the functioning and impact of the research center. In this vein, this dissertation relies on diverse methods, which will be described later, as well as on four major data sources: (1) archival data, (2) bibliographic and bibliometric data, (3) altmetrics, and (4) expert interviews:

(1) *Archival data*: The archival data consists of annual reports provided by the project leadership. On the basis of a standardized reporting template, each of the 26 CCES projects had to submit a full status report to the CCES management at the end of each project year.

[8] As it turned out in the process of data cleaning, a considerable number of the outputs were reported multiple times, not only within projects across years, but even across projects. The latter situation occurred when researchers were involved in more than one CCES project at a time.

Projects had a duration of three to five years each. Only after the successful examination could the project participants request their funding for the subsequent year. Between 2006 and 2016, this procedure yielded a total of 99 annual reports which were compiled to constitute a key basis of this dissertation. The reports (up to 50 pages each) neatly document the progress of the project activities. They disclose qualitative information on the scientific progress as well as quantitative information on human resources, research output, capacity-building, public outreach activities, and financial details. After studying the empirical and theoretical research center evaluation literature, all relevant data for the purpose of the study were collected from the annual reports, cleaned, and systematically coded into a relational database. The archival data was structured using unique identifiers on the (a) level of the 26 projects as well as on the (b) level of the participating researchers, on the annual basis, respectively:

(a) *Project level:* On the level of the project, information was retrieved and coded for each project and each of its operational years, as follows: *project team size* indicating the absolute number of people that were involved in the project, including not only researchers but also technicians and students, *cumulated fulltime equivalent* indicating the total of all project leadership[9] members' reported participation in the research center in fulltime equivalent (FTE), two variables for *gender representation* indicating both the absolute and relative share of females of the whole project team, two variables for *share of doctoral and Master students* indicating both the absolute and relative share of Master and doctoral students, and the *public outreach activities* indicating the number of external stakeholder oriented dissemination activities per project, in seven categories. Lastly, the *financial budget* indicating information on how the project's budget was composed, broken down by financial source (following a three-fold scheme: CCES funding, institutional in-kind funding, and external third party funding), in percent.

(b) *Individual level:* Besides the project level, information was retrieved on the level of the individual researcher participating in CCES. Due to the varying degree of biographical detail at the level of the participants as available in the archival data, the data collection and coding procedure was constrained to the level of 170 principle investigators and project partners (project leadership) who were engaged in the 26 projects. An additional group of 28 researchers who had submitted project proposals for CCES, but were rejected after review, were also incorporated into the dataset. These are not regarded

[9] The project leadership consists of one principle investigator and the project partners, the leaders of the subunits. Throughout the annual reports, the research center participation in fulltime equivalent was only documented consistently for members of the project leadership, and not for the entire project teams.

as a randomized "control group" in the experimental sense, but rather as a comparison group of individuals who were formally qualified for CCES participation, but were not selected. For all 198 researchers in the dataset, the following information was retrieved from the annual reports, as follows: *(multiple) CCES project affiliation* indicating which of the CCES projects the respective researcher was affiliated with in which year, and whether the researcher was affiliated to more than one project at the same time, or subsequently, *gender* indicating the sex[10] of the researcher, *institutional affiliation* indicating which of the six institutions of the ETH Domain the researcher was primarily affiliated with, *project role* indicating whether the researcher was the principal investigator or a project partner in the project, *academic title* indicating whether the researcher was a professor or not a professor, *academic age* indicating the year in which the researcher completed his or her doctorate, marking the beginning of their academic career, *disciplinary background* indicating whether the researcher is a social scientist, and *share of fulltime equivalent* indicating the share of the researcher's total annual working time dedicated to CCES, operationalized in FTE. Where necessary, complementing and confirming information was retrieved from personal websites.

(2) *Bibliographic and bibliometric data*: The most widely used indicators for measuring individual research performance are the number of publications and the citations they receive over time (Cozzens 1989, Bornmann and Daniel 2008). Thus, bibliographic and bibliometric data play an important role in the context of this dissertation. Starting from the list of 198 researchers, their entire publication history was retrieved from the *Web of Science*, which, along with *Scopus*, is considered the "gold standard" of data bases for bibliometric analyses (Harzing and Alakangas 2016, Mongeon and Paul-Hus 2016). By far the major share of document type indexed in the *Web of Science* database are peer-reviewed journal articles, which also turned out to be the case in the given dataset. The dataset includes both CCES publications but also all non-CCES publications before, during and after the research center participation, ultimately yielding 13'578 peer-reviewed journal articles published between 1980 and 2014[11]. The citation scores for each of the publications were retrieved in various options, including mean citation score (MCS), the mean normalized citation score (MNCS), percentile based indicators (top10), self-citation and total citation scores, provided by the *Centre for Science and Technology Studies* (CWTS) at the University of Leiden, Netherlands. Through the relational database and the unique identifiers, every CCES

[10] Only male or female were coded.
[11] The data was retrieved once in early 2015 even though the research center's operation went on until the end of 2016. Since the data for 2015 was not complete, the cut-off point was set at the end of 2014, to cover full years only.

publication was assigned to the authoring CCES researcher(s) and the corresponding CCES project. All remaining publications – before, simultaneous or after CCES – were coded with reference to the researchers as well.

(3) *Altmetrics:* The emergence of social media has not only heralded a new age for the public dissemination of scientific knowledge, but it has also opened up new opportunities for research evaluation. The so-called "altmetrics", data tracking user activities in social media environments, provide an innovative alternative to classic citation-based metrics (Bornmann 2014, Weller 2015, Haustein et al. 2016). An endeavor to quantitatively represent mentions and interactions on social media platforms like Twitter or Facebook, altmetrics are vividly discussed in terms of their potential to assess the societal impact of research (Cress 2014, Bornmann et al. 2019, Wooldridge and King 2019). By means of a research center evaluation, part of this dissertation will explore to what extent altmetrics are suitable for this purpose. Since altmetrics were introduced only in 2011, this limits the time frame for the investigation. Narrowing down the dataset to a subset for the years 2011 to 2015, six altmetrics sources are considered, including Twitter, Wikipedia, policy-related documents, Blogs, Facebook, and News. The altmetrics data was sourced from a locally maintained database shared by Altmetric (see www.altmetric.com). For research projects, the company shares the data for free. Using the Digital Object Identifier (DOI), mention counts for the six aforementioned altmetric sources were appended to each of the publications in the dataset.

(4) *Expert interviews*[12]*:* Unless a researcher can pool and integrate knowledge from different disciplines in herself or himself – resulting in an "interdisciplinarity in person" (Steiner 2002), which is rarely the case in practice – inter- and transdisciplinary research is a team effort. As outlined above, the interpersonal exchange can evoke challenges, even conflicts (Stokols et al. 2008b). In an attempt to account for the "human factor" of inter- and transdisciplinarity activities in the research center context, a series of expert interviews were conducted with members of the project leadership (Bogner et al. 2009, Meuser and Nagel 2009). The development of the interview guideline (see Appendix B) was preceded by a review of the research center evaluation and program evaluation literature, and preliminary analyses of the archival data. Additionally, focus group discussions were held with members of the research center management who helped identifying the key interview questions (Kitzinger 1994). Interview partners were selected by recommendation of the CCES management on the basis of their institutional affiliation and their exposure to

[12] The findings from the expert interviews were used for the self-evaluation of CCES (see Appendix A).

CCES activities, varying in intensity (single or multiple project participation) and duration (one or both phases). Between December 2013 and January 2014, a total of ten semi-structured expert interviews were conducted with project leaders (principal investigators or project partners) of the CCES projects, seven of which were conducted in person and three by telephone. The seven face-to-face interviews were recorded and transcribed (see Appendix C).[13] Details that would allow drawing conclusions on the identity of the interviewee were anonymized and indicated accordingly. Since the interviews were more about the content and less about the behavior of the respondents, they were transcribed without accounting for nonverbal sounds, mispronunciations, slang, grammatical errors, enunciated reductions, or filler words (McLellan et al. 2003).

Methods

The data is analyzed using different methodological approaches. The subsequent Part III, which is composed of three paper-based contributions (journal articles), outlines the strategies in detail. In brief: The *first article* builds on a quasi-experimental within-group research design and uses bibliometric analyses, multi-level statistics, and growth curve modelling. Based on archival data of the research center, the *second article* applies descriptive statistics, Spearman's correlation analysis, and multiple regression analysis. The *third article* uses Mantel-Haenszel statistics to compare altmetrics scores with bibliometric data related to the research center output.

[13] At the time the three telephone interviews were held, no technical equipment to record the interviews was available (Opdenakker 2006). The answers were documented by the interviewer in handwriting.

PART II

PAPER-BASED CONTRIBUTIONS

Chapter 4

Detailed account of the dissertation

This chapter constitutes the main body of the dissertation. It is divided into three sub-chapters, each of which is conceived as a journal article. Table 2 presents the purpose and key finding of the articles in a summarized form and thereby provides an idea of how they fit into the bigger scheme of the dissertation. It also gives and overview on which of the evaluation challenges discussed above (see 2.2) are addressed by the respective articles.

No	Paper-based contribution	Evaluation challenges						Purpose and key finding	Status
		Interdisciplinarity of research teams	*Transdisciplinarity and public engagement*	*Broader impact potential*	*Temporary lifespan*	*Participation intensity*	*Diversity of funding sources*		
1	**Article** Introducing and testing an advanced methodological quantitative approach for the evaluation of research centers: A case study on sustainability science							Advancing methodological refinements to existing bibliometrics-based research center evaluation approaches, the article finds that engagement in inter- and transdisciplinary research does not have a negative effect on individual research performance.	**Published** in *Research Evaluation*
2	**Article** Does public outreach impede research performance? Exploring the "researcher's dilemma" in a sustainability research center							Investigating the implications of engaging in public outreach in addition to classical academic publishing activities, the article conducts a series of statistical analyses on the basis of research center data. The results indicate a positive correlation between the two activities, contrary to what is widely believed.	**Published** in *Science and Public Policy*
3	**Working paper** Can Altmetrics Reflect Societal Impact Considerations? Exploring the Potential of Altmetrics in the Context of a Sustainability Science Research Center							With conflicting evidence circulating, the article contributes to better understanding the capacity of altmetrics for research evaluation in general, and research center evaluation in particular. The findings suggest that altmetrics are so far not suitable for capturing the societal impact of research in a straightforward way.	**Working paper**

Table 2. Overview of purpose and key findings of the contributions and the evaluation challenges they address. Highlighted fields indicate that the challenge is addressed in the respective article. The darker the field, the more comprehensive is the proposed solution.

4.1 Introducing and testing an advanced quantitative methodological approach for the evaluation of research centers: A case study on sustainability science

The inherent quality of research centers to address complex inter- and transdisciplinary problems is undisputed (Stahler and Tash 1994, Bozeman and Boardman 2003, Bishop et al. 2014). At the same time, research centers present unique challenges for quantitative research evaluation. Existing bibliometric evaluation approaches, as they would be used to assess departments or individual researchers, lack the capacity to capture some of the defining characteristics of research centers and their participants, including the following three in particular: First is the diversity of participants (*interdisciplinarity of research teams*). Researchers that come together in research centers have little in common except the fact that they are all participants of the same research center. While this diversity is crucial for inter- and transdisciplinary research to bear fruits (Lang et al. 2012), it comes with distinctive challenges in the bibliometric sense. Second is related to the aspect of transition (*temporary lifespan*). In the very context of research centers, those transitions can occur by moments marking the starting or end points of the research center participation, or by temporary commitments to projects. Depending on their project role, researchers have per se varying exposure to the research center context. And third concerns the intensity of the participation (*participation intensity*). It is rarely the case that researchers spend their entire time at research centers. Instead, they work at research centers depending on their capacities and functions, as a consequence of career mobility, or simply depending on the availability of financial resources.

The *first article*, accounting for the specific features of research centers, introduces an advanced quantitative approach for the ex-post evaluation of research centers. The approach builds on a quasi-experimental within-group design, bibliometric analyses, and multilevel statistics to assess average and individual causal effects of research center affiliation on participants along three dimensions of research performance. The evaluation approach is tested on the basis of CCES data. Three of the six evaluation challenges are explicitly addressed and resolved by means of the research design, fine-grained archival and bibliometric data, as well as a sophisticated statistical approach.

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Introducing and testing an advanced quantitative methodological approach for the evaluation of research centers: a case study on sustainability science

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Abstract

With the growing complexity of societal and scientific problems, research centers have emerged to facilitate the conduct of research beyond disciplinary and institutional boundaries. While they have become firmly established in the global university landscape, research centers raise some critical questions for research evaluation. Existing evaluation approaches designed to assess universities, departments, projects, or individual researchers fail to capture some of the core characteristics of research centers and their participants, including the diversity of the involved researchers, at what point in time they join and leave the research center, or the intensity of their participation. In addressing these aspects, this article introduces an advanced approach for the ex post evaluation of research centers. It builds on a quasi-experimental within-group design, bibliometric analyses, and multilevel statistics to assess average and individual causal effects of research center affiliation on participants along three dimensions of research performance. The evaluation approach is tested with archival data from a center in the field of sustainability science. Against a widely held belief, we find that participation in research centers entails no disadvantages for researchers as far as their research performance is concerned. However, individual trajectories varied strongly.

Key words: research center; bibliometrics; research performance; accelerated longitudinal design; growth curve modeling; sustainability science.

1. Introduction

Research centers have evolved into indispensable organizational instruments in the university landscape (Ikenberry and Friedman 1972; Rivers and Gray 2013; Smith et al. 2016). Their strength lies in the ability to handle complex problems that could not be addressed in the traditional departmental and discipline-based context (Sabharwal and Hu 2013; Corley et al. 2017). However, research centers operate at the interface of conflicting research policy developments: On the one hand, universities are increasingly encouraged by funding entities to conduct solution-oriented research to tackle the grand societal challenges like climate change, energy supply, or urbanization. Those applied research questions require collaboration across disciplinary boundaries and have ultimately led to an increased emergence of inter- and transdisciplinary research centers (Kueffer et al. 2012; SDSN 2017). At the same time, however, the academic 'publish or perish' system rewards efficiency in terms of individual research performance, which, given the coordination effort associated to inter- and transdisciplinary research, very often results in disciplinary and highly focused basic research (Talwar, Wiek and Robinson 2011; Lang et al. 2012; Wiek et al. 2014).

Despite the broad consensus on their systemic importance (Spangenberg 2011; Ziegler and Ott 2011), researchers are somewhat reluctant to participate in research centers, presumably due to concerns that this might negatively affect their careers (Stokols et al.

2008b; Su 2014). But is the skepticism empirically justified? A number of studies have investigated the question of whether and to what extent participation in research centers has an impact on the publication activities and collaboration behavior of individual researchers (Landry and Amara 1998; Wen and Kobayashi 2001; Bozeman and Rogers 2002; Gaughan and Bozeman 2002; Corley and Gaughan 2005; Lee and Bozeman 2005; Lin and Bozeman 2006; Mallon 2006; Boardman and Corley 2008; Ponomariov and Boardman 2010; Sabharwal and Hu 2013; Youtie, Kay and Melkers 2013). While most of the studies have found participation in research centers not to be disadvantageous in terms of individual research performance (usually measured in terms of publication productivity), methodological shortcomings put these findings into perspective. Against the systemic relevance of research centers, we herewith propose a comprehensive evaluation approach that further develops previous approaches theoretically and methodologically. We demonstrate and test the approach on the basis of a research center with a focus on sustainability science.

The approach we propose is comprehensive in that it entails the data collection procedure, an underlying quasi-experimental research design, and applies the latest available data analysis methods (i.e. multilevel analysis and growth curve modeling). The basic idea of the approach is to look at individual researchers and their entire publication record. The beginning of their research center participation, and of the corresponding publication activity, is thus seen as a transition from the previous publication activity. In the research design, this transition is understood as a 'treatment' while the time prior to the research center participation is regarded as the baseline. From an accountability perspective, it is important to evaluate not only the individual causal effects (ICEs) of research center participation on the individual researcher but also the summative average causal effect across all participants. For this purpose, advanced multilevel models serve to capture the hierarchical data structure, i.e., the publication activity over time (level 1) for different researchers (level 2) while at the same time providing ways to solve the aggregation problem. Multilevel models, thus, not only allow us to capture the average causal effect of the research center, but also make it possible to assess the effect on the individual. In contrast to conducting surveys with varying response rates, the combination of archival data with bibliometric data safeguards the objectivity of the evaluation approach as a whole.

This article is structured as follows: we start with a review of the research center evaluation literature, which we draw upon to develop the theoretical foundations of our evaluation approach. We then illustrate the shortcomings of existing approaches that we aim to resolve, before briefly describing the case that we use to test the evaluation approach. Data and methods are introduced thereafter. After presenting the results in detail, the article closes with a discussion of strengths, limitations, and policy implications of the approach.

2. Literature and theory

2.1 Research centers in the university context

Research centers are organizational entities within a university that exist chiefly to serve a research mission, are set apart from the departmental organization, and include researchers from more than one department (Bozeman and Boardman 2003: 17). Since the first research centers were founded in the USA in the 1970s, national innovation systems around the globe have increasingly made strategic use of research centers to address problems that are too complex for a single department to manage (Geiger 1990; Stokols et al. 2008a; Mittelstrass 2011; Rivers and Gray 2013; Su 2014). Beyond their ability to facilitate inter- and transdisciplinary research, they provide various opportunities for collaboration with sectors beyond academia, for training of future generations of academic workforce, for technology transfer and dissemination activities directed to various target audiences, for building network ties, and for career changes, among others (Santoro and Gopalakrishnan 2001; Feller, Ailes and Roessner 2002; Slaughter et al. 2002; Boardman and Corley 2008; Gaughan and Ponomariov 2008; Ponomariov and Boardman 2010; The Madrillon Group Inc. 2010; Ávila-Robinson and Sengoku 2017; Corley et al. 2017).

From an organizational viewpoint, there are vast differences between research centers across a multitude of dimensions, such as the number of their participants, their institutional and disciplinary composition, collaboration and networking opportunities, their funding schemes, their strategic goals, or their operative lifespan (Rogers, Youtie and Kay 2012; Rivers and Gray 2013; Sabharwal and Hu 2013; Bishop et al. 2014; Smith et al. 2016; Corley et al. 2017). Research centers are not substitutes for university departments, but rather require and complement them. For many researchers participating in university-based research centers, the department remains their primary affiliation, while only a share of their total working time is devoted to projects at the research center (Boardman and Bozeman 2007; Kassab, Schwarzenbach and Gotsch 2018).

2.2 Understanding the dynamics at research centers and the implications for research performance

A typical research center is characterized by intricate coordination processes and inter- and transdisciplinary knowledge exchange. The dominant output orientation in evaluation practice, however, hardly does justice to this reality (Cozzens and Turpin 2000; Coryn et al. 2007). According to a study on the 'Evaluation of Research Center and Network Programs at the National Institutes of Health' (NIH), based on a review of 61 cases from the years 1978 to 2009, 81% of the cases focused on scientific publications as the primary output to be assessed. Moreover, the review shows that 61% of all studies relies solely on descriptive statistics (The Madrillon Group Inc. 2010).

As a remedy to this narrow focus, Bozeman, Dietz and Gaughan (2001) developed an evaluation model to delineate what they label the Scientific and Technical Human Capital (STHC), defined as 'the sum of an individual researcher's professional network ties, technical knowledge and skills, and resources broadly defined' (Bozeman, Dietz and Gaughan 2001: 636). As such, their perspective focuses less on the discrete outputs but rather on the processes that enable researchers to expand their networks and improve their capabilities. Since its introduction, the STHC model has been applied in many areas of science and technology policy research, for example, to evaluate career development, research collaboration, or institutional interactions (Corley et al. 2017). It is the holistic view of the STHC model that has also made it the most prominent perspective for theorizing the dynamics in research centers, as can be seen from numerous examples in the literature (Bozeman and Corley 2004; Dietz and Bozeman 2005; Lin and Bozeman 2006; Boardman and Corley 2008; Ponomariov and Boardman 2010; Sabharwal and

Hu 2013). From this perspective, research centers are understood as 'organizational reservoirs' of STHC, to which all participants of the research center gain access, in particular during the research center's lifetime but also beyond (Ponomariov and Boardman 2010: 617).

We also draw on the STHC model to describe the implications of research center participation for individual research performance.[1] To provide a comprehensive perspective, we define research performance not only on the basis of publication productivity, but instead as measured by three indicators: (1) 'scientific productivity' in terms of the number of publications, (2) 'scientific impact' in terms of the number of citations, and (3) 'integration into the scientific community' in terms of the number of coauthors.

The basic assumption of the STHC model is that participation in a research center expands individual capabilities and networks. With regard to the first dimension, scientific productivity, this suggests that research centers provide more financial and human resources than would be the case in a departmental setting, thus, leading to an increased scientific productivity (Corley and Gaughan 2005; Bunton and Mallon 2006; Sabharwal and Hu 2013). Due to the denser network of contacts and additional communication mechanisms provided by the research center management, it can be assumed that the scientific publications produced at the research center will have a greater visibility, which in turn will increase the citation probability. Finally, the third dimension of research performance, integration into the scientific community, is likely to be boosted by joining the research center because of increased access to a pool of potential collaborators, which in some cases is even explicitly demanded by the funding entity (Gaughan and Ponomariov 2008; Ponomariov and Boardman 2010).

While we, in line with previous studies, acknowledge that the STHC model is in principle very well-suited for investigating and explaining the dynamics in research centers, we would like to concentrate on three key characteristics of research centers and their participants that have as yet been only insufficiently taken into account in previous evaluation studies. To this end, we would like to start from the STHC perspective and its basic assumptions outlined above, take up additional aspects, and thus form the theoretical basis for our evaluation approach.

2.2.1 *Diversity of participants ('diversity')*

It is in the nature of a research center that participants differ from each other in many respects and, by definition, have diverse disciplinary backgrounds. Leveraging this diversity effectively is one of the greatest strengths of research centers, because it makes the conduct and success of inter- and transdisciplinary research possible in the first place (Clark 2007: 1737; Lang et al. 2012). From the STHC perspective, the individual 'internal resources', understood as cognitive abilities or technical knowledge, are aggregated for the duration of the researcher's affiliation with the research center, thus, making them accessible to all other participants (Bozeman, Dietz and Gaughan 2001; Ponomariov and Boardman 2010). With regard to the research performance and scientific progress in general, the resources that a research center can bring together add up to a whole that is 'greater than the sum of its parts'. While this understanding of diversity is largely based on the disciplinary aspect, other characteristics such as the role of the participants in the research center as well as their academic age, gender, or institutional culture have shown to play a crucial role as well (Bishop et al. 2014; Corley et al. 2017).

Those who take on a management role, for example, not only have full access to the aggregated resources of the research center, but at the same time have an opportunity to develop leadership skills and thus an increased level of STHC (Elkins and Keller 2003; Gray 2008). A further strength of the STHC model is the 'recognition of the evolution of the scientist throughout his or her productive life cycle' (Bozeman, Dietz and Gaughan 2001). This is particularly important in view of the fact that previous studies have identified a generational 'cohort effect' on the impact of a research center when it comes to research performance (Sabharwal and Hu 2013).

While the STHC model in its original form does not make any gender-specific distinctions, a further development of the model brings in a cultural dimension, defined as 'the sum of an individual scientist's experiences that are gained while interacting with people from diverse cultural backgrounds' (Corley et al. 2017), one of which is gender. As women engage in inter- and transdisciplinary research centers at least as often as men (Corley and Gaughan 2005), participants in research centers are typically in contact with colleagues of different sexes, which, according to Corley et al. (2017), ultimately increases their overall level of STHC.

2.2.2 *Transition in and out of research centers ('transition')*

Another characteristic of research centers and their participants that has not yet been sufficiently taken into account is related to the fact that '[o]ver time, individuals, groups, and firms encounter acute events that involve transitioning from one state or role to another' (Bornmann, Mutz and Daniel 2009; Bliese, Adler and Flynn 2017). In the concrete context of research centers, those transitions can take place when marking the starting or end points of the affiliation, or during temporary commitments to projects.

The STHC model indeed assumes that the individual STHC is constantly changing. Theory says that 'the individual may "load" at a different level on the dimension[s] at any particular point in time' (Bozeman, Dietz and Gaughan 2001). If the individual STHC changes over time and by means of interaction, then in the context of a research center, this indicates that the moment of transition and period of affiliation must be taken into account. Previous studies have focused on incorporating affiliation versus nonaffiliation on an annual basis with a binary coding regime (Boardman and Corley 2008; Ponomariov and Boardman 2010; Sabharwal and Hu 2013; Bishop et al. 2014). However, this is not fully satisfactory for two reasons: First, because it has to be assumed that participants may be involved in more than one project at the research center, consecutively or simultaneously, which in turn implies a greater STHC development potential and impact on research performance. Second, the research center routine not only includes activities on the level of the project but also networking activities on the level of the center as a whole. Essentially, if one intends to assess the impact of participation in the research center based on individual research performance, one should consider the aspect of transition in all its complexity as conceptualized by the STHC model, both on the project level and on the organizational level.

2.2.3 *Intensity of participation ('intensity')*

The extent to which participation in a research center ultimately affects individual research performance is also a matter of exposure. As in classical experimental settings, the effect depends on the 'intensity' of the treatment (West, Cham and Liu 2014). As the participants in the vast majority of cases have further obligations in addition to their research center affiliation, it must also be assumed that the effect on their research performance varies accordingly. When spending only a share of the total working time at the

research center, the individual researcher not only has limited access to the aggregated STHC resources, but he or she also has fewer opportunities to develop their own STHC than would be possible in case of full-time affiliation. Boardman and Corley (2008) took an important step in this direction by asking the research center participants in their sample how much time they spent working alone and how much of their work involved other groups, sectors, or countries. However, similar to the approach by Ponomariov and Boardman (2010), which takes 'core institution affiliation' into account, both studies only integrate a 'binary' research center affiliation indicator. In other words, the intensity is not measured.

In the preceding sections, we have discussed three aspects that have not yet been sufficiently taken into account in previous quantitative evaluations of research centers. With this article, we introduce an advanced methodological approach for the ex post evaluation of research centers. In the chapter that follows, the evaluation approach and the remedies it brings are described in more detail.

3. Case description: Competence Center Environment and Sustainability

The case used to demonstrate the evaluation approach is the Competence Center Environment and Sustainability (CCES), a research center in Switzerland that operated for 10 years between 2006 and 2016 with a focus on sustainability science (Kassab, Schwarzenbach and Gotsch 2018). CCES is one of the four inter- and transdisciplinary research centers that were established to promote research, education, and societal outreach activities within and between the six institutions that constitute the ETH Domain. The ETH Domain comprises the two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as four independent research institutions: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). While the six institutions differ greatly in terms of their research cultures—ETH Zurich and EPFL being rather oriented toward basic research, while the other four are more application oriented—they also share thematic research priorities, which the ETH Board, the ETH Domain's management body, intended to consolidate through the foundation of the four research centers. As can be seen in Table 1, 170 senior researchers from the six institutions came together in CCES to work on a total of 26 inter- and transdisciplinary projects, covering five thematic priority areas of sustainability science: (1) Climate and Environmental Change, (2) Sustainable Land Use, (3) Food, Environment, and Health, (4) Natural Resources, and (5) Natural Hazards and Risks (i.e. 'diversity').

CCES was designed to operate in two phases, the first running from 2006 to 2010 and the second from 2011 to 2016. Of the 26 projects, 18 were conducted in the first phase and eight in the second phase. During the startup of the research center, review processes and administrative arrangements caused substantial delays to the beginnings of the projects. As a matter of fact, CCES affiliation did not take effect for all participants in the same year (i.e. 2006), but rather in a staggered manner. Depending on their project involvement, researchers also had varying exposure to the research center context. In some cases, the researchers' affiliation did not extend over the entire project duration, but ended along the way, opening opportunities for new participants to join at a time when the project and the research center were already in operation (i.e. 'transition').

Table 1. Sample description (researchers and publications)

Researchers ($N = 198$)			
		Absolute	Percent
Gender	Male	171	86
	Female	27	14
Cohort	Phase 1 (2006–2010)	102	52
	Phase 2 (2011–2016)	23	12
	Both phases (2006–2016)	45	23
	Comparison group	28	14
Institution	ETH Zurich	96	48
	EPFL	26	13
	Eawag	23	12
	WSL	27	14
	PSI	11	6
	Empa	5	3
	Other	10	5
Scientific background[a]	Social scientists	17	9
	Other disciplines	181	91
Year of PhD (cohorts)	Before 1990	66	33
	Between 1990 and 2000	87	44
	After 2000	21	11
	Missing information	24	12
Role	Professor	110	56
	Not professor	88	44

Publications (publication years x researchers; $N = 3{,}250$), annual			
	M	SD	Min/Max
Number of publications	4.37	3.98	1/31
Number of citations	46.52	80.52	0/1,503
Number of coauthors	24.10	121.58	0/5,405

[a]Classification based on Frascati Manual (OECD 2007).

The participants of CCES were also involved in their respective projects to varying degrees. Very few were engaged in a project full time; the majority of the researchers participated in CCES on a part-time basis, suggesting other research activity beyond the research center. Moreover, their exposure differed not only with regard to the temporality (full time vs. part time), but also with regard to participation in more than one project over the course of the research center's operation, either at the same time or consecutively (i.e. in terms of 'intensity').

4. Data and methods

4.1 Data

The main data basis consists of archival data in the form of 99 annual project reports of 26 projects over the course of 10 years, kindly provided by the CCES management.[2] From the reports, we retrieved data on the (1) individual researchers, (2) bibliometric data, and (3) institutional data on the research center. This data collection effort resulted in a longitudinal dataset that included observations of the same individuals over the course of their academic careers, thereby encompassing their affiliation with CCES.

4.1.1 *Researcher data*

We started by compiling a list of all 170 participants that were affiliated with CCES as principal investigators and project partners.[3] We

incorporated into the dataset an additional 28 researchers who had submitted project proposals for CCES but were rejected after review. We do not regard these researchers as a randomized control group in the classical experimental sense, but as a comparison group of individuals who were formally qualified for CCES affiliation, but were not selected. The group is, therefore, not matched to the personal profiles of CCES participants.

Following the research evaluation literature and to capture the multiple aspects of diversity (see Section 2.2.1), we coded researcher-specific information derived from the annual project reports such as gender, the scientific background, year of PhD (indicating the beginning of the academic career), role in project, and academic title (Corley and Gaughan 2005; OECD 2007; Cañibano and Bozeman 2009; Sabharwal and Hu 2013). Where necessary, complementing and confirming information was retrieved from personal websites.

To capture the aspect of transition (see Section 2.2.2), we coded the actual project affiliations of the individual researchers, including both starting and ending time points of their affiliation and stating whether they were affiliated with multiple CCES projects, either in parallel or subsequently (Cafri, Hedeker and Aarons 2015). Among the 170 participating researchers, affiliations ranged from single project affiliation during one phase of CCES to up to four project affiliations over the course of both phases.

Addressing the aspect of intensity (see Section 2.2.3), we retrieved information on the time commitment associated with individual CCES projects, as documented in the annual project reports in full-time equivalent (FTE) per researcher and year. Table 2 gives an idea of how the data were structured and coded (exemplary).

4.1.2 *Bibliometric data*

In a second step, we downloaded the full publication histories of all 198 individual researchers, using the *Clarivate Analytics Web of Science* database. As the research center was still operating at the time that we conducted this study, the cutoff date for publications was the end of 2014. In total, we collected bibliometric data on 13,578 peer-reviewed journal articles. As the first publication dated back to the year 1980, the study covers a timeframe of 35 years.

4.1.3 *Institutional data*

Using unique identifiers, each of the 13,578 articles published in peer-reviewed journals was assigned to one or more of the 198 researchers. Publications produced within the context of CCES were indicated accordingly, with reference to the project and the researcher(s). All remaining publications (before, during, or after CCES) were coded with reference to the researcher(s) as well.

4.2 Variables

As introduced above, we understand research performance along three dimensions, including 'scientific productivity' in terms of the number of publications, 'scientific impact' in terms of the number of citations, and 'integration into the scientific community' in terms of the number of coauthors. The three corresponding dependent variables to be used in the analysis are count variables. As Table 1 shows, we counted the number of publications, the number of citations with a citation window of 5 years, and the number of coauthors, per researcher and publication year ($N = 3{,}250$). Furthermore, with the exception of the number of publications, we used count rates (Fleiss, Levin and Paik 2003). For count rates, we did not analyze the annual citations, but instead looked at the annual number of citations per publication (annual number of citations divided by annual number of publications), that is, how many citations a researcher receives for a publication per year on average. The citations were counted on the same citation window, and the citations were not field normalized, because the vast majority of the papers were published in natural and life science journals.

We distinguish two types of covariates or factors: covariates 'between individuals', which describe the researchers, and covariates or factors 'within individuals', which characterize the time course. Specifically, our approach includes the following covariates:

1. *Between individuals*: Researchers had different characteristics (gender, age and year of PhD, role in project, academic title, and scientific background) and belonged not only to different age cohorts but also to four different person clusters. One comparison group of researchers did not participate in CCES (see Section 4.1.1), a second group participated only in phase 1 (2006–10), a third group participated in phase 2 (2011–6) only, and a fourth group participated in both phases (2006–16).
2. *Within individuals*: Researchers published their articles in the time range from 1980 to 2014 (publication year). They participated in CCES projects at different points in time and run as a

Table 2. Example of coding scheme on the researcher level indicating unique researcher_id (researcher identification), year (publication year), project_id_1 (identification of project 1), project_id_2 (identification of project 2), FTE_id_1 (full-time equivalent in project 1), not_FTE_id_1 (full-time equivalent outside of project 1), FTE_id_2 (full-time equivalent in project 2), not_FTE_id_1 (full-time equivalent outside of project 2), pub_cces (number of publications in CCES), and pub_non_cces (number of publications not in CCES)

researcher_id	year	project_id_1	project_id_2	FTE_id_1	not_FTE_id_1	FTE_id_2	not_FTE_id_2	pub_cces	pub_non_cces
57	2002	0	0	0	1	0	1	0	5
57	2003	0	0	0	1	0	1	0	6
57	2004	0	0	0	1	0	1	0	4
57	2005	0	0	0	1	0	1	0	5
57	2006	111	0	0.2	0.8	0	1	0	5
57	2007	111	0	0.2	0.8	0	1	2	6
57	2008	111	321	0.2	0.8	0.3	0.7	3	7
57	2009	111	321	0.2	0.8	0.3	0.7	5	8
57	2010	0	321	0	1	0.3	0.7	0	10
57	2011	0	321	0	1	0.3	0.7	0	11
57	2012	0	0	0	1	0	1	0	10
57	2013	0	0	0	1	0	1	0	12
57	2014	0	0	0	1	0	1	0	11

rule through different phases: no CCES, phase 1 (2006–10), phase 2 (2011–6).

4.3 Research design

The basic research design underlying the evaluation approach we propose is a quasi-experimental within-group design that models the full publication history of a group of researchers over time (Shadish, Cook and Campbell 2002). Given the theoretical considerations and characteristics discussed above (see Section 2.2), we found the *longitudinal interrupted accelerated design* (McDowall et al. 1983; Willett, Singer and Martin 1998; Galbraith, Bowden and Mander 2017), a more sophisticated version of the basic research design, to be most suitable.

Alleviating the challenge of diversity (Section 2.2.1), the design makes possible the examination of individual researchers of different age cohorts and different stages of their career with respect to their individual trajectory of bibliometric indicators in a longitudinal perspective (*longitudinal accelerated design*). Their participation is captured as a 'treatment' over time (binary: participation or no participation), which has causal effects on their bibliometric indicators. We assume that the individual times series of publication trajectories is 'interrupted' (*interrupted time series*) by the affiliation with CCES (Wagner et al. 2002). The bibliometric indicators (such as number of publications) change due to participation in CCES in a way that could not be predicted based on expectations arising from the previous course of the bibliometric indicators.

The research design considers the research performance on two levels: *micro* impact and *macro* impact. To assess the *micro* impact, the effect of each project on the bibliometric indicators is examined, weighted according to the time commitment in the project in FTE per researcher per year. Although this procedure concisely addresses the challenge of intensity (see Section 2.2.3), it comes with the disadvantage that information about the effects of a project is limited to its duration. But as scientific output is frequently published after the project completion (i.e. publication lag), *macro* impacts are additionally examined, that is, effects attributed to affiliation with the research center as a whole.

The research design we propose makes the evaluation approach relatively robust against many of the common threats to internal validity (Shadish, Cook and Campbell 2002: 55). The most typical ones in this context are instrumentation, maturation, and history. The threat of instrumentation is alleviated through the objectivity of the bibliometric data as retrieved from the standardized *Web of Science* database retrospectively. The threat of maturation is mitigated through the statistical modeling of a baseline, as will be described in more detail below (see Section 4.4). In the opportunity-driven context of research funding, the most severe threat to internal validity is history. It is not unlikely that concurrent research center affiliations or other events could cause the observed effect on the participating researchers. In the research design applied here, the treatment that research center participants receive is not a single-shot treatment but rather a continuous exposure. Furthermore, as neatly documented in the annual reports and the corresponding data, that exposure is different for every researcher. The treatment is operationalized in two ways: in a binary way (participation or no participation), as has been done in previous studies, and by capturing the participation intensity.

The evaluation approach is also robust against many of the threats to external validity (Shadish, Cook and Campbell 2002: 86). The research design and the statistical approach are sufficiently broad to be tailored to individual researchers, regardless of their disciplinary background or other characteristics relevant to the evaluation of their research performance. The approach can also be applied in different settings, provided the objectivity of the data is ensured (Christensen and Waraczynski 1988; Ferguson 2004). Relying on archival data is a strong safeguard against this threat. While this article demonstrates the evaluation approach using a concrete case of a research center, it can be used to study other cases as well, making it generalizable in the methodological sense. Finally, it is particularly robust, as it assumes a natural setting without the effects that could intervene and influence the effect under scrutiny in a laboratory setting (Shadish, Cook and Campbell 2002: 83).

4.4 Statistical approach

This section describes in detail the statistical approach as a central element of the evaluation approach. While the approach could be presented in general terms as well, the case of CCES is used an example to increase transparency and to demonstrate the applicability of the approach. We propose an univariate multilevel approach (Goldstein 2011; Hox, Moerbeek and van de Schoot 2018), consisting of the following five elements:

(1) *Measurement model*: Bibliometric indicators such as 'number of publications' are ordinary Poisson distributed count variables, positive integer values including zero (Cameron 1998; Hilbe 2014; Mutz, Wolbring and Daniel 2016). In the case of stronger overdispersion, where the variance does not equal the mean of the variables, a negative binomial regression model is applied. The criterion for overdispersion is the ratio of Pearson χ^2 and degrees of freedom, which according to the model estimation should not be much greater than 1.0 (Hilbe 2014: 82). The problem of zero-inflation with 'number of citations' (disproportional number of noncited publications) is considered to be a problem of overdispersion and handled with a negative binomial distribution. Rates are represented by an 'offset' in the regression model. As the logarithm of rates $\ln(n_p/n)$ equals the difference $\ln(n_p) - \ln(n)$, the corresponding regression model can be complemented simply by an additional variable, $\ln(n)$, that has a regression coefficient of 1.0, so that, again, $\ln(n_p)$ can be modeled as an outcome (Fleiss, Levin and Paik 2003: 347; SAS Institute Inc. 2014: 3144).

(2) *Impact of CCES publications*: As briefly described above, two types of publications are differentiated. One type consists of articles that were published in the context of a CCES project, as precisely documented in the annual reports of the CCES projects. The second type consists of publications that were not produced in the context of CCES (non-CCES). These are all publications in the dataset that were published prior to the establishment of the research center in 2006, as well as all publications since 2006 in which the 170 researchers were involved but that were not specified in the annual reports as CCES publications. The two types of publications are defined as variables as follows: One variable represents all publications (cumulative) of a researcher across all years. Another variable represents the publications that were not produced within CCES (non-CCES). Accordingly, two records (data rows) per year are produced for every researcher. In turn, the difference between the two records is the number of publications that a researcher published in the context of CCES. For the logarithmic transformed bibliometric

indicator y_{jic} of researcher i in publication year j in cohort c, the following first model component can be defined, whereby x_{jic} identifies the two different variables ($x_{jic} = 0$: all without CCES publications, $x_{jic} = 1$: all publications):

$$\ln(y_{jic}) = \beta_{00} + \beta_{01} x_{jic}, \tag{1}$$

where β_{00} as fixed effect denotes the mean value of the bibliometric indicator regarding all non-CCES publications, and β_{01} as fixed effect denotes the mean value of the bibliometric indicators of CCES publications. Eventually, the overall model estimation was based on the total number of publications (CCES/non-CCES), because model estimation and testing is more efficient for large sample sizes than for small ones.

(3) *Growth curve model*: With regard to the natural log link for the dependent variables, a linear trend is assumed, which if necessary can be extended to a nonlinear trend (polynomial time trend) as further model assumption. The growth model represents the development of a researcher irrespective of any effects in the sense of 'maturation', which might result from participating in the research center (see Section 4.3). As discussed above, it may be assumed that researchers in their individual trajectories of bibliometric indicators could deviate from this general trend more or less (interindividual differences in intraindividual changes). It may also be assumed that there are different growth trends in the different age cohorts: A researcher who started publishing in 1980 will most likely have a different trajectory than a researcher who began publishing in 2002 (Way et al. 2017). Growth curve models can be estimated either as a multivariate structural equation model (SEM; Duncan, Duncan and Strycker 2013) or as a univariate multilevel model (Raudenbush and Bryk 2002: 160; Goldstein 2011: 147; Hox, Moerbeek and van de Schoot 2018: 79). As the time span from 1980 to 2014 is rather long and a SEM would need a variable for each year, a multilevel model is preferred. Also, in a multilevel model, no missing values occur, as no fixed measurement occasions must be assumed (Hox, Moerbeek and van de Schoot 2018: 106). Based on all of these considerations, we chose the following three-level growth curve model for the bibliometric indicator y_{jic}, where individual trajectories (level 1) of researchers (level 2) are nested within age cohorts (level 3):

$$\begin{aligned}
\ln(y_{jic}) &= \beta_{00ic} + \beta_{1ic}(t_i - 2006) \\
\beta_{00ic} &= \beta_{00c} + u_{00ic} \\
\beta_{1ic} = \beta_{1c} + u_{1ic} \qquad & u_{00ic}, u_{1ic} \sim N\begin{pmatrix} \sigma^2_{u_{00}} & \sigma_{u_{001}} \\ \sigma_{u_{001}} & \sigma^2_{u_1} \end{pmatrix} \\
\beta_{00c} &= \beta_{00} + v_{00c} \\
\beta_{1c} = \beta_1 + v_{1c} \qquad & v_{00c}, v_{1c} \sim N\begin{pmatrix} \sigma^2_{v_{00}} & \sigma_{v_{001}} \\ \sigma_{v_{001}} & \sigma^2_{v1} \end{pmatrix},
\end{aligned} \tag{2}$$

where the publication year t is centered at the year 2006. The year 2006 is favored against the year 1980 (the first year of a publication in the sample) due to the fact that the starting point of CCES is 2006, and therefore, the year effect vanishes in 2006 (for $t_i = 2006$: β_0 (t_i-2006) = 0). In this way, other 'treatment' effects can be more easily identified (Galbraith, Bowden and Mander 2017: 5; Hox, Moerbeek and van de Schoot 2018: 110f). Due to more general time trends in growth of science (Bornmann and Mutz 2015), the overall timeline from 1980 to 2014 was of primary interest in our study and was given preference over the individual timelines starting from the first publications of a researcher, which would require centering on the publication year of the first publication of each researcher.

The individual trajectories of bibliometric indicators of a researcher can be represented by an individual random intercept, u_{00ic}, and a random slope of the year trend, u_{1ic}, and their corresponding variance–covariance matrix. The same is true for the cohort effects with random intercept and slope v_{00c} and v_{1c} for each cohort c. This model makes it possible to model not only the average linear time trends (fixed effects: β_{00}, β_1), but also the individual trajectories of researchers and cohorts, represented by the random effects model aspect. We can, thus, speak of a *cohort-sequential model* (Klaiber, Seeling and Mutz 2002; Hox, Moerbeek and van de Schoot 2018: 109). In addition, covariates can be added to the model that can explain the interindividual differences in intraindividual changes over time (e.g. age and year of PhD). These could essentially be represented as interactions. We also tested whether in addition to the linear and exponential trends there were also quadratic and cubic time trends.

(4) *Micro impact—multiple membership*: To estimate the *micro impact*, i.e. the intensity of participation in a project (see Section 2.2.3), we chose a multiple membership model (Goldstein 2011: 255f), in which for each publication year and researcher, using dummy variables (0/1), we coded the projects in which the researcher participated in (see Table 2). In addition, a zero project was coded for the FTE of the researcher's work and publication activity outside of the research center. To include the FTEs for each project, the FTEs were entered into the design matrix $D[D_{kjic}]$ instead of the ones (dummy variable). From this, the following model components resulted for $k = 1$ to K CCES projects (Cafri, Hedeker and Aarons 2015: 409f):

$$\ln(y_{jic}) = \beta_{00} + \sum_{k=1}^{K} D_{kjic} u_{2k} \qquad u_{21}, u_{22}, \ldots, u_{2K} \sim N(0, \sigma^2_{u2}), \tag{3}$$

where $u_{21}, \ldots, u_{2k}$ are the project effects as random effects, σ^2_{u2} the corresponding variance component, and D_{kjic} is the corresponding design matrix with the FTEs for each project per publication year and researcher.

(5) *Macro impact—segmented regression*: To test whether there is a *macro impact* of participation in CCES on the bibliometric indicators, we computed a segmented regression, which is a commonly used statistical approach for analysis of interrupted time series (Sauter, Mutz and Munro 1999; Wagner et al. 2002; Ramsay et al. 2003). Three situations are differentiated (no CCES, CCES phase 1, and CCES phase 2) and coded using dummy variables (0/1). Phases 1 and 2 account for an average and an individual change over time (interrupted time series). These effects can be interpreted causally, because according to the potential outcome concept (Rubin 2005), both the expected value under control (before CCES) and the expected value under treatment (phases 1 and 2) are available for each researcher (Mutz and Daniel 2012a, 2012b). From the differences between these expected values, individual and average causal effects of CCES participation can be calculated while controlling for all individual factors. The model components can be formulated as follows (Wagner et al. 2002: 302f):

$$\begin{aligned}
\ln(y_{jic}) = \beta_{00} + \beta_3(t_{jic} > 2005) + \beta_4(t_{jic} > 2010) \\
+ u_{3i}(t_{jic} > 2005) \quad u_{3i} \sim N(0, \sigma^2_{u3}),
\end{aligned} \tag{4}$$

where β_3 is the average causal effect of phases 1 and 2 (>2005) and β_4 is the additional average causal effect of phase 2

compared with phase 1. The random effect u_{3i} denotes the ICE of the two CCES phases for researcher i with the corresponding variance component σ^2_{u3}. Additional 'time after treatment effects' can be considered by including t_{jic}-2005 or t_{jic}-2010 in the model (Wagner et al. 2002: 302).

From the five statistical model components, a hierarchically nested sequence of increasingly complex models can be generated that represent different model assumptions (e.g. cohort effect, kind of polynomial trend, and effects of covariates), whereby the model components 'segmented regression' (macro impact) and 'multiple membership' (micro impact), as different models of the treatment effect, are not combined.

The individual models are then compared using the Bayesian information criterion (BIC). The smaller the BIC, the better the model fits the data. Models and the associated model components are rejected and discarded if the model components do not improve the BIC. The statistical analyses were carried out with a procedure in SAS software (PROC GLIMMIX) using maximum likelihood estimation/Laplace approximation (SAS Institute Inc. 2014: 3052f).

In econometrics and sociology, longitudinal data are usually modeled by fixed effects regression focusing on average effects (Allison 2009). To consider this alternative modeling strategy, additionally, a *fixed effects segmented regression model* was estimated (assuming residuals are not auto correlated), which consisted of five components: the effect of being a CCES publication or not, a quadratic trend model, the effects of the two phases, a time-lagged outcome variable ($y_{(j-1)ic}$), and the overall fixed effect for each researcher a_i, which may correlate with the predictor variables (a major difference to the growth curve model).

5 Results

5.1 Model comparison

The different model assumptions were formulated as statistical models for the three dependent variables of research performance, which could then be estimated using the data. The models are hierarchically nested, that is, derived from other models that are shown in Table 3 in the column labeled 'base' (e.g. M_3 from M_2). Instead of showing the model parameters of each model, the previous models are evaluated comparatively. We used the BIC as a relative measure for the model comparison. The model comparison allowed us to identify the crucial models and thus to rule out more complex model assumptions (e.g. cohort effects and time after treatment effect) at this stage.

The effect sizes were expressed in absolute units (e.g. number of publications). Effect size in terms of proportion of explained variance is only relevant for models that include predictors. For count regression data, several *R*-squared measures have been proposed (Cameron and Windmeijer 1996; Heinzl and Mittlböck 2003).

In addition to the null model (M_0), which contains only one random intercept for each researcher (i.e. u_{00ic}, Eq. 2), we tested whether the impact on the bibliometric indicators differed between CCES publications and non-CCES publications (M_1). Growth curve models are a class of models that describe the individual development of researchers over time, depicted in an individual linear regression with time as a predictor (M_2). A cohort effect model also includes the possible effect of age cohorts (M_3). With a polynomial time trend (M_4), the linear time trend is abandoned in favor of a quadratic polynomial ($y = b_0 + b_1x + b_2x^2$). With the next model component, a causal impact model (M_5), we tested whether there were individual effects of the projects with inclusion of the FTEs on the bibliometric indicators (micro impact). Of central importance are the models M_6 (macro impact) and M_7 (time after treatment), in which the average causal effects were estimated using segmented regression. Model M_8 tested whether there were different ICEs for each researcher. Models M_9–M_{15} provided indications concerning the effect of external variables on the individual growth process.

Regarding the variable 'number of publications' (scientific productivity), we found that in addition to the differentiation between CCES publications and non-CCES publications (M_1), the inclusion of the growth curve models (M_2, M_3, and M_4) led to great improvement of the BIC. For the variables 'number of citations' (scientific impact) and 'number of coauthors' (integration into the scientific community) the inclusion of further model components also led to the improvement of the BIC, but the improvement was comparatively small. As expected, across all three variables, the variability of the researchers in their individual trajectories played an important role. In addition, we found a causal effect of research center participation (M_5, M_6, and M_8). We also found a micro effect when including not only the FTEs, but also and especially an average causal effect of the research center (M_5) as well as ICEs (M_8). In contrast, in all three cases, the covariates did not lead to any appreciable improvement of the model. This also means that the person cluster (M_{10}) had no effect. The person cluster primarily differentiates between the 170 participating researchers and the 28 researchers (comparison group) who did not participate in CCES.

The growth curve model outperformed the fixed effects segmented regression (M_{16}) with respect to all outcome variables, also because the fixed effects regression considerably increases the number of estimated parameters (e.g. for each researcher), which in turn increases the BIC. For all outcome variables, statistically significant treatment effects can be found.

In sum, the model comparison shows that participation in the research center had a positive effect on all three dimensions of research performance—both overall (average causal effect) and regarding the individual development of a researcher (ICEs).

5.2 Model interpretation

In the following, we present the results of the parameter estimation for the models that were selected on the basis of the model comparison (M_0, M_8). This is done in comparison with a basic or null model that allows only the intercept of the otherwise fixed polynomial regression model varying across researchers (Eq. 2). Overall, the models fit the data well. The Pearson χ^2/df was close to 1.00. The Poisson distribution assumption was not violated. Each of the selected models represents one of the three dimensions of research performance.

5.2.1 *Average and individual causal effects on 'number of publications' (scientific productivity)*

The estimates for the segmented regression component in model M_8 indicate the average causal effect per researcher per year that participation in the different phases of the research center had on the researchers' number of publications (Table 4). For phase 1, the effect was $\beta_5 = 0.15$ and for phase 2, it was $\beta_6 = 0.1$, which means that the two phases had a comparable effect. To obtain the effect of both phases together, we added the two for a combined value of 0.25. As considerably more non-CCES publications were available than

Table 3. Model comparison for the three dependent variables

		Number of publications/NB		Total number of citations/NB		Number of coauthors/NB	
No	Model description	Base	BIC	Base	BIC	Base	BIC
Basic models							
M_0	Intercept—only	–	17,687.9	–	30,438.9		22,281.1
M_1	CCES/non-CCES	M_0	17,096.0	M_0	30,422.2	M_0	22,190.3
Growth curve models							
M_2	Linear growth curve model	M_1	15,091.2	M_1	30,227.6	M_0	21,668.3
M_3	Cohort effect	M_2	15,043.3	M_2	30,136.5	M_2	21,665.0
M_4	Polynomial time trend	M_3	14,972.5	M_3	29,680.3	M_2	21,662.6
Causal impact models							
M_5	Micro impact	M_4	14,927.8	M_4	29,591.0	M_4	21,612.8
M_6	Macro impact: ACEs	M_4	14,969.0	M_4	29,629.6	M_4	21,667.6
M_7	Time after treatment	M_6	14,973.7	M_6	29,514.8	M_6	21.674.2
M_8	Macro impact: ICEs	M_6	14,897.5	M_7	29,505.5	M_6	21,633.9
Individual CCES trajectories							
M_9	Individual CCES trajectories	M_8	14,905.1	M_8	29,508.7	M_8	21,618.9
Predictors of growth							
M_{10}	Person cluster	M_8	14,931.6	M_8	29,546.4	M_8	21,685.5
M_{11}	Gender	M_8	[a]	M_8	29,497.6	M_8	21,646.0
M_{12}	Institution budget	M_8	14,905.0	M_8	29,521.0	M_8	21,655.3
M_{13}	Institution: ETH or not	M_8	14,909.0	M_8	29,524.0	M_8	21,658.7
M_{14}	Number of researchers (FTE)	M_8	14,910.4	M_8	29,492.0	M_8	21,647.6
M_{15}	Covariates (e.g. year of PhD)	M_8	14,913.5	M_8	29,531.4	M_8	21,693.9
M_{16}	Fixed effects segmented regression	M_6	15,366.1	M_6	124,160.8	M_6	37,644.59

Notes: ICEs, individual causal effects; ACEs, average causal effects.

[a]Model estimation was not plausible (missing parameter values, zero standard errors, . . .).

CESS publications, the overall model estimation was based on the total number of publications because model estimation and testing is more efficient for large sample sizes than for small ones. Therefore, the specific effect 'CCES versus non-CCES' publications were not tested directly, but all publications (CCES + non-CCES) were compared non-CCES publications. Expressed in the form of publications per year, for $e^{\beta 0 + \beta 1 + \beta 5 + \beta 6} = e^{1.28 + 0.26 + 0.25}$ we had a value of 5.99 publications (CCES and non-CCES publications) compared with the phase before CCES participation, where the number of publications was $e^{\beta 0 + \beta 1} e^{1.28 + 0.26} = 4.66$. This means that CCES participation had an annual effect per researcher of approximately 1 1/3 more publications, when holding all other factors (e.g. time course) constant.

Likewise telling is the growth curve model that described the individual trajectory of a researcher. With the parameters (β_0, β_2, β_3, and β_4) there was nonlinear weakened growth with negative quadratic (β_3) and cubic components (β_4) in addition to the linear component (β_2; Figure 1). With the CCES publication effect (CCES-Pub, β_1) we are able to compare the scientific productivity in the context of CCES to the scientific productivity beyond CCES: whereas on average $e^{\beta_0 + \beta_1} - e^{\beta_0} = e^{1.28 + 0.26} - e^{1.28} = 1.06$ annual publications were generated per researcher in the context of CCES, 3.60 ($e^{\beta_0} = e^{1.28}$) papers were published outside of CCES (non-CCES publications). Somewhat less than one-fourth of all annual publications of a researcher were thus published in the context of CCES.

In the random effects model, the individual trajectory of a researcher's publication activity, irrespective of any effect from participation in CCES, can be seen clearly in different cohorts (Table 4). The time course is cubic overall (Figure 1). Only the linear component of the trajectory, which is made up of an intercept and a slope of publication year ('pubyear'), varied across individuals, as well as the slope of phase 1, which represents the individual bibliometric impact of CCES. To interpret that trajectory, we can use the variance und covariance components (e.g. $\sigma^2_{001(2)}$, $\sigma_{201(2)}$) and correlation coefficients (e.g. $\rho_{011(2)}$) that correspond with the 'random effects': There were differences in the intercepts and slope of 'pubyear', which means that researchers' publication careers began in very different ways, with different increases over time (slope). It is interesting that there is a high positive correlation between the individual intercept and the individual slope of a researcher, $\rho_{011(2)} = 0.70$, that is, a high number of publications at the start of CCES in 2006 (and, eventually, the start of his or her career in general) is associated with a strong increase in the number of publications in the following years, and vice versa. However, this is modified when looking at the cohorts for, which a negative relationship between intercept and slope was found ($\rho_{012} = -0.88$). In other words, the higher the average number of publications at the start of CCES in an age cohort (or the start of the age cohort in general, e.g. in the year 1999), the less steep the growth curve of this cohort and vice versa. This is a 'ceiling effect': For a cohort with a high level in scientific productivity in 2006, there is not much room left to increase their publication level in comparison to a cohort with a low level of scientific productivity in 2006.

Of particular importance is the statistically significant variance component of phase 1, $\sigma^2_{221(2)}$ of 0.20, which indicated that participation in CCES also had ICEs on a researcher's publication activity. In other words, 95% of the ICEs lie within a confidence interval of $\pm 1.96\sqrt{0.20} = \pm 0.877$ around the average causal effect of CCES participation, $\beta_5 = 0.15$, in phase 1. Expressed in units of publications, the ICEs for researchers varies between ($e^{\beta_0 + \beta_1 + \beta_5 - 0.877} - e^{\beta_0 + \beta_1} =$) −2.43 and ($e^{\beta_0 + \beta_1 + \beta_5 + 0.877} - e^{\beta_0 + \beta_1} =$) 8.36 publications. In other words, participation in CCES (despite the positive average

Table 4. Results for selected models for 'number of publications' (logarithmic transformed)

		Models			
		M_0		M_8	
Predictor	Parm	Estim	SE	Estim	SE
Fixed effects					
Intercept	β_0	1.29*	0.04	1.28*	0.09
CCES-Pub (=yes)	β_1			0.26*	0.02
Pubyear	β_2			0.41*	0.08
Pubyear**2	β_3			−0.25*	0.04
Pubyear**3	β_4			−0.05*	0.02
Segmented regression					
Phase 1 (=yes)	β_5			0.15*	0.06
Phase 2 (=yes)	β_6			0.10*	0.04
Random effects					
Level 1: Researcher					
Intercept	$\sigma^2_{001(2)}$	0.31**	0.03	0.25**	0.04
Intercept-pubyear	$\sigma_{011(2)}$			0.15**	0.03
	$\rho_{011(2)}$			0.70	
Pubyear	$\sigma^2_{111(2)}$			0.18**	0.04
Phase 1-Intercept	$\sigma_{201(2)}$			−0.09**	0.03
	$\rho_{201(2)}$			−0.40	
Phase 1-pubyear	$\sigma_{211(2)}$			−0.08**	0.03
	$\rho_{211(2)}$			−0.40	
Phase 1	$\sigma^2_{221(2)}$			0.20**	0.04
Level 2: Cohort					
Intercept	σ^2_{002}			0.15**	0.06
Intercept-pubyear	σ_{012}			−0.09**	0.03
	ρ_{012}			−0.88	
Pubyear	σ^2_{112}			0.06**	0.03
Pearson χ^2/df		1.79		0.85	
−2LogLiklihood		17, 677.4		14, 841.6	
BIC		17, 687.9		14, 897.5	

*P < 0.05 (*t*-value, $df_0 = 3{,}413$, $df_8 = 3{,}408$, $df_{16} = 3{,}403$),
**P < 0.05 (*z*-test).

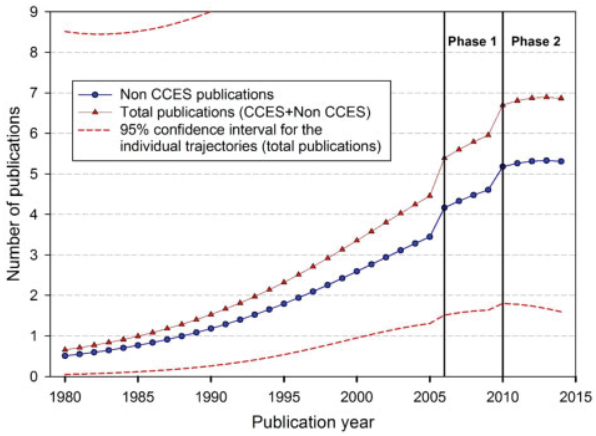

Figure 1. Predicted mean growth curve for number of publications (cumulative).

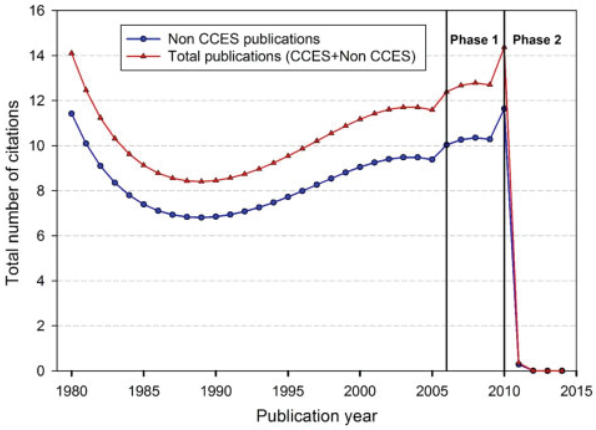

Figure 2. Predicted mean growth curve for number of citations (5-year citation window and cumulative).

effect) can also have had, individually, a negative effect on the number of publications.

As described above, the evaluation approach allows us to examine not only the macro impact but also the micro impact. The micro impact is the effect of the individual CCES project on a researcher's publication activity compared with the researcher's publication activity outside CCES (non-CCES project). Here we took into account the aspect of intensity, assessed in FTEs. This finds expression in model M_5 (micro impact), which also did well in the model comparison. Instead of a complete overview of the parameter estimates, however, we report only the crucial variance component, σ^2_P that described the variability of these project effects: This amounted to $\sigma^2_P = 0.12$. Expressed as micro impacts, the project effects varied in number of publications (CCES and non-CCES) per year and researcher from $(e^{\beta_0+\beta_1-1.96\sqrt{0.12}} - e^{\beta_0+\beta_1}) = -2.12$ publications to $(e^{\beta_0+\beta_1+1.96\sqrt{0.12}} - e^{\beta_0+\beta_1}) = 4.19$ publications.

5.2.2 *Average and individual causal effects on 'number of citations' (scientific impact)*

The variable 'number of citations' per researcher and year showed a striking cubic curve over time (Figure 2). On average, the citations decreased in the 1990s, which can also be attributed to different starting time points of publication activity, and then rose again up to 2010, with a dramatic decline after 2010, which is reflected in the negative sign of the regression coefficient (β_2, β_3, and β_4; Table 5). This decline occurs due to the citation window of 5 years. More recent publications simply have a lower probability of being cited than older publications.

Regarding the model estimations (M_8), we found an average effect per researcher and year that participation in the different phases of the research center had on the number of received citations (Table 5). For phase 1, the effect was 0.09 (β_5) and for phase 2, it was 0.15 (β_6). Expressed in the form of citations per year, for $e^{\beta_0+\beta_1+\beta_5+\beta_6} = e^{2.22+0.21+0.09+0.15}$ there was a value of 14.44 citations compared with the phase before CCES with a number of citations of $e^{2.22+0.21} = 11.35$; this means that CCES had an annual effect per researcher of approximately 3.09 more citations, when holding all other factors constant.

Due to the problem of the citation windows, the 'time after effects' ($\beta_7 = 0.57$, $\beta_8 = -3.66$, $\beta_{16} = -1.20$, and $\beta_{17} = 0.70$) are not interpreted.

Also regarding this second dimension of research performance, we found individual trajectories, represented by the random effects 'intercept' and 'pubyear' and the corresponding variance components ($\sigma^2_{001(2)}$ and $\sigma^2_{111(2)}$). Individual trajectories varied strongly,

Table 5. Results for selected models for 'number of citations' (logarithmic transformed)

		Models			
		M_0		M_8	
Predictor	Parm	Estim	SE	Estim	SE
Fixed effects					
Intercept	β_0	2.12*	0.04	2.22*	0.08
CCES-Pub (=yes)	β_1			0.21*	0.04
Pubyear	β_2			−0.28	0.27
Pubyear**2	β_3			−0.63*	0.26
Pubyear**3	β_4			−0.21*	0.08
Segmented regression					
Phase 1 (=yes)	β_5			0.09	0.07
Phase 2 (=yes)	β_6			0.15*	0.06
Time after-phase 1	β_7			0.57	0.41
Time after-phase 2	β_8			−3.66*	0.40
Random effects					
Level 1: Researcher					
Intercept	$\sigma^2_{001(2)}$	0.34**	0.04	0.30**	0.04
Pubyear	$\sigma^2_{111(2)}$			0.28**	0.07
Phase 1	$\sigma^2_{221(2)}$			0.10**	0.03
Level 2: Cohort					
Intercept	σ^2_{002}			0.01	0.02
Pubyear	σ^2_{112}			0.08	0.08
Scale	α	0.68**	0.02	0.45**	0.01
Pearson χ^2/df		1.1		1.09	
−2LogLiklihood		30,423.1		29,453.0	
BIC		30,438.9		29,505.5	

*P < 0.05 (*t*-value, $df_0 = 3{,}471$, $df_8 = 3{,}463$, $df_{16} = 3{,}454$),
**P < 0.05 (*z*-test).

Table 6. Results for selected models for 'number of coauthors' (logarithmic-transformed)

		Models			
		M_0		M_8	
Predictor	Parm	Estim	SE	Estim	SE
Fixed effects					
Intercept	β_0	1.35*	0.03	1.26*	0.04
CCES-Pub (=yes)	β_1			0.12*	0.03
Pubyear	β_2			0.21*	0.05
Pubyear**2	β_3			−0.15*	0.04
Pubyear**3	β_4			−0.03	0.02
Segmented regression					
Phase 1 (=yes)	β_5			0.08	0.05
Phase 2 (=yes)	β_6			0.07*	0.03
Random effects					
Level 1: Researcher					
Intercept	σ^2_{00}	0.13**	0.02	0.20**	0.03
Intercept-pubyear	σ_{01}			0.06**	0.02
	ρ_{01}			0.43	
Pubyear	σ^2_{11}			0.10**	0.02
Phase 1-Intercept	σ_{20}			−0.10**	0.03
	ρ_{20}			−0.57	
Phase 1-pubyear	σ_{21}			−0.07**	0.03
	ρ_{21}			−0.61	
Phase 1	σ^2_{22}			0.14**	0.03
Scale	α	0.18**	0.006	0.12**	0.005
Pearson χ^2/df		1.2	1.1		
−2LogLiklihood		22,265.3		21,560.2	
BIC		22,281.1		21,633.9	

*P < 0.05 (*t*-value, $df_0 = 3$, 414, $df_8 = 3{,}465$, $df_{16} = 3{,}458$),
**P < 0.05 (*z*-test).

also within the cohorts (σ^2_{002} and σ^2_{112}), which are not shown in Figure 2. Of particular interest were the ICEs of researchers, which were described with the variance component of phase 1, $\sigma^2_{221(2)} = 0.10$. The ICEs of CCES participation (compared with the time before CCES) were thus in an interval (with a probability of 0.95) from $(e^{\beta_0+\beta_1+\beta_5-1.96\sqrt{0.10}} - e^{\beta+\beta_1}=) -4.67$ to $(e^{\beta_0+\beta_1+\beta_5+1.96\sqrt{0.10}} - e^{\beta_0+\beta_1}=)$ 11.74 citations per researcher and year.

A scale parameter of $\alpha = 0.45$ indicated that a negative binomial distribution, which came from overdispersion in the count data, fit the data better than a Poisson model with α restricted to 0.

For the additional model for the effects of CCES projects (M_5; micro impact), we found a variance component parameter for the projects of $\sigma^2_p = 1.90$. Expressed as number of citations for all publications (CCES and non-CCES) per researcher and year, the project effects varied from $(e^{\beta_0+\beta_1-1.96\sqrt{1.9}} - e^{\beta_0+\beta_1}=) -10.49$ citations to $(e^{\beta_0+\beta_1+1.96\sqrt{1.96}} - e^{\beta_0+\beta_1}=)$ 156.80 citations.

5.2.3 *Average and individual causal effects on 'number of coauthors' (integration into the scientific community)*

Regarding the model estimations (M_8), we found an average effect per researcher and year that participation in the different phases of the research center had on number of coauthors (Table 6). For phase 1, the effect was 0.08 (β_5) and for phase 2, it was 0.07 (β_6). Expressed in the form of number of coauthors per researcher and per year, for $e^{1.26+0.12+0.08+0.07}$ there was a value of 4.6 coauthors compared with the phase before CCES with a number of publications (CCES and non-CCES publications) of $e^{1.26+0.12} = 3.97$, when holding all other factors constant. The time course of the number of coauthors was similar to that of the variable 'number of publications' (see Figure 3).

We again found strong individual differences between the researchers, which were also expressed in the variance/covariance components (σ^2_{00}, σ^2_{11}, and σ_{01}). Regarding the number of coauthors, the ICEs of CCES (compared with the time before CCES) were in an interval (with a probability of 0.95) from $(e^{\beta_0+\beta_1+\beta_5-1.96\sqrt{0.14}} - e^{\beta_0+\beta_1}=) -1.91$ to $(e^{\beta_0+\beta_1+\beta_5+1.96\sqrt{0.14}} - e^{\beta_0+\beta_1}=) +4.99$ coauthors per researcher per year ($\sigma^2_{22} = 0.14$).

For the additional model for the effects of CCES projects (M_5; micro impact), we found a variance component parameter for the projects of $\sigma^2_p = 0.08$, but it was not statistically significant ($z = 1.03$, $P > 0.05$). For this reason, single project effects are not interpreted.

6. Discussion

The global emergence of research centers has challenged traditional evaluation approaches as they are widely used to assess universities, departments, or individual researchers. Building on existing approaches, we introduced with this study a theoretically and methodologically refined approach for the ex post evaluation of research centers. The demonstration of the approach highlighted not only its major strengths but also a few limitations. Beyond the theoretical

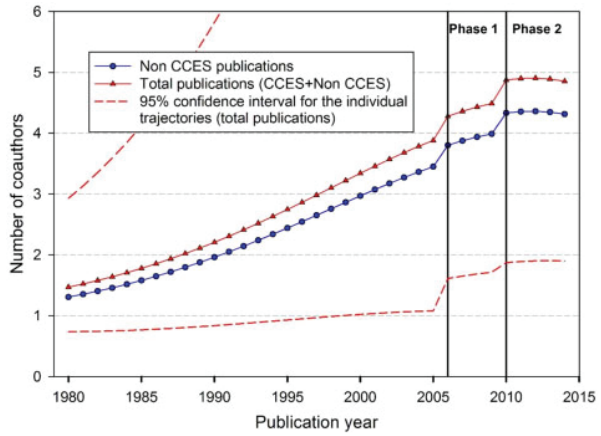

Figure 3. Predicted mean growth curve for number of coauthors (cumulative).

and methodological contributions, the concrete results of the evaluation have implications for research policy.

6.1 Strengths of the evaluation approach

One strength of the approach is its theoretical foundation, with the STHC model providing the central line of argumentation. From there, three characteristics of research centers and their participants were identified as major challenges to existing evaluation approaches: (1) the diversity of the participants ('diversity'), (2) at what moment in time the participants join and leave the research center ('transition'), and (3) the intensity of their participation ('intensity'). The evaluation approach introduced with this article addresses the three aspects and provides remedies by means of fine-grained data, the underlying research design, and an advanced statistical approach.

The data capture the 'diversity' of the participants through various covariates, including gender, scientific background, and academic age (year of PhD). Another data-related issue that the evaluation approach accounts for is the information on the researcher's affiliation with projects and phases of CCES, as retrieved from the archival data, thereby addressing the challenge of transition. The intensity of the researcher's participation is captured by the data on the FTE they spent at the research center per year. Another data-related strength of the evaluation approach is the reliance on archival and retrospectively collected bibliometric data, which safeguards the objectivity of the evaluation approach.

The quasi-experimental research design (*longitudinal interrupted accelerated design*) is central to the evaluation approach and primarily addresses the challenge of transition. It assumes that the affiliation with the research center interrupts the individual time series of publication trajectories in a way that could not be predicted based on the previous development of the bibliometric indicators, which is interpreted as a 'treatment' effect. The research design, then, is quite robust, as it withstands the major threats to internal and external validity, as described above (see Section 4.3). As a quasi-experimental within-group design, moreover, it does not require a randomized control group in the classical experimental sense.

Last, the statistical approach addresses all three aspects, by including growth curve modeling, a cohort-sequential model, a multiple membership model, and two ways of treatment operationalization. The statistical approach is quite comprehensive, as it not only allows the average causal effects to be assessed but also accounts for the ICEs, cohort effects, micro and macro effects of research center participation, as well as whether the effect on the research performance of the participant is restricted to the research center context or beyond. In particular, a great deal of value is added to the evaluation approach by the ability to identify the ICEs, as fixed effects models, conventionally applied, would fail to detect these.

6.2 Limitations of the evaluation approach

What is true for all longitudinal research designs is that the time horizon considered must cover a significant length. In the context of the evaluation approach proposed in this article, this implies that the assessment of the effect on research performance is constrained to more senior researchers with a 'long enough' academic career. Future research should indeed focus more on the career development of junior researchers to assess the capacity-building effect of research center participation (Corley, et al. 2017). Another crucial aspect for the evaluation approach is the availability of data. The data collection process required to apply the evaluation approach was rather time-consuming, as it entailed the coding from comprehensive archival data to a relational database to qualify for statistical analyses. Another, more critical limitation arises from the potential lags between the work on a publication and actual publication date as given in the annual reports. One solution could be to require reporting schemes to make such a differentiation. Overall, this article is conceived as giving an indication of how future reporting guidelines could be designed to facilitate the quantitative evaluation of research centers.

Another possible limitation of the study is the validity of the annual reports on which the study is based. It can be argued that the numbers, e.g. share of the total working time at the research center, respond more to bureaucratic rules than reflecting any realities of time allocation. However, this limitation does not necessarily apply to all data taken from the annual reports. The annual project reports had been prepared very meticulously as a base for the annual achievement report of the whole research center. For example, publications listed in the annual project reports were cross-checked by the research center management to avoid multiple mentions, thereby increasing the quality of the data.

Last, we acknowledge that some authors call for a differentiated use of the bibliometric method for evaluative purposes. We would like to highlight that the evaluation approach we propose is only suitable for assessing the research performance of a research center. However, and needless to say, other alternative evaluation approaches would be required to capture societal impacts, economic impacts, or educational or capacity-building impacts (Lin and Bozeman 2006; Corley 2007; Youtie and Corley 2011; Bornmann 2013; Rivers and Gray 2013; Hicks et al. 2015; Husbands Fealing et al. 2018; Kassab, Schwarzenbach and Gotsch 2018; Kassab 2019).

6.3 Implications

As outlined in the introduction, researchers are somewhat critical of research centers (and inter- and transdisciplinary research, for that matter) in the face of a supposed career-relevant conflict of interest. The results of this study, however, provide evidence that this skepticism is unfounded. Quite strikingly, on average, participation in research centers entails no disadvantages for researchers as far their

overall research performance is concerned, as measured in scientific productivity, the citation impact of their output, and their integration within the scientific community. These findings confirm the results of several previous studies, and yet the results presented here can be traced back to a distinctly more accurate methodological basis. The implications of this study are good news for intrinsically motivated researchers as well as for research policymakers, and finally, they are also invaluable in helping to improve the image of research centers and of inter- and transdisciplinary research in general.

Notes

1. As has been described above, research centers pursue a variety of goals. In this article, we focus on the research aspect, which we understand in terms of research performance.
2. Between 2013 and 2015, OK worked as an executive assistant to the CCES management. Afterwards he joined the Professorship for Social Psychology and Research on Higher Education at ETH Zurich, where he conducted this study in collaboration with the co-authors R.M. and H.D.D.
3. Project partners are those researchers whose names were on the project proposals, and who headed a subunit of the project.

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References

Allison, P. D. (2009) *Fixed Effects Regression Models*. London: Sage.

Ávila-Robinson, A., and Sengoku, S. (2017) 'Multilevel Exploration of the Realities of Interdisciplinary Research Centers for the Management of Knowledge Integration', *Technovation*, 62–63: 22–41.

Bishop, P. R., Huck, S. W., Ownley, B. H., Richards, J. K., and Skolits, G. J. (2014) 'Impacts of an Interdisciplinary Research Center on Participant Publication and Collaboration Patterns: A Case Study of the National Institute for Mathematical and Biological Synthesis', *Research Evaluation*, 23: 327–40.

Bliese, P. D., Adler, A. B., and Flynn, P. J. (2017) 'Transition Processes: A Review and Synthesis Integrating Methods and Theory', *Annual Review of Organizational Psychology and Organizational Behavior*, 4: 263–86.

Boardman, C., and Bozeman, B. (2007) 'Role Strain in University Research Centers', *The Journal of Higher Education*, 78: 430–63.

Boardman, C., and Corley, E. A. (2008) 'University Research Centers and the Composition of Research Collaborations', *Research Policy*, 37: 900–13.

Bornmann, L. (2013) 'What Is Societal Impact of Research and How Can It Be Assessed? A Literature Survey', *Journal of the American Society for Information Science and Technology*, 64: 217–33.

Bornmann, L., and Mutz, R. (2015) 'Growth Rates of Modern Science: A Bibliometric Analysis Based on the Number of Publications and Cited References', *Journal of the Association for Information Science and Technology*, 66: 2215–22.

Bornmann, L., Mutz, R., and Daniel, H.-D. (2009) 'The Influence of the Applicants' Gender on the Modeling of a Peer Review Process by Using Latent Markov Models', *Scientometrics*, 81: 407–11.

Bozeman, B., and Boardman, C. (2003) *Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community, Transforming Organizations Series*. Washington, DC: IBM Endowment for the Business of Government.

Bozeman, B., and Corley, E. A. (2004) 'Scientists' Collaboration Strategies: Implications for Scientific and Technical Human Capital', *Research Policy*, 33: 599–616.

Bozeman, B., and Rogers, J. D. (2002) 'A Churn Model of Scientific Knowledge Value: Internet Researchers as a Knowledge Value Collective', *Research Policy*, 31: 769–94.

Bozeman, B., Dietz, J., and Gaughan, M. (2001) 'Scientific and Technical Human Capital: An Alternative Model for Research Evaluation', *International Journal of Technology Management*, 22: 716–40.

Bunton, S. A., and Mallon, W. T. (2006) 'The Impact of Centers and Institutes on Faculty Life: Findings from a Study of Basic Science and Internal Medicine Faculty at Research-Intensive Medical Schools', *Academic Medicine*, 81: 734–43.

Cafri, G., Hedeker, D., and Aarons, G. A. (2015) 'An Introduction and Integration of Cross-Classified, Multiple Membership, and Dynamic Group Random-Effects Models', *Psychological Methods*, 20: 407.

Cameron, A. C. (1998) *Regression Analysis of Count Data*. Cambridge: CUP.

Cameron, A. C., and Windmeijer, F. A. G. (1996) 'R-Squared Measures for Count Data Regression Models with Applications to Health-Care Utilization', *Journal of Business & Economic Statistics*, 14: 209–20.

Cañibano, C., and Bozeman, B. (2009) 'Curriculum Vitae Method in Science Policy and Research Evaluation: The State-of-the-Art', *Research Evaluation*, 18: 86–94.

Christensen, L. B., and Waraczynski, M. A. (1988) *Experimental Methodology*. Boston: Allyn and Bacon.

Clark, W. C. (2007) 'Sustainability Science: A Room of Its Own', *Proceedings of the National Academy of Sciences of the United States of America*, 104: 1737–8.

Corley, E. A. (2007) 'A Use-and-Transformation Model for Evaluating Public R&D: Illustrations from Polycystic Ovarian Syndrome (PCOS) Research', *Evaluation and Program Planning*, 30: 21–35.

Corley, E. A., and Gaughan, M. (2005) 'Scientists' Participation in University Research Centers: What Are the Gender Differences?', *The Journal of Technology Transfer*, 30: 371–81.

Corley, E. A., Bozeman, B., Zhang, X., and Tsai, C.-C. (2017) 'The Expanded Scientific and Technical Human Capital Model: The Addition of a Cultural Dimension', *The Journal of Technology Transfer*, 44: 681–99.

Coryn, C. L. S., Hattie, J. A., Scriven, M., and Hartmann, D. J. (2007) 'Models and Mechanisms for Evaluating Government-Funded Research: An International Comparison', *American Journal of Evaluation*, 28: 437–57.

Cozzens, S. E., and Turpin, T. (2000) 'Processes and Mechanisms for Evaluating and Monitoring Research Outcomes from Higher Education: International Comparisons', *Research Evaluation*, 9: 3–4.

Dietz, J. S., and Bozeman, B. (2005) 'Academic Careers, Patents, and Productivity: Industry Experience as Scientific and Technical Human Capital', *Research Policy*, 34: 349–67.

Duncan, T. E., Duncan, S. C., and Strycker, L. A. (2013) *An Introduction to Latent Variable Growth Curve Modeling: Concepts, Issues, and Application*. New York: Taylor & Francis Group.

Elkins, T., and Keller, R. T. (2003) 'Leadership in Research and Development Organizations: A Literature Review and Conceptual Framework', *The Leadership Quarterly*, 14: 587–606.

Feller, I., Ailes, C. P., and Roessner, J. D. (2002) 'Impacts of Research Universities on Technological Innovation in Industry: Evidence from Engineering Research Centers', *Research Policy*, 31: 457–74.

Ferguson, L. (2004) 'External Validity, Generalizability, and Knowledge Utilization', *Journal of Nursing Scholarship*, 36: 16–22.

Fleiss, J. L., Levin, B., and Paik, M. C. (2003) *Statistical Methods for Rates and Proportions*, 3rd edn. Hoboken, New Jersey: John Wiley & Sons.

Galbraith, S., Bowden, J., and Mander, A. (2017) 'Accelerated Longitudinal Designs: An Overview of Modelling, Power, Costs and Handling Missing Data', *Statistical Methods in Medical Research*, 26: 374–98.

Gaughan, M., and Bozeman, B. (2002) 'Using Curriculum Vitae to Compare Some Impacts of NSF Research Grants with Research Center Funding', *Research Evaluation*, 11: 17–26.

Gaughan, M., and Ponomariov, B. (2008) 'Faculty Publication Productivity, Collaboration, and Grants Velocity: Using Curricula Vitae to Compare Center-Affiliated and Unaffiliated Scientists', *Research Evaluation*, 17: 103–10.

Geiger, R. L. (1990) 'Organized Research Units—Their Role in the Development of University Research', *The Journal of Higher Education*, 61: 1–19.

Goldstein, H. (2011) *Multilevel Statistical Models*, 4th edn. Hoboken, New Jersey: John Wiley & Sons.

Gray, B. (2008) 'Enhancing Transdisciplinary Research through Collaborative Leadership', *American Journal of Preventive Medicine*, 35 (Supplement): S124–32.

Heinzl, H., and Mittlböck, M. (2003) 'Pseudo R-Squared Measures for Poisson Regression Models with Over-or Underdispersion', *Computational Statistics & Data Analysis*, 44: 253–71.

Hicks, D., Wouters, P., Waltman, L., De Rijcke, S., and Rafols, I. (2015) 'The Leiden Manifesto for Research Metrics', *Nature*, 520: 429.

Hilbe, J. M. (2014) *Modeling Count Data*. Cambridge: CUP.

Hox, J. J., Moerbeek, M., and van de Schoot, R. (2018) *Multilevel Analysis: Techniques and Applications*, 3rd edn. New York: Routledge.

Husbands Fealing, K., Lane, J. I., King, J. L., and Johnson, S. R. (2018) *Measuring the Economic Value of Research: The Case of Food Safety*. Cambridge: CUP.

Ikenberry, S. O., and Friedman, R. C. (1972) *Beyond Academic Departments: The Story of Institutes and Centers*. London: Jossey-Bass.

Kassab, O. (2019) 'Does Public Outreach Impede Research Performance? Exploring the "Researcher's Dilemma" in a Sustainability Research Center', *Science and Public Policy*, 46: 710–20.

Kassab, O., Schwarzenbach, R. P., and Gotsch, N. (2018) 'Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain', *GAIA - Ecological Perspectives for Science and Society*, 27: 226–34.

Klaiber, V., Seeling, U., and Mutz, R. (2002) 'Veränderung der Holzfeuchte im Rundholz von Fichten (*Picea abies* (L.) Karst.) in Abhängigkeit von Art und Dauer der Lagerung—Abschätzung Mittels Einer Kohorten-Sequenzanalyse [Reduction of Moisture Content in Logs of Norway Spruce (*Picea abies* (L.) Karst.) as a Function of Type and Duration of the Storage—Estimation with a Cohort Sequential Analysis]', *Allgemeine Forst- und Jagdzeitung*, 173: 162–72.

Kueffer, C. et al. (2012) 'Enabling Effective Problem-Oriented Research for Sustainable Development', *Ecology and Society*, 17: 8.

Landry, R., and Amara, N. (1998) 'The Impact of Transaction Costs on the Institutional Structuration of Collaborative Academic Research', *Research Policy*, 27: 901–13.

Lang, D. J. et al. (2012) 'Transdisciplinary Research in Sustainability Science: Practice, Principles, and Challenges', *Sustainability Science*, 7: 25–43.

Lee, S., and Bozeman, B. (2005) 'The Impact of Research Collaboration on Scientific Productivity', *Social Studies of Science*, 35: 673–702.

Lin, M. W., and Bozeman, B. (2006) 'Researchers' Industry Experience and Productivity in University–Industry Research Centers: A "Scientific and Technical Human Capital" Explanation', *The Journal of Technology Transfer*, 31: 269–90.

Mallon, W. T. (2006) 'The Benefits and Challenges of Research Centers and Institutes in Academic Medicine: Findings from Six Universities and Their Medical Schools', *Academic Medicine*, 81: 502–12.

McDowall, D., McCleary, R., Meidinger, E. E., and Hay, R. A. Jr. (1983) *Interrupted Time Series*. London: Sage.

Mittelstrass, J. (2011) 'On Transdisciplinarity', *Trames*, 15: 329–38.

Mutz, R., and Daniel, H.-D. (2012a) 'The Generalized Propensity Score Methodology for Estimating Unbiased Journal Impact Factors', *Scientometrics*, 92: 377–90.

Mutz, R., and Daniel, H.-D. (2012b) 'Skewed Citation Distributions and Bias Factors: Solutions to Two Core Problems with the Journal Impact Factor', *Journal of Informetrics*, 6: 169–76.

Mutz, R., Wolbring, T., and Daniel, H.-D. (2016) 'The Effect of the "Very Important Paper" (VIP) Designation in Angewandte Chemie International Edition on Citation Impact: A Propensity Score Matching Analysis', *Journal of the Association for Information Science and Technology*, 68: 2139–53.

OECD (2007) *Revised Field of Science and Technology (FOS) Classification in the Frascati Manual, Working Party of National Experts on Science and Technology Indicators*. Paris: OECD.

Ponomariov, B., and Boardman, C. (2010) 'Influencing Scientists' Collaboration and Productivity Patterns through New Institutions: University Research Centers and Scientific and Technical Human Capital', *Research Policy*, 39: 613–24.

Ramsay, C. R., Matowe, L., Grilli, R., Grimshaw, J. M., and Thomas, R. E. (2003) 'Interrupted Time Series Designs in Health Technology Assessment: Lessons from Two Systematic Reviews of Behavior Change Strategies', *International Journal of Technology Assessment in Health Care*, 19: 613–23.

Raudenbush, S. W., and Bryk, A. S. (2002) *Hierarchical Linear Models: Applications and Data Analysis Methods*. London: Sage.

Rivers, D., and Gray, D. O. (2013) 'Evaluating Cooperative Research Centers: A Strategy for Assessing Proximal and Distal Outcomes and Associated Economic Impacts', in Link A. N.and Vonortas N. (eds) *Handbook on the Theory and Practice of Program Evaluation*, pp. 291–322. Cheltenham: Edward Elgar Publishing.

Rogers, J. D., Youtie, J., and Kay, L. (2012) 'Program-Level Assessment of Research Centers: Contribution of Nanoscale Science and Engineering Centers to US Nanotechnology National Initiative Goals', *Research Evaluation*, 21: 368–80.

Rubin, D. B. (2005) 'Causal Inference Using Potential Outcomes: Design, Modeling, Decisions', *Journal of the American Statistical Association*, 100: 322–31.

Sabharwal, M., and Hu, Q. (2013) 'Participation in University-Based Research Centers: Is It Helping or Hurting Researchers?', *Research Policy*, 42: 1301–11.

Santoro, M. D., and Gopalakrishnan, S. (2001) 'Relationship Dynamics between University Research Centers and Industrial Firms: Their Impact on Technology Transfer Activities', *The Journal of Technology Transfer*, 26: 163–71.

SAS Institute Inc. (2014) *SAS/STAT® 13.2 User's Guide*. Cary, NC: SAS Institute Inc.

Sauter, U. H., Mutz, R., and Munro, B. D. (1999) 'Determining Juvenile-Mature Wood Transition in Scots Pine Using Latewood Density', *Wood and Fiber Science*, 31: 416–25.

SDSN (2017), 'Getting Started with the SDGs in Universities: A Guide for Universities, Higher Education Institutions, and the Academic Sector. Australia, New Zealand and Pacific Edition', Sustainable Development Solutions Network—Australia/Pacific. Melbourne: SDSN. <http://ap-unsdsn.org/wp-content/uploads/University-SDG-Guide_web.pdf>

Shadish, W. R., Cook, T. D., and Campbell, D. T. (2002) *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Boston: Houghton Mifflin Company.

Slaughter, S., Campbell, T., Holleman, M., and Morgan, E. (2002) 'The "Traffic" in Graduate Students: Graduate Students as Tokens of Exchange between Academe and Industry', *Science, Technology & Human Values*, 27: 282–312.

Smith, A. M., Lai, S. Y., Bea-Taylor, J., Hill, R. B. M., and Kleinhenz, N. (2016) 'Collaboration and Change in the Research Networks of Five Energy Frontier Research Centers', *Research Evaluation*, 25: 472–85.

Spangenberg, J. H. (2011) 'Sustainability Science: A Review, an Analysis and Some Empirical Lessons', *Environmental Conservation*, 38: 275–87.

Stokols, D., Hall, K. L., Taylor, B. K., and Moser, R. P. (2008a) 'The Science of Team Science: Overview of the Field and Introduction to the Supplement', *American Journal of Preventive Medicine*, 35: 77–89.

Stokols, D. et al. (2008b) 'The Ecology of Team Science: Understanding Contextual Influences on Transdisciplinary Collaboration', *American Journal of Preventive Medicine*, 35 (Supplement): S96–S115.

Su, X. (2014) 'Academic Scientists' Affiliation with University Research Centers: Selection Dynamics', *Research Policy*, 43: 382–90.

Talwar, S., Wiek, A., and Robinson, J. (2011) 'User Engagement in Sustainability Research', *Science and Public Policy*, 38: 379–90.

The Madrillon Group Inc. (2010) *Evaluation of Research Center and Network Programs at the National Institutes of Health—A Review of Evaluation Practice, 1978-2009*. Bethesda: The Madrillon Group Inc.

Wagner, A. K., Soumerai, S. B., Zhang, F., and Ross-Degnan, D. (2002) 'Segmented Regression Analysis of Interrupted Time Series Studies in Medication Use Research', *Journal of Clinical Pharmacy and Therapeutics*, 27: 299–309.

Way, S. F. et al. (2017) 'The Misleading Narrative of the Canonical Faculty Productivity Trajectory', *Proceedings of the National Academy of Sciences of the United States of America*, 114: E9216–23.

Wen, J., and Kobayashi, S. (2001) 'Exploring Collaborative R&D Network: Some New Evidence in Japan', *Research Policy*, 30: 1309–19.

West, S. G., Cham, H., and Liu, Y. (2014) 'Causal Inference and Generalization in Field Settings: Experimental and Quasi-Experimental Designs', in H. T. Reis and C. M. Judd (eds) *Handbook of Research Methods in Social and Personality Psychology*, pp. 49–80. Cambridge: CUP.

Wiek, A. et al. (2014) 'Toward a Methodological Scheme for Capturing Societal Effects of Participatory Sustainability Research', *Research Evaluation*, 23: 117–32.

Willett, J. B., Singer, J. D., and Martin, N. C. (1998) 'The Design and Analysis of Longitudinal Studies of Development and Psychopathology in Context: Statistical Models and Methodological Recommendations', *Development and Psychopathology*, 10: 395–426.

Youtie, J., and Corley, E. A. (2011) 'Federally Sponsored Multidisciplinary Research Centers: Learning, Evaluation, and Vicious Circles', *Evaluation and Program Planning*, 34: 13–20.

Youtie, J., Kay, L., and Melkers, J. (2013) 'Bibliographic Coupling and Network Analysis to Assess Knowledge Coalescence in a Research Center Environment', *Research Evaluation*, 22: 145–56.

Ziegler, R., and Ott, K. (2011) 'The Quality of Sustainability Science: A Philosophical Perspective', *Sustainability: Science, Practice, & Policy*, 7: 31–44.

4.2 Does public outreach impede research performance? Exploring the "researcher's dilemma" in a sustainability research center

Researchers and universities are increasingly urged to communicate their findings to the general public (Andrews et al. 2005, Johnson et al. 2014, Thune et al. 2016). Despite the broad consensus about the necessity of this task, researchers are still reluctant to engage in public outreach activities (Poliakoff and Webb 2007, Bentley and Kyvik 2011). The major reason lies in the fact that the trend towards more accountability steers researchers and their groups into a dilemma situation: on the one hand, the academic "publish or perish" system pressurizes them to produce as many scientific publications as possible in the limited time available. At the same time, they are expected to dedicate a share of their capacities to so-called "public outreach activities", the outputs of which are barely or at least not adequately accounted for in the relevant metrics and career promotion (Ecklund et al. 2012, Martinez-Conde 2016). Empirically speaking, the jury is still out on how engagement in public outreach activities actually affects the research performance: While some scholars found engagement in public outreach to have a positive effect on a researcher's performance (Jensen et al. 2008, van Looy et al. 2011, Van der Weijden et al. 2012), others found the two activities to be independent, neither impeding nor improving the other (Gulbrandsen and Smeby 2005, Mostert et al. 2010). The approach used in the study at hand differs from previous ones in that it deals with the issue in the context of a research center in the field of sustainability science. This comes with at least two advantages: first, because a research center is an organizationally and temporally closed system in which the respective outputs – that is, scientific outputs and outputs from public outreach activities – can be clearly assigned to one another. And second, because sustainability science, as a very solution-oriented research field, is an exemplary context for the dilemma described above (Mobjörk 2010, Stock and Burton 2011, Shahadu 2016).

The *second article* carries out a series of analyses on the basis of CCES data, including descriptive statistics, correlation analysis, and multiple regression analysis. The empirical findings contribute to putting the "researcher's dilemma" into perspective. Some more than others, all six evaluation challenges are addressed by means of the archival and bibliometric data, as well as the inclusion of respective control variables.

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Does public outreach impede research performance? Exploring the 'researcher's dilemma' in a sustainability research center

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Abstract

Researchers and universities are increasingly urged to communicate their findings to the general public. Despite the broad consensus about the necessity of this task, researchers are still reluctant to engage in public outreach activities. One major reason is that while being somewhat time consuming, engagement in public outreach is not adequately reflected in the metrics that are relevant for career advancement. The study at hand examines to what extent this dilemma is empirically justified. A series of statistical analyses are carried out on the basis of data from a sustainability science research center in Switzerland. The study comes to the conclusion that research performance is overall positively associated to engagement in public outreach activities. This insight has implications for the academic incentive and evaluation system.

Key words: public outreach; research center; sustainability science; research performance

1. Introduction

The old dream of unconditional support for basic research is long over. Governmental budget cuts and global competition for research funds have maneuvered the classic 'ivory tower' university system into rough waters. Paradigmatic shifts labeled as diverse as mode 2 knowledge production (Gibbons et al. 1994; Nowotny et al. 2003), postacademic science (Ziman 2002), or the triple-helix of university–government–industry relations (Etzkowitz and Leydesdorff 2000) all highlight the increased expectation toward academic research to yield growth-inducing innovation and applied knowledge of societal relevance (D'Este et al. 2018; Hessels et al. 2009). Furthermore, mounting demands for public accountability have led to new policies in the allocation of funds, including the increased focus on prospective 'dissemination strategies' in grant proposals (Holbrook 2010), or even the earmarking of fixed percentages for reaching out to the tax-paying public (Martin 2011).

Not all researchers are pleased about this development because it steers them and their groups into a fundamental dilemma situation: on the one hand, the academic 'publish or perish' system pressurizes them to produce as many scientific publications as possible in the limited time available. At the same time they are expected to dedicate a share of their capacities to so-called 'public outreach activities', the outputs of which are barely or at least not adequately accounted for in the relevant metrics and career promotion. In other words, there is an evident mismatch between the academic's mandate and the academic reward system.

The jury is still out on how engagement in public outreach activities actually affects the research performance of individuals and their groups. The aim of this study is to shed some light into this research policy discourse. A few studies have already addressed this question empirically. The study at hand differs from previous studies in that it deals with the issue in the context of a research center in the field of sustainability science. This comes with at least two advantages: first, because a research center is an organizationally and temporally closed system in which the respective outputs—that is, scientific outputs and outputs from public outreach activities—can be clearly assigned to one another. And second, because sustainability science, as a very solution-oriented field of study, is an exemplary field for the dilemma described above.

The remainder of this article is structured as follows. Section 2 is a literature review. It is followed by the description of the case. In Section 4, data and methods are presented. Section 5 reports the results. The last section discusses the findings and draws conclusions for further research while consolidating the implications for research policy.

2.Public outreach and the researcher's dilemma

2.1 What are public outreach activities?

The role and responsibility of academia in finding solutions for the grand societal challenges of our time—like climate change, energy supply, urbanization, or sustainable mobility—is widely

acknowledged (SDSN 2017). The biggest shortcoming in this context, however, remains the ineffective linkage between knowledge and action. Originally assumed that research findings would simply 'trickle down' to where they would be needed, this somewhat unrealistic notion was soon replaced by the so-called 'transfer and translate model'. According to this model, 'research is characterized as a product that needs to be taken up by the relevant user communities. Activities to facilitate this transfer often include efforts to translate technical, jargon-laden science into terms that can be understood by the layperson' (Van Kerkhoff and Lebel 2006: 450).

Various terms have been utilized to name these efforts, including 'public outreach' (Andrews et al. 2005), 'science outreach' (Johnson et al. 2014), 'science communication' (Burns et al. 2003), 'popularization' (Myers 2003), 'knowledge dissemination' (Green et al. 2009), or 'public engagement' (Watermeyer 2015). Just as there is no real consensus on the terminology, there is also no common understanding on where 'research' ends and where 'public outreach' begins. The activities rather lie on a continuum of different genres 'from arcane technical laboratory discussions on the one end, via conference presentations, and published literature, to lectures and writings for wider audiences outside the peer group on the other end' (Bauer and Jensen 2011).

Rowe and Frewer (2005) suggested a straightforward typology, differentiating three types of public outreach activities: by 'public communication' they mean the dissemination of information by researchers to the public. This type is characterized by a one-way information flow and no direct involvement of the recipients. In the type 'public consultation', as the name suggests, researchers actively seek and obtain information and feedback from the public. In the third type, 'public participation', information is exchanged between researchers and the public through a bidirectional and dialog-based manner (Rowe and Frewer 2005: 255). What all three types have in common is the aim to create societal added value by processing and communicating research findings. The types differ, as described, with regard to the direction of knowledge flow on the one hand, but also in terms of the effort needed. The largest effort is associated with public participation, which is underpinned by a complex transdisciplinary process (Lang et al. 2012). In turn, the smallest effort is attached to public communication, because researchers design the output themselves without involving representatives of sectors beyond academia (Jensen et al. 2008). Therefore, it is also the type that is most frequently applied in practice, especially when public outreach activities are carried out as pro forma activities, as is succinctly described by Bauer and Jensen (2011): 'the intrinsic motivation of engage the public because it is fun or part of a personal ethos is crowded-out by institutional incentives and defined duties that are set by institutional commitments'. The study at hands follows the typology of Rowe and Frewer (2005) and defines public outreach activities in the way they understand public communication, that is, a one-way dissemination of knowledge for the benefit of society.

2.2 The 'researcher's dilemma': which factors play a role?

The researcher's dilemma is based on the consideration that researchers have to decide whether to spend their time exclusively on classical academic activities to produce scientific publications, or to additionally engage in public outreach activities. While the former is rewarded by the current academic system, as evident in rankings or recruitment processes, for example, researchers barely receive recognition for the latter, if any at all. This 'persistent ambiguity' (Olmos-Peñuela et al. 2015) has profound negative implications on the motivation and ultimately on the quality of the activities.

Several studies have focused on identifying which factors play a role in whether or not researchers engage in public outreach activities (Bentley and Kyvik 2011; Kuehne and Olden 2015; Llopis et al. 2018). Some researchers, according to one study, have an intrinsic motivation to contribute to society (Greenwood and Riordan 2001). Others feel a moral obligation toward the tax-paying public (Martinez-Conde 2016; Peters 2013). For some, the commitment even goes hand in hand with an increased feeling of their own reputation (Liang et al. 2014). Again, others enjoy conveying knowledge to children through play, also because they believe these activities can improve their teaching and communication skills (Andrews et al. 2005).

It has also been found that academic age plays a role, with public outreach increasing with experience (Bauer and Jensen 2011; Poliakoff and Webb 2007). Academic identity in terms of past experiences was also identified as a possible determinant (Olmos-Peñuela et al. 2015), or the disciplinary background, with the distinction that public outreach is more frequently conducted in 'soft sciences' (i.e. humanities and social sciences) rather than by representatives of 'hard sciences', including natural sciences or medicine (Winter 2004). Finally, some studies also show differences in nationality (Miller 1998), gender (Johnson et al. 2014), and organizational contexts (Johnson et al. 2014; Thune et al. 2016).

Factors that have been found to hinder researchers from engaging in public outreach activities include lack of time (Andrews et al. 2005; Gascoigne and Metcalfe 1997; Poliakoff and Webb 2007), doubts about own communication skills (Besley and Tanner 2011), lack of interest (Checkoway 2001), lack of information on public outreach opportunities, and lack of support for conducting public outreach activities (Andrews et al. 2005; Kim and Fortner 2008). Most consistently, the lack of the 'right incentives' and 'appreciation' by supervisors, colleagues, departments, and the academic system in general were identified as obstacles (Amey et al. 2002; Andrews et al. 2005; Jensen et al. 2008; Martín-Sempere et al. 2008; Wise et al. 2002). In other words, public outreach activities are commonly considered as 'incompatible with a successful academic career' (Martinez-Conde 2016), even as professionally risky (Ecklund et al. 2012).

2.3 How do public outreach activities and research performance relate?

As the results of numerous studies have shown, there is a fundamental tension between engaging in public outreach activities and the rewards researchers presumably receive for them. Rumor holds that public outreach activities will come at the expense of research performance. This understanding is reinforced by a few yet often cited surveys conducted by the Royal Society (2006) and the Wellcome Trust (2000), which reported their respondents to have said 'public engagement was done by those who were "not good enough" for an academic career' (Royal Society 2006). Another prominent example for this belief is the so-called 'Sagan effect'. Named after the astrophysicist Carl Sagan, it suggests that researchers with too much public visibility are not taken seriously by their peers, but are rather seen as popular scientists with a lack of rigor, which in turn weakens their reputation in expert communities and can thus negatively influence their careers. Paradoxically, over the course of his career Sagan

averaged one journal article per month (Jensen et al. 2008), so the question necessarily arises whether the researcher's dilemma is really legitimate, or whether the opportunity costs are just an 'urban legend'?

The few larger-scale empirical studies that have been conducted on this matter come to mixed results. Either they find that the engagement in public outreach activities has a positive effect on researchers performance (Bentley and Kyvik 2011; Jensen et al. 2008; van der Weijden et al. 2012; Van Looy et al. 2011), or that they are independent, neither impeding nor improving the other (Gulbrandsen and Smeby 2005; Mostert et al. 2010). The assumption that public outreach is per se bad for research performance has, to the best of the author's knowledge, no quantitative empirical evidence.

2.4 Testing the relationship in the context of a research center

The study at hand aims to take up this discussion and provide empirical evidence that differs from previous ones in that it is assessed in the context of a research center, which is understood here as an 'entity within a university that exists chiefly to serve a research mission, is set apart from the departmental organization, and includes researchers from more than one department' (Bozeman and Boardman 2003: 17).

There are at least two advantages in studying the phenomenon in the context of a research center: first, most of the previous studies have taken into account all public outreach activities and scientific publications of researchers or their groups without the respective outputs necessarily showing any immediate association in terms of content. The research center, in contrast, pursuing a concise mission, is a temporally-closed system in which public outreach activities can be clearly assigned to corresponding scientific publications. Second, previous studies have distinguished researchers on the basis of their disciplinary backgrounds. Although it certainly makes sense to consider the different traditions of the disciplines, the context of the research center allows focusing on the commonalities of researchers, namely the field of research they are engaged in. This enables a comparative assessment across researchers and their groups.

The specific case at hand concerns a research center in the field of sustainability science, a field 'focused on practical application of theories, tools and methodologies from different disciplines and bringing together scientists and stakeholders to define important research questions and objectives in dealing with sustainability challenges' (Shahadu 2016). In contrast to highly specialized basic research, the inter- and transdisciplinary character of sustainability science makes it a prime example for the dilemma described above (Kassab et al. 2018). Before exploring the relationship empirically, the two following sections describe the case under scrutiny, the data, and the methods applied.

3. Case description: the Competence Center Environment and Sustainability of the ETH Domain[1]

The ETH Domain is a union of six research institutions in Switzerland and comprises two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as the four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag). Directly supervised by the Swiss Federal Council and the Parliament, the ETH Board is responsible for the strategic management of the ETH Domain and undertakes supervision of its institutions. In 2006, the ETH Board established four inter- and transdisciplinary research centers and provided funds for an operation of ten years (two phases: 2006–2010 and 2011–2016). This study looks at one of these four centers, the Competence Center Environment and Sustainability (CCES), which engaged more than 800 people and operated between 2006 and 2016 to facilitate inter- and transdisciplinary research, education, and public outreach within and between the institutions that constitute the ETH Domain. According to its business plan (CCES 2005), CCES was established with the mission to 'identify the relevant questions and the appropriate answers to foster the sustainable development of a future society while minimizing the impact on the environment' (CCES 2005). To comprehensively achieve this mission, CCES operated in three areas of activity: research, education, and public outreach. Activities at CCES were clustered in eighteen projects along five thematic areas of environment and sustainability science: (1) Climate and Environmental Change, (2) Sustainable Land Use, (3) Food, Environment, and Health, (4) Natural Resources, and (5) Natural Hazards and Risks. Some exemplary projects included *OPTIWARES*, in which researchers worked on optimizing the use of wood as a renewable energy source, or the *GEOTHERM* project, which investigated the sustainable use of enhanced geothermal systems, or the *RECORD* project, which studied the ecological, hydrological, and social dynamics in the context of river restoration.

After the completion of the first phase (2006–2010), the eighteen projects went through a rigorous review and eight of them were selected for the second phase (2011–2016). Since some of the team's constellations changed remarkably between the two phases, projects of the second phase are not regarded as follow-up projects of the first phase but rather as new projects, adding up to twenty-six projects overall.

4. Data and methods

4.1 Archival data: research performance and public outreach activities

As part of the administrative routine at the research center, the principle investigators of the twenty-six projects compiled detailed reports on an annual basis. This archival data in the form of ninety-nine annual project reports, kindly provided by the CCES management, constituted the main data source of this study. The reports disclose a broad spectrum of information related to the research center activities. For the purpose of this study, all relevant data regarding the (1) research performance and (2) the public outreach activities were retrieved on the project level (Mostert et al. 2010). With ninety-nine, the number of observations (see Table 1) is equivalent to the number of annual reports.

As to the research performance, participants of CCES published $N = 496$ peer-reviewed journal articles. The corresponding bibliometric data were retrieved from the *Clarivate Analytics Web of Science* and attributed to one of the research center's twenty-six projects. For each of the peer-reviewed journal articles, the total number of citations was retrieved and cumulated on the project level.

The public outreach activities were documented in the annual project reports on the basis of a sixfold reporting scheme, as

Table 2. Descriptive statistics of key variables.

Variable	Variable name	Number of observations (annual reports)	Mean	SD	Min	Max
Set 1: Research performance						
Number of peer-reviewed journal articles	*no_pub*	99	4.78	5.48	0	24
Total number of citations	*total_cit*	99	133.08	236.02	0	1294
Prior research performance	*prepot*	99	4.76	3.18	1.98	17.26
Set 2: POA						
Type 1: Publications for stakeholders outside the scientific community	*POA_publications*	99	0.73	1.58	0	9
Type 2: Press interviews	*POA_interviews*	99	2.13	4.79	0	30
Type 3: Courses, seminars, and workshops for stakeholders outside the scientific community	*POA_courses*	99	0.96	2.41	0	17
Type 4: Public information events for local or regional authorities or residents	*POA_events*	99	0.53	1.29	0	9
Type 5: Events, courses, or other activities at schools	*POA_schools*	99	0.35	1.00	0	6
Type 6: Other events	*POA_other*	99	0.19	0.74	0	6
Set 3: Project-related variables						
Project team size	*groupsize*	99	39.64	13.84	16	78
Accumulated FTE of leadership team	*fte_leadership*	99	1.08	0.56	0.2	2.7
Number of female team members	*female_number*	99	9.73	4.38	3	20
Number of Master and Doctoral students	*phdmas_number*	99	9.92	5.07	3	24
Relative share of third-party contributions	*third_party_share*	99	0.52	0.60	0	3.84

POA, public outreach activities.

Table 1. Six types of POA.

	Type	Abbreviation	Instances
1	Publications for stakeholders outside the scientific community (e.g. public administration)	*POA_publications*	72
2	Press interviews (e.g. newspapers, radio/TV broadcasts)	*POA_interviews*	211
3	Courses, seminars and workshops for stakeholders outside the scientific community	*POA_courses*	95
4	Public information events for local or regional authorities or residents	*POA_events*	52
5	Events, courses, or other activities at schools	*POA_schools*	35
6	Other events	*POA_other*	19
	Total		484

POA, public outreach activities.

indicated in Table 2. Patents, a seventh category, were not considered in the data collection process, because of their marginal occurrence (less than one per year in total) over the course of the research center's activity. In sum and over the twenty-six projects, the public outreach activities at CCES added up to $N = 484$.

4.2 Variables

The archival data was coded for the purpose of this study and can be classified into three sets (see Table 1):

The first set consists of variables that are related to research performance. First is the variable 'number of peer-reviewed journal articles' (*no_pub*), which represents the cumulative number of respective publications per year and per project. The variable 'total number of citations' (*total_cit*) is a bibliometric measure of the citation frequency, also cumulated per year and per project. The variable 'prior research performance' (*prepot*) is a measure of the average research performance of the team members before their participation in the research center. In creating this variable, the number of peer-reviewed journal articles of all participants was taken into account, meaning their entire publication history before they participated in the research center. For the time before the research center, the project teams were virtually assembled. Since the citation frequency has a decisive informative value about research performance over time, the indicator was calculated from the cumulative number of *total_cit* divided by the number of publications (*no_pub*) divided by the number of leading researchers (one principle investigator and the leaders of the subunits of the projects). For example, one of the projects had a leadership team consisting of seven researchers. Their entire publication output prior to participating in the research center (first publication until and including 2006) amounted to 276 publications. Until the year before their research center participation (which in this case started in 2007), those publications had accumulated a total of 14,993 citations. The 'prior research performance' (*prepot*) variable is thus: $14{,}993/276/7 = 7.76$. In sum, for each of the twenty-six projects there is a value that describes the research performance before participation in the research center.

The second set of variables is the public outreach activities. These were coded according to their frequency, per year and per project, using the typology from the annual project reports (Table 2).

The third set is variables related to the respective projects. For each project in each year there is a variable for the 'project team size' (*groupsize*), which represents the headcount number of all

participants of the project, professors, senior researchers, Master and Doctoral students, project engineers, technicians, and laboratory staff. According to a study by van der Weijden et al. (2012), group size plays a decisive role in that 'there is a trade-off between societal orientation and trying to create a large research group'. Since not all participants are involved in research centers with identical workloads (Kassab et al., under review), there is another variable capturing 'accumulated FTE of leadership team' (*fte_leadership*), including the principal investigator and the leaders of the subunits of the projects. For each year there is also a variable for 'number of female team members' (*female_number*) indicating the absolute number of women for each project, since Johnson et al. (2014) found there to be gender-specific rationales for the commitment in public outreach activities. As various studies have identified a correlation between the engagement in public outreach activities and the academic experience of researchers (Bauer and Jensen 2011; Jensen et al. 2008; Olmos-Peñuela et al. 2015), there is a variable for the absolute 'number of Master and Doctoral students' (*phdmas_number*) in the respective project per year. Finally, there is a variable of financial nature. CCES activities were financed in a threefold funding scheme, consisting of (1) CCES contributions, (2) in-kind contributions from the participating institutions, and (3) third-party contributions from private sector or public administration. While the former two financial sources come from within the academic realm, the latter represents the interaction with the 'outside' world (Spaapen and Van Drooge 2011). For every project, the 'relative share of third-party contributions' of the overall budget was computed on an annual basis (*third_party_share*).

4.3 Methods

The analysis consists of three stages, starting with a graphical description of the data to identify patterns for the relationship between research performance and public outreach activities. This first step allows an intuitive comparative assessment of the six types of public outreach activities and the number of scientific publications at the level of the twenty-six projects of the research center.

Second, a Spearman's correlation is calculated to assess the relationship between research performance, the public outreach activities, and the other relevant variables. Spearman's correlation is preferred to Pearson's correlation because the variables are not normally distributed and because it is not as sensitive to potential outliers.

Third, a series of multiple regression analyses are run to examine the strength and statistical significance of the relationship between research performance and the six different types of public outreach activities. Since the dataset contains observations for twenty-six projects with an operative of three to five years (yielding ninety-nine data rows), the models must be specified to account for within-group (or within-project) correlation (Liang and Zeger 1986). Therefore, the analyses are run using cross-sectional time series generalized estimating equation (GEE) models with robust standard errors 'clustering' on individual observations (using the 'xtgee' command in STATA 14). GEE models estimate population-averaged treatment effects (instead of subject-specific treatment effects) and account for within-group correlations among responses over time and allow for time-varying covariates (Karimli et al. 2015; Zinn et al. 2007). The unique project identifier (*project_id*) is specified as panel variable. In both stages two and three, research performance is operationalized by two different dependent variables. On the one hand, by the number of publications (*no_pub*), and on the other, by the citation frequency (*total_cit*). For each public outreach activity, a separate model is calculated for each of the dependent variables, including six control variables each (see Tables 4 and 5).

5. Results

5.1 Stage 1: different strategies and patterns for public outreach

Figure 1 illustrates the twenty-six projects of the research center along the horizontal axis. For each project, the public outreach activities are displayed stacked as bars. The bars are sorted from left to right by the number of publications in each project (large dot). The values are cumulated over the entire duration of the respective project and weighted according to the average size of the project team (publications per capita). The small dots show the relative share of third-party funds that the project has raised over its duration as a proportion of the overall budget.

Based on this initial analysis, three patterns can be identified: First, there were projects in the research center that had a higher per capita research performance (number of publications) than public outreach activities (eleven projects). Second, in exactly the opposite direction, there were projects in the research center that carried out more public outreach activities per capita than producing scientific publications (eleven projects). And third, there were projects in which both types of output roughly balanced each other out (four projects).

In other words, on the basis of this analysis, there is no conclusive indication of how research performance and public outreach activities are related. Rather, the composition of the bars indicates that the individual projects differed greatly in terms of their public outreach strategy. This not only underlines the thematic diversity of the projects, but also shows their different management approaches, existing experiences in the team, and also which projects have generated results to potentially spark public interest, which is particularly evident when looking at the number of press interviews (Type 2). No obvious pattern can be inferred in terms of the small dots that mark the share of third-party funds of the overall budget.

5.2 Stage 2: Spearman's correlation

As Table 3 indicates, there are statistically significant and moderately positive correlations between four out of six types of public outreach activities and the number of publications (*no_pub*). No statistically significant correlation exists between the number of publications and press interviews (Type 2) and events, courses, or other activities at schools (Type 5). As to the total citations, there is evidence suggesting positive correlation between all types of public outreach activities but the press interviews (Type 2). Overall, some types of public outreach activities seem to be more closely related to scientific publishing activities than others, with the press articles (Type 2) showing no statistically significant correlation in either case.

5.3 Stage 3: multiple regression analyses

5.3.1 Number of publications as dependent variable

Table 4 displays the results of six multiple regression analyses each using a cross-sectional time series GEE model to examine the effect of individual types of public outreach activities on the number of publications, controlling for various project-specific characteristics as introduced above. The results suggest a positive and statistically significant relationship between the number of publications and five

Table 3. Correlation between public outreach activities and research performance indicators.

			Spearman's ρ		N
		Variable name	Number of publications (*no_pub*)	Total citations (*total_cit*)	Annual project reports
POA	Type 1	*POA_publications*	0.31*	0.31*	99
	Type 2	*POA_interviews*	0.14	0.28	99
	Type 3	*POA_courses*	0.30*	0.38*	99
	Type 4	*POA_events*	0.21*	0.23*	99
	Type 5	*POA_schools*	0.15	0.21*	99
	Type 6	*POA_other*	0.32*	0.30*	99
POA (6-item scale, Cronbach's alpha = 0.62)		*POA_scale*	0.34*	0.45*	99
Control variables		*groupsize*	0.19	0.29*	99
		female_number	0.20*	0.25*	99
		phdmas_number	0.17	0.26*	99
		fte_leadership	0.24*	0.24*	99
		prepot	−0.11	−0.03	99
		third_party_share	0.05	0.18	99

POA, public outreach activities. Significance level: *P < 0.05.

Table 4. Multiple regression analyses with the number of publications as dependent variable.

Variables	(1) *no_pub*	(2) *no_pub*	(3) *no_pub*	(4) *no_pub*	(5) *no_pub*	(6) *no_pub*
POA_publications	0.136***					
	(0.0223)					
POA_interviews		0.0453***				
		(0.00673)				
POA_courses			0.0483***			
			(0.0169)			
POA_events				0.131***		
				(0.0246)		
POA_schools					0.0176	
					(0.0440)	
POA_other						0.161***
						(0.0366)
groupsize	−0.0199***	−0.0148**	−0.0119*	−0.0150**	−0.0148**	−0.0150**
	(0.00726)	(0.00700)	(0.00709)	(0.00730)	(0.00707)	(0.00711)
female_number	0.0565***	0.0350**	0.0453***	0.0380***	0.0510***	0.0495***
	(0.0141)	(0.0140)	(0.0139)	(0.0146)	(0.0138)	(0.0140)
phdmas_number	0.0654***	0.0584***	0.0424***	0.0519***	0.0509***	0.0523***
	(0.0164)	(0.0161)	(0.0163)	(0.0161)	(0.0160)	(0.0159)
fte_leadership	0.295***	0.271***	0.337***	0.278**	0.366***	0.340***
	(0.105)	(0.105)	(0.106)	(0.109)	(0.104)	(0.106)
prepot	0.0452**	0.0310	0.0419*	0.0423*	0.0367*	0.0372*
	(0.0228)	(0.0233)	(0.0221)	(0.0223)	(0.0222)	(0.0224)
third_party_share	−0.217***	−0.183**	−0.232***	−0.232***	−0.226***	−0.202**
	(0.0809)	(0.0784)	(0.0806)	(0.0808)	(0.0815)	(0.0812)
Constant	0.548**	0.708***	0.618**	0.759***	0.623**	0.614**
	(0.262)	(0.266)	(0.256)	(0.260)	(0.254)	(0.255)
Observations	99	99	99	99	99	99
Number of groups	26	26	26	26	26	26
Observations per group						
Min	3	3	3	3	3	3
Average	3.8	3.8	3.8	3.8	3.8	3.8
Max	5	5	5	5	5	5
Wald χ^2 (7)	89.77	102.52	66.40	85.55	59.29	79.20
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. Significance levels: ***P < 0.01, **P < 0.05, *P < 0.1.

Table 5. Multiple regression analyses with the total citations as dependent variable.

Variables	(1) *total_cit*	(2) *total_cit*	(3) *total_cit*	(4) *total_cit*	(5) *total_cit*	(6) *total_cit*
POA_publications	0.129***					
	(0.00510)					
POA_interviews		0.0594***				
		(0.00114)				
POA_courses			0.103***			
			(0.00272)			
POA_events				0.126***		
				(0.00467)		
POA_schools					−0.106***	
					(0.00986)	
POA_other						0.160***
						(0.00674)
groupsize	−0.00641***	−0.00452***	0.00215**	−0.00512***	−0.00130	−0.00587***
	(0.00116)	(0.00109)	(0.00108)	(0.00122)	(0.00121)	(0.00115)
female_number	0.135***	0.111***	0.129***	0.115***	0.129***	0.127***
	(0.00223)	(0.00213)	(0.00204)	(0.00235)	(0.00233)	(0.00220)
phdmas_number	0.0423***	0.0562***	0.0143***	0.0427***	0.0343***	0.0402***
	(0.00273)	(0.00268)	(0.00263)	(0.00278)	(0.00279)	(0.00268)
fte_leadership	0.559***	0.474***	0.563***	0.507***	0.575***	0.578***
	(0.0160)	(0.0151)	(0.0153)	(0.0169)	(0.0165)	(0.0159)
prepot	0.117***	0.0972***	0.121***	0.114***	0.104***	0.107***
	(0.00348)	(0.00345)	(0.00320)	(0.00350)	(0.00358)	(0.00337)
third_party_share	0.0157	0.0469***	0.0318***	−0.0279**	−0.0743***	0.0263**
	(0.0130)	(0.0129)	(0.0122)	(0.0137)	(0.0137)	(0.0129)
Constant	1.852***	1.984***	1.793***	2.128***	2.023***	2.018***
	(0.0463)	(0.0455)	(0.0434)	(0.0472)	(0.0480)	(0.0445)
Observations	99	99	99	99	99	99
Number of groups	26	26	26	26	26	26
Observations per group						
Min	3	3	3	3	3	3
Average	3.8	3.8	3.8	3.8	3.8	3.8
Max	5	5	5	5	5	5
Wald χ^2 (7)	7,455.59	10,197.47	9,441.46	7,215.96	6,295.28	7,862.83
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses.
Significance levels: ***P < 0.01, **P < 0.05, *P < 0.1.

types of public outreach activities, with the exception of events, courses, or other activities at schools (Type 5). For example, for every additional publication for stakeholders outside the scientific community (Type 1), a 0.136 unit increase in the number of publications is predicted, holding all other variables constant. Much smaller are the coefficients in the case of press interviews (Type 2; 0.045), or in the case of courses, seminars, and workshops for stakeholders outside the scientific community (Type 3; 0.048). Across all six models, the coefficients for the project team size (*groupsize*) and the relative share of the third-party contributions (*third_party_share*) show negative signs statistically different from zero. The sizes of the coefficients for the former, however, are very small (e.g. −0.002 in Model 1), while the ones of the latter are quite noticeable (−0.232 in Model 3). Almost all other coefficients of the covariates show positive and statistically significant correlations with the dependent variable, including the number of female team members (*female_number*), the number of Master and Doctoral students (*phdmas_number*), and the accumulated full-time equivalents (FTE) of the project leadership (*fte_leadership*). Overall, the results seem to lend support to the notion that public outreach activities are positively correlated to research performance in terms of the number of publications. As the STATA command used does not provide the *R*-squared values, the regression analyses were additionally run without the clustering 'xtgee' command (not reported in Table). Over the six models, the results indicate the predictors to explain between 14 and 20 per cent of the variance.

5.3.2 Total citations as dependent variable

Table 5 displays the results of six multiple regression analyses using the same statistical procedure and specifications as above to examine the effect of the public outreach activities on the total citations. Somewhat similar to what was found for the number of publications (Table 4), the results suggest a positive and statistically significant relationship as well. For every additional course, seminar, and workshop for stakeholders outside the scientific community (Type 3), a 0.103 unit increase in the number of total citations is predicted, holding all other variables constant. Events, courses, or other activities at schools (Type 5) again stand out as an exception, this time even showing a negative sign. Like with the number of publications, the coefficients for the project team size (*groupsize*) show negative signs and statistical significance in five out of six cases. Unlike above, the relative share of the third-party contributions (*third_party_share*) does not show negative signs throughout, but only for

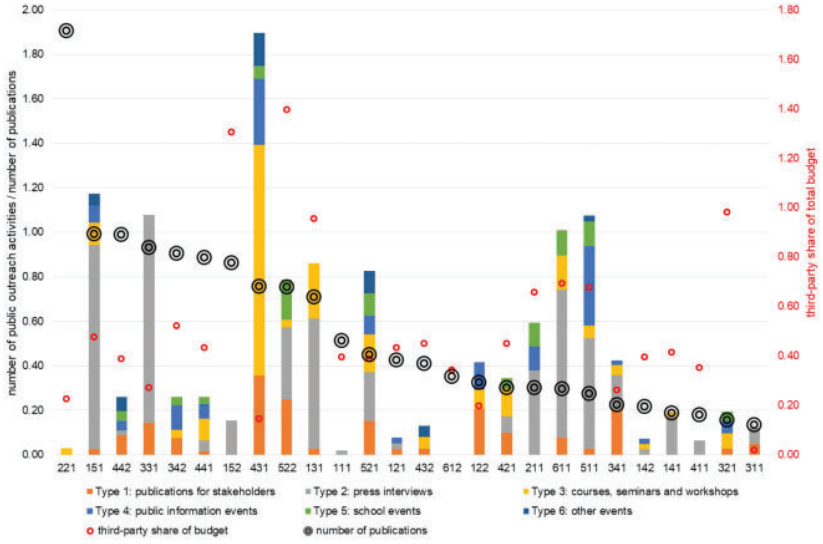

Figure 1. Public outreach activities by type and project, compared to number of peer-reviewed journal articles (cumulated over the entire research center operation; weighted by average project team size).

public information events for local or regional authorities or residents (Type 4) and events, courses, or other activities at schools (Type 5), however, with statistical significance in all cases. Almost all other coefficients of the covariates show positive and statistically significant correlations with research performance in terms of total citations, similar to the analyses above. In this case, the accumulated FTE of the project leadership (*fte_leadership*) stands out, predicting an increase of 0.563 units in the number of total citations for every additional course, seminar, and workshop for stakeholders outside the scientific community (Type 3). Summarizing, the empirical evidence corroborates that engaging in public outreach activities is positively correlated to total citations. Like above, the regression analyses were also run without the 'xtgee' command to determine the *R*-squared values (not reported in Table). Over the six models, the results indicate the predictors to explain between 17 and 26 per cent of the variance.

6. Discussion and conclusion

Researchers and universities are increasingly requested to translate and proactively communicate their findings to the tax-paying public. However, there is a belief among researchers that the time spent on public outreach activities comes at the cost of their core business, drafting and publishing scientific articles. In view of the prevailing 'publish or perish' mentality in academia, the demand for public outreach activities maneuvers researchers into an intricate dilemma situation.

On the basis of data from a research center in the field of sustainability science, this study investigated how engagement in public outreach activities is related to research performance. The context of a research center was especially suitable for this inquiry as scientific publications and public outreach activities are directly related to each other, as documented in the archival data. At the same time, sustainability science in particular is a field that aims to find solutions for the grand societal challenges of our time, which makes public outreach an indispensable activity for researchers.

Confirming the findings of some previous empirical investigations, this study concludes that there is no per se negative correlation between engaging in public outreach activities and the production of scientific publications. By means of three different types of analyses, this study thus provides further evidence not only that the researcher's dilemma is an 'urban legend', but also that in entails no disadvantage, especially in the context of a research center, to engage in the public dissemination of knowledge in addition to the conduct of research.

And yet, of course, it is not black or white. Not all types of public outreach activities are equally positively related to research performance. With regard to the number of publications, writing publications for stakeholders outside the scientific community (Type 1), organizing public information events for local or regional authorities or residents (Type 4), as well as staging other events (Type 6) has shown to have the strongest effect. Against the fact that these types in particular require substantial efforts in terms of time and organization, these findings are somewhat surprising. Interestingly, the same holds true for the alternative operationalization of research performance, the total citations. These results could be interpreted as meaning that both a cognitive 'translation' activity as well as immediate personal exchange with the public is positively associated with research performance. Thus, the results support the idea of 'productive interaction' (Spaapen and Van Drooge 2011), which assume that 'exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant'. According to this approach, the interaction brings added value for both sides, which is reflected in an increased research performance on the part of the researchers rather than in a reduced one. The findings also indicate that the project team size plays a noticeable role (Mostert et al. 2010; van der Weijden et al. 2012), showing a negative correlation with research performance. This may appear obvious, as a larger group needs more coordination, which can come at the expense of efficiency. In contrast, however, the results of the statistical analyses have underlined the importance of taking into account not only the number of researchers, but also the intensity of their participation in the project, using, for example, full-time equivalents (Kassab et al., under review). Another result of the study is that there are indeed gender- and experience-specific effects (Johnson et al. 2014). Controlled for the project team size, the absolute number of women and of Master and Doctoral students has a positive effect in both cases of research

performance and a significant effect in almost all types of public outreach. It seems that women are disproportionately involved in public outreach activities. Likewise, the emerging generation of researchers seems to be increasingly interested in these tasks. This contrasts with previous findings suggesting that public outreach activities were mostly taken care of by the more senior researchers (Bauer and Jensen 2011; Poliakoff and Webb 2007).

6.1 Limitations and further research

This study has a number of limitations, the five most relevant of which shall be discussed. Probably the most central one is the fact that it is not possible to make a final statement about the causal direction of the identified relationship: Does engaging in public outreach activities result in more scientific publications and citations? Or does the generation of more scientific publications increase the chance of conducting more public outreach activities? While there is already theoretical literature to explain both mechanisms, further qualitative micro-level research would be necessary to shed more light on this matter empirically.

Second, while there is a widely-recognized measure for the actual impact of scientific publications, namely citations, there is still nothing comparable with regard to public outreach activities. In this study, only the concrete activities were considered rather than their actual impact. The so-called 'altmetrics' (Bornmann et al. 2019; Costas et al. 2015; Piwowar 2013; Ravenscroft et al. 2017; Robinson-Garcia et al. 2018) could possibly provide a solution to this problem. Altmetrics are 'usually based on activity on social media platforms, which relates to scholars or scholarly content. Typical examples of altmetrics include tweets, mentions in blog posts, readership counts on Mendeley, posts, likes, and shares on social networks such as Facebook and Google Plus' (Bornmann and Haunschild 2017). While the focus on social media to indicate impact beyond academia is a promising way forward, their mainstream use is still largely undermined by a number of methodological issues that scholars of the field are working to resolve (Bornmann and Haunschild 2018a,b; Haunschild and Bornmann 2018).

Third, it was not possible to take into account the varying efforts associated with the different types of public outreach activities on the basis of the archival data. While press interviews are mostly written or co-written by professional journalists, which means little to no effort on the side of the researchers, organizing events with the local population, for example, entails numerous preparatory tasks with varying complexity. A survey among researchers could provide a valid weighting of the associated efforts.

Fourth, the data for the study were collected annually at the project level and not at the level of the individual researchers. Although there are indications that this type of analysis makes more sense at project team level (Mostert et al. 2010), mainly because of the division of labor, it would certainly be worthwhile to conduct a comparable study at the level of individual researchers.

Last and fifth, the study is based on data from a specific case of a research center in Switzerland, a highly developed and competitive country. Needless to say, this limits the generalizability of the results per se. Further research, for example, in the form of other case studies, would be required to see whether the pattern holds true in other countries, world regions, and academic systems. However, the results of the present study form a building block in the entire discussion about the relationship between scientific- and publicly-oriented output, as well as in the discussion about the evaluation and impact assessment of research centers.

6.2 Policy recommendations

The results of this study have raised further contentions about the researcher's dilemma described above: there is no negative correlation between research performance and engagement in public outreach activities. With this study, the question of the dilemma was investigated for the first time in the context of a research center. But this insight alone will not be sufficient to resolve it. What is rather needed is a cultural shift and opening of the academic evaluation system, as prominently exemplified by the forthcoming UK's 2021 Research Excellence Framework (REF). 'Impact', one of the REF's three underlying criteria, assesses 'reach and significance of impacts on the economy, society, culture, public policy or services, health, the environment or quality of life' and carries a weight of 25 per cent (REF 2019). This decision succinctly shows how research policy and research funding organizations can play a crucial role toward that shift. In times of global academic competitiveness, however, concerted action is required to make the cultural change happen in a systemic way. Because, as long as engagement in public outreach activities is not explicitly part of an assessment or academic promotion practice, researchers will continue to refrain from investing much time in them, regardless of whether they are intrinsically motivated or asked to do so solely for accountability reasons.

Note

1. For a more detailed description, please refer to Kassab et al. (2018).

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References

Amey, M. J., Brown, D. F., and Sandmann, L. R. (2002) 'A Multidisciplinary Collaborative Approach to a University-Community Partnership: Lessons Learned', *Journal of Higher Education Outreach and Engagement*, 7/3: 19–26.

Andrews, E. et al. (2005) 'Scientists and Public Outreach: Participation, Motivations, and Impediments', *Journal of Geoscience Education*, 53/3: 281–93.

Bauer, M. W., and Jensen, P. (2011) 'The Mobilization of Scientists for Public Engagement', *Public Understanding of Science*, 20/1: 3–11.

Bentley, P., and Kyvik, S. (2011) 'Academic Staff and Public Communication: A Survey of Popular Science Publishing across 13 Countries', *Public Understanding of Science*, 20/1: 48–63.

Besley, J. C., and Tanner, A. H. (2011) 'What Science Communication Scholars Think about Training Scientists to Communicate', *Science Communication*, 33/2: 239–63.

Bornmann, L., and Haunschild, R. (2017) 'Does Evaluative Scientometrics Lose Its Main Focus on Scientific Quality by the New Orientation Towards Societal Impact?', *Scientometrics*, 110/2: 937–43.

——, and —— (2018a) 'Do Altmetrics Correlate with the Quality of Papers? A Large-Scale Empirical Study Based on F1000Prime Data', *Plos One*, 13/5: e0197133.

——, and —— (2018b) 'Normalization of Zero-inflated Data: An Empirical Analysis of a New Indicator Family and Its Use with Altmetrics Data', *Journal of Informetrics*, 12/3: 998–1011.

——, ——, and Adams, J. (2019) 'Do Altmetrics Assess Societal Impact in a Comparable Way to Case Studies? An Empirical Test of the Convergent Validity of Altmetrics Based on Data from the UK Research Excellence Framework (REF)', *Journal of Informetrics*, 13/1: 325–40.

Bozeman, B., and Boardman, C. (2003) *Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community, Transforming Organizations Series*. Washington, DC: IBM Endowment for the Business of Government.

Burns, T. W., O'Connor, D. J., and Stocklmayer, S. M. (2003) 'Science Communication: A Contemporary Definition', *Public Understanding of Science*, 12/2: 183–202.

CCES (2005), 'Competence Center Environmental and Sustainability (CCES) of the ETH Domain: Business Plan', (Competence Center Environmental and Sustainability of the ETH Domain) <https://www.ethz.ch/content/dam/ethz/special-interest/dual/cces-dam/documents/CCES_BP_2005_11_22_final.pdf> accessed 24 April 2019.

Checkoway, B. (2001) 'Renewing the Civic Mission of the American Research University', *The Journal of Higher Education*, 72/2: 125–47.

Costas, R., Zahedi, Z., and Wouters, P. (2015) 'Do 'Altmetrics' Correlate with Citations? Extensive Comparison of Altmetric Indicators with Citations from a Multidisciplinary Perspective', *Journal of the Association for Information Science and Technology*, 66/10: 2003–19.

D'Este, P., Ramos-Vielba, I. Woolley, R. et al. (2018) 'How Do Researchers Generate Scientific and Societal Impacts? Toward an Analytical and Operational Framework', *Science and Public Policy*, 45/6: 752–63.

Ecklund, E. H., James, S. A., and Lincoln, A. E. (2012) 'How Academic Biologists and Physicists View Science Outreach', *PloS One*, 7/5: e36240.

Etzkowitz, H., and Leydesdorff, L. (2000) 'The Dynamics of Innovation: from National Systems and 'Mode 2' to a Triple Helix of University–Industry–Government Relations', *Research Policy*, 29/2: 109–23.

Gascoigne, T., and Metcalfe, J. (1997) 'Incentives and Impediments to Scientists Communicating Through the Media'', *Science Communication*, 18/3: 265–82.

Gibbons, M. et al. (1994) *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Green, L. W. et al. (2009) 'Diffusion Theory and Knowledge Dissemination, Utilization, and Integration in Public Health', *Annual Review of Public Health*, 30: 151–74.

Greenwood, M. R. C., and Riordan, D. G. (2001) 'Civic Scientist/civic Duty', *Science Communication*, 23/1: 28–40.

Gulbrandsen, M., and Smeby, J.-C. (2005) 'Industry Funding and University Professors' Research Performance', *Research Policy*, 34/6: 932–50.

Haunschild, R., and Bornmann, L. (2018) 'Field- and Time-normalization of Data with Many Zeros: An Empirical Analysis Using Citation and Twitter Data', *Scientometrics*, 116/2: 997–1012.

Hessels, L. K., Van Lente, H., and Smits, R. (2009) 'In Search of Relevance: The Changing Contract Between Science and Society'', *Science and Public Policy*, 36/5: 387–401.

Holbrook, J. B. (2010) 'The Use of Societal Impacts Considerations in Grant Proposal Peer Review: A Comparison of Five Models', *Technology & Innovation*, 12/3: 213–24.

Jensen, P. et al. (2008) 'Scientists Who Engage with Society Perform Better Academically', *Science and Public Policy*, 35/7: 527–41.

Johnson, D. R., Ecklund, E. H., and Lincoln, A. E. (2014) 'Narratives of Science Outreach in Elite Contexts of Academic Science', *Science Communication*, 36/1: 81–105.

Karimli, L. et al. (2015) 'Matched Child Savings Accounts in Low-Resource Communities: Who Saves?', *Global Social Welfare*, 2/2: 53–64.

Kassab, O., Schwarzenbach, R. P., and Gotsch, N. (2018) 'Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain', *GAIA - Ecological Perspectives for Science and Society*, 27/2: 226–34.

——, Mutz, R., and Daniel, H.-D. (submitted) 'Introducing and Testing an Advanced Methodological Approach for the Evaluation of Research Centers: A Case Study on Sustainability Science'. Manuscript under review.

Kim, C., and Fortner, R. W. (2008) 'Great Lakes Scientists' Perspectives on K-12 Education Collaboration', *Journal of Great Lakes Research*, 34/1: 98–108.

Kuehne, L. M., and Olden, J. D. (2015) 'Opinion: Lay Summaries Needed to Enhance Science Communication', *Proceedings of the National Academy of Sciences*, 112/12: 3585–6.

Lang, D. J. et al. (2012) 'Transdisciplinary Research in Sustainability Science: Practice, Principles, and Challenges', *Sustainability Science*, 7/1: 25–43.

Liang, K. Y., and Zeger, S. L. (1986) 'Longitudinal Data Analysis Using Generalized Linear Models', *Biometrika*, 73/1: 13–22.

Liang, X. et al. (2014) 'Building Buzz: (Scientists) Communicating Science in New Media Environments', *Journalism & Mass Communication Quarterly*, 91/4: 772–91.

Llopis, O. et al. (2018) 'Scientists' Engagement in Knowledge Transfer and Exchange: Individual Factors, Variety of Mechanisms and Users', *Science and Public Policy*, 45/6: 790–803.

Martín-Sempere, M. J., Garzón-García, B., and Rey-Rocha, J. (2008) 'Scientists' Motivation to Communicate Science and Technology to the Public: Surveying Participants at the Madrid Science Fair', *Public Understanding of Science*, 17/3: 349–67.

Martin, B. R. (2011) 'The Research Excellence Framework and the 'Impact Agenda': Are We Creating a Frankenstein Monster?', *Research Evaluation*, 20/3: 247–54.

Martinez-Conde, S. (2016) 'Has Contemporary Academia Outgrown the Carl Sagan Effect?', *Journal of Neuroscience*, 36/7: 2077–82.

Miller, J. D. (1998) 'The Measurement of Civic Scientific Literacy', *Public Understanding of Science*, 7: 203–23.

Mostert, S. P. et al. (2010) 'Societal Output and Use of Research Performed by Health Research Groups', *Health Research Policy and Systems*, 8: 30.

Myers, G. (2003) 'Discourse Studies of Scientific Popularization: Questioning the Boundaries', *Discourse Studies*, 5/2: 265–79.

Nowotny, H., Scott, P., and Gibbons, M. (2003) 'Introduction: 'Mode 2' Revisited: The New Production of Knowledge', *Minerva*, 41/3: 179–94.

Olmos-Peñuela, J., Benneworth, P., and Castro-Martínez, E. (2015) 'What Stimulates Researchers to Make Their Research Usable? Towards an 'Openness' Approach', *Minerva*, 53/4: 381–410.

Peters, H. P. (2013) 'Gap Between Science and Media Revisited: Scientists as Public Communicators', *Proceedings of the National Academy of Sciences*, 110/3: 14102–9.

Piwowar, H. (2013) 'Altmetrics: Value All Research Products', *Nature*, 493/7431: 159.

Poliakoff, E., and Webb, T. L. (2007) 'What Factors Predict Scientists' Intentions to Participate in Public Engagement of Science Activities?', *Science Communication*, 29/2: 242–63.

Ravenscroft, J. et al. (2017) 'Measuring Scientific Impact Beyond Academia: An Assessment of Existing Impact Metrics and Proposed Improvements', *Plos One*, 12/3: e0173152.

REF (2019), 'Panel Criteria and Working Methods' (Research Excellence Framework (REF) 2021) <https://www.ref.ac.uk/media/1084/ref-2019_02-panel-criteria-and-working-methods.pdf> accessed 24 April 2019.

Robinson-Garcia, N., van Leeuwen, T. N., and Ràfols, I. (2018) 'Using Altmetrics for Contextualised Mapping of Societal Impact: From Hits to Networks', *Science and Public Policy*, 45/6: 815–26.

Rowe, G., and Frewer, L. J. (2005) 'A Typology of Public Engagement Mechanisms', *Science, Technology, & Human Values*, 30/2: 251–90.

Royal Society, (2006) 'Factors Affecting Science Communication: A Survey of Scientists and Engineers' <https://royalsociety.org/topics-policy/publications/2006/science-communication/> accessed 24 April 2019.

SDSN (2017) 'Getting Started with the SDGs in Universities: A Guide for Universities, Higher Education Institutions, and the Academic Sector. Australia, New Zealand and Pacific Edition' in Sustainable Development Solutions Network - Australia/Pacific (ed.). Melbourne. <http://ap-unsdsn.org/wp-content/uploads/University-SDG-Guide_web.pdf> accessed 24 April 2019.

Shahadu, H. (2016) 'Towards an Umbrella Science of Sustainability', *Sustainability Science*, 11/5: 777–88.

Spaapen, J., and Van Drooge, L. (2011) 'Introducing 'Productive Interactions' in Social Impact Assessment', *Research Evaluation*, 20/3: 211–18.

Thune, T. et al. (2016) 'Universities and External Engagement Activities: Particular Profiles for Particular Universities?', *Science and Public Policy*, 43/6: 774–86.

van der Weijden, I., Verbree, M., and Van Den Besselaar, P. (2012) 'From Bench to Bedside: The Societal Orientation of Research Leaders: The Case of Biomedical and Health Research in the Netherlands', *Science and Public Policy*, 39/3: 285–303.

Van Kerkhoff, L., and Lebel, L. (2006) 'Linking Knowledge and Action for Sustainable Development', *Annual Review of Environment and Resources*, 31

Van Looy, B. et al. (2011) 'Entrepreneurial Effectiveness of European Universities: An Empirical Assessment of Antecedents and Trade-offs', *Research Policy*, 40/4: 553–64.

Watermeyer, R. (2015) 'Lost in the 'Third Space': The Impact of Public Engagement in Higher Education on Academic Identity, Research Practice and Career Progression', *European Journal of Higher Education*, 5/3: 331–47.

Wellcome Trust (2000) *The Role of Scientists in Public Debate*. London: The Wellcome Trust.

Winter, E. (2004) 'Public Communication of Science and Technology: German and European Perspectives', *Science Communication*, 25/3: 288–93.

Wise, G., Retzleff, D., and Reilly, K. (2002) 'Adapting Scholarship Reconsidered and Scholarship Assessed to Evaluate University of Wisconsin-extension Outreach Faculty for Tenure and Promotion', *Journal of Higher Education Outreach and Engagement*, 7/3: 5–18.

Ziman, J. (2002) *Real Science: What It Is and What It Means*. Cambridge: Cambridge University Press.

Zinn, J. S. et al. (2007) 'Doing Better To Do Good: The Impact of Strategic Adaptation on Nursing Home Performance', *Health Services Research*, 42/3 Pt 1: 1200–18.

4.3 Can altmetrics reflect societal impact considerations? Exploring the potential of altmetrics in the context of a sustainability science research center

As accountability to taxpayers is gaining more and more leverage, the allocation of public research funding is increasingly tied to societal impact considerations (Holbrook 2010, LERU 2017). Research proposals, for example, include sections in which applicants have to discuss the broader contribution of the projected research and identify strategies for creating societal value, for example, in the form of public outreach activities (Martin 2011, Thune et al. 2016). While the impact of concrete activities like school visits or local stakeholder workshops is relatively straightforward to assess, as demonstrated in the case of the Research Excellence Framework's (REF) impact case studies (Watermeyer and Hedgecoe 2016, Ravenscroft et al. 2017), it is more difficult to evaluate the societal impact on the basis of research outputs alone. A relatively new attempt in this respect are the so-called "altmetrics", an endeavor to represent mentions and interactions on social media platforms like Twitter or Facebook (Thelwall et al. 2013). With their breadth, diversity and speed, they are thought to have a great potential for capturing societal impact. At the same time, however, they are also associated with disadvantages, such as being used commercially, being susceptible to manipulation, or simply offering poor data quality (Bornmann 2014). The present study explores the potential of altmetrics for assessing societal impact of research in the context of research centers.

The *third article* (working paper) starts by outlining how funding decisions at CCES were not only based on the prospect of scientific excellence, but also on societal impact considerations. Under the hypothesis that altmetrics are capable of assessing this impact, the study compares papers of researchers either accepted or rejected for funding by CCES and the altmetrics scores their research received thereafter, respectively. Six altmetrics sources are considered in the empirical analyses, including Twitter, Wikipedia, policy-related documents, Blogs, Facebook, and News. The article is an explorative study that aims to better understand the potential of altmetrics for research evaluation in general, and research center evaluation in particular. Thereby, it contributes to solving four of the six challenges associated to research center evaluations.

Kassab, O., Bornmann, L., Haunschild, R. (working paper). Can Altmetrics Reflect Societal Impact Considerations? Exploring the Potential of Altmetrics in the Context of a Sustainability Science Research Center.

WORKING PAPER

Can Altmetrics Reflect Societal Impact Considerations?

Exploring the Potential of Altmetrics in the Context of a Sustainability Science Research Center

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Abstract

Societal impact considerations play an increasingly important role in research evaluation. Especially in the context of publicly funded research, proposal templates commonly include sections to outline strategies for achieving broader impact. Both the assessment of the strategies as well as the later evaluation of their success are associated to challenges in their own right. Ever since their introduction, altmetrics have been discussed as a remedy for assessing the societal impact of research output. On the basis of data from a research center in Switzerland, this study explores their potential for this purpose. The study is based on the papers (and the corresponding metrics) published by about 200 either accepted or rejected applicants for funding by Competence Center Environment and Sustainability (CCES). The results of the study seem to indicate that altmetrics are not suitable for reflecting the societal impact of research: the metrics do not correlate with ex-ante considerations of an expert panel.

Key words

Bibliometrics, altmetrics, MHq indicator, sustainability science, research center, societal impact

1 Introduction

Many studies dealing with the societal impact of research begin by describing a paradigmatic transformation in research policy that has presumably led to an increased accountability of publicly funded research. Researchers and universities, according to this narrative, would increasingly have to justify their work towards the tax-paying public. This almost confrontational portrayal of the relationship could make the reader believe that the public is concerned with a petty cost-benefit calculation to tease out their return on investment. However, the simplified view undermines the potentially genuine interest of societal actors to inform and educate themselves on the basis of scientific facts. Especially in times of rapid technological developments, the interaction between science and society is easier than ever.

The very emergence of social media, for example, has heralded a new age for the public dissemination of scientific knowledge. It therefore comes as no surprise that "altmetrics", an endeavor to quantitatively represent mentions and interactions on social media platforms like Twitter or Facebook, have been proposed as a means to evaluate the societal impact of research ex post (see the literature overview by Bornmann 2014). Yet despite the consensus over their potential for impact assessment, the jury is still out as to what kind of impact altmetrics scores actually reflect. Addressing this puzzle, Bornmann et al. (2019) compared peer assessments of societal impact of research with altmetrics scores for the corresponding publications. Their results reveal that altmetrics seem to measure public "discussions" around research rather than societal impact, further qualifying that the latter may more likely be assessed by experts of a specific field. However, there are also other empirical findings suggesting a contrary reasoning. Wooldridge and King (2019), for example, used the same dataset as Bornmann et al. (2019), but other methods, and concluded that "the work presented in this study provides direct evidence, for the first time, of a correlation between expert peer review of the societal impact of research and altmetric data from the publications defining the underpinning research" (p. 281). Against the backdrop of these contradicting results, it is necessary to advance further empirical investigations about the correlation between assessments of societal impact of research and altmetrics scores.

Taking up the question in the context of a research center, the Competence Center Environment and Sustainability (CCES) in Switzerland, the study examines altmetrics scores of journal articles published by researchers either accepted or rejected for funding by CCES. As a research field "defined by the problems it addresses rather than by the disciplines it employs" (Clark 2007), sustainability science represents a prime case for solution-oriented research of high societal relevance (Yarime et al. 2012, Brandt et al. 2013, Wiek et al. 2014, Kassab 2019). Thus, whether the research was funded or rejected depended not solely on the assessment of the scientific quality, but initially on whether the prospect of societal impact was explicitly outlined in the proposal or not (Competence Center Environment and Sustainability 2006). We explore in this study whether

this latter criterion is reflected in later altmetrics scores: Do papers of researchers funded by CCES receive higher altmetrics scores than papers from rejected researchers? Or in other words, using another dataset than Bornmann et al. (2019) and Wooldridge and King (2019), this study targets the question whether altmetrics scores are consistent with ex ante assessments of societal impact considerations or not.

The remainder of the article is structured as follows: section 2 introduces the case and describes the hypothesized relationship between societal impact assessments and altmetrics scores. Section 3 then gives an overview of the data and the methods used for the investigation. Section 4 presents the results of the study, and section 5 discusses them to draw conclusions. Finally, section 6 outlines the limitations of the study while giving indications for further research and recommendations

2 Can altmetrics reflect societal impact considerations?

2.1 Case description: A sustainability science research center in Switzerland

The Competence Center Environment and Sustainability (CCES) was founded in 2006 for a period of ten years (until 2016) to foster inter- and transdisciplinarity within and between the six institutions that constitute the ETH Domain, a union of Swiss federal universities and research institutes. Strategically managed by the ETH Board, the ETH Domain comprises the two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag).

CCES was established with the mission to "identify the relevant questions and the appropriate answers to foster the sustainable development of a future society while minimizing the impact on the environment" (CCES 2005). To comprehensively achieve this mission, CCES operated in three areas of activity: research, capacity-building, and public outreach. Goals have been set for each of the three areas, with a total of five goals. In the area of "research", three goals were defined: (1) foster major inter- and transdisciplinary research advancements in the areas of environment and sustainability, (2) establish the CCES partner institutions as national and international focal points for the areas of environment and sustainability, and (3) achieve a long-term structuring effect and a coherent strategy for the areas of environment and sustainability. In the area of "capacity-building", the goal was to (4) establish a strong and wide-ranging education program for the areas of environment and sustainability. And lastly, the goal set in the area of "public outreach" was to (5) achieve a visible societal impact with a focus on socio-economic implementation.

Activities at CCES were clustered in 26 projects along five thematic areas of environment and sustainability science: (1) Climate and Environmental Change, (2) Sustainable Land Use, (3) Food, Environment, and Health, (4) Natural Resources, and (5) Natural Hazards and Risks. Some exemplary projects included *OPTIWARES*, in which researchers worked on optimizing the use of wood as a renewable energy source, *TRAMM*, which aimed at developing early warning systems for rapid mass movements in steep terrain, or the *ADAPT* project, which studied social and environmental constraints for large-scale dams and water resource management (Kassab et al. 2018).

2.2 Societal impact considerations in the evaluation procedure

The few aforementioned synopses demonstrate exemplarily that projects funded by the research center were characterized by a strong practice-orientation. This property is based on the notion that sustainability science concentrates on the most pressing challenges facing human society and the development of concrete solutions (Yarime et al. 2012, Kajikawa et al. 2014, SDSN 2017). In order to find these solutions, however, it is not only necessary to overcome disciplinary boundaries, through interdisciplinarity, but also to transcend the university ecosystem and engage other stakeholders from society, business and politics, through transdisciplinarity approaches (Pohl 2010, Lang et al. 2012). In terms of the underlying research mode, sustainability science thus differs considerably from basic research (Clark 2007, Mobjörk 2010, Kates 2011, Miller 2013).

The special attention given to inter- and transdisciplinarity as well as the objective to develop applied solutions was explicitly reflected in the CCES evaluation procedure. For the purpose of assessing the project proposals, an ad-hoc Research Council (RC) was established. Consisting of 17 researchers from the ETH Domain institutions, the RC was responsible for reviewing the proposals with respect to their overall suitability for CCES (see goals above). In particular, it was the task of the RC to evaluate the added value of the project for CCES, stressing (1) societal relevance either as a goal to be achieved during the project duration or with an identified follow-up implementation phase, (2) the importance of the project for long term sustainability and for a durable structuring effect, (3) the relevance in the international context, and in particular, the potential for applications in developing countries (Competence Center Environment and Sustainability 2006). As this focus suggests, the assessments of the RC were primarily based on the prospect of societal impact, reflecting the three aforementioned dimensions, and did not include an evaluation of the scientific quality. In fact, only if the projects passed the initial assessment, they were forwarded to the next stage, which consisted of a classical peer review procedure coordinated by the ETH Zurich Research Commission.Given the still inconclusive debate about the validity of altmetrics for reflecting the societal impact of research, the question that lies at the heart of this study is whether or not there is a relationship between ex ante assessments of societal impact and

altmetrics scores? We approach the answer to this question indirectly: According to the CCES evaluation procedure outlined above, special emphasis was attributed to the prospect of societal impact. Under the premise that research funded through CCES would yield more societal impact than the research of rejected applicants, and assuming that altmetrics scores are capable to reflect this impact, the hypothesis arises that the *researchers funded by CCES achieve higher impact in terms of altmetrics scores with their research than those who were not funded*. Should the findings of this study corroborate the hypothesis, this would lead to the conclusion that altmetrics are indeed capable of reflecting ex ante societal impact considerations of the RC. However, should the results not confirm the hypothesis, this does not automatically imply the opposite. Rather, this would raise the question of what else altmetric scores are indicative of. In fact, a refutation of the hypothesis could also be interpreted in a way that the RC did not take sufficient account of societal impact considerations in the assessments (even though this was explicitly demanded) but rather focused on other aspects. In what follows, we describe the data and the methods we use to test the hypothesis empirically.

3 Data and methods

3.1 Description of altmetrics

We acknowledge that altmetrics are heterogeneous in many ways and specifically with regards to which aspect of societal impact they actually reflect (if any). We considered six different altmetric sources in this study, including Twitter, Wikipedia, policy-related documents, blogs, Facebook and news. They differ strongly with regards to the effort and the process preceding the actual mention, content and substance of the information that is communicated, and also the readership. While a Tweet or a Facebook post is shared at the touch of a button, the threshold for Wikipedia entries, blog posts, or mentions in news outlets is much higher. Also, the demographic background of the readership of policy-related documents as opposed to Facebook posts is much more specific. Nevertheless, we chose those types since they have been frequently used and investigated in previous altmetrics studies (see Bornmann et al. 2019), qualifying them as "standard" sources:

Twitter (see www.twitter.com) is a very popular microblogging platform. Tweets may refer to the content of scientific publications, but it seems that they do not correlate with traditional citations (Bornmann 2015). Instead, they may reflect discussion around these publications (Haustein et al. 2014b), possibly by public users (Haustein et al. 2014a, Yu 2017), but this is not entirely clear as outlined by Sugimoto et al. (2016). The results by Andersen and Haustein (2015) suggest that tweets reflect attractiveness of papers for a broader audience. However, contradicting results are also available: "A multi-year campaign has sought to convince us that counting the number of tweets about papers has value. Yet, reading tweets about dental journal articles suggested

the opposite. This analysis found: obsessive single issue tweeting, duplicate tweeting from many accounts presumably under centralized professional management, bots, and much presumably human tweeting duplicative, almost entirely mechanical and devoid of original thought" (Robinson-Garcia et al. 2017). In the study at hand, the number of tweets (and retweets) including references to scientific papers in our dataset is counted.

Wikipedia (see https://www.wikipedia.org) is a free encyclopedia platform which includes editable content (Mas-Bleda and Thelwall 2016). Although contributors to this platform include scholarly references, most of them do not refer to research papers (Priem 2014). If scientific papers are cited, Open Access (OA) papers seem to be preferred (Teplitskiy et al. 2015, Dehdarirad et al. 2018). Guglielmi (2018) reports on Wikipedia's most frequently mentioned papers. However, this list does not correspond with lists based on traditional citations: study results suggest that Wikipedia mentions do not correlate with citations (Samoilenko and Yasseri 2014). A Wikipedia case study with papers on Wind Power showed that < 1% of relevant papers have been cited on Wikipedia "implying that the direct societal impact through the Wikipedia is extremely small for Wind Power research" (Serrano-López et al. 2017). Against the backdrop of their results, the authors recommend not to use Wikipedia data for research evaluation purposes (see also Sugimoto et al. 2016). Kousha and Thelwall (2017) found that only 5% of papers had any citation from Wikipedia – based on a significantly larger sample of papers than considered by Serrano-López et al. (2017). In this study, the number of Wikipedia articles with reference to papers in our dataset is counted.

Policy-related documents are an important source of altmetrics, since one is interested in the impact of science on the policy realm (OPENing UP 2016, Vilkins and Grant 2017). Mentions in these documents are searched using text mining databases of, for instance, the World Health Organization or European Food Safety Authority (Bornmann et al. 2016, Haunschild and Bornmann 2017). Haunschild and Bornmann (2017) reported that the company Altmetric tracks more than 100 policy sources (in 2015). Tattersall and Carroll (2018) analyzed nearly 100 papers published by authors from the University of Sheffield: the "research topics with the greatest policy impact are medicine, dentistry, and health, followed by social science and pure science". Papers published OA seem to have an advantage to be cited in policy-related documents (Vilkins and Grant 2017). However, the impact of papers (OA or not) on these documents is usually very low, as the results of Haunschild and Bornmann (2017) reveal: "less than 0.5% of the papers published in different subject categories are mentioned at least once in policy-related documents" (p. 1209). The study of Bornmann et al. (2016) show that "only 1.2 % (n = 2,341) have at least one policy mention" (p. 1477). The authors analyzed a large set of 191,276 publications from the field of climate change, which is policy-relevant. In this study, the number of policy-related documents with references to papers in our dataset is counted.

Blogs are written about scientific papers including formal or informal citations of papers (Shema 2014). These citations can be counted – with the limitation that informal citations lead to uncertainty (Priem and Hemminger 2010, Luzón 2013, Shema et al. 2014). Since blogs allow extended informal discussions about research, they are an interesting altmetrics source (Fausto et al. 2012, Shema et al. 2012a). Blogging may be a bridge between the general public and the research area (Bonetta 2007, Bar-Ilan et al. 2014) whereby bloggers seem to have preference for papers from high-impact journals and research in the life and behavioral sciences (Shema et al. 2012b). However, a study revealed that bridging public and research "was one of the less popular motivations for academics to blog" (Mewburn and Thomson 2013). The literature overview published by Sugimoto et al. (2016) shows that the coverage of papers in blog mentions is low and also the correlation between blog mentions and traditional citations. In this study, the number of blog posts with references to the papers in our dataset is counted.

Facebook is a popular social networking and social media platform (Bik and Goldstein 2013). Since users share papers among themselves, mentions of papers in posts or Facebook likes can be counted. Ringelhan et al. (2015) investigated whether "Facebook likes" are an indicator of scientific impact. Their results show "an interdisciplinary difference in the predictive value of Facebook likes, according to which Facebook likes only predict citations in the psychological area but not in the non-psychological area of business or in the field of life sciences". In this study, the number of Facebook posts with references to scientific papers in our dataset are counted (note that we did not include likes).

News attention relates to scientific papers mentioned in news reports (via direct links or unique identifiers in, e.g., the *New York Times*). On the basis of these paper mentions, public attention can be counted. The overview of altmetrics studies published by Sugimoto et al. (2016) reveals that the correlation between mentions of papers in news reports and traditional citations is between low and medium. In our altmetrics dataset from November 2017, we identified more than 2,000 different news sources which are analyzed for news counts. In this study, the number of news articles with references to scientific papers in our dataset is counted.

3.2 Dataset used

We used the Web of Science (WoS, Clarivate Analytics) custom data of our in-house database and the database from the Competence Centre for Bibliometrics (CCB, see: http://www.bibliometrie.info/) both derived from the Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (AHCI) produced by Clarivate Analytics (Philadelphia, USA). All publications published between 2011 and 2015 with a DOI were exported with the following information: DOI, WoS UT (unique accession number from WoS), WoS subject categories, publication year, citation counts with a three-year citation

window starting after the publication year, and Hazen percentiles. Percentiles are field- and time-normalized impact scores that are between 0 (low citation impact) and 100 (high citation impact) (see Bornmann et al. 2013). Raw citation data were taken from the database maintained by the CCB. Other bibliographic and bibliometric data were taken from our in-house database. Both databases were last updated at the end of April 2019. We kept only those publications which fulfilled the following two criteria: (1) the publication belongs to a field (overlapping WoS category, see Rons 2012, Rons 2014) to which at least one research center publication belongs to; (2) a requirement of at least 10 publications per field and publication year combination has been set.

Altmetrics data were sourced from a locally maintained database using data shared with us by Altmetric (see https://www.altmetric.com) and dumped on 08 October 2019. For research projects, the company shares the data for free. The data include altmetric counts from sources such as social networking; blogging; microblogging; wikis; and policy-relevant usage. We appended a mention count to each DOI using the following altmetrics sources: Twitter, Facebook, blogs, news, policy documents, and Wikipedia (see above). One DOI not known to the altmetrics database was recorded as 'not mentioned'. Altmetrics data and information about their unit status (applied for research center funding which was accepted or not) were appended to the publications via their DOI. Figure 1 provides a schematic overview of how the respective units were constructed: unit 0 contains all WoS papers which do not belong to units 1 or 2. Unit 1 contains the publications of 28 participants who had submitted project proposals for CCES, but were not funded. Unit 2, in turn, contains the publications of 170 participants that were affiliated with CCES as principal investigators and project partners. Unit 2 is further subdivided into units 3 and 4. Unit 4 contains the papers that were published in the research center context, while unit 3 contains papers that accepted applicants published beyond their project at the research center. The numbers of mentioned and not mentioned publications in the different altmetrics sources broken down by unit status and publication year are shown in Table 1.

We acknowledge that the subdivision into units and the comparison between the units is a simplification of reality, especially with regard to the hypothesis to be tested. While the CCES evaluation procedure took place on the project level at a specific moment in time, the units here are constructed on the level of the entire publication output of researchers that were funded or not funded by CCES. Furthermore, we focus in this study on scientific publications as the main research output of the research center. While it would have been beneficial to consider other outputs as well, such as those emanating from public outreach activities (Kassab 2019), we are constrained by the fact that altmetrics data are only available for outputs that have a DOI (i.e. papers). However, besides altmetrics data, we also considered citation data (1) to compare the results with those based on altmetrics data and (2) to investigate whether societal impact assessments correspond with traditional impact scores.

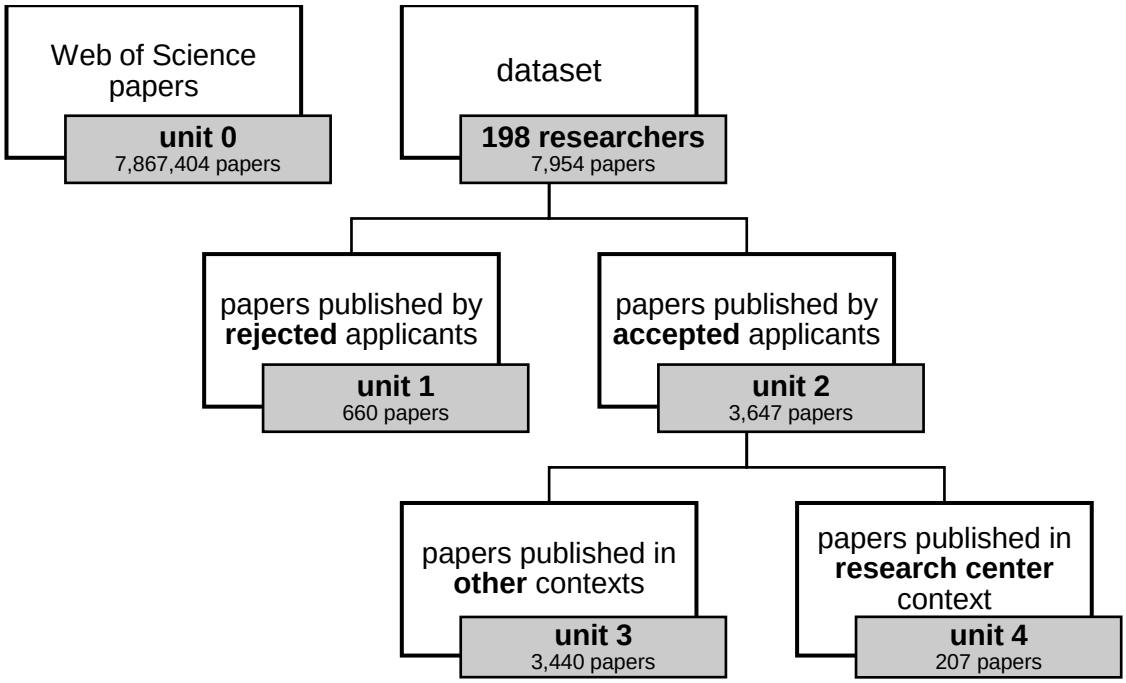

Figure 1: Schematic overview of the units and number of papers per unit.

		Twitter		Facebook		Blogs		News		Policy documents		Wikipedia		Citation	
unit	**publication year**	**mentioned**	**not mentioned**	**mentioned**	**not mentioned**	**mentioned**	**not mentioned**	**mentioned**	**not mentioned**	**mentioned**	**not mentioned**	**mentioned**	**not mentioned**	**cited**	**not cited**
0	**2011**	139,766	1,233,952	34,842	1,338,876	35,790	1,337,928	20,922	1,352,796	29,028	1,344,690	28,036	1,345,682	1,057,600	316,118
	2012	312,073	1,181,879	77,809	1,416,143	43,989	1,449,963	29,490	1,464,462	28,391	1,465,561	28,024	1,465,928	1,149,376	344,576
	2013	398,950	1,194,767	115,234	1,478,483	52,390	1,541,327	47,867	1,545,850	28,422	1,565,295	27,288	1,566,429	1,245,496	348,221
	2014	510,575	1,144,363	105,419	1,549,519	56,832	1,598,106	59,324	1,595,614	24,927	1,630,011	25,303	1,629,635	1,305,474	349,464
	2015	627,508	1,123,571	17,5196	1,575,883	60,213	1,690,866	76,049	1,675,030	20,868	1,730,211	24,118	1,726,961	1,394,085	356,994
1	**2011**	27	99	8	118	15	111	4	122	17	109	5	121	120	6
	2012	58	94	25	127	23	129	9	143	21	131	5	147	139	13
	2013	59	113	21	151	20	152	18	154	13	159	7	165	163	9
	2014	61	87	8	140	14	134	19	129	16	132	5	143	146	2
	2015	35	27	17	45	7	55	8	54	5	57	1	61	61	1
2	**2011**	75	690	15	750	39	726	15	750	46	719	23	742	734	31
	2012	179	650	36	793	52	777	16	813	42	787	21	808	788	41
	2013	285	611	74	822	75	821	53	843	40	856	27	869	862	34
	2014	301	511	57	755	59	753	51	761	25	787	12	800	782	30
	2015	165	180	51	294	24	321	30	315	8	337	7	338	336	9
3	**2011**	72	627	14	685	34	665	14	685	39	660	22	677	668	31
	2012	173	618	36	755	47	744	14	777	39	752	21	770	750	41
	2013	271	560	70	761	68	763	47	784	31	800	26	805	797	34
	2014	294	489	56	727	58	725	51	732	23	760	12	771	755	28
	2015	164	172	51	285	24	312	30	306	8	328	7	329	328	8
4	**2011**	3	63	1	65	5	61	1	65	7	59	1	65	66	0
	2012	6	32	0	38	5	33	2	36	3	35	0	38	38	0
	2013	14	51	4	61	7	58	6	59	9	56	1	64	65	0
	2014	7	22	1	28	1	28	0	29	2	27	0	29	27	2
	2015	1	8	0	9	0	9	0	9	0	9	0	9	8	1

Table 1: Number of mentioned and not mentioned (and cited and not cited) papers, respectively, broken down by data source, publication year and funded or not-funded groups. Note: WoS papers (unit 0; neither accepted, nor rejected for funding), papers published by rejected applicants (unit 1), and papers published by accepted applicants (unit 2). The papers from accepted applicants are further divided into papers from funded projects (unit 4) and papers published in other contexts (unit 3)

3.3 Mantel-Haenszel quotient (MHq)[1]

In this study, we compare the impact of papers published by various units (e.g., papers published by rejected or accepted applicants, see Figure 1). Since altmetrics data are concerned by field-specific differences (like citation data), field-normalized indicators should be used instead of raw data for group comparisons. However, it is a critical drawback of altmetrics data that they are inflated by zeros: in the current study, 5,586,077 papers (71.0%) have no impact in any altmetrics source. For zero-inflated data it is not possible to use methods for field-normalization that are usually applied in bibliometrics (methods based on mean citations or citation percentiles, see Bornmann et al. 2013). Since Bornmann and Haunschild (2018) and Haunschild and Bornmann (2018) proposed the MHq indicator that is especially designed for dealing with zero-inflated data in field-normalization, we used the indicator in the current study.

For pooling data from multiple 2×2 cross tables based on such subgroups (which are part of the larger population including all papers in the considered time period), MH analysis is a popular method (Mantel and Haenszel 1959, Hollander and Wolfe 1999, Sheskin 2007). According to Fleiss et al. (2003), the method "permits one to estimate the assumed common odds ratio and to test whether the overall degree of association is significant. Curiously, it is not the odds ratio itself but another measure of association that directly underlies the test for overall association … The fact that the methods use simple, closed-form formulas has much to recommend it" (p. 250). The results by Radhakrishna (1965) demonstrate that the MH approach seems to be valid.

The MH analysis results in a summary odds ratio for multiple 2×2 cross tables, which Bornmann and Haunschild (2018) and Haunschild and Bornmann (2018) name MHq. For the comparison of the papers published by the applicants with reference sets in view of impact, the 2×2 cross tables (which are pooled) consist of the number of papers mentioned and not mentioned in subject category and publication year combinations *f*. In the 2×2 subject-specific cross table (see Table 2), the cells a_f, b_f, c_f, and d_f, are defined as follows:

- a_f is the number of mentioned papers published by unit *g* (e.g., rejected applicants) in subject category and publication year *f*,
- b_f is the number of not mentioned papers published by unit *g* in subject category and publication year *f*,
- c_f is the number of mentioned papers in subject category and publication year *f*,
- d_f is the number of not mentioned papers published in subject category and publication year *f*. Note that the papers of group *g* are also part of the papers in the world.

[1] The explanation of the MHq indicator has been mainly adopted from Bornmann and Haunschild (2018) and Haunschild and Bornmann (2018).

	Number of mentioned papers	Number of not mentioned papers
Group *g*	a_f	b_f
World	c_f	d_f

Table 2: 2 x 2 subject-specific cross table

The following dummy variables are needed for the MH analysis:

$$R_f = \frac{a_f d_f}{n_f} \text{ and } R = \sum_{f=1}^{F} R_f, \quad (1)$$

$$S_f = \frac{b_f c_f}{n_f} \text{ and } S = \sum_{f=1}^{F} S_f, \quad (2)$$

$$P_f = \frac{a_f + d_f}{n_f} \text{ and } Q_f = 1 - P_f \quad (3)$$

Where $n_f = a_f + b_f + c_f + d_f$

MHq is simply:

$$\text{MHq} = \frac{R}{S} \quad (4)$$

The CIs for MHq are calculated following Fleiss et al. (2003). The variance of ln MHq is estimated by:

$$\widehat{Var}(\ln MHq) = \frac{1}{2}\left\{\frac{\sum_{f=1}^{F} P_f R_f}{R^2} + \frac{\sum_{f=1}^{F}(P_f S_f + Q_f R_f)}{RS} + \frac{\sum_{f=1}^{F} Q_f S_f}{S^2}\right\} \quad (5)$$

The CI for the MHq can be constructed with

$$MHq_L = \exp\left[\ln(MHq) - 1.96\sqrt{\widehat{Var}[\ln(MHq)]}\right] \quad (6)$$

$$MHq_U = \exp\left[\ln(MHq) + 1.96\sqrt{\widehat{Var}[\ln(MHq)]}\right] \quad (7)$$

World (reference sets)	Paper is mentioned	Paper is not mentioned	Number of papers	MHq
Subject category 1	44	20	64	
Subject category 2	30	16	46	
Subject category 3	16	12	28	
Subject category 4	0	20	20	
Total				**1.00 [0.61, 1.64]**
Publication set A				

Subject category 1	18	13	31	
Subject category 2	15	9	24	
Subject category 3	13	9	22	
Subject category 4	0	10	10	
Total				**0.81 [0.46, 1.44]**
Publication set B				
Subject category 1	26	7	33	
Subject category 2	15	7	22	
Subject category 3	3	3	6	
Subject category 4	0	10	10	
Total				**1.30 [0.66, 2.53]**

Table 3: Small world example for the Mantel-Haenszel quotient (MHq)

We used the data in Table 3 to produce a small world example for explaining the MHq: The world consists of papers in four subject categories. The papers of two units (publication set A and B) determine the world. For each unit, the numbers of mentioned and not mentioned papers as well as the corresponding proportion of mentioned papers are listed. For example, the unit named as publication set B has published 26 mentioned and 7 not mentioned papers in subject category 1. The proportion of the papers mentioned is 0.27. It is an advantage of the MHq that the world average has a value of 1: this value indicates that there is no difference between the chances of a focal publication set and the reference sets (i.e., the world) of being mentioned (e.g., on Wikipedia). A MHq value less than 1.0 indicates lower chances for the publications in the set of being mentioned compared with the reference sets. The MHq values in Table 3 can be interpreted as follows: the chances of the papers in publication set A of being mentioned are 0.81 times as large as the world's papers chances. The chances of the papers in set B of being mentioned are 1.3 times greater than the world's papers chances. It is an advantage of the MHq that the result can be expressed as a percentage, which is relative to the world average. Expressed as percentages, therefore, the difference between publication set B and the world is

$$100 * (1.3 - 1.0) = 30\% \quad (8)$$

Thus, the publications in set B have 30% higher chances for being mentioned than the world's publications. We added also CIs to the MHqs in Table 3. Since the CIs of both publication sets (A and B) overlap substantially among themselves and with 1.0 (the world MHq), they do not differ statistically significantly from one another and the world average.

4 Results

Figure 2 displays the MHq values (based on six altmetrics sources) for all WoS papers in the given years (unit 0: red points; neither accepted, nor rejected), papers published by rejected applicants (unit 1: green squares), and papers published by accepted applicants (unit 2: blue diamonds). The papers from accepted applicants are further differentiated into papers written in the context of projects funded by the research center (unit 4: orange diamonds) and papers published in other contexts (unit 3: yellow diamonds). For all MHq values, CIs are indicated. Since the paper numbers from funded projects for some publication years are too low, they could not be presented in the figure.

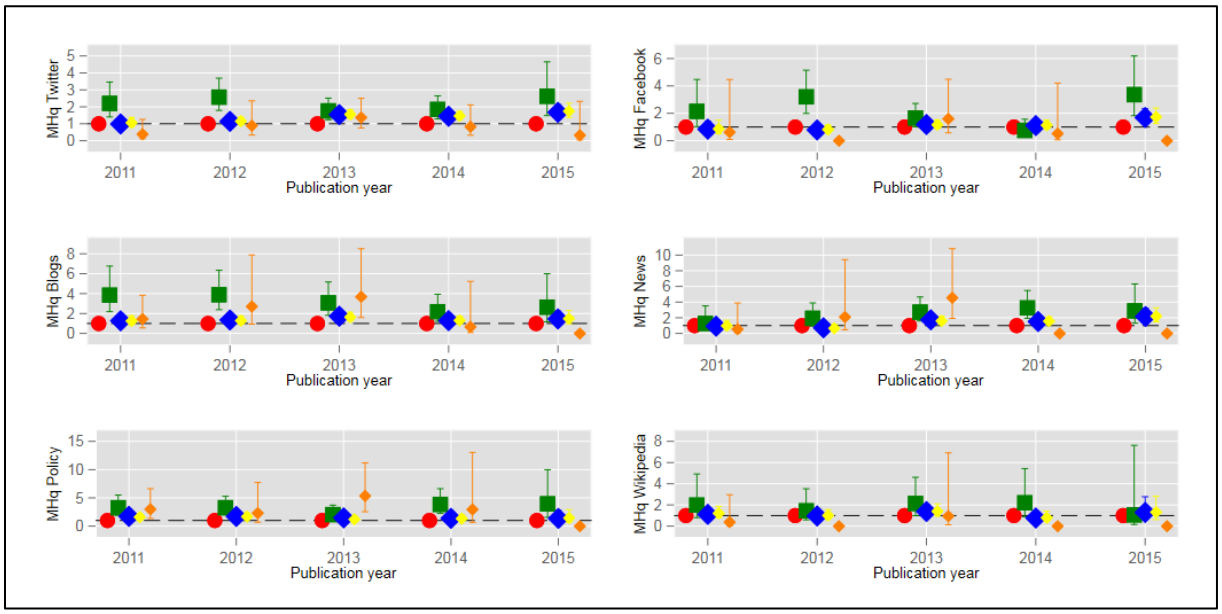

Figure 2: MHq values based on six altmetrics sources for all WoS papers (unit 0: red points; neither accepted, nor rejected), papers published by rejected applicants (unit 1: green squares), and papers published by accepted applicants (unit 2: blue diamonds). The papers from accepted applicants are further divided into papers from funded projects (unit 4: orange diamonds) and papers published in other contexts (unit 3: yellow diamonds). For some years, the values of unit 4 are missing because the numbers of mentioned papers are too low.

The results as summarized in Figure 2 do not support the hypothesis that funded researchers achieve higher altmetrics scores with their research than those who were not funded by the research center. For example, the MHq values based on Twitter data for the papers published by rejected applicants (green squares) are consistently higher than the papers published by accepted applicants (blue diamonds). The differences between both groups are statistically significant in 2011 and 2012, but not in 2013 to 2015 (here, the CIs mostly overlap). Quite strikingly, the figure also reveals that papers published by accepted applicants in the context of the funded research center projects (orange diamonds) even receive lower Twitter scores than the papers they published outside of the research center project (yellow diamonds). The results for the other altmetric scores mainly concur with the Twitter results. Only the findings for the policy-related documents show a different picture: Research-center-based papers published between 2012 and 2014 (orange diamonds) received higher

altmetric scores than the papers by the same researchers which do not emanate from research center projects (yellow diamonds). However, the results are not statistically significant and are not confirmed by the results for 2011 (results for 2015 are not available).

We further analyzed whether the ex-ante societal impact considerations are reflected in citation scores. The results are shown in Figure 3. The figure reveals that the results are more or less in agreement with the altmetrics results (with papers published by rejected applicants performing similar to or better than those of funded applicants). If we inspect the aggregated MHq results based on the papers from all years, papers published by accepted applicants (MHq=3.31) have a higher citation impact than papers published by rejected applicants (MHq=2.87). Since the CIs of both groups overlap, however, the results are not statistically significant. We obtained similar results (missing substantial differences between the groups), when we compared median citations (accepted applicants=9, rejected applicants=9) and percentile citation scores (accepted applicants=73.0, rejected applicants=70.0) of both groups.

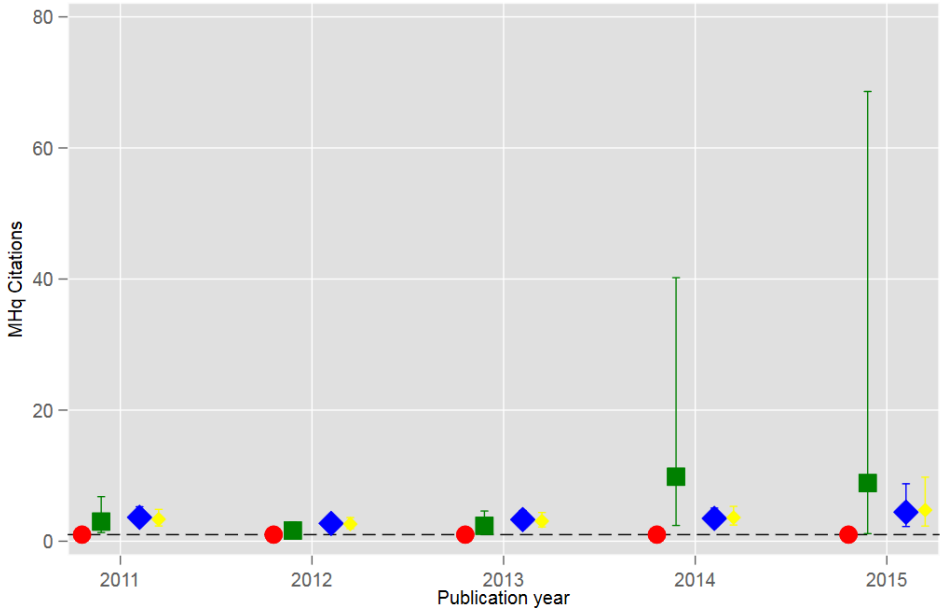

Figure 3: MHq values based on citation counts for all WoS papers (unit 0: red points; neither accepted, nor rejected for funding), papers published by rejected applicants (unit 1: green squares), papers published by accepted applicants (unit 2: blue diamonds), and papers published in other contexts from accepted applicants (unit 3: yellow diamonds). Papers published from funded projects (unit 4) are not shown, because the numbers of uncited papers are too low.

5 Discussion and conclusion

Universities and researchers are increasingly under pressure to disclose how their research contributes to the welfare of society to garner political support and funding (Puschmann 2014, Thune et al. 2016, Bornmann and Haunschild 2017). In light of this development, assessing the societal impact of research is a critically debated issue among evaluation scholars and research policy experts. Because of their widespread use, social media have been at the heart of methodological discussions over the past years, including both their potential (e.g., speed, broadness) as well as their shortcomings (e.g., data quality, zero-inflated data). However, the critical question whether social media, or altmetrics for that matter, are able to reflect societal impact is so far not answered due to conflicting empirical evidence. Against this background, the aim of this study was to contribute to solving this puzzle. For this purpose, the present paper compared ex-ante assessments on the societal relevance of research with altmetrics scores that the respective research received in the years after. A research center from the field of sustainability science (CCES) and the societal impact assessments made by the members of an ad-hoc Research Council (RC) served as case study for this investigation. In conclusion, the proposed hypothesis that researchers funded by CCES achieve higher impact in terms of altmetrics scores with their research than those who were not funded could not be confirmed based on the results. We found no correlation between the RC's assessment and the corresponding altmetric scores. With a few exceptions, this finding seems to be confirmed in the case of all six types of altmetrics. For comparison with altmetrics, we investigated the relationship with citation scores as well. The results are similar to those based on altmetrics: the correlation is not in the expected direction.

Our results might be interpreted in such a way that altmetrics are not entirely suitable for reflecting the societal impact of research. However, since we investigated only one case-specific evaluation procedure and the results are not homogeneous throughout the different types of altmetric scores, this conclusion cannot be drawn with certainty. We conclude therefore that more research is needed to better understand what altmetrics are reflecting, particularly in light of their heterogeneity. Further research should clarify whether altmetric scores rather capture "unknown attention or unstructured noise produced by published research" (Moed 2017, Bornmann et al. 2019), or some sort of "public discussion" (Haunschild et al. 2019), or anything else altogether.

Our results, at the same time, could be interpreted with a critical view of the RC's assessments. Did the members of the RC select the "right" projects in the first place, or how should the missing correlation between the ex-ante assessments and the received citations be interpreted?

Another questions is whether the members of the RC were qualified to judge the societal impact of proposed research? In most cases, expert panels are composed only of researchers rather than of representatives of other sectors of society, which was also true for in the case of CCES. This circumstance may have led to the fact that the potential societal impact could not be accurately

judged, or that the aspect of societal impact was not given enough importance in the evaluation procedure. Overall, we note that our findings can take the discussion forward, but also, that they should be interpreted with caution.

6 Limitations, further research, and recommendations

The study revealed that the ex-ante assessments considering societal impact of research and the altmetric scores of the same research do not correlate. We could conclude the debate at this point and throw altmetrics overboard as a potential measure of societal impact. But, of course, this study has several limitations that need to be discussed.

One key aspect is related to the fact that altmetrics are still "in their infancy" in many ways. For example, are altmetrics really a good proxy for societal impact? Are social media mentions in themselves societal impact? Does a mention or interaction on social media automatically imply that there has been a cognitive engagement with the content of the research, and that societal impact has occurred? Or is it perhaps a buzzword-laden title, zeitgeist or a fame related reason why some research output scores higher on altmetrics than others (Hall 2014)? And what can we say about all the research that does not have any mentions on Twitter or Wikipedia? It would be highly questionable to conclude that no societal impact has been achieved in all these null observation cases. Furthermore, our study does not differentiate between "self-mentions" or in-house users (the own department or the university's communications team) and mentions and interactions by other (more independent) individuals and entities. Despite being somewhat complex, further research should account for these aspects, as well as for the actual content of the tweets or Facebook posts. This latter strategy could allow for a better understanding of the intentions and meanings of social-media-based interactions with research. By looking at the content or the timing of the mentions in more detail, we could possibly identify different strategies in using social media, which could help us formulate new hypotheses.

The results of this work have again shown that the true value added of altmetrics is not yet entirely clear but rather ranges on a scale between societal impact and unstructured noise. This fundamental problem concerns all six types of altmetrics that have been considered in this study (with a more or less extent). With regard to the inability of tweets to measure the societal impact of research, the results of the present study are consistent with those of Haustein et al. (2014b) and Andersen and Haustein (2015). From our point of view, especially off-the-cuff re-tweets are simply too inflationary to imply a serious engagement with the content of the work. Mentions on Wikipedia also do not seem to reflect the societal relevance of research (Kousha and Thelwall 2017). Then, it does not yet seem to be common practice to incorporate scientific research into policy and policy-related documents, neither in the field of climate change, as Bornmann et al. (2016) found, nor in likewise societally relevant field of sustainability science, as the present study showed. This finding

also underlines that the dialog and knowledge transfer between science and policy is far from established (Hessels et al. 2009). At the same time, it must be given fair consideration that, as with classical citations, it can take up to several years for the results of scientific studies to become relevant and cited in policy documents. The time window of the present study was simply too small. Finally, the valid assessment of societal impacts by means of blogging, Facebook or in news outlets largely suffers from the fact that there is a bias towards publications from renowned journals (Shema et al. 2012a), or very specific fields of interest (Ringelhan et al. 2015). Although our findings seem to lend additional support in favor of the argument that altmetrics are not capable of reflecting the societal impact of research, much more research will need to be done before we can actually have a clear picture of what altmetrics are capable of.

Another limitation of this study is related to the evaluation process itself, and less to the shortcomings of altmetrics. Even though the prospect of societal impact was a key criterion for the RC, the assessments were not based on standardized rating scales along individual criteria but rather on a holistic rating, we can only assume that societal impact considerations played a role in the evaluation process rather than having clearly traceable evidence for the specific weighting this critical aspect ultimately had. One remedy for future evaluations could therefore be to assess societal impact as a single dimension using a standardized scale.

A related limitation of the study is associated with the heterogeneity of the societal impact. Societal impact can manifest itself in different ways, for example in the form of policy impact, environmental impact, health impact, or educational impact. Due to the holistic rating in the assessment process, it is not clear what kind of societal impact was in the focus of the experts' attention. This heterogeneity is also an issue for altmetrics. A Twitter mention compared to a mention in a policy document, for example, has not only made a different way, but it probably has a different kind of impact as well.

With regard to the societal impact of research, this study focused exclusively on the published journal papers and the corresponding altmetrics scores they received. It certainly could bring added value if other outputs were taken into account as well, such as outputs that researchers produce within the framework of public outreach activities. Specifically designed to catalyze the societal impact of research, for example, stakeholder publications or teaching material and their respective altmetrics scores could much more accurately reflect the societal impact of research. However, in order for these alternative types of outputs to receive an altmetrics score, they would have to be assigned a unique identifier such as a DOI in the future (see https://www.doi.org/).

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References

Andersen, J. P., S. Haustein. 2015. Influence of Study Type on Twitter Activity for Medical Research Papers. In: *The 15th Conference of the International Society for Scientometrics and Informetrics.* Edited by A. A. Salah, Y. Tonta, A. A. A. Salah, C. Sugimoto, U. Al. Istanbul, Turkey: ISSI, Boaziçi University Printhouse. 26-36.

Bar-Ilan, J., H. Shema, M. Thelwall. 2014. Bibliographic References in Web 2.0. In: *Beyond bibliometrics: harnessing multi-dimensional indicators of performance.* Edited by B. Cronin, C. R. Sugimoto. Cambridge, MA, USA: MIT Press. 307-325.

Bik, H. M., M. C. Goldstein. 2013. An Introduction to Social Media for Scientists. *Plos Biology* 11/4: e1001535.

Bonetta, L. 2007. Scientists enter the blogosphere. *Cell* 129/3: 443-445.

Bornmann, L. 2014. Do altmetrics point to the broader impact of research? An overview of benefits and disadvantages of altmetrics. *JOURNAL OF INFORMETRICS* 8/4: 895-903.

Bornmann, L. 2015. Alternative metrics in scientometrics: A meta-analysis of research into three altmetrics. *SCIENTOMETRICS* 103/3: 1123-1144.

Bornmann, L., R. Haunschild. 2017. Does evaluative scientometrics lose its main focus on scientific quality by the new orientation towards societal impact? *Scientometrics* 110/2: 937-943.

Bornmann, L., R. Haunschild. 2018. Normalization of zero-inflated data: An empirical analysis of a new indicator family and its use with altmetrics data. *JOURNAL OF INFORMETRICS* 12/3: 998-1011.

Bornmann, L., L. Leydesdorff, R. Mutz. 2013. The use of percentiles and percentile rank classes in the analysis of bibliometric data: opportunities and limits. *JOURNAL OF INFORMETRICS* 7/1: 158-165.

Bornmann, L., R. Haunschild, W. Marx. 2016. Policy documents as sources for measuring societal impact: how often is climate change research mentioned in policy-related documents? *SCIENTOMETRICS* 109/3: 1477-1495.

Bornmann, L., R. Haunschild, J. Adams. 2019. Do altmetrics assess societal impact in a comparable way to case studies? An empirical test of the convergent validity of altmetrics based on data from the UK research excellence framework (REF). *JOURNAL OF INFORMETRICS* 13/1: 325-340.

Brandt, P. et al. 2013. A review of transdisciplinary research in sustainability science. *Ecological economics* 92: 1-15.
CCES. 2005. *Competence Center Environmental and Sustainability (CCES) of the ETH Domain: Business Plan*. Zurich: Competence Center Environmental and Sustainability of the ETH Domain.
Clark, W. C. 2007. Sustainability Science: A room of its own. *Proceedings of the National Academy of Sciences* 104/6: 1737-1738.
Competence Center Environment and Sustainability. 2006. *CCES selection and evaluation of research projects*. Zurich, Switzerland: Competence Center Environment and Sustainability.
Dehdarirad, T., F. Didegah, H. Sotudeh. 2018. Which Type of Research is Cited More Often in Wikipedia? A Case Study of PubMed Research. In: *Proceedings of the science and technology indicators conference 2018 Leiden "Science, Technology and Innovation indicators in transition".* Edited by P. Wouters. Leiden, the Netherlands: University of Leiden.
Fausto, S., F. A. Machado, L. F. J. Bento, A. Iamarino, T. R. Nahas, D. S. Munger. 2012. Research Blogging: Indexing and Registering the Change in Science 2.0. *Plos One* 7/12: e50109.
Fleiss, J., B. Levin, M. C. Paik. 2003. *Statistical methods for rates and proportions.* 3. edition. Hoboken, NJ, USA: Wiley.
Guglielmi, G. 2018. Wikipedia's top-cited scholarly articles - revealed. *NATURE* 557/7705: 291-292.
Hall, N. 2014. The Kardashian index: a measure of discrepant social media profile for scientists. *Genome Biology* 15/7: 424.
Haunschild, R., L. Bornmann. 2017. How many scientific papers are mentioned in policy-related documents? An empirical investigation using Web of Science and Altmetric data. *SCIENTOMETRICS* 110/3: 1209-1216.
Haunschild, R., L. Bornmann. 2018. Field- and time-normalization of data with many zeros: an empirical analysis using citation and Twitter data. *SCIENTOMETRICS* 116/2: 997–1012.
Haunschild, R., L. Leydesdorff, L. Bornmann, I. Hellsten, W. Marx. 2019. Does the public discuss other topics on climate change than researchers? A comparison of explorative networks based on author keywords and hashtags. *Journal of Informetrics* 13/2: 695-707.
Haustein, S., V. Larivière, M. Thelwall, D. Amyot, I. Peters. 2014a. Tweets vs. Mendeley readers: How do these two social media metrics differ? *it – Information Technology 2014; 56(5):* 56/5: 207-215.
Haustein, S., I. Peters, J. Bar-Ilan, J. Priem, H. Shema, J. Terliesner. 2014b. Coverage and adoption of altmetrics sources in the bibliometric community. *SCIENTOMETRICS* 101/2: 1145–1163.
Hessels, L. K., H. Van Lente, R. Smits. 2009. In search of relevance: the changing contract between science and society. *Science and Public Policy* 36/5: 387-401.
Hollander, M., D. A. Wolfe. 1999. *Nonparametric Statistical Methods.* New York, NY, USA: Wiley.
Kajikawa, Y., F. Tacoa, K. Yamaguchi. 2014. Sustainability science: the changing landscape of sustainability research. *Sustainability Science* 9/4: 431-438.
Kassab, O. 2019. Does public outreach impede research performance? Exploring the 'researcher's dilemma' in a sustainability research center. *Science and Public Policy* 46/5: 710-720.
Kassab, O., R. P. Schwarzenbach, N. Gotsch. 2018. Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain. *GAIA - Ecological Perspectives for Science and Society* 27/2: 226-234.
Kates, R. W. 2011. What kind of a science is sustainability science? *Proceedings of the National Academy of Sciences* 108/49: 19449-19450.
Kousha, K., M. Thelwall. 2017. Are wikipedia citations important evidence of the impact of scholarly articles and books? *Journal of the Association For Information Science and Technology* 68/3: 762-779.
Lang, D. J. et al. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science* 7/1: 25-43.
Luzón, M. J. 2013. Public Communication of Science in Blogs: Recontextualizing Scientific Discourse for a Diversified Audience. *Written Communication*.
Mantel, N., W. Haenszel. 1959. Statistical Aspects of the Analysis of Data from Retrospective Studies of Disease. *Journal of the National Cancer Institute* 22/4: 719-748.

Mas-Bleda, A., M. Thelwall. 2016. Can alternative indicators overcome language biases in citation counts? A comparison of Spanish and UK research. *SCIENTOMETRICS* 109/3: 2007-2030.
Mewburn, I., P. Thomson. 2013. Why do academics blog? An analysis of audiences, purposes and challenges. *Studies in Higher Education* 38/8: 1105-1119.
Miller, T. R. 2013. Constructing sustainability science: emerging perspectives and research trajectories. *Sustainability Science* 8/2: 279-293.
Mobjörk, M. 2010. Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. *Futures* 42/8: 866-873.
Moed, H. F. 2017. *Applied evaluative informetrics.* Cham: Springer.
OPENing UP. 2016. *Deliverable D5.1 – Altmetrics Status Quo. OPENing UP new methods, indicators and tools for peer review, impact measurement and dissemination of research results. Project acronym: OpenUP*. Brussels, Belgium: European Commission.
Pohl, C. 2010. From transdisciplinarity to transdisciplinary research. *Transdisciplinary Journal of Engineering Science* 1: 65-73.
Priem, J. 2014. Altmetrics. In: *Beyond bibliometrics: harnessing multi-dimensional indicators of performance.* Edited by B. Cronin, C. R. Sugimoto. Cambridge, MA, USA: MIT Press. 263-288.
Priem, J., B. M. Hemminger. 2010. Scientometrics 2.0: toward new metrics of scholarly impact on the social Web. *First Monday* 15/7.
Puschmann, C. 2014. (Micro) blogging science? Notes on potentials and constraints of new forms of scholarly communication. In: *Opening Science: The Evolving Guide on How the Internet is Changing Research, Collaboration and Scholarly Publishing.* Edited by S. Bartling, S. Friesike. Cham: Springer. 89-106.
Radhakrishna, S. 1965. Combination of results from several 2 x 2 contingency tables. *Biometrics* 21: 86-98.
Ringelhan, S., J. Wollersheim, I. M. Welpe. 2015. I Like, I Cite? Do Facebook Likes Predict the Impact of Scientific Work? *Plos One* 10/8: e0134389.
Robinson-Garcia, N., R. Costas, K. Isett, J. Melkers, D. Hicks. 2017. The unbearable emptiness of tweeting—About journal articles. *Plos One* 12/8: e0183551.
Rons, N. 2012. Partition-based Field Normalization: An approach to highly specialized publication records. *Journal of Informetrics* 6/1: 1-10.
Rons, N. 2014. Investigation of Partition Cells as a Structural Basis Suitable for Assessments of Individual Scientists. In: *Proceedings of the science and technology indicators conference 2014 Leiden "Context Counts: Pathways to Master Big and Little Data".* Edited by P. Wouters. Leiden, the Netherlands: University of Leiden. 463-472.
Samoilenko, A., T. Yasseri. 2014. The distorted mirror of Wikipedia: a quantitative analysis of Wikipedia coverage of academics. *EPJ Data Science* 3/1: 1.
SDSN. 2017. *Getting started with the SDGs in universities: A guide for universities, higher education institutions, and the academic sector. Australia, New Zealand and Pacific Edition.* Melbourne: SDSN.
Serrano-López, A. E., P. Ingwersen, E. Sanz-Casado. 2017. Wind power research in Wikipedia: Does Wikipedia demonstrate direct influence of research publications and can it be used as adequate source in research evaluation? *SCIENTOMETRICS* 112/3: 1471-1488.
Shema, H. 2014. Scholarly blogs are a promising altmetric source. *Research Trends* /37: 11-13.
Shema, H., J. Bar-Ilan, M. Thelwall. 2012a. Self-citation of bloggers in the science blogosphere. In: *Science and the Internet.* Edited by A. Tokar et al. Düsseldorf, Germany: Düsseldorf University Press. 183-192.
Shema, H., J. Bar-Ilan, M. Thelwall. 2012b. Research Blogs and the Discussion of Scholarly Information. *Plos One* 7/5: e35869.
Shema, H., J. Bar-Ilan, M. Thelwall. 2014. Do blog citations correlate with a higher number of future citations? Research blogs as a potential source for alternative metrics. *Journal of the Association For Information Science and Technology* 65/5: 1018-1027.
Sheskin, D. 2007. *Handbook of parametric and nonparametric statistical procedures.* 4th edition. Boca Raton, FL, USA: Chapman & Hall/CRC.
Sugimoto, C. R., S. Work, V. Larivière, S. Haustein. 2016. *Scholarly use of social media and altmetrics: a review of the literature*. https://arxiv.org/abs/1608.08112 (accessed April, 5).

Tattersall, A., C. Carroll. 2018. What Can Altmetric.com Tell Us About Policy Citations of Research? An Analysis of Altmetric.com Data for Research Articles from the University of Sheffield. *Frontiers in Research Metrics and Analytics* 2/9.

Teplitskiy, M., G. Lu, E. Duede. 2015. *Amplifying the Impact of Open Access: Wikipedia and the Diffusion of Science*. August 11).

Thune, T., I. Reymert, M. Gulbrandsen, P. Olaf Aamodt. 2016. Universities and external engagement activities: Particular profiles for particular universities? *Science and Public Policy* 43/6: 774-786.

Vilkins, S., W. J. Grant. 2017. Types of evidence cited in Australian Government publications. *SCIENTOMETRICS* 113/3: 1681-1695.

Wiek, A., S. Talwar, M. O'Shea, J. Robinson. 2014. Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation* 23/2: 117-132.

Wooldridge, J., M. B. King. 2019. Altmetric scores: An early indicator of research impact.70/3: 271-282.

Yarime, M. et al. 2012. Establishing sustainability science in higher education institutions: towards an integration of academic development, institutionalization, and stakeholder collaborations. *Sustainability Science* 7/1: 101-113.

Yu, H. 2017. Context of altmetrics data matters: an investigation of count type and user category. *SCIENTOMETRICS* 111/1: 267-283.

PART III

CONCLUSION AND DISCUSSION

Chapter 5

Conclusion

Research centers are the Swiss Army Knives of academia. Their unprecedented versatility absorbed many of the expectations that had challenged the traditional university model and its researchers as a consequence of substantive transformations in the higher education system. Not only can research centers facilitate the application of interdisciplinary research approaches for the study of intricate problems, but they also support the development of applied solutions through networking with stakeholders beyond academia. At the same time, they provide a nurturing environment for a problem-based education and capacity-building both for early career researchers as well as more experienced ones. They also maintain a plethora of channels for the interaction with industry, public administration, politics, and the public, among other things. In brief, their systemic relevance for the university landscape is beyond question. Contrary to their mushrooming expansion across the globe, however, the development of evaluation approaches capable of adequately assessing and evaluating their impact had lagged behind, primarily for methodological reasons and lack of data availability. Filling part of this gap was the aim of this dissertation. Within the framework of three articles, the dissertation yielded a series of insights not only of methodological nature, but also related to the more applied sides of evaluation practice and research policy.

The *first article* made explicit that a fair bibliometrics-based evaluation of research centers must take into account specific features of research centers and their participants. These foremost include characteristics that distinguish research centers from departments, such as their temporary lifespan or the fact that, in most cases, researchers only spend a certain share of their working time at research centers. By incorporating fine-grained archival data on participation intensity and transition, as well as several researcher level variables into a quasi-experimental research design, the shortcomings were solved methodologically. As far as the implications for research policy are concerned, the results demonstrate that involvement in a research center does not have a negative effect on individual research performance. This finding, too, is of critical value for inter- and transdisciplinary research in view of the belief that engaging in research other than disciplinary research could hamper an academic career. Because only when researchers feel confident to transgress their own disciplinary

specialization, without having to fear opportunity costs, can much needed solutions to complex problems be developed, such as those required in sustainability science.

The *second article* empirically investigated the "researcher's dilemma", which is based on the notion that researchers have to decide whether to spend their time exclusively on academic activities to produce scientific publications, or to additionally engage in public outreach. Compared to prior studies, the article understood the research center as a bound organizational entity in which the respective scientific and non-scientific outputs are related both in terms of content and temporality. This framework was particularly suitable from a theoretical viewpoint as the transdisciplinary interaction with stakeholders from different sectors (here: science and "practice") is thought to initiate discussions with benefits for both sides. In terms of practical implications, the results suggest that research performance and engaging in public outreach are positively correlated. In other words, the third article provided empirical evidence to partially refute the "researcher's dilemma". Lastly, the article put forth an approach to investigate the relationship of two presumably diverging activities in the context of a research center. In a similar way, future evaluation studies could address the relationship between research and teaching, or between research and patenting activities, among others.

The *third article* explored the potential of altmetrics for assessing the societal impact of research. For this purpose, the study hypothesized that researchers accepted for funding by the research center would achieve higher societal impact with their research than researchers who were rejected. The hypothesis was tested on the basis of bibliometric data and corresponding altmetrics scores. The investigation came to the conclusion that there is no correlation between the funding decision by peers and the corresponding altmetrics scores the researchers received for their output later. From a practical perspective, the bottom line is that altmetrics so far do not seem to be suitable for assessing the societal impact of research outputs in a straightforward way. At the same time, however, it must be pointed out that the results could just as well be interpreted to mean that considerations of broader impact potential were not sufficiently taken into account in the funding decision process, even though this was defined as a selection criterion. Both these readings have implications for future evaluations of research centers.

This dissertation started off with the question of how research centers could be evaluated adequately. As the above synthesis of the three articles shows, quantitative approaches can only illustrate partial aspects of the impact and must therefore be complemented by qualitative approaches in the sense of a methodological triangulation. One way forward was indicated in the self-evaluation of CCES (see Appendix A). If a comprehensive evaluation is to be carried out, good preparation is essential. Knowledge and consideration of the goals, governance

modes, or funding schemes of the object of study can provide a meaningful starting point for the decision which data and methods are best suited for the inquiry. Furthermore, outlining the potential range of impacts, for example, by developing and orientating to a logic model, can be very helpful. In this sense, future research center evaluations could be guided by the logic model that was developed in the framework of this dissertation (see Figure 4). The proposed logic model is as generic as possible to depict a theory of change applicable to research centers in general. In each of its stages – resources, processes, outputs, and impacts – the logic model differentiates between three levels, including the individual researcher's level, the project level, and the research center level. Other than introduced in the conceptual part (see 2.3), the impact structure here does not assume sequential impacts (short-term, intermediate and long-term), but instead defines two realms: impact *within* academia and impact *beyond* academia. This is the case as a chronological impact sequence cannot be traced in the majority of cases, especially in ex-post evaluations. The arrows in the generic logic model also do not represent a complete depiction of a causal chain, but rather refer from level to level to illustrate the considerations of the underlying theory of change. This aspect also ensures the practicability of the logic model, which would otherwise be overloaded with arrows.

As far as the practical implications are concerned, one of the most revealing findings of the dissertation is that engaging in inter- and transdisciplinary research centers does not seem to impede the individual's research productivity, other than is widely assumed. The fact that this applies both to the conduct of inter- and disciplinary research as well as to the additional engagement in public outreach activities, puts much of the hesitation and prejudice against research centers into perspective.

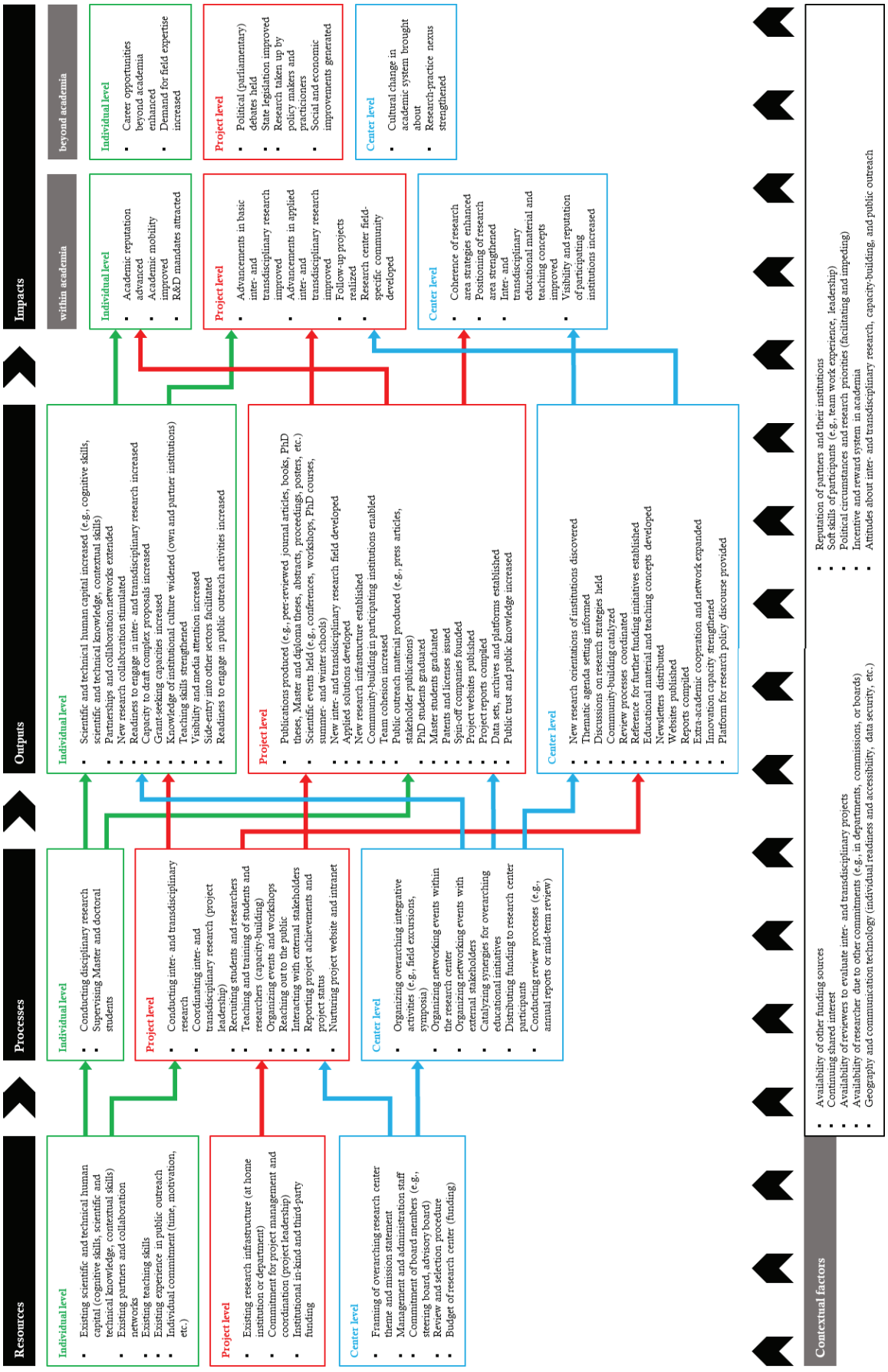

Figure 4. Generic logic model for the evaluation of research centers

Chapter 6

Limitations and further research

Needless to say, the research conducted in the context of this dissertation is subject to limitations that need to be discussed. While each of the three articles addressed respective limitations separately, this chapter summarizes overarching ones and similarly suggests pathways for further research. As exemplified by the quotes throughout the chapter, some of the issues were brought up in the expert interviews, but were not addressed with emphasis in the framework of this dissertation.

Generalizability of the results

One fundamental limitation that equally applies to all case studies is related to the issue of external validity. For example, the findings of this dissertation suggest that engaging in research centers does not adversely affect research performance. But can this per se be applied to all inter- and transdisciplinary fields, or is this only true for sustainability science? This question remains open. On the other hand, it is clear that the methodological approaches explored, developed and tested within the framework of this dissertation can be applied more broadly. In fact, they would strongly benefit from application to other case studies. The approaches should by no means dust up as "grey literature" in the internal archives, but must be presented, published, and discussed in the community. Such a proactive exercise would also solve part of the problem that has been described as follows: the "absence of any central clearinghouse for information on methodologies, experiences, or findings stemming from these evaluations (…) the absence of a central repository means that evaluation knowledge (…) is not accumulating. It means that each evaluation must begin without reference to past findings and tools that could inform evaluation design and lead to improved data quality and targeting of studies" (Madrillon 2010).

Ex-post evaluation and causality

The use of archival data, publication histories dating back to the 1980s, and interviews with experts (see Appendix C), some of which were no longer affiliated with the research center at the time of the interview, implies that the evaluation approaches were implemented ex-post. Ex-post designs, which are very prevalent in the social sciences, are problematic for several

reasons. In the literature, three problems are mentioned (Behnke et al. 2010): Unlike in experimental settings, causal relationships can only be determined to a very limited extent because independent and dependent variables are collected at the same time. The second problem relates to the control variables, which can significantly alter the relationship between the independent variables and the dependent variables. It is by no means their number alone that is decisive, but above all, their theoretical integration. The third problem is related to the variance of the independent variables. Compared to experimental designs, it is basically impossible in ex-post designs to determine clearly isolable, linear causal relationships. This is specifically the case when the impact is likely to extend beyond the realm of academia to the political, public, administrative and industrial spheres, as is evidently the case with research centers. Moreover, ex-post designs have problems coping with intervening effects, including those reinforcing and weakening the actual impact. Therefore, the specific contribution of a research center to the change in a situation cannot be ultimately and definitively distinguished from other influencing factors. As alternatives to ex-post evaluations, ex-ante evaluations or monitoring research could provide more causal accuracy. In ex-ante evaluations, which take place before or during the starting phase of the research center, research centers could be assessed in terms of goal setting or financial viability. Monitoring research, in turn, involves keeping up to date with the progress of a specific project and requires experts with distinct theoretical, technical and field knowledge in the respective subject area of the research center. Monitoring researchers often act in a multiple role, for example by participating in the conception of the research center or in the application for funding.

Data availability

As illustrated in the generic logic model, the potential impacts of the research center concern not only to the key areas of (a) research, (b) capacity-building and (c) public outreach, but also extend to extra-academic contexts such as (d) industry, (e) public administration or politics. The dissertation at hand did not equally encompass all these areas because the case study did not provide data to allow for their coverage. Rather, the generic logic model draws on findings compiled both in the course of this dissertation as well as on findings generated in the literature. Further research is conceivable and necessary in each of the contexts mentioned above:

(a) *Research:* Quite strikingly, the research publication output at CCES was limited to peer-reviewed journal articles. It would be interesting, if applicable at all, to also consider other research outputs – for example books, book chapters, or conference proceedings – and to include them in the bibliometric analyses. It might also be instructive to study the institutional affiliations of all co-authors in the dataset, and not only those involved in the

research center. This could provide exciting insights into the evolution of individual networks, especially as networking is regarded as one of the major goals of research centers. At the same time, however, there are indications from the expert interviews that would put this into perspective:

> *"It's just as long as the project runs. Once the project ends, then there's no reason to cooperate as much, from my point of view. But of course that can change again if there are certain new projects, because you know the people, the people know you. The probability of collaborating in the future may increase, of course."* (Respondent 7: 45-48)

Another equally intriguing question relates to the longer-term observation of individual research performance. This would allow detecting whether participation in a research center had a lasting effect or whether it flattens out after a specific phase. Analyzing a time horizon of around ten years or more after the lifespan of the research center could yield interesting insights.

(b) *Capacity-building:* While "competencies acquired in individual disciplines remain a fundamental precondition for tasks defined [inter- and] transdisciplinarily" (Mittelstrass 2011), the exposure to inter- and transdisciplinary research centers can strongly influence the development of scientific technical and human capital (Bozeman et al. 2001). Within the scope of this dissertation, this aspect was primarily touched on theoretically. The recognition that leadership, team work or other soft skills, personal networks, and the visibility of researchers, among other things, increase in the course of research center participation, would call for an in-depth monitoring of career paths (Thomas et al. 2004, Watermeyer 2015, Haider et al. 2018). Even though the expert interviews have already given initial indications of such a development, they are by no means representative of all participants.

> *"Those people got their early training in a very stimulating environment, and I think that is the highest leverage activity we can do, to provide the actual students with an environment that is different than that of their professors, where they work across the disciplines on more complex problems."* (Respondent 7: 284-287)

(c) *Public outreach:* While citations are a widely recognized indicator for the scientific impact of research output, a major shortcoming of research evaluation in general is related to the operationalization and assessment of the societal impact (Jaffe 2015). Vividly discussed as a potential remedy, altmetrics are still in the early stages of their development and will more likely be a reasonable option in the medium- to long-term, as this dissertation found.

(d) *Industry:* Science, technology, and innovation (STI) policy research analyses patents as tangible and quantifiable performance indicators (Jaffe et al. 1993, Dietz and Bozeman 2005, Ponomariov 2013, Jaffe and De Rassenfosse 2017). Patent filings and patent citations are understood as a successful knowledge transfer between research and industry. The occurrence of patents in the annual reports of present case study was marginal (less than one patent per year over the course of the entire lifespan), making it unsuitable for statistical purposes. Another opportunity to assess the impact on industry is provided by studying financial data. One feature of the present case study was the funding scheme, according to which applicants were required to obtain "matching funds" from third parties like industry or public administration. The empirical remedy proposed in this dissertation consisted of including a control variable to capture the third party share of the overall budget. Yet against the background of the theorized linkage between funding from industry and impact on industry (Spaapen and Van Drooge 2011), a closer look, for example by means of an in-depth case study, could shed more light on the matter.

(e) *Public administration or politics:* Similar to patents, there are approaches in the evaluation literature to capture the impact of research in the form of research uptake and changed practices and policies (Lagarde 2011, Sumner et al. 2011, Bornmann et al. 2016). However, this will hardly be plausible in a large-scale statistical study. Instead, process tracing could provide insights to identify the incremental steps between knowledge production and uptake by stakeholders in public administration or politics.

Assessing levels of inter- and transdisciplinarity (in research centers)

This dissertation introduced research centers as inherently inter- and transdisciplinary and presented the field of sustainability science as a prime example of this mode of research. Although the case study examined here could thus be understood as a best case scenario with view on the purpose of this dissertation, the potential gap between inter- and transdisciplinarity in theory and practice should still be taken into account. Against the background of definitory discrepancies and conceptual grey areas, the unambiguous of the terminology is not possible without reservation. While there have been attempts to assess levels of interdisciplinarity on the basis of disciplinary backgrounds of researchers, the classification of journals they publish in, by assigning publications to subject categories, or by reviewing constellations of researchers in grant proposals (Porter et al. 2007, Mutz et al. 2015), these approaches primarily focus on the outputs, and not the underlying processes that preceded them. Moreover, these strategies are even less capable of capturing transdisciplinary processes. To assess the degree of inter- and transdisciplinarity, here too, the qualitative case study approach perhaps offers the most

promising approach from a methodological point of view, as it would allow an in-depth analysis of backgrounds and integration processes by means of expert interviews or surveys.

Delineating sustainability science

Less a limitation but rather an indication for further research concerns the delineation of the field of sustainability science. Previous approaches to describe the field were presented and discussed above (see 3.2). In the context of this dissertation, the CCES research center, the participating researchers, and their research output served as a starting point for the definition. This understanding was based on the assumption that CCES provided a platform for researchers to engage in sustainability science. Since the affiliation with CCES was preceded by an application process on the basis of project proposals as well as a two-staged peer review procedure, the approach used to delineate the field in the context of this dissertation could be described as a "verified bottom-up" approach. In fact, this approach is very different from the widely used keyword search approach (Yarime et al. 2010, Schoolman et al. 2012), according to which the occurrence of *sustainability* in titles of abstracts automatically qualifies publications as contributions to sustainability science. Quite strikingly, in all titles of the publications considered within the context of this dissertation, the term occurred only 93 times, which is equivalent to less than one percent of the whole dataset. This phenomenon is consistent with the argument that publications do not necessarily need a "sustainability label" in order to be classified as sustainability science (Kates 2011). Another characteristic aspect of the approach used here is related to the fact that the entire publication histories of the participants were considered rather than focusing only on the publications they generated in the research center context. This was specifically the case in the second article, which applied a longitudinal research design to detect the "treatment" effect of CCES. This chronological aspect is interesting insofar as many of the participating researchers had not yet experienced interdisciplinary collaboration prior to their affiliation with CCES, as succinctly described in the following quote:

> *"I think it was CCES that kind of turned us into environmental scientists. [...] Before that, we have been ecologists, and bio geo-chemists, and so on, but [...] for the very first time, we stopped being a collection of disciplines, and that was a big effect."* (Respondent 7: 220-223)

This statement may be interpreted as meaning that participation in CCES has fostered some degree of integration across the engaged disciplines, and also, that individual researchers have only become environmental scientists (or sustainability scientists) through participation in the research center. The fact that there has indeed been some kind of consolidation as a result of

CCES participation becomes clear when subdividing the dataset into two parts, contrasting the publications *before* the research center with the publications *after* the founding of CCES.

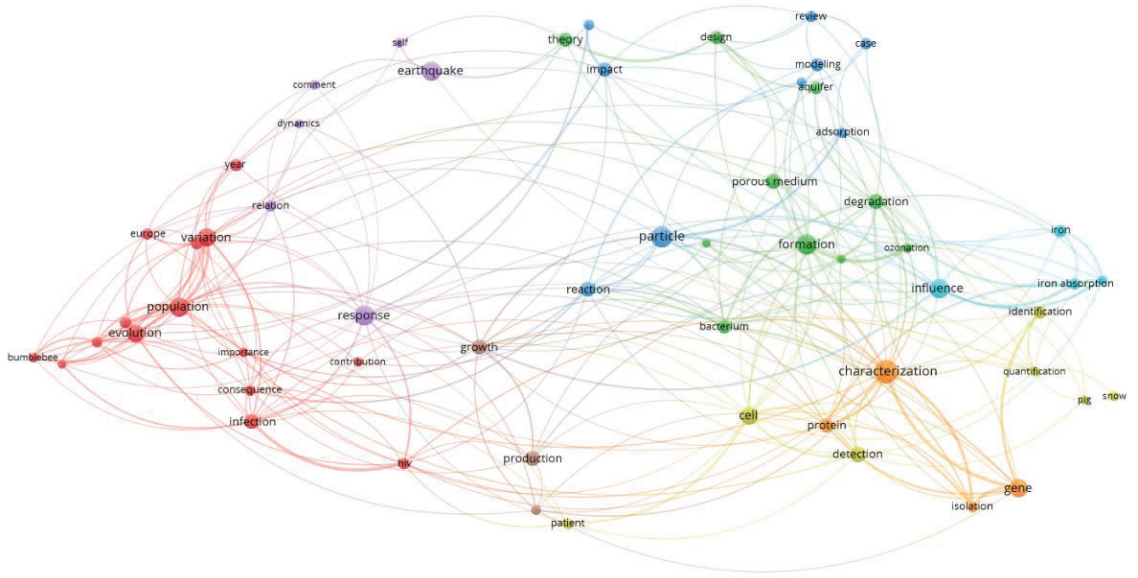

Figure 5. Term co-occurrence map based on Web of Science data, using the titles of 5049 peer-reviewed journal articles published between **1980 and 2005**. Setting the minimum number of occurrences of a term to 15, the analysis yielded 96 terms. With 60 percent of the most relevant selected, the map includes the most frequent 57 terms: particle (91 occurrences), response (82 occurrences), formation (78 occurrences), earthquake and population (76 occurrences each). The map was computed using the VOSviewer software, version 1.6.11 (van Eck and Waltman 2010).

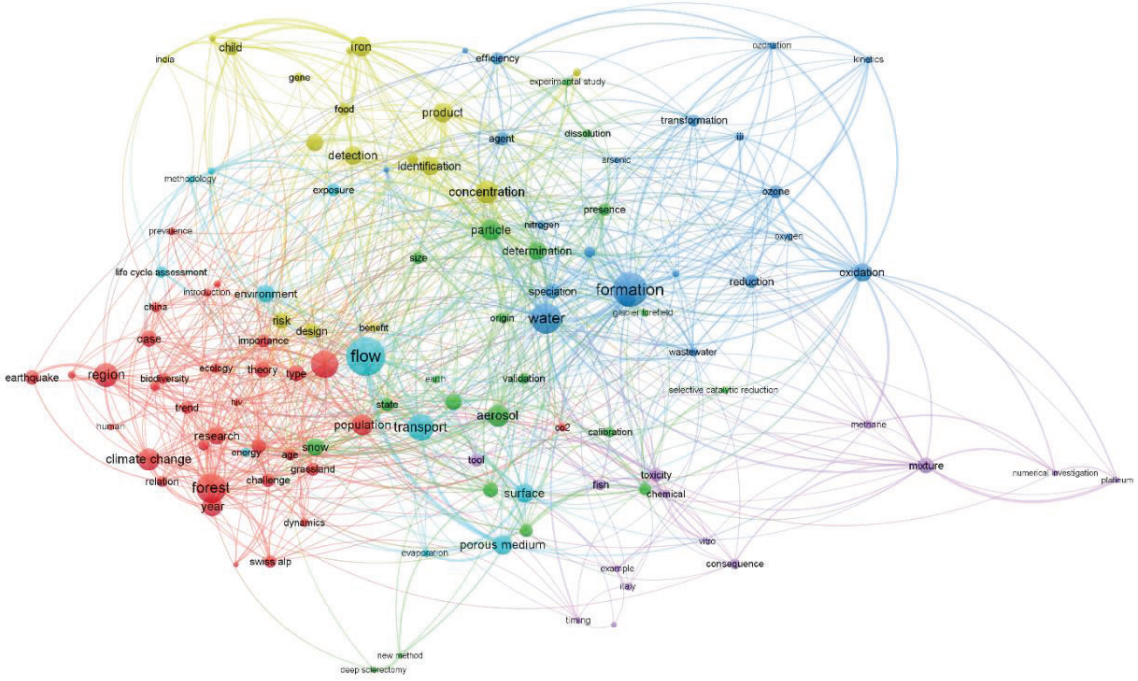

Figure 6. Term co-occurrence map based on Web of Science data, using the titles of 9159 peer-reviewed journal articles published between **2006 and 2015**. Setting the minimum number of occurrences of a term to 15, the analysis yielded 195 terms. With 60 percent of the most relevant selected, the map includes the most frequent 117 terms: flow (166 occurrences), formation (142 occurrences), water (122 occurrences), forest (118 occurrences), and diversity (107 occurrences). The map was computed using the VOSviewer software, version 1.6.11 (van Eck and Waltman 2010).

The figures contrast two sections of the dataset that differ with respect to the time frame they cover. Each of the figures illustrates the term co-occurrence in publication titles with density of the terms indicating the frequency. Wherever the co-occurrence is particularly dense, this is represented by colored clusters. Figure 5 shows the term co-occurrence map for the titles of all peer-reviewed journal articles published between 1980 and 2005. This first time frame thus represents the publication history *prior* to the establishment of CCES. Figure 6 illustrates the period *since* the founding of the research center in 2006 until the end of 2014. This direct comparison shows that the co-occurrence of terms in the later time window has densified significantly in contrast to the first one. This phenomenon suggests that a stronger focus may have emerged over time with regards to the research topics, so that certain combinations occur more frequently in the titles of publications than before CCES. One example in Figure 6 is the co-occurrence of "climate change" with "human", "forest", or "biodiversity" (cluster on the left). In sum, this dissertation has introduced an alternative approach to delineating sustainability science. But ultimately, the findings prove once again that there is still some research to be done to better understand and characterize the field that is still undergoing change.

Chapter 7

Recommendations

This dissertation has demonstrated that research centers can catalyze and unfold a broad range of impacts. They are suitable, for example, for the production of knowledge that could not be generated in the departmental structures of universities. They can also enhance the visibility and positioning of a researcher, research field, university, or national research system. They can shape networks, form structures and also contribute to the promotion of young talent. They can act as entrance points for cooperation between universities and other sectors, raise awareness among politicians on certain issues and contribute to concrete problem solutions. Moreover, they can be drivers of cultural change in the academic reward and evaluation system. In Appendix A, five recommendations for the design, management and operation of research centers were formulated: (1) provide incentives to facilitate inter- and transdisciplinary capacity-building, (2) coordinate inter- and transdisciplinarity through integrative leadership, (3) benefit from synergies in governance bodies for operation and evaluation, (4) operate a lean management and reporting policy, and (5) maintain networks through data management and research infrastructure. In addition, this dissertation has also yielded insights that can be formulated as recommendations for future research center evaluations:

Digitize the reporting routine

The data quality is decisive for the conduct of an evaluation. Thus, the reporting routine that generates this data is a crucial matter to which a great deal of attention should be attributed. At the same time, reporting procedures must not be too burdensome because they would cost researchers too much time at the expense of "more important" activities.

> *"Putting one's own part of the report together is easy. It is getting the stuff from everybody else. Kind of thinking: 'Is this right?' – No, they have misunderstood this, they have left out, you know there is someone who they haven't put on their list. You have to give it back and chase them. All that just took time and was the least attractive part, I thought."* (Respondent 1: 273-276)

The experiences gained from collecting, coding and cleaning archival data in the context of this dissertation were quite revealing. The annual reports were compiled in a standardized

template. Although these reports underwent careful examination, they were not systematically checked across projects. While discrepancies of financial nature within a project could be identified instantly, it occurred several times that publications or other outputs were declared twice or even thrice in cases where projects had overlapping research personnel. Only after the data was prepared for the purpose of the analyses did this problem become apparent and was corrected. Critically speaking, this implies that the assessment of a research center only on the basis of the standard reporting approach, which focuses on quantitative indicators, may be flawed despite the inherent "objectivity" of the data. In fact, this is true not only for the evaluation of research centers, but for research evaluation more generally. By making a few adjustments, for example by means of a digitized and centralized database, many of these issues could be solved. In the process of digitalization, many universities have already introduced such systems and measures. Multiple mentions of publications, for example, can thus promptly be recognized and signaled. A digital reporting solution would also enhance the efficiency for the research center management and also facilitate future evaluations on the basis of bibliometric data, the collection of which required a significant effort in the context of this dissertation. Taking data protection aspects into account, it would also be possible to optimize the targeted collection of other data relevant to the evaluation, such as the full-time equivalents, individual involvement in the research center and in public outreach activities, biographical data, or self-assessments of networks and career development. Besides, a strategically planned reporting routine could also serve scholars and practicioners conducting ex-ante evaluations or monitoring research, as outlined above.

Provide conceptual clarity

Related to the reporting procedure is the problem of clear concept specification. Because only if it is unambiguously clear what certain activities refer to can researchers provide concise information. While there are distinct typologies for standard scientific outputs (i.e., books, peer-reviewed journal articles, etc.), data collection on less mainstream activities and outputs could lead to inconsistencies across the reportings. In the present case, there was a straightforward seven-fold distinction for the public outreach activities on the basis of which the project leadership could provide inputs for the reporting. Elsewhere, however, researchers are requested to report on "dissemination activities" without providing further detail. This does not just overburden researchers, but it also renders a cross-comparison impossible. A clear specification from the outset can alleviate this problem.

> *"What is actually the goal of outreach? If it was for the practical relevance, I could achieve that differently. Or do you want to make sure that your institution will be supported in the future as well? Is that why we organize events where the population comes into contact with researchers? Until you haven't clearly defined what you want, you should forbid using the word 'outreach'. As with EU projects, where they speak of 'dissemination activities'. You know that they want you to do those, but the goals are entirely unclear."* (Respondent 5: 253-258)

Define specific and measurable goals

Goal setting is a very complex and at times highly political process. In the programming phase of a research center, this task is additionally complicated by the fact that there is no clear idea of the expected impacts. This uncertainty has an immediate implication on the definition of the goals, which in most cases are formulated broadly and generally, at best directionally. A sharper formulation of the goals would not only provide the prerequisites for stringent and coherent leadership, concerted and result-oriented research, capacity-building activities and public outreach, but also for assessing the research center's goal achievement. The generic logic model proposed above could help formulating "smart" (specific measurable achievable reasonable time bound) goals.

Involve extra-academic experts in review processes

Qualitative evaluation schemes of scientific quality (i.e., peer review) reach their limits as soon as the research under scrutiny transgresses multiple disciplinary boundaries. As argued further above, the evaluation of interdisciplinary research can be conducted most comprehensively when peer review panels are staffed by experts from the relevant disciplinary backgrounds. However, as soon as transdisciplinary research has to be assessed, panels consisting exclusively of researchers mostly lack the capacity of assessing the impact beyond academia. In light of this shortcoming, it would be advisable to involve extra-academic experts in evaluation panels and boards of inter- and transdisciplinarity research centers. In the specific case of CCES, for example, one industry representative was a part of the nine-member Advisory Board, which gave the extra-academic perspective a rather marginal voice. Depending on the research area, experts from other sectors such as agriculture, energy, or the mobility industry could be incorporated and consulted. Even though there are already initial approaches, such as the Partnership Council of the World Food System Center at ETH Zurich, in which foundations and industrial partners are represented, there is still much more potential in such bodies. Having extra-academic experts integrated into in the review process could not only contribute to better assessing the societal impact of the research, but possibly also to catalyzing it.

Chapter 8

Outlook

As the world is integrating into a "global village" (McLuhan 1994), societal challenges like public health, food security or water scarcity are no longer just issues of local relevance, but rather exemplify the need for international coordination and holistic solutions. Equipped with a broad expertise and global collaboration opportunities, universities and research centers are already taking a lead in addressing these challenges. One side effect of this development, however, is that researchers can no longer "hide" in their ivory towers, but that they have to embrace their role as public figures whose research endeavors can easily be "followed" and accessed through various channels. Partly boosted by the universities themselves, by means of providing open access to research output, by issuing press releases, mentions on institutional social media accounts, or public information events, researchers and their contributions are increasingly exposed to a wider audience. Although this transparency brings many advantages in the sense of democratizing knowledge, it also bears a risk. It may occur, for example, that different research approaches to assessing the same phenomenon are played off against each other, as the heated debate on climate change excellently illustrates. While sound skepticism is the basis of all scientific work, propagating divergent results can lead to a polarization of the public debate. This results in two pragmatic options for policy action: Either certain research results are strategically used to scientifically substantiate political positions ("This study proves that there is no man-made climate change"), or the politicians deliberately ignore the findings altogether ("The results contradict each other, we cannot trust science"). In such a worst case scenario, research is embedded in a delicate dynamic of conflicting interests.

In the interwoven fabric of the academic sphere, evaluation in its various forms plays a greater role today than ever before. On the basis of evaluation results, scientific contributions are published or rejected, funding is granted or cut, grants and prizes are awarded or not, thematic focuses are defined or shifted, institutions and study programmes are accredited or dissolved, professors get tenured or not, and individual careers are influenced in many other ways. Needless to say, the key role of evaluation also involves a responsibility. Especially in view of the danger that decisions may be influenced by political interests, nepotism and other types of bias, it is of central importance that evaluation approaches are based on scientific

principles. The tools of scientific evaluation must therefore be continuously developed to assure that the object of evaluation can be adequately assessed. The dissertation at hand has illustrated the importance of this task using the example of inter- and transdisciplinary research centers. What remains is the hope that it has thereby made a small contribution to improving the status quo of research evaluation.

References (for Parts I and III)

References of Part II are enclosed in the individual articles.

Agasisti, T., G. Barbato, M. Dal Molin, M. Turri. 2019. Internal quality assurance in universities: does NPM matter? *Studies in Higher Education* 44/6: 960-977.

Alexander, F. K. 2000. The Changing Face of Accountability: Monitoring and Assessing Institutional Performance in Higher Education. *The Journal of Higher Education* 71/4: 411-431.

Andrews, E., A. Weaver, D. Hanley, J. Shamatha, G. Melton. 2005. Scientists and Public Outreach: Participation, Motivations, and Impediments. *Journal of Geoscience Education* 53/3: 281-293.

Ávila-Robinson, A., S. Sengoku. 2017. Multilevel exploration of the realities of interdisciplinary research centers for the management of knowledge integration. *Technovation* 62-63/April 2017: 22-41.

Barth, M., J. Godemann, M. Rieckmann, U. Stoltenberg. 2007. Developing key competencies for sustainable development in higher education. *International Journal of Sustainability in Higher Education* 8/4: 416-430.

Becher, T., P. R. Trowler. 2001. *Academic Tribes and Territories.* 2nd edition. Buckingham: The Society for Research into Higher Education and Open University Press.

Behnke, L., N. Baur, N. Behnke. 2010. *Empirische Methoden der Politikwissenschaft.* Paderborn: Schöningh.

Bentley, P., S. Kyvik. 2011. Academic staff and public communication: a survey of popular science publishing across 13 countries. *Public understanding of science* 20/1: 48-63.

Bettencourt, L. M. A., J. Kaur. 2011. Evolution and structure of sustainability science. *Proceedings of the National Academy of Sciences* 108/49: 19540-19545.

Bishop, P. R., S. W. Huck, B. H. Ownley, J. K. Richards, G. J. Skolits. 2014. Impacts of an interdisciplinary research center on participant publication and collaboration patterns: A case study of the National Institute for Mathematical and Biological Synthesis. *Research Evaluation* 23/4: 327-340.

Bleiklie, I., J. Enders, B. Lepori, C. Musselin. 2011. New public management, network governance and the university as a changing professional organization. In: *The Ashgate Research Companion to New Public Management.* Edited by T. Christensen, P. Laegreid. Ashgate. 161-176.

Boardman, C., B. Bozeman. 2007. Role strain in university research centers. *The Journal of Higher Education* 78/4: 430-463.

Boardman, C., E. A. Corley. 2008. University research centers and the composition of research collaborations. *Research policy* 37/5: 900-913.

Bogner, A., B. Littig, W. Menz. 2009. *Interviewing Experts.* London: Palgrave Macmillan.

Bohunovsky, L. et al. 2019. Wissenschaft im Wandel: Hochschulen und die Sustainable Development Goals. *GAIA - Ecological Perspectives for Science and Society* 28/1: 63-65.

Bornmann, L. 2014. Do altmetrics point to the broader impact of research? An overview of benefits and disadvantages of altmetrics. *Journal of Informetrics* 8/4: 895-903.

Bornmann, L., H.-D. Daniel. 2008. What do citation counts measure? A review of studies on citing behavior. *Journal of Documentation* 64/1: 45-80.

Bornmann, L., S. Mittag, H.-D. Daniel. 2006. Quality assurance in higher education – meta-evaluation of multi-stage evaluation procedures in Germany. *Higher Education* 52/4: 687-709.

Bornmann, L., R. Haunschild, W. Marx. 2016. Policy documents as sources for measuring societal impact: how often is climate change research mentioned in policy-related documents? *Scientometrics* 109/3: 1477-1495.

Bornmann, L., R. Haunschild, J. Adams. 2019. Do altmetrics assess societal impact in a comparable way to case studies? An empirical test of the convergent validity of altmetrics based on data from the UK research excellence framework (REF). *Journal of Informetrics* 13/1: 325-340.

Bozeman, B., J. D. Rogers. 2002. A churn model of scientific knowledge value: Internet researchers as a knowledge value collective. *Research policy* 31/5: 769-794.

Bozeman, B., C. Boardman. 2003. *Managing the New Multipurpose, Multidiscipline University Research Centers: Institutional Innovation in the Academic Community.* Transforming Organizations Series. Washington DC: IBM Endowment for the Business of Government.

Bozeman, B., E. A. Corley. 2004. Scientists' collaboration strategies: implications for scientific and technical human capital. *Research policy* 33/4: 599-616.

Bozeman, B., C. Boardman. 2014. *Research collaboration and team science: A state-of-the-art review and agenda.* Cham: Springer.

Bozeman, B., J. Youtie. 2017. *The strength in numbers: The new science of team science.* Princeton: Princeton University Press.

Bozeman, B., J. Dietz, M. Gaughan. 2001. Scientific and technical human capital: an alternative model for research evaluation. *International Journal of Technology Management* 22/7-8: 716-740.

Brandt, P. et al. 2013. A review of transdisciplinary research in sustainability science. *Ecological economics* 92: 1-15.

Brewer, G. D. 1999. The challenges of interdisciplinarity. *Policy Sciences* 32/4: 327-337.

Brown, R. R., A. Deletic, T. H. F. Wong. 2015. How to catalyse collaboration: Turn the fraught flirtation between the social and biophysical sciences into fruitful partnerships with these five principles. *Nature* 525/7569: 315-318.

Brunn, S. D. 2014. Cyberspace knowledge gaps and boundaries in sustainability science: topics, regions, editorial teams and journals. *Sustainability* 6/10: 6576-6603.

Bunton, S. A., W. T. Mallon. 2006. The impact of centers and institutes on faculty life: Findings from a study of basic science and internal medicine faculty at research-intensive medical schools. *Academic Medicine* 81/8: 734-743.

Buter, R. K., A. F. J. Van Raan. 2013. Identification and analysis of the highly cited knowledge base of sustainability science. *Sustainability Science* 8/2: 253-267.

Cañibano, C., B. Bozeman. 2009. Curriculum vitae method in science policy and research evaluation: the state-of-the-art. *Research Evaluation* 18/2: 86-94.

Carew, A. L., F. Wickson. 2010. The TD wheel: a heuristic to shape, support and evaluate transdisciplinary research. *Futures* 42/10: 1146-1155.

CCES. 2005. *Competence Center Environmental and Sustainability (CCES) of the ETH Domain: Business Plan*. Zurich: Competence Center Environmental and Sustainability of the ETH Domain.

Clark, B. R. 1998. The entrepreneurial university: Demand and response. *Tertiary Education and management* 4/1: 5-16.

Clark, W. C. 2007. Sustainability Science: A room of its own. *Proceedings of the National Academy of Sciences* 104/6: 1737-1738.

Clark, W. C., N. M. Dickson. 2003. Sustainability science: the emerging research program. *Proceedings of the National Academy of Sciences* 100/14: 8059-8061.

CNRS. 2016. *Rapport du comité consultatif. Évaluation scientifique du CNRS.* Paris: CNRS.

Corley, E. A. 2007. A use-and-transformation model for evaluating public R&D: Illustrations from polycystic ovarian syndrome (PCOS) research. *Evaluation and Program Planning* 30/1: 21-35.

Corley, E. A., M. Gaughan. 2005. Scientists' participation in university research centers: what are the gender differences? *The Journal of Technology Transfer* 30/4: 371-381.

Corley, E. A., B. Bozeman, X. Zhang, C.-C. Tsai. 2017. The expanded scientific and technical human capital model: the addition of a cultural dimension. *The Journal of Technology Transfer* 44/3: 681-699.

Coryn, C. L. S., J. A. Hattie, M. Scriven, D. J. Hartmann. 2007. Models and mechanisms for evaluating government-funded research: An international comparison. *American Journal of Evaluation* 28/4: 437-457.

Cozzens, S. E. 1989. What do citations count? The rhetoric-first model. *Scientometrics* 15/5-6: 437-447.

Cozzens, S. E. 1997. The knowledge pool: Measurement challenges in evaluating fundamental research programs. *Evaluation and Program Planning* 20/1: 77-89.

Cozzens, S. E., T. Turpin. 2000. Processes and mechanisms for evaluating and monitoring research outcomes from higher education: international comparisons. *Research Evaluation* 9/1: 3-4.

Cozzens, S. E., P. Healey, A. Rip, J. Ziman. 1990. *The Research System in Transition.* Boston: Kluwer Academic Publishers.

Cress, P. E. 2014. Using Altmetrics and Social Media to Supplement Impact Factor: Maximizing Your Article's Academic and Societal Impact. *Aesthetic Surgery Journal* 34/7: 1123-1126.

D'Este, P., M. Perkmann. 2011. Why do academics engage with industry? The entrepreneurial university and individual motivations. *The Journal of Technology Transfer* 36/3: 316-339.

De Boer, H. F., J. Enders, L. Leisyte. 2007. Public sector reform in Dutch higher education: The organizational transformation of the university. *Public Administration* 85/1: 27-46.

Dietz, J. S., B. Bozeman. 2005. Academic careers, patents, and productivity: industry experience as scientific and technical human capital. *Research policy* 34/3: 349-367.

Dixon, K., D. Coy. 2007. University governance: governing bodies as providers and users of annual reports. *Higher Education* 54/2: 267-291.

Ecklund, E. H., S. A. James, A. E. Lincoln. 2012. How academic biologists and physicists view science outreach. *PloS one* 7/5: e36240.

Elsevier. 2015. *Sustainability Science in a Global Landscape*. Amsterdam: Elsevier B.V.

Etzkowitz, H., L. Leydesdorff. 2000. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. *Research policy* 29/2: 109-123.

Etzkowitz, H., R. Viale. 2010. Polyvalent knowledge and the entrepreneurial university: A third academic revolution? *Critical Sociology* 36/4: 595-609.

Etzkowitz, H., A. Webster, C. Gebhardt, B. R. C. Terra. 2000. The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research policy* 29/2: 313-330.

Feller, I., C. P. Ailes, J. D. Roessner. 2002. Impacts of research universities on technological innovation in industry: evidence from engineering research centers. *Research policy* 31/3: 457-474.

Ferlie, E., L. Fitzgerald, A. Pettigrew. 1996. *The new public management in action.* Oxford: Oxford University Press.

Ferlie, E., C. Musselin, G. Andresani. 2008. The steering of higher education systems: A public management perspective. *Higher Education* 56/3: 325-348.

Ferlie, E., C. Musselin, G. Andresani. 2009. The governance of higher education systems: A public management perspective. In: *University Governance.* Edited by C. Paradeise, E. Reale, I. Bleiklie, E. Ferlie. Dordrecht: Springer. 1-19.

Frølich, N. 2005. Implementation of new public management in Norwegian universities. *European Journal of Education* 40/2: 223-234.

Funnell, S. C., P. J. Rogers. 2011. *Purposeful Program Theory: Effective Use of Theories of Change and Logic Models.* San Francisco: Jossey-Bass.

Gallo, S. A., S. R. Glisson. 2018. External Tests of Peer Review Validity Via Impact Measures. *Frontiers in Research Metrics and Analytics* 3/22: 1-17.

García-Gallego, A., N. Georgantzís, J. Martín-Montaner, T. Pérez-Amaral. 2015. (How) Do research and administrative duties affect university professors' teaching? *Applied Economics* 47/45: 4868-4883.

Garner, J., A. L. Porter, M. Borrego, E. Tran, R. Teutonico. 2013. Facilitating social and natural science cross-disciplinarity: Assessing the human and social dynamics program. *Research Evaluation* 22/2: 134-144.

Gaughan, M., B. Bozeman. 2002. Using curriculum vitae to compare some impacts of NSF research grants with research center funding. *Research Evaluation* 11/1: 17-26.

Gaughan, M., B. Ponomariov. 2008. Faculty publication productivity, collaboration, and grants velocity: using curricula vitae to compare center-affiliated and unaffiliated scientists. *Research Evaluation* 17/2: 103-110.

Geiger, R. L. 1990. Organized research units - their role in the development of university research. *The Journal of Higher Education* 61/1: 1-19.

Gertler, P. J., S. Martinez, P. Premand, L. B. Rawlings, C. M. J. Vermeersch. 2011. *Impact Evaluation in Practice.* Washington DC: The International Bank for Reconstruction and Development / The World Bank.

Geuna, A., B. R. Martin. 2003. University Research Evaluation and Funding: An International Comparison. *Minerva* 41/4: 277-304.

Gibbons, M., L. Georghiou. 1987. *Evaluation of Research. A selection of current practices.* Paris: OECD.

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, M. Trow. 1994. *The new production of knowledge: The dynamics of science and research in contemporary societies.* London: Sage.

Gray, D. O., M. Lindblad, J. Rudolph. 2001. Industry–university research centers: a multivariate analysis of member retention. *The Journal of Technology Transfer* 26/3: 247-254.

Gulbrandsen, M., J.-C. Smeby. 2005. Industry funding and university professors' research performance. *Research policy* 34/6: 932-950.

Haider, L. J. et al. 2018. The undisciplinary journey: early-career perspectives in sustainability science. *Sustainability Science* 13/1: 191-204.

Harzing, A.-W., S. Alakangas. 2016. Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison. *Scientometrics* 106/2: 787-804.

Haustein, S., T. D. Bowman, R. Costas. 2016. Interpreting "altmetrics": viewing acts on social media through the lens of citation and social theories. In: *Theories of informetrics and scholarly communication. A Festschrift in Honor of Blaise Cronin.* Edited by S. R. Sugimoto. Berlin: De Gruyter. 372-405.

Hirsch-Hadorn, G., D. Bradley, C. Pohl, S. Rist, U. Wiesmann. 2006. Implications of transdisciplinarity for sustainability research. *Ecological economics* 60/1: 119-128.

Holbrook, J. B. 2010. The use of societal impacts considerations in grant proposal peer review: A comparison of five models. *Technology & Innovation* 12/3: 213-224.

Hood, C. 1995. The "new public management" in the 1980s: Variations on a theme. *Accounting, organizations and society* 20/2-3: 93-109.

Horta, H., J. Huisman, M. Heitor. 2008. Does competitive research funding encourage diversity in higher education? *Science and Public Policy* 35/3: 146-158.

IEKE. 2016. *Internationale Expertenkommission zur Evaluation der Exzellenzinitiative. Endbericht.* Berlin: Institut für Innovation und Technik (iit).

Ikenberry, S. O., R. C. Friedman. 1972. *Beyond Academic Departments: The Story of Institutes and Centers.* London: Jossey-Bass.

Jaffe, A. B. 2015. *A Framework for Evaluating the Beneficial Impacts of Publicly Funded Research.* Motu Note. Volume 15. Wellington: Motu Economic and Public Policy Research Trust.

Jaffe, A. B., G. De Rassenfosse. 2017. Patent citation data in social science research: Overview and best practices. *Journal of the Association for Information Science and Technology* 68/6: 1360-1374.

Jaffe, A. B., M. Trajtenberg, R. Henderson. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. *the Quarterly journal of Economics* 108/3: 577-598.

Jahn, T., M. Bergmann, F. Keil. 2012. Transdisciplinarity: Between mainstreaming and marginalization. *Ecological economics* 79: 1-10.

Jantsch, E. 1972. Inter- and transdisciplinary university: A systems approach to education and innovation. *Higher Education* 1/1: 7-37.

Jensen, P., J.-B. Rouquier, P. Kreimer, Y. Croissant. 2008. Scientists who engage with society perform better academically. *Science and Public Policy* 35/7: 527-541.

Jerneck, A. et al. 2011. Structuring sustainability science. *Sustainability Science* 6/1: 69-82.

Johnson, D. R., E. H. Ecklund, A. E. Lincoln. 2014. Narratives of science outreach in elite contexts of academic science. *Science Communication* 36/1: 81-105.

Kajikawa, Y. 2008. Research core and framework of sustainability science. *Sustainability Science* 3/2: 215-239.

Kajikawa, Y., F. Tacoa, K. Yamaguchi. 2014. Sustainability science: the changing landscape of sustainability research. *Sustainability Science* 9/4: 431-438.

Kajikawa, Y., J. Ohno, Y. Takeda, K. Matsushima, H. Komiyama. 2007. Creating an academic landscape of sustainability science: an analysis of the citation network. *Sustainability Science* 2/2: 221-231.

Kassab, O., R. P. Schwarzenbach, N. Gotsch. 2018. Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain. *GAIA - Ecological Perspectives for Science and Society* 27/2: 226-234.

Kates, R. W. 2011. What kind of a science is sustainability science? *Proceedings of the National Academy of Sciences* 108/49: 19449-19450.

Kellogg Foundation. 2001. *Logic model development guide: Logic models to bring together planning, evaluation & action.* Battle Creek: W.K. Kellogg Foundation.

Kim, T. 2008. Changing university governance and management in the UK and elsewhere under market conditions: Issues of quality assurance and accountability. *Intellectual Economics (Intelektine Ekonomika)* 2/4: 33-42.

Kitzinger, J. 1994. The methodology of Focus Groups: the importance of interaction between research participants. *Sociology of Health & Illness* 16/1: 103-121.

Klein, J. T. 1990. *Interdisciplinarity: History, Theory, and Practice.* Detroit: Wayne State University Press.

Kneale, D., J. Thomas, K. Harris. 2015. Developing and optimising the use of logic models in systematic reviews: exploring practice and good practice in the use of programme theory in reviews. *PloS one* 10/11: e0142187.

Komiyama, H., K. Takeuchi. 2006. Sustainability science: building a new discipline. *Sustainability Science* 1/1: 1-6.

Kötter, R., P. W. Balsiger, S. Bailis, J. Wentworth. 1999. Interdisciplinarity and transdisciplinarity: a constant challenge to the sciences. *Issues in Interdisciplinary Studies* 17: 87-120.

Krull, W. 2005. Exporting the Humboldtian University. *Minerva* 43/1: 99-102.

Kueffer, C. et al. 2012. Enabling effective problem-oriented research for sustainable development. *Ecology and Society* 17/4: 8.

Kuhlmann, S., A. Rip. 2018. Next-Generation Innovation Policy and Grand Challenges. *Science and Public Policy* 45/4: 448-454.
Kutílek, M., D. R. Nielsen. 2007. Interdisciplinarity of hydropedology. *Geoderma* 138/3-4: 252-260.
Lagarde, M. 2011. How to do (or not to do) … Assessing the impact of a policy change with routine longitudinal data. *Health Policy and Planning* 27/1: 76-83.
Landry, R., N. Amara. 1998. The impact of transaction costs on the institutional structuration of collaborative academic research. *Research policy* 27/9: 901-913.
Lang, D. J. et al. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science* 7/1: 25-43.
Lange, S. 2007. The Basic State of Research in Germany: Conditions of Knowledge Production Pre-Evaluation. In: *The Changing Governance of the Sciences.* Edited by R. Whitley, J. Gläser. Dordrecht: Springer. 153-170.
Laredo, P. 2007. Revisiting the Third Mission of Universities: Toward a Renewed Categorization of University Activities? *Higher Education Policy* 20/4: 441-456.
Lawrence, R. J. 2004. Housing and health: from interdisciplinary principles to transdisciplinary research and practice. *Futures* 36/4: 487-502.
Lee, S., B. Bozeman. 2005. The impact of research collaboration on scientific productivity. *Social Studies of Science* 35/5: 673-702.
Lepori, B. 2006. Public research funding and research policy: a long-term analysis for the Swiss case. *Science and Public Policy* 33/3: 205-216.
LERU. 2017. *Productive interactions: societal impact of academic research in the knowledge society*. Leuven: League of European Research Universities.
Lin, M. W., B. Bozeman. 2006. Researchers' industry experience and productivity in university–industry research centers: A "scientific and technical human capital" explanation. *The Journal of Technology Transfer* 31/2: 269-290.
Lok, C. 2010. Science funding: Science for the masses. *Nature News* 465/7297: 416-418.
Madrillon. 2010. *Evaluation of Research Center and Network Programs at the National Institutes of Health - A Review of Evaluation Practice, 1978-2009*. Bethesda: The Madrillon Group Inc.
Mallon, W. T. 2006. The Benefits and Challenges of Research Centers and Institutes in Academic Medicine: Findings from Six Universities and Their Medical Schools. *Academic Medicine* 81/6: 502-512.
Martin, B. R. 2011. The Research Excellence Framework and the 'impact agenda': are we creating a Frankenstein monster? *Research Evaluation* 20/3: 247-254.
Martinez-Conde, S. 2016. Has contemporary academia outgrown the Carl Sagan effect? *Journal of Neuroscience* 36/7: 2077-2082.
McLaughlin, J. A., G. B. Jordan. 2015. Using Logic Models. In: *Handbook of Practical Program Evaluation.* Edited by K. E. Newcomer, H. P. Hatry, J. S. Wholey. Volume 4. New Jersey: John Wiley & Sons. 62-87.
McLellan, E., K. M. MacQueen, J. L. Neidig. 2003. Beyond the qualitative interview: Data preparation and transcription. *Field methods* 15/1: 63-84.
McLuhan, M. 1994. *Understanding media: The extensions of man.* Cambridge: MIT press.
Meuser, M., U. Nagel. 2009. The Expert Interview and Changes in Knowledge Production. In: *Interviewing Experts.* Edited by A. Bogner, B. Littig, W. Menz. London: Palgrave Macmillan. 17-42.
Meyer, L. 2007. Collegial participation in university governance: A case study of institutional change. *Studies in Higher Education* 32/2: 225-235.
Miller, T. R. 2013. Constructing sustainability science: emerging perspectives and research trajectories. *Sustainability Science* 8/2: 279-293.
Mitchell, P. H. 2005. What's In A Name? Multidisciplinary, Interdisciplinary, and Transdisciplinary. *Journal of Professional Nursing* 21/6: 332-334.

Mittelstrass, J. 1993. Unity and Transdisciplinarity. *Interdisciplinary Science Reviews* 18/2: 153-157.
Mittelstrass, J. 2011. On transdisciplinarity. *Trames* 15/4: 329-338.
Mobjörk, M. 2010. Consulting versus participatory transdisciplinarity: A refined classification of transdisciplinary research. *Futures* 42/8: 866-873.
Molas-Gallart, J., A. Salter, P. Patel, A. Scott, X. Duran. 2002. *Measuring Third Stream Activities. Final Report to the Russell Group of Universities.* Edited by SPRU. Sussex: University of Sussex.
Mongeon, P., A. Paul-Hus. 2016. The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics* 106/1: 213-228.
Montesinos, P., J. M. Carot, J. M. Martinez, F. Mora. 2008. Third mission ranking for world class universities: Beyond teaching and research. *Higher Education in Europe* 33/2-3: 259-271.
Morse, J. M. 1991. Approaches to Qualitative-Quantitative Methodological Triangulation. *Nursing Research* 40/2: 120-123.
Mostert, S. P., S. P. H. Ellenbroek, I. Meijer, G. van Ark, E. C. Klasen. 2010. Societal output and use of research performed by health research groups. *Health Research Policy and Systems* 8: 30.
Mutz, R., L. Bornmann, H.-D. Daniel. 2015. Cross-disciplinary research: What configurations of fields of science are found in grant proposals today? *Research Evaluation* 24/1: 30-36.
Neumann, R. 2003. A Disciplinary Perspective on University Teaching and Learning. In: *Access and Exclusion. International Perspectives on Higher Education Research.* Edited by M. Tight. Oxford: Elsevier Science. 217-245.
Nightingale, P., A. Scott. 2007. Peer review and the relevance gap: ten suggestions for policy-makers. *Science and Public Policy* 34/8: 543-553.
Nowotny, H., P. Scott, M. Gibbons. 2001. *Re-thinking science: Knowledge and the public in an age of uncertainty.* New Jersey: John Wiley & Sons.
Nowotny, H., P. Scott, M. Gibbons. 2003. Introduction: "Mode 2" Revisited: The New Production of Knowledge. *Minerva* 41/3: 179-194.
Nybom, T. 2003. The Humboldt Legacy: Reflections on the Past, Present, and Future of the European University. *Higher Education Policy* 16/2: 141-159.
O'Byrne, D., W. Dripps, K. A. Nicholas. 2015. Teaching and learning sustainability: An assessment of the curriculum content and structure of sustainability degree programs in higher education. *Sustainability Science* 10/1: 43-59.
OECD. 2003. *Governance of Public Research. Toward Better Practices.* Paris: OECD.
Opdenakker, R. 2006. Advantages and disadvantages of four interview techniques in qualitative research. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* 7/4: Art. 11.
Paradeise, C., E. Reale, I. Bleiklie, E. Ferlie. 2009. *University Governance.* Dordrecht: Springer.
Parker, L. D. 2013. Contemporary University Strategising: The Financial Imperative. *Financial Accountability & Management* 29/1: 1-25.
Patton, M. Q. 1990. *Qualitative evaluation and research methods.* Thousand Oaks: Sage.
Petts, J., S. Owens, H. Bulkeley. 2008. Crossing boundaries: Interdisciplinarity in the context of urban environments. *Geoforum* 39/2: 593-601.
Pohl, C. 2010. From transdisciplinarity to transdisciplinary research. *Transdisciplinary Journal of Engineering Science* 1: 65-73.
Pohl, C., P. Krütli, M. Stauffacher. 2017. Ten Reflective Steps for Rendering Research Societally Relevant. *GAIA-Ecological Perspectives for Science and Society* 26/1: 43-51.

Pohl, C. et al. 2011. *Questions to evaluate inter-and transdisciplinary research proposals*. Bern: Network for Transdisciplinary Research (td-net) of the Swiss Academies of Arts and Sciences.

Poliakoff, E., T. L. Webb. 2007. What factors predict scientists' intentions to participate in public engagement of science activities? *Science Communication* 29/2: 242-263.

Ponomariov, B. 2013. Government-sponsored university-industry collaboration and the production of nanotechnology patents in US universities. *The Journal of Technology Transfer* 38/6: 749-767.

Ponomariov, B., C. Boardman. 2010. Influencing scientists' collaboration and productivity patterns through new institutions: University research centers and scientific and technical human capital. *Research policy* 39/5: 613-624.

Ponomariov, B., E. Welch, J. Melkers. 2009. Assessing the outcomes of student involvement in research: educational outcomes in an engineering research center. *Research Evaluation* 18/4: 313-322.

Porter, A., A. S. Cohen, J. D. Roessner, M. Perreault. 2007. Measuring researcher interdisciplinarity. *Scientometrics* 72/1: 117-147.

Porter, A. L., F. A. Rossini. 1985. Peer review of interdisciplinary research proposals. *Science, technology, human values* 10/3: 33-38.

Puschmann, C. 2014. (Micro) blogging science? Notes on potentials and constraints of new forms of scholarly communication. In: *Opening Science: The Evolving Guide on How the Internet is Changing Research, Collaboration and Scholarly Publishing.* Edited by S. Bartling, S. Friesike. Cham: Springer. 89-106.

Ravenscroft, J., M. Liakata, A. Clare, D. Duma. 2017. Measuring scientific impact beyond academia: An assessment of existing impact metrics and proposed improvements. *PloS one* 12/3: e0173152.

REF. 2019. *Panel criteria and working methods*. Research Excellence Framework (REF) 2021.

Rieder, S., L. Lehmann. 2002. Evaluation of New Public Management Reforms in Switzerland: Empirical Results and Reflections on Methodology. *International Public Management Review* 3/2: 25-43.

Rivers, D., D. O. Gray. 2013. Evaluating cooperative research centers: a strategy for assessing proximal and distal outcomes and associated economic impacts. In: *Handbook on the Theory and Practice of Program Evaluation.* Edited by A. N. Link, N. Vonortas. Cheltenham: Edward Elgar Publishing. 291-322.

Robinson, J. 2008. Being undisciplined: Transgressions and intersections in academia and beyond. *Futures* 40/1: 70-86.

Rogers, J. D., J. Youtie, L. Kay. 2012. Program-level assessment of research centers: Contribution of Nanoscale Science and Engineering Centers to US Nanotechnology National Initiative goals. *Research Evaluation* 21/5: 368-380.

Rogers, P. J. 2008. Using programme theory to evaluate complicated and complex aspects of interventions. *Evaluation* 14/1: 29-48.

Rokaya, P., R. Sheikholeslami, S. Kurkute, M. Nazarbakhsh, F. Zhang, M. G. Reed. 2017. Multiple factors that shaped sustainability science journal: a 10-year review. *Sustainability Science* 12/6: 855-868.

Rosenfield, P. L. 1992. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Social Science & Medicine* 35/11: 1343-1357.

Royse, D., B. A. Thyer, D. K. Padgett. 2016. *Program Evaluation: An Introduction to an Evidence-Based Approach.* Boston: Cengage Learning.

Rytmeister, C. 2009. Governing University Strategy: Perceptions and practice of governance and management roles. *Tertiary Education and management* 15/2: 137-156.

Sabharwal, M., Q. Hu. 2013. Participation in university-based research centers: Is it helping or hurting researchers? *Research policy* 42/6: 1301-1311.

Salter, B., T. Tapper. 2000. The Politics of Governance in Higher Education: The Case of Quality Assurance. *Political Studies* 48/1: 66-87.

Santoro, M. D., S. Gopalakrishnan. 2001. Relationship Dynamics between University Research Centers and Industrial Firms: Their Impact on Technology Transfer Activities. *The Journal of Technology Transfer* 26/1: 163-171.

Schneidewind, U. 2016. Die „Third Mission" zur „First Mission" machen? *die hochschule. journal für wissenschaft und bildung* 25/1: 14-22.

Schoolman, E. D., J. S. Guest, K. F. Bush, A. R. Bell. 2012. How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. *Sustainability Science* 7/1: 67-80.

Schröder, S., F. Welter, I. Leisten, A. Richert, S. Jeschke. 2014. Research performance and evaluation—Empirical results from collaborative research centers and clusters of excellence in Germany. *Research Evaluation* 23/3: 221-232.

Schubert, T. 2008. *New Public Management und Leistungsmessung im deutschen Forschungssektor: Theorie, Umsetzung und Wirkungsanalyse (Dissertation).* Friedrich-Alexander-Universität Erlangen-Nürnberg.

Schwan, G. 2019. Sustainable Development Goals: A call for global partnership and cooperation. *GAIA - Ecological Perspectives for Science and Society* 28/2: 73-73.

Schwinges, R. C. (Ed.) 2001. *Humboldt International. Der Export des deutschen Universitätsmodells im 19. und 20. Jahrhundert.* Basel: Schwabe & Co AG.

SDSN. 2017. *Getting started with the SDGs in universities: A guide for universities, higher education institutions, and the academic sector. Australia, New Zealand and Pacific Edition.* Melbourne: SDSN.

Shahadu, H. 2016. Towards an umbrella science of sustainability. *Sustainability Science* 11/5: 777-788.

Sinnewe, E., M. B. Charles, R. Keast. 2016. Australia's Cooperative Research Centre Program: A transaction cost theory perspective. *Research policy* 45/1: 195-204.

Slaughter, S., L. L. Leslie. 1997. *Academic capitalism: Politics, policies, and the entrepreneurial university.* Baltimore: The Johns Hopkins University Press.

Slaughter, S., T. Campbell, M. Holleman, E. Morgan. 2002. The "traffic" in graduate students: Graduate students as tokens of exchange between academe and industry. *Science, Technology & Human Values* 27/2: 282-312.

Smith, A. M., S. Y. Lai, J. Bea-Taylor, R. B. M. Hill, N. Kleinhenz. 2016. Collaboration and change in the research networks of five Energy Frontier Research Centers. *Research Evaluation* 25/4: 472-485.

Spaapen, J., L. Van Drooge. 2011. Introducing 'productive interactions' in social impact assessment. *Research Evaluation* 20/3: 211-218.

Spangenberg, J. H. 2011. Sustainability science: a review, an analysis and some empirical lessons. *Environmental Conservation* 38/3: 275-287.

Stahler, G. J., W. R. Tash. 1994. Centers and Institutes in the Research University: Issues, Problems, and Prospects. *The Journal of Higher Education* 65/5: 540-554.

Stauffacher, M., C. Zingerli, P. Fry, C. Pohl, P. Krütli. 2012. Science Meets Practice: A Winter School Offers New Perspectives. *GAIA-Ecological Perspectives for Science and Society* 21/2: 145-147.

Steiner, D. 2002. Human ecology as transdisciplinary science, and science as part of human ecology. In: *Human Ecology.* Edited by M. Nauser, D. Steiner. London: Routledge. 73-102.

Stock, P., R. J. F. Burton. 2011. Defining Terms for Integrated (Multi-Inter-Trans-Disciplinary) Sustainability Research. *Sustainability* 3/8: 1090-1113.

Stockmann, R., W. Meyer. 2014. *Evaluation. Eine Einführung.* Opladen: Verlag Barbara Budrich UTB.

Stokes, D. E. 1997. *Pasteur's quadrant: Basic science and technological innovation.* Washington DC: Brookings Institution Press.

Stokols, D., K. L. Hall, B. K. Taylor, R. P. Moser. 2008a. The science of team science: overview of the field and introduction to the supplement. *American Journal of Preventive Medicine* 35/2: 77-89.

Stokols, D., S. Misra, R. P. Moser, K. L. Hall, B. K. Taylor. 2008b. The Ecology of Team Science: Understanding Contextual Influences on Transdisciplinary Collaboration. *American Journal of Preventive Medicine* 35/2, Supplement: S96-S115.

Stufflebeam, D. L., L. S. Coryn. 2014. *Evaluation theory, models and applications.* San Francisco: Jossey-Bass.

Su, X. 2014. Academic scientists' affiliation with university research centers: Selection dynamics. *Research policy* 43/2: 382-390.

Sumner, A., J. Crichton, S. Theobald, E. Zulu, J. Parkhurst. 2011. What shapes research impact on policy? Understanding research uptake in sexual and reproductive health policy processes in resource poor contexts. *Health Research Policy and Systems* 9/1: S3.

SWIR. 2015. *Examen systématique des effets de l'instrument Pôles de recherche nationaux PRN (série 1, 2001–2013). Rapport et recommandations du Conseil suisse de la science et de l'innovation CSSI, sur mandat du Secrétariat d'Etat à la formation, à la recherche et à l'innovation SEFRI. Rapport final.* Berne: Schweizerischer Wissenschafts- und Innovationsrat.

Thelwall, M., S. Haustein, V. Larivière, C. R. Sugimoto. 2013. Do altmetrics work? Twitter and ten other social web services. *PloS one* 8/5: e64841.

Thomas, P. A., M. Diener-West, M. I. Canto, D. R. Martin, W. S. Post, M. B. Streiff. 2004. Results of an academic promotion and career path survey of faculty at the Johns Hopkins University School of Medicine. *Academic Medicine* 79/3: 258-264.

Thune, T., I. Reymert, M. Gulbrandsen, P. Olaf Aamodt. 2016. Universities and external engagement activities: Particular profiles for particular universities? *Science and Public Policy* 43/6: 774-786.

Tress, B., G. Tress, G. Fry. 2005. Researchers' experiences, positive and negative, in integrative landscape projects. *Environmental Management* 36/6: 792-807.

Tress, B., G. Tress, G. Fry. 2006. Defining concepts and process of knowledge in integrative research. In: *From Landscape Research to Landscape Planning.* Edited by B. Tress, G. Tress, G. Fry, P. Opdam. Dordrecht: Springer.

Turk-Bicakci, L., S. Brint. 2005. University–industry collaboration: patterns of growth for low-and middle-level performers. *Higher Education* 49/1-2: 61-89.

Turner, V. K., K. Benessaiah, S. Warren, D. Iwaniec. 2015. Essential tensions in interdisciplinary scholarship: navigating challenges in affect, epistemologies, and structure in environment–society research centers. *Higher Education* 70/4: 649-665.

Turpin, T. 1997. CRCs and Transdisciplinary Research: What are the Implications for Science? *Prometheus* 15/2: 253-265.

UN. 1987. *United Nations: Our Common Future. World Commission on Environment and Development.* Oxford: Oxford University Press.

Van der Weijden, I., M. Verbree, P. Van Den Besselaar. 2012. From bench to bedside: The societal orientation of research leaders: The case of biomedical and health research in the Netherlands. *Science and Public Policy* 39/3: 285-303.

van Eck, N. J., L. Waltman. 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84/2: 523-538.

van Looy, B., P. Landoni, J. Callaert, B. Van Pottelsberghe, E. Sapsalis, K. Debackere. 2011. Entrepreneurial effectiveness of European universities: An empirical assessment of antecedents and trade-offs. *Research policy* 40/4: 553-564.

van Rijnsoever, F. J., L. K. Hessels. 2011. Factors associated with disciplinary and interdisciplinary research collaboration. *Research policy* 40/3: 463-472.

Waas, T., A. Verbruggen, T. Wright. 2010. University research for sustainable development: definition and characteristics explored. *Journal of cleaner production* 18/7: 629-636.

Watermeyer, R. 2015. Lost in the 'third space': the impact of public engagement in higher education on academic identity, research practice and career progression. *European Journal of Higher Education* 5/3: 331-347.

Watermeyer, R., A. Hedgecoe. 2016. Selling 'impact': peer reviewer projections of what is needed and what counts in REF impact case studies. A retrospective analysis. *Journal of Education Policy* 31/5: 651-665.

Weingart, P., N. Stehr. 2000. *Practising Interdisciplinarity.* Toronto: University of Toronto Press.

Weller, K. 2015. Social media and altmetrics: An overview of current alternative approaches to measuring scholarly impact. In: *Incentives and Performance. Governance of Research Organizations.* Edited by I. M. Welpe, J. Wollersheim, S. Ringelhan, M. Osterloh. Cham: Springer. 261-276.

Wen, J., S. Kobayashi. 2001. Exploring collaborative R&D network: some new evidence in Japan. *Research policy* 30/8: 1309-1319.

Whitmer, A. et al. 2010. The engaged university: providing a platform for research that transforms society. *Frontiers in Ecology and the Environment* 8/6: 314-321.

Wickson, F., A. L. Carew, A. W. Russell. 2006. Transdisciplinary research: characteristics, quandaries and quality. *Futures* 38/9: 1046-1059.

Wiek, A., L. Withycombe, C. L. Redman. 2011. Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science* 6/2: 203-218.

Wiek, A., S. Talwar, M. O'Shea, J. Robinson. 2014. Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation* 23/2: 117-132.

Woelert, P., V. Millar. 2013. The 'paradox of interdisciplinarity' in Australian research governance. *Higher Education* 66/6: 755-767.

Wooldridge, J., M. King. 2019. Altmetric scores: An early indicator of research impact. *Journal of the Association for Information Science Technology* 70/3: 271-282.

Yarime, M., Y. Takeda, Y. Kajikawa. 2010. Towards institutional analysis of sustainability science: a quantitative examination of the patterns of research collaboration. *Sustainability Science* 5/1: 115-125.

Yarime, M. et al. 2012. Establishing sustainability science in higher education institutions: towards an integration of academic development, institutionalization, and stakeholder collaborations. *Sustainability Science* 7/1: 101-113.

Youtie, J., E. A. Corley. 2011. Federally sponsored multidisciplinary research centers: Learning, evaluation, and vicious circles. *Evaluation and Program Planning* 34/1: 13-20.

Youtie, J., L. Kay, J. Melkers. 2013. Bibliographic coupling and network analysis to assess knowledge coalescence in a research center environment. *Research Evaluation* 22/3: 145-156.

Ziman, J. 2000. Real Science: What it is and what it means. Cambridge: Cambridge University Press.

APPENDICES

Appendix A

Self-evaluation of CCES

Appendix B

Guideline for the expert interviews

Appendix C

Transcription of the expert interview with Respondent 1 (R1)

Transcription of the expert interview with Respondent 2 (R2)

Transcription of the expert interview with Respondent 3 (R3)

Transcription of the expert interview with Respondent 4 (R4)

Transcription of the expert interview with Respondent 5 (R5)

Transcription of the expert interview with Respondent 6 (R6)

Transcription of the expert interview with Respondent 7 (R7)

Appendix A: Self-evaluation of CCES

The research center evaluation literature is abundant in studies concentrating on partial aspects of a research center's impact. The selective perception, or "tunnel view" as Stockmann and Meyer (2014) label it, bears the risk of misjudging the research center and its impact as a whole. The aspect that by far gained most attention in the research center evaluation literature is the impact that participation has on the individual's research performance. A relatively large number of empirical investigations have shown that participation has implications in terms of publication productivity and quality, and research collaboration (Landry and Amara 1998, Wen and Kobayashi 2001, Bozeman and Rogers 2002, Gaughan and Bozeman 2002, Corley and Gaughan 2005, Lee and Bozeman 2005, Lin and Bozeman 2006, Mallon 2006, Boardman and Corley 2008, Ponomariov and Boardman 2010, Sabharwal and Hu 2013, Youtie et al. 2013). Closely related are the impacts that participation has been shown to have on career development and mobility of the affiliated researcher (Ponomariov et al. 2009), technology transfer activities (Gray et al. 2001, Santoro and Gopalakrishnan 2001, Slaughter et al. 2002, Dietz and Bozeman 2005, Turk-Bicakci and Brint 2005), student placement (Feller et al. 2002), capacity-building (Corley 2007, Youtie and Corley 2011), or grant-seeking skills (Bozeman and Corley 2004, Bunton and Mallon 2006). Due to their applied character and the confidentiality of the content, most research center evaluation studies end up as "grey literature" in internal archives (Madrillon 2010). The few reports that do get published typically read as if the evaluations had been carried out in isolation from all other ones, ultimately requiring evaluation practicioners to work out new solutions on a case-by-case basis.

The article below (Kassab et al. 2018) uses the concrete case of CCES to show how a research center in an exemplary inter- and transdisciplinary field, sustainability science, can be evaluated using qualitative methods. It combines approaches from program evaluation with the experiences of evaluation in inter- and transdisciplinary contexts and uses methodological triangulation, integrating various data sources, including:

- ten semi-structured expert interviews with project leaders conducted between December 2013 and January 2014 (see Appendix C),
- 99 annual project reports (archival data),
- Zingerli, C. (2011). CCES Winter School 2011. Sustainability Science Meets Practice. Final Report. April 2011. Internal document.
- CCES (2009). Competence Center Environment and Sustainability. Evaluation January 21-24, 2009. Report by the Advisory Board. February 2009. Internal document.

- CCES (2010). Competence Center Environment and Sustainability. Evaluation November 17-19, 2010. Report by the Advisory Board. December 2009. Internal document.
- CCES (2014). Competence Center Environment and Sustainability. Mid-term review February 27, 2014. Report by the Advisory Board. April 2014. Internal document.

The article concludes with a synthesis of general recommendations for future design and evaluation of research centers, as well as policy implications for inter- and transdisciplinary research, capacity-building, and public outreach activities.

Kassab, O., Schwarzenbach, R. P., Gotsch, N. (2018). Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach: The Competence Center Environment and Sustainability (CCES) of the ETH Domain. *GAIA - Ecological Perspectives for Science and Society* 27/2: 226-234.

Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach

The Competence Center Environment and Sustainability (CCES) of the ETH Domain

Omar Kassab, René P. Schwarzenbach, Nikolaus Gotsch

While there is a growing consensus about the role of academia in tackling the grand challenges of sustainability, the current incentive and reward system does not yet provide the right environment. Inter- and transdisciplinary research centers can bring about the needed cultural change.

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The Competence Center Environment and Sustainability (CCES) of the ETH Domain
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Abstract

Research centers have emerged as organizational structures to meet the manifold expectations raised towards sustainability science, a field characterized by high levels of inter- and transdisciplinarity. In this article, we assess the impact of the Competence Center Environment and Sustainability (CCES) of the ETH Domain. Encompassing more than 800 participants from six research institutions in Switzerland, the research center has been in operation for ten years (2006 to 2016). Focusing on its three areas of activity – research, education, and outreach – we analyze which decisions have influenced the development and legacy of CCES. We formulate five recommendations, which could prove useful for the future design and evaluation of comparable enterprises. Finally, we conclude that the academic incentive and reward system has to open up for inter- and transdisciplinarity. Research centers like CCES can facilitate this cultural change by providing the necessary academic environment and forming a new generation of researchers in key fields.

Keywords

competence center, environmental science, impact assessment, inter- and transdisciplinary research, program evaluation, project evaluation, research center, sustainability science

Addressing the grand challenges of sustainability requires inter- and transdisciplinary research approaches (Clark and Dickson 2003, Ziegler and Ott 2011), problem-driven education (Kajikawa 2008, Wiek et al. 2011), and novel modes of public engagement and knowledge transfer (Nowotny et al. 2001, Pohl 2008, Hessels et al. 2009, Talwar et al. 2011). In their versatility, research centers have proved to be suitable organizational structures to meet these manifold requirements. They bring together researchers and stakeholders from different backgrounds to jointly conduct solution-oriented research (Boardman and Corley 2008, Lang et al. 2012). They expose researchers to broad networks and opportunities with implications on capacity building (Corley et al. 2006, Youtie and Corley 2011). And, finally, research centers nurture various horizontal and vertical channels to facilitate outreach activities geared towards society (Bozeman and Boardman 2003).

Here we present the results of a case study covering a large research center in the field of environment and sustainability science. Besides assessing the impacts, we discuss which design and management decisions have evoked which developments and implications. In the following, we first give a short description of our object of analysis: the Competence Center Environment and Sustainability (CCES) of the ETH Domain[1]. We then briefly outline the approach we used to assess the impact of the research center. Due to the large size of the center, we will, however, have to confine our discussion to a few representative projects. We conclude with a synthesis of general recommendations from operating the center, as well as some critical remarks, which we hope are useful for the design but also the evaluation of comparable enterprises in the future.

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The Competence Center Environment and Sustainability (CCES) of the ETH Domain

Under the direct supervision of the Swiss Federal Council and the Parliament, the ETH Board, the strategic management body of the ETH Domain, established four inter- and transdisciplinary research centers[2] in 2006 and provided funds for an operation of ten years (two phases: 2006 to 2010 and 2011 to 2016). One of the four so-called competence centers was the CCES, with the mission to "identify the relevant questions and the appropriate answers to foster the sustainable development of our future society while minimizing the impact on the environment" (CCES 2005, p. 1). This was to be accomplished within the scope of three areas of activity: research, education, and outreach.[3]

Organization, Thematic Definition, and Review Process

Three governance bodies were established:

- a Steering Board, consisting of the leaders of the main participating institutions, which was responsible for the overall strategy and planning, the allocation of resources, and the scientific and institutional profile of CCES;
- a Management Board, consisting of senior researchers, responsible for defining the thematic areas as well as acquiring and prescreening submitted research proposals;
- an Executive Office with an Executive Manager. Located at the leading house ETH Zurich, the Executive Manager was in charge of the administrative and financial functioning of the center.

As it turned out in the early phase of CCES, there were striking conflicts of interest associated to the Management Board, as some of its members had envisaged submitting a project proposal themselves. Consequently, the Management Board was dissolved once it had defined the thematic scope (table 1, p. 228), replacing it with a Delegate of the Steering Board.

Launched in early 2006, the call for proposals attracted 24 submissions. This number was quite considerable in light of two constraining factors: first, the proposals were required to be drafted by researchers from at least three of the six participating institutions, which, in many cases, meant that cooperation had to be initiated between researchers who had not previously known each other. And second, many of those researchers had little to no prior experience in drafting inter- or transdisciplinary research proposals.

For the evaluation of the proposals, an ad hoc Research Council consisting of members of the ETH Zurich research commission complemented by researchers from EPFL, Eawag, and WSL was established. All proposals were sent out for review, which turned out to be a rather intricate endeavor due to the unavailability of enough independent experts capable of evaluating inter- and transdisciplinary projects. This led to an unsatisfactory review process, which was in turn heavily criticized by the applicants. Finally, the Research Council recommended the Steering Board to fund 18 of the 24 projects in the first phase (2006 to 2010) (table 1).

Because of these negative experiences, the Steering Board appointed an international Advisory Board composed of eight highly regarded academics and of one industry representative. The Advisory Board was tasked to continuously evaluate the progress made within CCES and to select the projects that qualified for the second phase (2011 to 2016), for which the ETH Board had provided half of the funds of the first phase. On the basis of written proposals, presentations, and interviews, the Advisory Board recommended eight projects (see table 1).

CCES in Numbers

More than 800 people from all six ETH Domain institutions were involved in CCES: roughly 300 professors and senior researchers, about 200 PhD students and postdocs, while the remaining participants included Master students, project engineers, technicians, laboratory, and administrative support staff. About one fifth of the overall CCES Community members were female, with a lower share on the level of principal investigators and project partners (14 percent). The overall CCES budget provided by the ETH Board was CHF 45 million of which 30 million were spent during the first phase, and 15 million during the second. Funds had to be "matched" at least by an equivalent of institutional in-kind funding and additional external third-party funds. The overall funding volume added up to about CHF 130 million. Performance indicators of the CCES activities are summarized in table 2 (p. 229).

Evaluation and Impact Assessment

As publicly funded research is becoming subject to ever more intensive accountability (Martin 2011), evidence-based evaluation is gaining more and more relevance. But while methods for the assessment of departments or individual researchers are well established, evaluations of whole research centers raise new questions. Existing approaches, especially quantitative ones, lack the capacity to capture some of the core characteristics of research centers and their participants, like their diversity (Kassab et al. submitted). On the other hand, purely qualitative evaluation approaches generally come with the advantage of scrutiny at the expense of time and generalizability (Bornmann 2013, Newcomer et al. 2015). >

1 The ETH Domain comprises the two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag).

2 The themes of the other three centers were: *Energy and Mobility* (CCEM), *Materials Science and Technology* (CCMX), *Biomedical Imaging* (NCCBI).

3 The concept of "outreach" here is understood in the sense of "popularization" (Jensen et al. 2008), as activities done by researchers aiming at the non-specialized public. The information flow is one-way and there is no involvement of the public per se in the sense that public feedback is not required or specifically sought (Rowe and Frewer 2005, p. 255). Table 2 (p. 229) summarizes these activities as documented in the annual reports.

TABLE 1: Overview of the 18 CCES projects. They cover the five thematic areas climate change, food, natural hazards, natural resources, sustainable land use as well as a data management platform. Projects indicated with (*) have received funding for both phases of CCES (phase 1: 2006 to 2010, phase 2: 2011 to 2016). An overview with more detailed descriptions of the individual projects is available online: *https://www.oekom.de/supplementary-files.html#c12531*.

EDUCATION AND RESEARCH UNIT (ERU)/RESEARCH PLATFORM	PROJECT ACRONYM/INSTITUTIONAL PARTICIPATION (affiliation of principal investigator named first)	PROJECT SYNOPSIS
CLENCH* – Climate and Environmental Change** ***www.cces.ethz.ch/research/clench	*BigLink* ETH Zurich, WSL	biosphere-geosphere interactions: linking climate change, weathering, soil formation and ecosystem evolution
	BioChange Eawag, ETH Zurich, WSL	genetic diversity, contemporary evolution and the maintenance of biodiversity in changing alpine environments
	ClimPol ETH Zurich, EPFL, Eawag	climate policy making for enhanced technological and institutional innovations
	*OPTIWARES** PSI, ETH Zurich, Empa	optimization of the use of wood as a renewable energy source
	*MAIOLICA** ETH Zurich, EPFL, Eawag, WSL, Empa	modelling and experiments on land-surface interactions with atmospheric chemistry and climate
FEH* – Food, Environment and Health** ***www.cces.ethz.ch/research/feh	*BactFlow* ETH Zurich, EPFL, Eawag	impact of environmental "stealth" pathogens on food safety and human health
	GEDIHAP WSL, ETH Zurich, Eawag	role of genetic diversity in host-pathogen interactions in dynamic environments
HazRi* – Natural Hazards and Risks** ***www.cces.ethz.ch/research/hazri	*APUNCH* ETH Zurich, EPFL, WSL	advanced process understanding and prediction of hydrological extremes and complex hazards
	COGEAR ETH Zurich, EPFL	coupled seismogenic geohazards in Alpine regions
	EXTREMES EPFL, ETH Zurich, WSL	spatial extremes and environmental sustainability: statistical methods and applications in geophysics and the environment
	*TRAMM** WSL, ETH Zurich, EPFL	triggering of rapid mass movements in steep terrain
NatuRe* – Natural Resources** ***www.cces.ethz.ch/research/nature	*ADAPT* ETH Zurich, Eawag, EPFL	adapt planning and operation of large dams to social needs and environmental constraints: integrated water resource management study in the Zambezi Basin
	CARMA ETH Zurich, EPFL, PSI	carbon management in power generation
	*GEOTHERM** ETH Zurich, EPFL, PSI	geothermal reservoir processes: research towards the creation and sustainable use of enhanced geothermal systems
	*RECORD Catchment** Eawag, ETH Zurich, WSL, EPFL	coupled ecological, hydrological and social dynamics in restored and channelized corridors of a river at the catchment scale
SuLu* – Sustainable Land Use** ***www.cces.ethz.ch/research/sulu	*GeneMig** WSL, ETH Zurich, EPFL, Eawag	genetic variation and species migration under environmental change: views of science, environmental management, and the general public
	*MOUNTLAND** WSL, ETH Zurich, EPFL	prioritization for adaption to climate and socio-economic changes – backcasting tolerable future states to match supply and demand for ecosystem services in mountainous areas
Research Platform ***www.cces.ethz.ch/research/platforms***	*Swiss Experiment** WSL, EPFL, ETH Zurich, Eawag	the Swiss Experiment interdisciplinary data management platform

Besides, research centers typically perform not just research, but also training or active knowledge transfer into society (outreach). The wide spectrum of activities has immense implications when it comes to impact assessment. While there are somewhat established measures for the assessment of scientific impact (mainly through bibliometric indicators), a huge debate is held over how to capture the "societal impact" of research (impact that transcends the ecosystem of academia, i. e., into society or industry) in a scientifically meaningful way (Etzkowitz and Leydesdorff 2000, Gray et al. 2001, Spaapen and Van Drooge 2011, Bornmann 2013). Despite some advances including policy document analysis, or social media readership, there is by far no consensus yet among scholars and policy makers (Van der Weijden et al. 2012, Piwowar 2013, Wiek et al. 2014, LERU 2017).

Our Approach to Research Center Evaluation

Given the complexity of research centers and the breadth of their impact, we propose a case study approach using mixed methods to assess the phenomenon in depth. Aligning our approach to the practice of program evaluation (Newcomer et al. 2015), we understand the evaluation of a research center, borrowing from Patton (1997, p. 23), as a systematic collection of information about the *context, resources, processes, outputs* and *impacts* to make judgements about the research center, its effectiveness, and inform decision-making (Carew and Wickson 2010, Madrillon Group 2010).

The overall *context* and which *resources* have been mobilized in the case of CCES have been described above. Our approach therefore evaluates the *process, output,* and *impact* (Van Drooge and Spaapen 2017, Holzer et al. 2018). When speaking of *process,* we refer to the activities integral to the work at the research center, including the problem definition, the design of the research strategy, data collection, knowledge production, teamwork, networking, discussion, and synthesis (Talwar et al. 2011, Holzer et al. 2018). *Output,* in turn, is defined as tangible products resulting from the process, such as scientific publications, PhD theses, conferences, press articles, or public information events. And lastly, *impact* is understood as the "net effect" of the research center on the scientific community or society (Rossi et al. 2003, Link and Vonortas 2013). The evaluation should be concerned with both direct and indirect, but also with intended and unintended impacts, especially as the latter tend to be systematically disregarded in a "tunnel view" (Stockmann and Meyer 2014).

The following is structured along the three areas of activity of CCES: research, education, and outreach. The scope of the evaluation is defined with view on the five CCES goals as stated in the research center's business plan (CCES 2005, p. 1) and summarized in table 3 (p. 230). To also capture the organizational structure of CCES, we distinguish between two groups of actors: 1. the CCES Management, consisting of the Executive Office, the Steering Board, the Delegate of the Steering Board, and the Advisory Board, and 2. the members of the CCES Community on the project level, mainly represented by the principal investigators and the leading project partners. Our mixed methods approach is based on the document analysis of archival data (about 100 annual project reports), the synthesis of expert reports (by the Advisory Board), ten semi-structured interviews with principal investigators and project coordinators, and a comprehensive bibliometric analysis.

Research

> *I think it was CCES that kind of turned us into environmental scientists. [...] Before that, we have been ecologists, and bio geochemists, and so on, but [...] for the very first time, we stopped being a collection of disciplines, and that was a big effect.*
>
> Senior CCES participant

CCES Management

Process: The CCES Management was primarily involved in managing financial resources and reviewing the annual reporting. At the same time, it also tried to increase the coherence among the CCES Community by organizing field excursions or scientific conferences (goal 3). However, the success was rather moderate. The projects remained quite isolated, and if at all, there were links within the five thematic areas due to the multiple role of researchers, institutional ties, or academic proximity. Even though CCES has surely contributed significantly to the densification of the inter-institutional network within the ETH Domain, we note that some of the participants saw it primarily as "yet another funding source".

Output: In view of the overall output generated at CCES (table 2), the targeted funding of environmental and sustainability science has indeed led to advancements in the area (goal 1). Likewise, it contributed to the national and international visibility of researchers and their respective institutions (goal 2).

Impact: CCES facilitated research that could not have been carried out by a single ETH Domain institution alone. Principle investigators praised CCES for having "catalyzed the scientific process" (goal 1). Despite the initial reservation, numerous leading researchers devoted a considerable amount of their time to inter- and even transdisciplinary research. Beyond the financial contributions by CCES, the opportunity to "widen individual networks" was identified as a major driver. And as is evident by the newly stimulated research beyond CCES (e. g., in the context of EU funded projects), the return on investment has been reached and exceeded (goal 1). >

TABLE 2: Output of CCES (2006 to 2016). In absolute numbers, the output might appear rather moderate. In fact, however, productivity was high since the majority of the 800 CCES participants were engaged at the research center on a part-time level.

SCIENTIFIC PUBLICATIONS	NUMBER
peer-reviewed journal publications	1,276
PhD theses	185
Master/diploma theses	417
abstracts/proceedings/presentations/posters at scientific conferences/congresses/workshops	2,599
SCIENTIFIC EVENTS ORGANIZED BY THE PROJECTS	
conferences/workshops etc. (open to an audience beyond project partners/participants)	254
PhD courses/summer schools, etc.	92
other events	104
OUTREACH ACTIVITIES	
publications for stakeholders outside the scientific community (e. g., public administration)	227
press articles (newspapers, radio/TV broadcasts, etc.)	504
courses/seminars/workshops for stakeholders outside the scientific community	235
public information events for local/regional authorities/residents	144
events/activities at schools (courses)	168
other events	142
patents	8

TABLE 3: Goals of CCES along the three areas of activity.

AREA OF ACTIVITY		GOAL
RESEARCH	1	Foster major inter- and transdisciplinary research advancements in the areas of environment and sustainability.
	2	Establish the CCES partner institutions as national and international focal points for the areas of environment and sustainability.
	3	Achieve a long-term structuring effect and a coherent strategy for the areas of environment and sustainability.
EDUCATION	4	Establish a strong and wide-ranging education program for the areas of environment and sustainability.
OUTREACH	5	Achieve a visible societal impact with a focus on socio-economic implementation.

CCES Community (Examples)

Process: Hardly any of the researchers involved in the *TRAMM* project had known each other before CCES. While at the beginning it was a great challenge even to decide on common terminology, it was the early implementation of joint field experiments that triggered "key experiences" conducive to the team cohesion process (goal 3). The project furthermore benefited from the close collaboration with the association *Fachleute Naturgefahren FAN (Swiss Practitioners in Natural Hazards)*, an established expert community that supported the identification and involvement of key stakeholders. The *MOUNTLAND* project, in turn, profited from the existence of an executive "project coordinator", who actively took charge in overseeing and fostering the inter- and transdisciplinary process along the way (Pohl et al. 2015). Over the course of *MOUNTLAND*, an aspect regarded as instrumental to the process was the strong "personal connection" researchers and stakeholders alike had to the case study regions. This significantly contributed to the commitment and ownership of the project and its results, even beyond its completion (Huber and Rigling 2014). While an unclear allocation of responsibilities can often lead to misunderstandings and inefficiencies in the process, the *RECORD* project has been able to avoid many problems by an explicit "division of tasks". For instance, social scientists, whose role more often than not is somewhat vague in solution-oriented research, were mainly responsible for structuring the project process and coordinating the transdisciplinary stakeholder involvement (Schirmer 2013), bringing an added value to the entire project team.

Output: Table 2 summarizes the outputs of the CCES Community members over the course of ten years. At first glance, the absolute numbers might appear rather low given the size of the research center. However, considering that a significant part of the researchers were engaged in CCES only on a part-time level, the achievements can be judged as quite satisfactory (goal 1). Moreover, the findings of a comprehensive bibliometric study have shown that participation in CCES, on average, had modest positive impacts on the individual's research performance (Kassab et al. submitted).

Impact: Through its applied research, *TRAMM* has shown new pathways for practice. Based on the project's findings, the Swiss Federal Office for the Environment (BAFU) has developed a concept for an *Early Warning System (EWS)* for rapid mass movements, which has been proposed to the Swiss Federal Council (goal 5). An important legacy of the *ADAPT* project is an "Open-source data base for the Zambesi river basin", which makes all data collected in the project publicly accessible (Matos et al. 2015). With this platform, *ADAPT* not only provided data management, analysis and visualization tools, but also contributed to the empowerment of stakeholders, who often experience "research tourism" (Huber and Rigling 2014), especially in North-South relations. In view of the significant hydropower potentials in the Zambesi river basin, the exchange database represents an important contribution in favor of the African partners (goal 5).

Education

> *I learned that it is not only about how I bring my results to the practitioners, but also the other way round.*
>
> CCES winter school participant

CCES Management

Process: The CCES Management focused on a few educational activities that could not be performed by the projects. These activities were launched in the first, and carried out in the second phase. The positioning of the Executive Office at ETH Zurich was pivotal in this respect, as it was embedded in a broad institutional and personal network and extensive experiences.

Output: In close collaboration with the MINT Learning Center at ETH Zurich, the CCES Management coordinated the *CCES@School* project, for which several CCES participants have "translated" their findings into Swiss high school teaching materials (Hänger et al. 2017). Partnering with ETH Seed Sustainability, the *Public Admin Dialog* project coordinated a series of Bachelor and Master theses on the interface between CCES and Swiss Public Administration (i.e., cantonal environmental offices). And finally, the CCES Winter School *Science Meets Practice* (Stauffacher et al. 2012), which trains early career researchers to conduct a dialog with external stakeholders, benefited from the expertise of the Transdisciplinarity Lab (TdLab) at ETH Zurich, where the format is still maintained today (goal 4).

Impact: Since there is still rather little room in the Swiss high school curriculum for interdisciplinary, problem-driven education, the teaching materials of *CCES@School* had to be broken down into disciplinary units. Those, however, have been received with enthusiasm by a large number of teachers (goal 4). While the *Public Admin Dialog* was indeed able to build some bridges between universities, individual researchers, and public administrations, the academic reward structure continues to represent a major hurdle to such initiatives. For many researchers, the effort associated with supervising inter- and transdisciplinary Bachelor or Master theses was disproportionate to the "scientific return" (i.e., data, funding).

Lastly, more than 150 PhD students and postdocs took part in the six editions of the CCES Winter School. The majority of the participants judged this experience as a "very useful asset" in their professional education.

CCES Community (Examples)

Process: Many of the CCES projects organized regular meetings (colloquia) for their PhD students. Especially the exchange among students from different subunits of the projects increased team cohesion and fostered inspiration. In addition to the broad network, they were exposed to alternative ways of thinking, research approaches, and methods. In some projects, researchers from different institutions jointly supervised the Master and PhD theses, which also densified the CCES Community network at the level of the more senior researchers.

Output: Within the projects, 417 Master theses and 185 PhD theses were completed over the course of ten years. A total of 92 courses for PhD students and summer schools were staged by the projects, such as the *Winter School on Landscape Genetics* organized by the *GENEMIG* project (Bolliger et al. 2010), or the Bernoulli semester on *Risk, Rare Events, and Extremes* organized by the *EXTREMES* project at EPFL.

Impact: The most eminent and lasting educational impact of CCES was the opportunity given to a large number of students and early career researchers to get involved in inter- and transdisciplinary research and outreach. Getting involved in such activities can significantly contribute to the visibility of young researchers to external stakeholders, which in some instances even resulted in placements in industry or public administration. It should, however, also be pointed out that this type of research entails a certain "risk" for young researchers, including the dependency on other team members, as well as task overload, thus commonly requiring a closer supervision than in purely disciplinary research.

Outreach

The problem is whether these activities are valued or not.
If I invest a month to produce a stakeholder publication,
I will eventually be asked: where are the scientific papers?

Senior CCES participant

CCES Management

Process: With significant administrative duties during the first phase, there was little room to stage major outreach activities. However, a pragmatic approach to those duties made possible, for example, the use of the annual project reporting for communication and outreach purposes (goal 5).

Output: Over the course of ten years, the CCES Management hosted a website (including intranet) with comprehensive information about all activities at the research center. Updating their respective project websites was one of the tasks of the project leadership in the context of the annual reporting, which guaranteed an ongoing maintenance of the overall online presence. Besides, the CCES Management coordinated a *CCES Newsletter* almost throughout its entire operation. During the second phase, the newsletter was included as a separate chapter in 19 issues of the *ProClim-Flash* journal of the Swiss Academy of Sciences (SCNAT). Appearing twice a year, the journal has a broad readership from specialist associations and public administration. Another initiative launched together with the SCNAT was the *Science Policy Dialog*. At two workshops, 50 high-level representatives from politics, public administration, business, science, and the science-policy interface discussed and identified strategies and institutional prerequisites for improving the dialog between science and politics. Among others, a strong political polarization of the debate or dissent within the scientific community was identified as hindering factors. Direct personal contact between researchers and politicians or the readiness to engage in dialog on equal footing, in turn, were recognized as favoring factors. And lastly, four large public conferences and symposia (in 2007, 2010, 2014, and 2016) significantly increased the visibility of CCES and its activities (goal 5).

Impact: In light of the relatively constrained scope the CCES Management operated in, the outreach activities achieved a considerable impact beyond the involved scientific community (goal 5). While the CCES Management did not address society at large, it did reach many key players and decision-makers in science, politics and administration.

CCES Community (Examples)

Process: In order to render the knowledge transfer as effective as possible, *ADAPT* had carried out a comprehensive "needs assessment" with stakeholders in advance. Corresponding outreach formats were then "tailored" to meet their demands, including several workshops with participants from research and policy in Zambia and Mozambique, a larger conference, and a summary brochure. The *Klimahörpfad (climate audio path)* of the *BigLink* project is another good example for transdisciplinary outreach. In close cooperation with a climate protection foundation and a tourism association, the project developed an audio guide that can be combined with a mountain hike. Visitors can follow stations of a path and experience in a truly "tangible" way what insights the project has produced (goal 5).

Output: More than 1400 outreach activities directed towards stakeholders were realized by the members of the CCES Community (table 2). The largest share (35 percent) were dissemination activities via newspapers, radio, or television broadcasts. Other significant formats were stakeholder publications (16 percent), seminars and workshops (16 percent), activities at schools (12 percent), or public information events (10 percent).

Impact: The *ADAPT* stakeholder brochure summarized the research results with concrete technical recommendations. However, many of the recommendations were lost in the complex fabric between research and application and were not considered in the >

construction of a new dam in the region. A similar phenomenon occurred in *MOUNTLAND*. Although some of the core findings were disseminated through leading professional journals, they were not perceived by all the key people in charge of the decision-making. In summary, we must note that even a very thoughtful outreach strategy does not yet guarantee for a successful knowledge transfer (goal 5).

Assessment Summary

The five goals of CCES have been achieved to varying degrees. While goal 1 was primarily attained on the level of the CCES Community, goals 2 and 3 were reached through a complementary approach between CCES Community and CCES Management. Goal 4 was not reached in terms of establishing an educational program, but rather in the sense of fostering the capacity building of young researchers. Although all projects in the CCES Community made substantial efforts to highlight and promote the societal impact of their research (goal 5), only few actually contributed to the immediate solution of a "real world" problem. The activities initiated by the CCES Management could also only contribute in part to achieving the broader impact and thus to achieving goal 5 overall.

General Conclusions and Recommendations

Those who have already explored the challenges of inter- and transdisciplinarity in greater detail (or have been exposed to them) may find confirmation in many of our experiences summarized below. Nevertheless, we hope that our conclusions and recommendations are beneficial for all those who are interested in, supportive of, or tasked with the design of research, education and outreach in inter- and transdisciplinary contexts.

Provide incentives to facilitate inter- and transdisciplinary capacity building: For many of the participants, CCES was associated with a comprehensive learning experience, especially in terms of the capacity to design, plan and implement inter- and transdisciplinary research, education, and outreach. While many of the participants were rather reluctant to take part in such a complex enterprise at the beginning, CCES managed to motivate numerous leading researchers to get involved through concrete incentives like funding and networking opportunities. As a result, the broad participation in CCES has contributed to community building within the ETH Domain, which has materialized, for example, in the form of numerous inter- and transdisciplinary follow-up projects. Another capacity building process stems from the three-part funding scheme. Quite indicative, the acquisition of third-party funding has increased by 40 percent per project between the first and second phase (Bozeman and Corley 2004, Bunton and Mallon 2006).

Coordinate inter- and transdisciplinarity through integrative leadership: Due to their complexity, all CCES projects were divided into subunits, many of which worked along disciplinary lines. While this division may be necessary for operational purposes, the actual "crux" of inter- and transdisciplinarity lies in the integration process (Klein 2008). One key design aspect the successful projects had in common was the appointment of an executive "coordinator" (Elkins and Keller 2003, Gray 2008, Lang et al. 2012) from the very beginning of the projects. Beyond catalyzing the collaboration among the disciplines, the project coordinator could oversee the external stakeholder engagement to increase the mutual benefit of the transdisciplinary exchange. Timely trainings for designated project coordinators could provide an incentive (Kueffer et al. 2012). There is also an abundant number of handbook-like instructions for the design and conduct of inter- and transdisciplinary projects (Talwar et al. 2011, Lang et al. 2012, Pohl et al. 2017).

Benefit from synergies in governance bodies for operation and evaluation: The Advisory Board was established and entrusted with assessing the progress of the projects, which ultimately provided a transparent and legitimate basis for the funding decision for the second phase (see above). This allowed the Steering Board to concentrate on the operational issues of the research center. Both the division of tasks as well as the interaction between the two boards proved to be very fruitful. Advisory boards composed of members both reflecting the disciplinary diversity as well as having experience with inter- and transdisciplinary research can create an added value not only for a smooth operation, but also for an integrated evaluation.

Operate a lean management and reporting policy: Research, education, and outreach in inter- and transdisciplinary contexts are quite demanding and time-consuming. In turn, unnecessarily complicated bureaucratic requirements are counterproductive. CCES researchers were grateful for a supportive mentality on the part of the CCES Management, lean administration, and minimal reporting. However, such a policy also implies that one must be willing and prepared to "advance trust" towards the participants, which, in the case of CCES, has worked to the satisfaction of both sides. Ultimately, the fact that relatively little capacity had to be allocated to administrative matters has effectively enabled participants to focus more on their core tasks in research, education, and outreach.

Maintain networks through data management and research infrastructure: Research in the field of environment and sustainability often generates huge amounts of data. In order to make this data available to other researchers, minimize redundancies, create synergies, and to facilitate the scientific progress, a professional data management is integral. Even after the completion of CCES, the data management and storage platforms developed in the projects are still used. The same applies to the field installations which were set up for experiments in several CCES projects. Beyond generating data, they have also played an important role in team building processes. And lastly, they have provided a platform to engage with external stakeholders, for example in the context of excursions or workshops.

Research Centers as Drivers of Cultural Change

CCES represents a clear, visible and measurable added value to the whole ETH Domain with regard to science and capacity building, particularly to strengthening the interdisciplinary approaches leading to transdisciplinary solutions with impact for science and application at the local, national and global level.

Advisory Board

Solution-oriented sustainability science presents quite a challenge to the academic system. While scientists today are primarily judged on the basis of their disciplinary academic productivity, collaborations in research centers generate inter- and transdisciplinary publications and other outputs that are not equally recognized as classical performance metrics or employment criteria (Wiek et al. 2014). Looming "opportunity costs", which could have negative implications for individual career development, create a serious resistance within the academic community towards this profile (Turner et al. 2015, Haider et al. 2018). As long as the current "incentive incongruity" (Su 2014) is in place and the commitment to engaging in research centers compared to departments is not adequately supported, there will always be reservations towards research centers, despite the general consensus over their importance.

A comprehensive evidence-based evaluation can provide a constructive contribution and remedy alike. The greatest methodological challenge remains the assessment of societal impact (Mostert et al. 2010, Bornmann 2013). First attempts for quantitative approaches have already been made, such as the use of so-called altmetrics, which rely on user statistics of social media (Thelwall et al. 2013). For the evaluation of other impacts, for example in policy or industry, there are also ways forward, based on policy document analyses or patents (Dietz and Bozeman 2005) and spin-offs (Steffensen et al. 2000), respectively. To get to the bottom of the phenomenon of societal impact, however, we have chosen semi-structured interviews with key participants of the research center. This ensured the identification of the effect and allowed us to trace the causal process with empirical precision. Needless to say, when using a case study, the question of generalizability arises. Through the different and complementary methods, however, we tried to find a good balance between depth and width to synthesize the above recommendations.

We conclude that there is a need for a cultural change to reward (and not punish) researchers engaged in inter- and transdisciplinary projects. This does by no means infer that disciplinary research should become less valued, but rather that the academic system should further broaden its evaluation and incentive scheme. Science policy makers and research funding organizations play a crucial role in this respect, because simply providing more funding for inter- and transdisciplinary research will not bring about the cultural change as long as the incongruity between mandate and reward remains in place. Besides the evidence-based evaluation on a case study level, one more pragmatic way forward could be "awards" to convey appreciation, consequently increasing a researcher's visibility and career promotion. *MOUNTLAND,* for example, was awarded with the *swiss-academies award for transdisciplinary research (td-award)* in 2013 (Huber and Rigling 2014).

Research centers like CCES can facilitate this cultural change, in at least three concrete ways: 1. Compared to the relatively small community of (mostly) social scientists that focus on theory and practice of inter- and transdisciplinarity, research centers as instruments have the capacity to mobilize researchers from various disciplinary backgrounds and other stakeholders to work on complex themes of high societal relevance. Engaging this "critical mass" of researchers, some of which may be enjoying a high reputation in their disciplines, can significantly improve the image of inter- and transdisciplinarity. 2. As experienced in the case of CCES, research centers can contribute to community building, yielding follow-up projects in inter- and transdisciplinary fields. 3. With young researchers who get trained and motivated to work on solution-oriented sustainability themes, research centers can contribute to forming a new generation in key fields, further enlarging the "critical mass".

Reflecting upon ten years of CCES, it is our hope that future generations will encounter better framework conditions to pursue an academic career in the field of sustainability science. We believe that research centers like CCES can help provide the necessary academic environment.

References

Boardman, C., E. A. Corley. 2008. University research centers and the composition of research collaborations. *Research Policy* 37/5: 900–913.

Bolliger, J., G. Le Lay, R. Holderegger. 2010. Landscape genetics: How landscapes affect ecological processes. *GAIA* 19/3: 238–240.

Bornmann, L. 2013. What is societal impact of research and how can it be assessed? A literature survey. *Journal of the American Society for Information Science and Technology* 64/2: 217–233.

Bozeman, B., C. Boardman. 2003. *Managing the new multipurpose, multidiscipline university research centers: Institutional innovation in the academic community.* Washington, D.C.: IBM Endowment for the Business of Government.

Bozeman, B., E. A. Corley. 2004. Scientists' collaboration strategies: Implications for scientific and technical human capital. *Research Policy* 33/4: 599–616.

Bunton, S. A., W. T. Mallon. 2006. The impact of centers and institutes on faculty life: Findings from a study of basic science and internal medicine faculty at research-intensive medical schools. *Academic Medicine* 81/8: 734–743.

Carew, A. L., F. Wickson. 2010. The TD wheel: A heuristic to shape, support and evaluate transdisciplinary research. *Futures* 42/10: 1146–1155.

CCES (Competence Center Environment and Sustainability). 2005. *CCES – Business plan*. Zurich: CCES.

Clark, W. C., N. M. Dickson. 2003. Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences* 100/14: 8059–8061.

Corley, E. A., C. Boardman, B. Bozeman. 2006. Design and the management of multi-institutional research collaborations: Theoretical implications from two case studies. *Research Policy* 35/7: 975–993.

Dietz, J. S., B. Bozeman. 2005. Academic careers, patents, and productivity: Industry experience as scientific and technical human capital. *Research Policy* 34/3: 349–367.

Elkins, T., R. T. Keller. 2003. Leadership in research and development organizations: A literature review and conceptual framework. *Leadership Quarterly* 14/4: 587–606.

Etzkowitz, H., L. Leydesdorff. 2000. The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university-industry-government relations. *Research Policy* 29/2: 109–123.

Gray, B. 2008. Enhancing transdisciplinary research through collaborative leadership. *American Journal of Preventive Medicine* 35/2, Suppl.: S124–S132.
Gray, D. O., M. Lindblad, J. Rudolph. 2001. Industry-university research centers: A multivariate analysis of member retention. *Journal of Technology Transfer* 26/3: 247–254.
Haider, L. J. et al. 2018. The undisciplinary journey: Early-career perspectives in sustainability science. *Sustainability Science* 13/1: 191–204.
Hänger, B., J. Lipscher, R. Schumacher. 2017. Klimawandel im gymnasialen Chemie- und Physikunterricht. *Gymnasium Helveticum* 39/2: 18–20.
Hessels, L. K., H. Van Lente, R. Smits. 2009. In search of relevance: The changing contract between science and society. *Science and Public Policy* 36/5: 387–401.
Holzer, J. M., N. Carmon, D. E. Orenstein. 2018. A methodology for evaluating transdisciplinary research on coupled socio-ecological systems. *Ecological Indicators* 85: 808–819.
Huber, R., A. Rigling. 2014. Commitment to continuous research is a key factor in transdisciplinarity: Experiences from the *Mountland* project. *GAIA* 23/3: 256–262.
Jensen, P., J.-B. Rouquier, P. Kreimer, Y. Croissant. 2008. Scientists who engage with society perform better academically. *Science and Public Policy* 35/7: 527–541.
Kajikawa, Y. 2008. Research core and framework of sustainability science. *Sustainability Science* 3/2: 215–239.
Kassab, O., R. Mutz, H.-D. Daniel. Submitted. *Introducing and testing a new methodological approach for the evaluation of research centers: A case study on sustainability science.*
Klein, J. T. 2008. Evaluation of interdisciplinary and transdisciplinary research: A literature review. *American Journal of Preventive Medicine* 35/2, Suppl.: S116–S123.
Kueffer, C. et al. 2012. Enabling effective problem-oriented research for sustainable development. *Ecology and Society* 17/4: 8.
Lang, D. J. et al. 2012. Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science* 7/1: 25–43.
LERU (League of European Research Universities). 2017. *Productive interactions: Societal impact of academic research in the knowledge society.* Leuven, BE: LERU.
Link, A. N., N. Vonortas. 2013. *Handbook on the theory and practice of program evaluation.* Cheltenham, UK: Edward Elgar.
Madrillon Group. 2010. *Evaluation of research center and network programs at the National Institutes of Health: A review of evaluation practice, 1978–2009.* Vienna, VA: Madrillon Group.
Martin, B. R. 2011. The *Research Excellence Framework* and the "impact agenda": Are we creating a Frankenstein monster? *Research Evaluation* 20/3: 247–254.
Matos, J. P., A. J. Schleiss, J. Mertens, B. Wehrli. 2015. Developing an open-source database for the Zambezi river basin. *International Journal on Hydropower and Dams* 22: 28–33.
Mostert, S. P., S. P. H. Ellenbroek, I. Meijer, G. van Ark, E. C. Klasen. 2010. Societal output and use of research performed by health research groups. Health *Research Policy and Systems* 8: 30.
Newcomer, K. E., H. P. Hatry, J. S. Wholey. 2015. *Handbook of practical program evaluation.* New Jersey: John Wiley & Sons.
Nowotny, H., P. Scott, M. Gibbons. 2001. *Re-thinking science: Knowledge and the public in an age of uncertainty.* New Jersey: John Wiley & Sons.
Patton, M. Q. 1997. *Utilisation-focused evaluation: The new century text.* Thousand Oaks, CA: Sage.
Piwowar, H. 2013. Altmetrics: Value all research products. *Nature* 493/7431: 159–159.
Pohl, C. 2008. From science to policy through transdisciplinary research. *Environmental Science and Policy* 11/1: 46–53.
Pohl, C. et al. 2015. How to successfully publish interdisciplinary research: Learning from an Ecology and Society Special Feature. *Ecology and Society* 20/2: 23.
Pohl, C., P. Krütli, M. Stauffacher. 2017. Ten reflective steps for rendering research societally relevant. *GAIA* 26/1: 43–51.
Rossi, P. H., M. W. Lipsey, H. E. Freeman. 2003. *Evaluation: A systematic approach.* London: Sage.
Rowe, G., L. J. Frewer. 2005. A typology of public engagement mechanisms. *Science, Technology, and Human Values* 30/2: 251–290.
Schirmer, M. 2013. Das *RECORD*-Projekt: Flussrevitalisierung, eine ökologische Massnahme in einem komplexen Umfeld. *Aqua & Gas* 93/3: 22–28.
Spaapen, J., L. Van Drooge. 2011. Introducing "productive interactions" in social impact assessment. *Research Evaluation* 20/3: 211–218.
Stauffacher, M., C. Zingerli, P. Fry, C. Pohl, P. Krütli. 2012. Science meets practice: A winter school offers new perspectives. *GAIA* 21/2: 145–147.
Steffensen, M., E. M. Rogers, K. Speakman. 2000. Spin-offs from research centers at a research university. *Journal of Business Venturing* 15/1: 93–111.
Stockmann, R., W. Meyer. 2014. *Evaluation. Eine Einführung.* Opladen: Barbara Budrich UTB.
Su, X. 2014. Academic scientists' affiliation with university research centers: Selection dynamics. *Research Policy* 43/2: 382–390.
Talwar, S., A. Wiek, J. Robinson. 2011. User engagement in sustainability research. *Science and Public Policy* 38/5: 379–390.
Thelwall, M., S. Haustein, V. Larivière, C. R. Sugimoto. 2013. Do altmetrics work? Twitter and ten other social web services. *PloS one* 8/5: e64841.
Turner, V. K., K. Benessaiah, S. Warren, D. Iwaniec. 2015. Essential tensions in interdisciplinary scholarship: Navigating challenges in affect, epistemologies, and structure in environment-society research centers. *Higher Education* 70/4: 649–665.
Van der Weijden, I., M. Verbree, P. van den Besselaar. 2012. From bench to bedside: The societal orientation of research leaders: The case of biomedical and health research in the Netherlands. *Science and Public Policy* 39/3: 285–303.
Van Drooge, L., J. Spaapen. 2017. Evaluation and monitoring of transdisciplinary collaborations. *Journal of Technology Transfer.* doi: 10.1007/s10961-017-9607-7.
Wiek, A., L. Withycombe, C. L. Redman. 2011. Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science* 6/2: 203–218.
Wiek, A., S. Talwar, M. O'Shea, J. Robinson. 2014. Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation* 23/2: 117–132.
Youtie, J., E. A. Corley. 2011. Federally sponsored multidisciplinary research centers: Learning, evaluation, and vicious circles. *Evaluation and Program Planning* 34/1: 13–20.
Ziegler, R., K. Ott. 2011. The quality of sustainability science: A philosophical perspective. *Sustainability* 7/1: 31–44.

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Appendix B: Guideline for the expert interviews

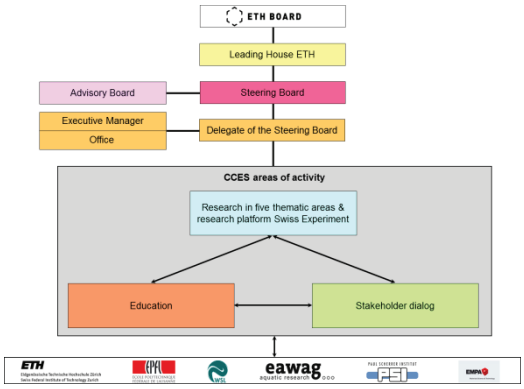
Guideline for the expert interviews (December 2013)

CCES Impact Analysis

Background CCES and impact analysis	10 minutes
Getting started	5 minutes
Interview (1) Structuring effect (2) Education (3) Implementation (4) Research quality	60 minutes
General questions and feedback	15 minutes
Conclusion	

Background CCES and Impact Analysis (10 min)

- Brief personal introduction
- If necessary, short background on CCES with the help of the organizational chart



Background CCES Impact Analysis:

- Various stakeholders are interested to hear about the impact CCES had
- Quantitative indicators (see table) are not ideal, because they do not show the entire picture

1.	**Scientific publications** (only published, not submitted/forthcoming)	2006 to 2011	2012	Total
1.1	No. of peer-reviewed ISI journal publications	605	191	796
1.2	No. of peer-reviewed non-ISI journal publications	109	33	142
1.3	No. of PhD theses	120	28	148
1.4	No. of master/diploma theses	316	48	364
1.5	No. of abstracts/proceedings/presentations/posters at scientific conferences/congresses/workshops	1,913	309	2222

2.	**Scientific events organized by the project/by project partners**	2006 to 2011	2012	Total
2.1	No. of conferences/workshops etc. (open to an audience beyond project partners/participants)	183	29	212
2.2	No. of PhD courses/summer schools, etc.	66	16	82
2.3	No. of other events	73	18	91

- Financial indicators are important, but can only be interpreted on a general level: CCES budget for 2006-2016 = CHF 45 Million, raised third-party funds in 2006-2012 = CHF 60 Million!

- Expert interviews are more differentiated and allow for free expression of opinion
- Idea of the analysis: not an official mandate of the ETH Board, but personal motivation and interest of the SB, AB and the CCES office. Doctoral dissertation project.
- What will happen to the results? Interpret and evaluate interviews, draw conclusions for CCES and future research funding instruments.

Getting started (5 min)

General remarks:
- interview will be recorded on tape
- estimated duration: 1-1.5 hours

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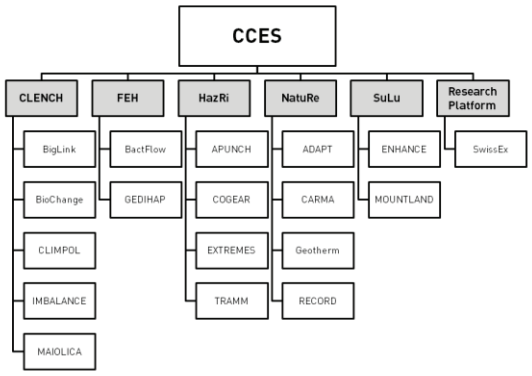
1) What was your personal motivation to participate in CCES?

2) How has your attitude towards participating in CCES changed over time?

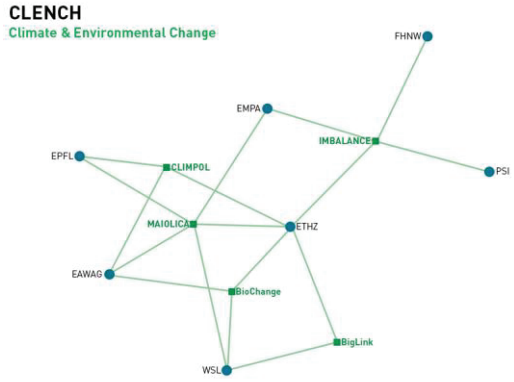
Interview (60 min)

(1) Structuring effect

Goal: Achieve a long-term institutional structuring effect and integrate research strategies and orientations



ERU overview



ERU CLENCH in detail

1) Within the context of your CCES-Project(s), how strong were your project-related contacts with:

	No contact	Very weak	weak	normal	strong	Very strong	Comment
Project partners **at** your institution							
Project partners **outside** of your institution							
Within your ERU							
With projects in other ERUs							

2) How have these contacts changed **over time**:

	No change	Intensified	Weakened	Comment
Project partners **at** your institution				
Project partners **outside** of your institution				
Within your ERU				
With projects in other ERUs				

3) Were new contacts established through your participation at CCES? If yes, how and where?

4) If yes, how high is the chance that these new contacts will be sustained?

5) In your opinion, to what extent did CCES contribute to the development of the "community"?

6) Would you say that CCES had a community building or learning effect that will continue to have an impact beyond CCES? (keywords: grant-seeking capacity, co-authorship)

7) To what extent did CCES impact on your career development and mobility? How was it with others?

8) Did your CCES participation influence your research focus and orientation?

(2) Education

Goal: Establish a long-term education program

1) Have your PhD students or Post-Docs participated in a CCES Winter School?
   Science meets Practice, since 2011, approx. 25 people

   If yes, what was the impact/value of these activities?
   If not, why not? What would need to be changed?

2) Have you or your PhD students or Post-Docs participated in CCES@School?
   Examples: River restoration, Hydroweb, ClimPol@School, PhenoCam

   If yes, what was the impact/value of these activities?
   If not, why not? What would need to be changed?

3) Have you or your PhD students or Post-Docs participated in Public Admin Dialog projects?
   KVU, ETH Seed Sustainability, Master theses

   If yes, what was the impact/value of these activities?
   If not, why not? What would need to be changed?

(3) Implementation

Goal: Achieve a societal impact through public outreach and focus on socio-economic implementation

3.	Outreach	2006 to 2011	2012	Total
3.1	No. of publications for stakeholders outside the scientific community (e.g. public administration)	151	26	177
3.2	No. of press articles (newspapers, radio/TV broadcasts, etc.)	423	41	464
3.3	No. of courses/seminars/workshops for stakeholders outside the scientific community	176	20	196
3.4	No. of public information events for local/regional authorities/residents	113	16	129
3.5	No. of events/activities at schools (courses)	138	15	153
3.6	No. of other events	88	11	99
3.7	No. of patents	8	0	8

Source: CCES-Report 2012

1) Within the framework of your CCES project, you were engaged in public outreach activities. What were your expectations while preparing and realizing those activities?

2) What are the opportunity costs for the implementation of these activities?

3) When do you consider these activities as successful? When as failures?

4) To what extent do these activities play a role for your work outside of the CCES framework?

5) Did the CCES framework contribute to an increase in the activities?

6) Did the CCES framework contribute to the success of these activities?

7) In your opinion, how important are outreach activities and how could CCES contribute to their success?

8) Did CCES (actively or passively) contribute to a stronger communication between science and practice? If yes, how? And not, why not?

(4) Research Quality

Goal: Foster major advancements in research and achieve a leading presence in the field of Environment and Sustainability

1) From your point of view, have scientific results been generated that would not have been possible without CCES?

2) If yes, which property of CCES has facilitated this?

3) In general, participating in research centers requires more time and coordination effort. With view on the research findings: was it worth it?

4) What did participating in CCES mean for your research?

5) Would you say that new research fields have emerged through collaboration in CCES?

6) From the viewpoint of a researcher, what advantages did the participation in CCES have?

7) From the viewpoint of a researcher, what disadvantages did the participation in CCES have?

8) Has CCES helped the ETH Domain to gain a leading presence in the fields of environment and sustainability? If yes, how?

9) Comparing the periods „before CCES“ and „since CCES“: how has the international reputation of the ETH Domain in the research fields environment and sustainability changed?

General questions and feedback (15 min)

1) Looking back, was CCES a useful research funding instrument?

2) Should research projects continue to be funded in a research center setup?
   If yes, what should be supported concretely? PhD students, Post-Docs, field infrastructure etc.?
   If not, why not?

3) Should “research platforms” (like SwissEx) continue to be funded in a research centers?
   If yes, why?
   If no, why not?

4) Should education, teaching and dialog activities continue to be funded by research centers?
   If yes, what should be supported concretely?
   If not, why not?

Conclusion

- Thanks for your support
- Interview will be transcribed and then sent out for authorization

Appendix C: Transcription of the expert interviews

Transcription of the expert interview with Respondent 1 (R1)

The expert interview was held on 2 December 2013 between 14:30 hrs and 16:30 hrs at the interviewee's office. It was conducted in English by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: First, a few general questions regarding CCES: What was your personal motivation to participate in CCES?

R1: It was the possibility of conducting some interesting research with colleagues from other disciplines. Also, the initiative arrived just at the moment where I had seen how to solve important problems that had preoccupied me for a time, which are closely related to issue of ((research question)) and that was a possibility to work on this in an intensive way.

OK: Would you say that this motivation has changed over time? Have your expectations been fulfilled?

R1: It was really just the right thing at the right time, from a research point of view. And this worked very well. I think we have had a lot of impact, relatively speaking. ((Research question)) always tends to be behind the scenes. It is not like it goes on the front page of Science and Nature. But relatively speaking, that work is quite highly cited. Relative to ((research field)) papers.

<u>Category 1: Structuring effect</u>

OK: Within the context of your CCES project, how strong were your project-related contacts. With, first of all, partners at ((institution)), and with partners outside of ((institution))?

R1: They were not enormously strong. We worked with ((partner)) a little bit and then we worked with ((partner)) a little bit. More with ((partner)) than with ((partner)). The postdoc who is supposed to be the glue there was not perhaps the ideal person. He was quite strong but he wanted to work with me rather than with the other two. That was not as good as I would have hoped. On the other hand, within the ETH Domain, we had quite good contacts with ((institution)), I co-supervised two research students. And then another research student in ((location)) at the ((institution)). And then we had a postdoc who worked at the ((institution)) for three years and then came and worked here for two years. And then we had a research student whom I wasn't formally supervising but acting as an external advisor in ((research field)) at the ((institution)). So we wrote four to five, maybe even six papers with him, several papers jointly on different things with people at the ((institution)). That was quite successful. ((researcher)), who is the important person at the ((institution)), he and I met last week. We are trying to put something together again. We are working on the continuation of ((project)). We are trying to do something as part of that. I have another PhD student who works here and is part of ((project)).

OK: Speaking about these five ERUs, including the research platforms SwissEx, OSPER and GDC, and ((project)) is here. Would you say you had contact beyond ((project)), maybe within your own unit or even across the units?

R1: With ((project)), yes. Because we were getting data from them. So one of the papers that we just have published in ((journal)) was based on data got from ((project)). And now we will be doing this kind of working as part of this follow up but didn't really have and direct contact with people from other projects.

OK: Were completely new contacts established through the CCES project?

R1: Yes. I didn't know any of the people I worked with. Well, I knew ((researcher)) before the project began, but very slightly. I didn't know the people at the ((institution)) in ((research field)), I didn't know the people at the ((institution)). I didn't know either ((researcher)) who was part of the ((project)) though he did his own thing really.

OK: You mentioned that you met ((researcher)) last week? Would you say that CCES has allowed you to meet people and that these contacts will be sustained even after the project has finished? Would you say that these new contacts are somewhat sustainable?

R1: Well some of them are, and some of them are not. ((person)) is appointed as a ((position)) part-time at ((institution)). So it is easy to go and see him. If we want to talk, if he is here, I can go and we can talk for half an hour. My main contacts in ((location)) at the ((research field)), the main guy there was a PhD student who has now left and he is no longer in ((location)) but in ((location)). We finished off his papers at the end of last year and they were published earlier this year. But I haven't heard from him since. I will probably get a Christmas card. If he were to come across something he might as well come back to us because he had a fruitful collaboration.

OK: In that sense, would you say that there has been a development of a community?

R1: Yes. I mean for example, having discovered ((location)), we will go for a group retreat in ((location)) after Christmas and hopefully that will give us, with a bit of luck, the chance to go and talk to ((researcher)) at the ((institution)).

OK: Would you say that, let us say, if you would do a project with people you met through the CCES project, do you think that going through CCES together has formed you into a group within which you can work in future as well? For example, if you would apply for a grant together, would this be easier now?

R1: Well, yes it would be if we wished to do so. I think so, Yes. But of course you have a basic level of understanding and trust.

OK: Would you say that CCES participation influenced your own research orientation or your research focus?

R1: I am not sure either those two. I have been thinking of getting back and working on ((research field)). I have been working on a variety of things in ((research field)). In a sense that it provided money, lots of opportunities for looking at interesting data. In that sense it influenced it. But I would have probably done that anyway but I would have done it more slowly, I guess, because we wouldn't have had so much resources, so many contacts, and so on. So in that sense, yes and no. It accelerated things.

Category 2: Education

OK: Now you mentioned PhD Students earlier and postdocs, do you know if any of these have participated in the CCES Winter School?

R1: I don't think so, no.

OK: If not, why not?

R1: Well, for my point of view, I looked at it. I sent it around, the last announcement. It seemed to be conducted mostly in ((language)), which is a difficulty for people from ((region)). As far as I understood, stakeholder meetings and stuff. I looked at the video and that would be a potential problem for some of them. And the thing is that it might be useful for ((research field)) scientists, but for ((researchers)) and ((researchers)), who behave in a rather different way, research in a rather different way, and have different sorts of impacts, maybe less so. There is an additional problem for people, specifically at ((institution)), is that the research students at ((research field)) have a lot of teaching duty here. And they don't have time to go and spend two weeks somewhere else, especially not during term time. So, you know, they will be looking forward to ((month)) and thinking, once the exams are over, "at last I will be able to do some research". But otherwise, they spend a day a week at least for teaching, teaching preparation and it is just too much to be able to say: "Great, I have go two weeks free. I can go and do this".

OK: Did you come across CCES@School? Do you think that there could have been an added value in joining these activities? Or is it too far away from what schools do?

R1: Not really aware of this. The problem is what we would need to start with is already second year university material. That is what we start from. What is a ((research question))? So going into high school and talking about that would be quite difficult to integrate. You could talk about the data and you could talk about the potential results of analyses. But there has to be a big whole, where you go from, what will you do, to the data and results of the analysis. And that is the bit we actually work on mostly. And it would be most interesting to explain to students but they don't have the baggage. One has to do motivational talks to first year university students. I think it is a bit too upstream, frankly. This is not to say that it couldn't be done, but it would have to have a larger

educational effort as to what ((research field)) means rather than something specifically to do with CCES.

OK: I see the same issue with the third set of questions I have in mind, on Public Admin Dialog. This would have worked as well to a certain extent. Would you say that Master students here would have had the interest of having theses with a more practical element?
R1: Yes, sure. Our students do an internship in industry. One of the students will be doing her Masters projects after Christmas. She is currently working with ((organization)) in ((location)), I think. But I am sure she is the sort of person who could potentially be interested in doing such a project. If ((political entity)) came to us and said: "We would like to do this better. Can you help?" and if we could work, I am sure she would find that interesting.

OK: Would you think that it would be easier for students to get a finished package? "Can you work on this?" Or rather students, in coordination with the Offices, would develop their own theses? What would be more interesting, from your viewpoint?
R1: Well, either really. If she comes back and says: "Look, I worked on this thing with ((organization)) but I just got started and I clearly facing some problem that ((organization))", I could talk to ((organization)) and we could identify something. Equally, I was just in a process trying to write down an idea I had for modelling ((research theme)) data which is a different way of modelling and thinking she should have access to lots of data, it would be interesting if this idea works because it would be potentially useful if it did work. But there, of course, I am coming from an academic point of view. Having seen something working or not in practice she might come back from the applied side: "This didn't work and we don't know why" and that would be equally interesting to figure out why. Either. In the meantime, we do have, last year we did a project with ((political entity)), on trying to analyze ((research question)) and such liken and we are currently finishing a project with ((organization)) on ((research question)) which both you could think of as spin offs of ((project)). ((organization)) is essentially a commercial project but I don't think they would have come to us if we hadn't done CCES work and become "well-known" for this.

<u>Category 3: Implementation</u>

OK: You have also engaged, be it with ((project) or with ((project)), in a number of outreach activities. What were your expectations when you prepared those?
R1: Our engagement, in terms of ((project)), were mostly not outside the scientific community. For example, we ran a six month period with the ((research unit)) here, where we brought between 150 and 200 people which was a focus research period on ((research field)). And that promulgated our ideas. I ran a thing in ((location)) on ((research theme)). But again, that was to really to scientists. The problem is "the scientific community" isn't well-defined because there are scientific communities, for example, on ((research theme)), our natural peers, but also community of

((researchers)), who might use our methods, or ((researchers)). So, from my point of view, maybe talking intensively to people in applied communities is “stakeholders outside our scientific community”. ((researcher)) has quite a high profile and he is often interviewed so I think this counts as press articles. I don’t think he does this for public information events or local residents. That is more the thing that the ((organization)) does. And that is just part of its usual mandate. For example, ((researcher)) would go and talk about the latest thing in ((research theme)) just as part of his job. As far as I know we didn’t do anything at schools, as far as I can remember and any of the other things here (table). Personally, I didn’t take part in any of the events for non-scientists and I don’t know quite if ((partner)) went into local authorities or towns to explain to them how they should organize their ((issue)). I don’t know what expectations we would have had.

OK: Let’s talk about the six month programme you mentioned earlier. This obviously had opportunity costs. Because if you organize such an event, you cannot publish papers to the extent you would normally? What would you say are the opportunity costs and is it worth it to do such thing and what was the impact?

R1: Well, if you go back five years, ((year)). At that point in ((project)), I would say quite of a lot of things were well understood. At least in principle. It was known, again, in principle, how one could go about modelling ((research field)), for example, because the fundamental ((research field)) work had been around 1980/85 but nobody actually tried to put it into practice, or at least, hardly ever. And yet it was obvious and is becoming increasingly obvious, to model ((issue)) and ((issue)), has become more and more important. Also, to model complex ((research theme)), actually, to get them understand the ((issue)) of those better. For me the goal of the ((project)), personal goal, is to have to find the time and the resources to really be able to push that forward. Now, the six month research programme that we had was in the second half ((year)), so it was kind of, when did ((project)) begin, ((year)), so it was about the half-way point. And that was a very good moment because we were able to find some people, worldwide, who were interested in the topic, who had made contributions, and we had three workshops each about 70 people, for a week, and then longer-term visitors who were on campus for a month. So this was held at the ((name)) center which is a ((name)) which is a ((research field)) research center but is in principle for applications of ((research field)) or possibly ((research field)). And it can involve people from other domains. And what we did was, we basically got in many of the people worldwide who work in the area, or who worked on applied topics related to the area. And got them together and got them to talk and I think, as a result of that, in ((year)), I would say that we are largely, there is lots to do, but we have a better understanding how to do this modelling, at least for ((research question)). I think we have moved on much more from ((year)) to ((year)) than we had from ((year)) to ((year)), for example, worldwide. The stimulus effect was very large. Both for us and on an international level. And now we get to the point where people are using some of the software that was written for our project. ((researcher)) wrote an R package which is now being used by ((researchers)) to do analyses, and being published in ((journal)).

OK: Would you say that CCES, or what came along with it, meaning the interdisciplinarity or the inter-institutionality has promoted for example this six month programme? Did CCES facilitate the organization of such a programme?

R1: It didn't particularly facilitate the organization, I would say. It dovetailed very nicely because we simultaneously were able to engage people from more applied disciplines who might use these ideas and people from the ((research field)) who might have the ideas and who might be stimulated by problems coming from the applied side. We were dealing with, just a month ago it came up, I don't know if it was stimulated by the discussions at the programme in ((year)), but for example, there is a problem with ((research question)) and other things. If you fit models too often in ((research question)) you are interested in the ((research question)) for different ((research question)), so you might be interested in ((research question)). Now, if you fit separate models to those you can end up with, which is what one would naturally do because there is nothing better to do, what you might end up with is predicting the 100 years ((research question)) at ((research question)), which doesn't make sense. The two hour one must be bigger. That implies certain constraints on what ((research question)) you should fit. We have got this practical problem and which I didn't know any methods for dealing with it turned out somebody who attended workshops had produced some theory on the problem and we were able to apply to data. I don't know if it was stimulated by meeting applied workers but it is a sort of thing that could have well been stimulated by meeting applied workers and hearing what they didn't know to deal with that.

OK: So, was it just the right time that you did the programme, or just the right funding or was it the funding that you had anyways through CCES? Or the network?

R1: Many things. The network is less through CCES than through my professional contacts worldwide. But it was also very useful to have CCES. And to have ((researcher)) to come and explain what it is like to model such and such.

<u>Category 4: Research</u>

OK: From your point of view, would the scientific results that were generated over the course of the CCES project have been possible without CCES as well?

R1: Possible, but with much more effort in the sense that I could have asked for two postdocs and three PhD students myself and I might conceivable have got them from the SNF, but I doubt it. And having those resources and being able to have people work simultaneously on different aspects of problems did indeed push things forward, I think. In a way that CCES made possible but that would be very difficult with other funding instruments. And I think we did make some, from my perspective, major steps forward in the particular things I am talking about.

OK: Which property of CCES would you say has been the most useful, facilitated this?

R1: I think the fact that we were able to put this up, I must give credit to ((researcher)) who sort of stimulated me, he pushed me basically to be in charge of this, he saw the possibilities and found some of the people. I think the fact we were able to have ((researchers)) and ((researchers)) in the same group of people was something that a very essential, otherwise it wouldn't have worked. Now, as ((researchers)), we integrated better with the ((researchers)) than the ((researchers)) at the ((institution)) and ((partner)). But ((partner)) orientation is different anyway, and it is more towards ((research field)), and such like. More generalist. And so it would have been more difficult to integrate him anyway.

OK: Now, very bluntly speaking, participating in research centers requires a bit more of an effort such as perhaps travelling, coordinating. Would you say, in light of the findings, that is was worth it?

R1: The thing I found most burdensome was writing the annual reports, I must confess. And ((research manager)) can certainly confirm this because they were always very late. Just because it was a pain in the neck to pull them together. The first part of the project, we got together once a month with the younger people of the project in ((location)) once a month, and so say, for a morning or an afternoon, and we would talk about the work, give presentations and discuss it. That was important but a bit of a burden. But it wasn't a major burden. Overall, if I look back now, I think it was worth it. When I looked after finishing any one of the annual reports, and I looked back, that was garstly and I will never want to do it again, immediately afterwards. I mean one problem was my fault as it didn't have any administrator tied to it. So whenever it came into checking money or chasing people for bits of their report or whatever it was down to me to do it. Of course, I am far too busy to do this in an efficient way.

OK: Would you say that new fields of research have emerged or speaking about yourself, would you say it took you in a direction that you hadn't thought of?

R1: I am not sure about that. I am not sure I would say it goes as far as that. Certainly, there is existing domains of research different directions appeared. Whether a new field emerged, I don't think so. At least from my perspective. Perhaps for the more applied domains, for example, for ((research field)), for this sort of thing that ((researcher)) and ((researcher)) were doing, perhaps that has been different because they, for the first time, were looking at ((research field)), ((research field)), and I don't think anybody had done that before in their domain, on the other hand, looking at citations isn't a very good guide especially if the stuff appeared a few months ago. But I don't see many people picking this up and running with it yet. But I mean the things more important in the long run is to send well equipped young people out because they have got different tools from their elders and they will slowly but surely change their field as they use the tools throughout their careers.

OK: You have mentioned a few things already but let me be a bit more straightforward here and ask you: from a viewpoint of a researcher, what were the advantages and the disadvantages for you to participate in CCES?

R1: One thing is having a research focus, working on a specific project which one might not necessary have as an individual. You might become more distracted by other things, not negligible. The other is the fact of having to talk to people from different disciplines on reasonable way having to interact with them having to learn from them, hopefully having to teach them a little bit, in some cases. Of course the money. The fact of having however many Postdocs and PhD students was more or less very useful for getting such momentum and critical mass. Those were the main advantages. Main disadvantages were, it takes more time, but you just have to view this as an investment and hope the investment pays off. As I say, the annual report. I know that ((research manager)) did his best to make the whole thing as light as possible but nevertheless it is more effort to put together a 30 page report for CCES than a 4 page report for the SNF, that is quite a lot more effort. Putting one's own part of the report together is easy. It is getting the stuff from everybody else. Kind of thinking: "Is this right?". No, they have misunderstood this, they have left out, you know there is someone who they haven't put on their list. You have to give it back and chase them. All that just took time and was the least attractive part, I thought. And of course there is the overhead of being asked to produce transparencies for meetings, go to meetings to make presentations to the Advisory Board. All this kind of stuff. I don't mind that but it does take time. But this is just part of the overhead. If you have CHF 1.6 million from CCES, you have to expect that would have to work a little bit for it.

OK: Would you say that from your point of view, the ETH Domain, through CCES, has become internationally more visible? Has CCES catalysed the international presence of the ETH Domain in this field of Environment and Sustainability?

R1: I don't if anybody would say the ETH Domain or CCES if you said to them ((research field)). But I am pretty sure most people would say ((location)). If you would ask them: "Who does work on this worldwide ((research field))?" I think they would say ((researcher)) in ((location)) has a group working on things like this. In that sense, the CCES and the ETH Domain have had an impact. Most people don't even know the ETH Domain exists, even in Switzerland. If people want to put together a session on the topic or related thing on a conference or a scientific meeting, they might very well send me an email and ask "Could you possibly take part, submit an abstract?". So I think this had an effect.

General questions:

OK: Looking back, very general, was CCES a useful research funding instrument?

R1: Oh yes, definitely.

OK: Should research projects continue to be funded in a CCES style? CCES will finish in 2016. Would you recommend that there shall be a new framework to fund projects in a way that CCES has done?

R1: One of the issues that was seen with CCES, I believe within ((institution)), and I don't know how correct it is, that a lot of the money was going to ((location)). I think looking at the projects here on your sheet. I think there are two that were based ((location)), or possibly three. ((project)), ((project)), I think was sort of related to ((institution)) and maybe ((project)). ((project)) was ((location)) but I am really not sure about any others. So from that point of view, it was seen as "unfair" use of ((institution)) funding, certainly by our ((management)), what I was told. Though I never discussed this with ((management)) directly. So great care would need to be taken to be clear that this gave access to scientists right across the ETH Domain. Otherwise it is just perceived, rightly or wrongly as being money that was put into the corner for one or the other. It would be ((institution)), it could be ((institution)), ((institution)); it doesn't really matter. But if the point is to get into penetration with different people at different places, you have got to have that as a possibility. That could be a serious drawback. I think that is the main drawback I experienced, I think.

OK: In terms of ((project))? You also participated in ((project)).

R1: Well, in a very peripheral way. Right now, we are participating in ((project)) in a more central and integral way. Our participation in ((project)) was about getting the data but not really in setting up any experiments or anything of that.

OK: What do you think about ((project)) as it is different in nature? Where do you see the advantages?

R1: I can imagine that there are two problems. It was very difficult to judge data gathering and compare it with data exploitation. ((project)) was about data gathering and data organization and then, down the road, making data accessible, and then making data fairly analysable. Which is where we come in, the last bit. Just setting the old ((project)) in place takes an awful lot of effort. In a sense, what you have in the end is a number of data bases. It is difficult to make those valuable without the last bit, the exploitation. That inevitable comes a bit a far bit down the road. Then, another problem is: what is unique to it isn't too obvious. Another problem is that if there is a huge investment in getting the data, then for example environmental time series you really want long time series. The data in high quality and the quality that one gets from the little work stations that are used for example up in ((location)) is not totally obvious that this is high quality. And there is a lot of missing data. They are only available for four months a year. Of course it is better to have that, we have so far got ((time frame)) of data from up there. About 58 percent are missing of the

data have been using, for different reasons. You need to put a big, sustained, long-term effort into getting high quality data and that is obvious just going to be expensive. And one has to think: “What is the added value compared to long term ((institution)) series?” The case I know most about is the ((location)) data. There we had 24 work stations in different places in different summers and then five kilometres away is the ((location)) where there is 30 years of data of day to day. Probably pretty well checked, calibrated, the ((location)) data, which was ((project)) data from our colleagues ((researcher)) group seemed to be fairly reliable but I couldn’t put my hand on my heart and say: “They are absolutely fine”. I am sure our colleagues have done their best. I expect ((organization)) is better. For people who want to do specific experiments about ((research question)) or other things, and they take the ((research infrastructure)) and stay there for a week or two measuring things, I am sure that is a valuable thing and that ((project)) is giving tons of data there. But when experiments run on longer term, I am not quite so sure if they are quality. So I suppose those are two of the problems.

OK: Would you invest in education, teaching and outreach activities in the future if you were to allocate the money?

R1: I am sure they are important. I mean our position is a bit anomalous, always because explaining to people about ((research)) results and how they might be used for ((research)) work and how for the ((research)) is a bit difficult. But it is not that is shouldn’t be done. I am sure that is a good idea. I just don’t have enough experience myself how it should be modified, in what proportion it should be done.

OK: Do you think in 10 years’ time, the impact CCES has left behind, will still be felt?

R1: Nobody in this building would know what CCES was. Whether people remember the research in 10 years’ time, probably, I am sure they will. We have one paper, for example, published in ((year)), I think it has been cited now ((number)) times. If that carries on, it will clearly have a had a big impact in 10 years’ time. Of course, it might be that some better method comes along in ((year)) and everybody has forgotten but that is just the ways things are and we are best things that we are the ones to publish the one in ((year)) rather than letting someone else get there faster. So I think, potentially at least, as far as one can judge, from a research point of view, it would have been very successful if anyone ever looks at the financial acknowledgments, which I sort of doubt, there they will see the words CCES. So in that sense, it will have had its impact.

OK: Would you say that CCES has started a wave and I guess you would agree on this. To summarize, would you do it again?

R1: Yes. If I had known in 2006 that it was going to be this much administrative work, I might have asked for administrative help, I think. Though that would have been a bit foolish because most of the year you don’t need that help. I should probably be better organized with my local resources. The thing is that ((institution)), at least in ((research field)), we don’t have people to work on the

grants so we need to do it ourselves or our secretaries to do it. If you have a quarter secretary, which I do, they are usually quite busy with just ordinary stuff. But that was a headache as I am sure is probably more a headache for ((research manager)) than it was for me. On the other hand, knowing the scientific results, there are something I would do differently of course but of all the scientific results justified the work, from my point of view. Let me just say for the record, that I very much appreciated the support we had from the CCES office. Interactions with them were never difficult. Of course, ((research manager)) got occasionally frustrated but he was always calm and polite and friendly. Interactions I had with him and ((research manager)) and before him ((research manager)), were always very good, I thought.

Transcription of the expert interview with Respondent 2 (R2)

The expert interview was held on 3 December 2013 between 11:00 hrs and 13:00 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: Was war den Deine persönliche Motivation am CCES teilzunehmen?

R2: Meine Beteiligung am CCES hängt ein bisschen mit dem ((project)) an der ((institution)) zusammen. Man hatte mich beauftragt, etwas auf die Beine zu stellen. Die interdisziplinäre Forschung hatte mir schon immer gefallen. Und dann sind wir auf den ((research field)) gekommen weil ich dachte, das sei ein Ort, wo man verschiedene Leute, ((research field)), zusammenbringen könnte. Es hat mich interessiert den ((research field)) anzuschauen und ein globales Bild zu kriegen. Parallel ist auch diese ((organization)) gekommen in den ((location)) und in ((location)) und ich dachte, das sei eine spannende Sache und auch etwas Neues. Ich hatte noch nie am ((research field)) gearbeitet und das war eine Herausforderung.

OK: Hat sich über die Jahre geändert?

R2: Nein. Ich bin sehr froh, dass ich es gemacht habe. Ich habe sehr viel gelernt, durch diese Projekte, erstmals intern in der Schweiz, viele Leute kennengelernt und Kontakte geknüpft. An der ((institution)) zum Beispiel hatte ich vorher praktisch niemanden gekannt. Jetzt kenne ich quasi die Hälfte der ((institution)). Wir haben dann auch mit anderen Departementen, ((department)), ((department)), bilaterale Kontakte geknüpft. Das ist sehr positiv und ich habe Sachen gemacht, die ich sonst nicht hätte machen können. Das ist ein Aspekt und das zweite ist, durch das CCES Projekt habe ich überhaupt internationale Kontakte knüpfen können, mit EU Projekten, amerikanischen Forschungsgemeinschaften, ((organization)), wo sich Zusammenarbeiten ergeben haben, die sonst nicht möglich gewesen wären. Für mich war es eine sehr erfolgreiche Sache, ich habe viel gelernt.

<u>Kategorie 1: Structuring effect</u>

OK: Sind im Rahmen Deiner CCES Projektarbeit Kontakte entstanden mit Projektpartnern an der ((institution)), mit Projektpartnern ausserhalb der ((institution))?

R2: An der ((institution)) selbst sind ein paar neue Kontakte entstanden. Nicht alle Kontakte haben jedoch auch neue Projekte hervorgerufen. Über zwei Doktoranden und andere Projekte sind Zusammenarbeiten entstanden. Ich habe ja mein ((organization)) und die Leute kommen und fragen, wie wir zusammenarbeiten können. Daraus sind viele Projekte und Kollaboration, vor allem mit der ((institution)), entstanden. ((institution)) und ((institution)) waren im ((project)) starke Partner.

OK: Waren das überwiegend Partner im ((project)) oder auch anderswo? Hattest Du auch Kontakte in anderen Projekten?

R2: Mit ((project)) habe ich einen Doktoranden betreut. Da hat sich eine Langzeitzusammenarbeit entwickelt. Sonst nicht so viel. Dadurch habe ich ein bisschen einen Überblick bekommen, was sonst noch gemacht wird. Leider hat der Tag nur 24 Stunden, und ((project)) war ja nicht mein Hauptprojekt.

OK: Du hast auch gänzlich neue Kontakte hergestellt. Denkst du, dass diese Kontakte auch nach Ende des CCES Projektes noch weiterhin bestehen werden? Was ist Deine Einschätzung?

R2: Ich glaube schon. Ich habe jetzt noch laufende Projekte. Sollte ich im Bereich ((research field)) weiter machen, dann werde ich diese Bereiche sicherlich aufsuchen. Wir konnten gut zusammenarbeiten.

OK: Gab es eine Art Gruppenbildungseffekt?

R2: Ja. Ich weiss von Gruppen an der ((institution)) und der ((institution)). Und sogar an der ((institution)) haben sich neue Konstellationen gebildet, die weiter machen werden. Da hat sich, denke ich, einiges gemacht an Kontakten.

OK: Du würdest schon sagen, es hat sich eine Art Community gebildet und verstärkt?

R2: Ich denke schon. Ich bin kein ((position)). Und das macht einen Unterschied, was man längerfristig bilden kann. Als nicht ((position)) hat man an der ((institution)) weniger Möglichkeiten so etwas längerfristig aufrecht zu erhalten. Wir haben einfach nicht die Ressourcen, wie wenn ich eine Gruppe hätte. Ich habe jetzt noch zwei Postdocs, die das weitermachen und vorher einen Doktoranden. Aber für längerfristig ist alles immer „soft money“ und man hat auch nicht vom Chef die nötige Unterstützung als wenn man unabhängig wäre.

OK: Meinst Du, dass sich durch diese Arbeit am CCES Projekt etwas an Deiner Karriere oder an der Karriere Deiner Kollegen entwickelt hat?

R2: Für mich nicht unbedingt. Das liegt auch an der Struktur der ((institution)). Für mich ist es okay. Es war für mich eine klare Quelle für Geld für Postdocs und Doktoranden aber es hat mir auch Türen geöffnet, das EU Projekt zu kriegen. Sonst hätte ich das wahrscheinlich nicht gekriegt und jetzt sehen wir wie es weitergeht. Auch die Kontakte mit den USA sind nur möglich, weil wir diese Initiative mit dem ((project)) hatten. Von demher hat sich schon etwas am Profil gemacht, denn gewisse Leute kennen mich wegen dieses Projektes und es gibt zum Beispiel einen Postdoc, der mit mir gearbeitet hat. Nicht nur wegen ((project)), aber immerhin konnte er besser Kontakte knüpfen, die ihm jetzt geholfen haben, einen Lectureship zu kriegen. Die Visibility ist gestiegen, das hat schon was gebracht.

OK: Würdest Du sagen, dass ((project)) Deinen Forschungsschwerpunkt oder Deine Ausrichtung mitdefiniert hat?

R2: Während dieser Zeit, angefangen 2007, und seither ist das ein fester Bestandteil meiner Forschung. Es braucht einen guten Teil meiner Zeit. Noch immer habe ich zwei Postdocs und noch einiges mit Doktoranden.

<u>Kategorie 2: Education</u>

OK: Haben Doktoranden oder Postdocs von Dir am der CCES Winter School teilgenommen?

R2: Der jetzige PhD Student hat teilgenommen, letztes Jahr. Und er war eigentlich sehr zufrieden und vor ein paar Jahren waren nicht meine Studenten, aber zwei Studenten, die im ((project)) waren, Teilnehmer der Winter School.

SB: Was war die Wirkung der CCES Winter School?

R2: Schwer zu sagen. Aber ((name)), mein jetziger PhD Student, es war auch sein Fokus, die Zusammenarbeit mit der Presse, hat sehr positives Feedback gegeben. Es hat ihm etwas gebracht und er hat gelernt, wie man solche Sachen macht.

OK: Hast Du oder Studierende von Dir an CCES@School teilgenommen?

R2: Nein.

OK: Hättest Du Dir vorstellen können, daran mitzuarbeiten? Und wenn ja, unter welchen Voraussetzungen? Siehst Du da Potential?

R2: Das ist eine Frage der Zeit und der Ressourcen. Wir hatten keine Ressourcen um das zu machen. Wenn man eine grössere Gruppe hätte, dann könnte man da mehr erreichen, auch längerfristig. Was wir gemacht haben, es gibt diesen ((public outreach activity)) als Outreach Aktivität und wir sind dabei eine Broschüre für das allgemeine Publikum zu entwickeln, die als Guide runtergeladen werden kann. Andererseits organisieren die ((organization)) Kurse für die Schulen. Durch diesen Kanal können wir unsere Kenntnisse an die Schulen bringen. Wir haben einige Energie investiert, und das kommt jetzt auch in den Schulen an. So haben wir das aufgrund des Zeitmangels gelöst. Das Problem bei solchen Sachen ist, wie wird das anerkannt? Wenn ich jetzt sage, ich habe einen Monat in dies oder das investiert, fragt man mich: wo sind die Papers? Das ist die Motivation. Aber wir haben trotzdem einen Effort gemacht, das an das Publikum zu bringen, indirekt. Es ist eigentlich eine win-win-Situation: für uns ein Kanal, der etabliert ist und für die, sie kriegen ein paar neue Inputs und Materialien für ihr Programm.

Kategorie 3: Implementation

OK: Du warst im Rahmen von ((project)) an Outreach Aktivitäten beteiligt? Was waren Deine Erwartungen?

R2: Ich habe schon ab und zu verschiedene Vorträge gehalten in Schulen und ich finde es einerseits als Teil unseren Jobs. Ich habe zum Beispiel auch eine Studienwoche für Mittelschüler organisiert. Wir waren am ((location)). Es macht also auch Spass anderen Leuten etwas beizubringen und diese schätzen es sehr.

OK: Wie wichtig sind diese Aktivitäten generell für Dich? Machst Du das auch ohnehin?

R2: Ich mache solche Aktivitäten auch ohne CCES. In den letzten paar Jahren ist es auch eine Frage der Zeit geworden, aufgrund der vielen Projekte. Bei dem ((public outreach activity)) zum Beispiel haben wir viel Zeit investiert, die Postdocs und ich. ((researcher)) zum Beispiel hat sehr viel gemacht. Wir wollen es auch pflegen. Wir sind in Kontakt mit den ((partner)), die Touren anbieten. Wenn sie Fragen haben, können sie sich jederzeit an uns wenden. Ich finde es einen wichtigen Teil, dass wir auch im Nachfolgeprojekt und auch im EU Projekt ist ein Teil Outreach. Dort müssen wir auch Materialien liefern.

OK: Wann siehst Du denn diese Aktivitäten als Erfolg? Wann hat es sich gelohnt?

R2: Es ist eine Frage der Response. Am Anfang waren wir ein bisschen enttäuscht in der Nutzung des ((public outreach activity)). Das war aber eine Frage der schlechte Werbung. Ein paar Wochen später ist jemand dorthin gegangen und alle hatten Kopfhörer an, mp3-Player ausgeliehen. Man kann es auch gut an den Downloads messen.

OK: Es gab ja zum Beispiel auch einen Artikel darüber und auf der CCES Seite. Was hast Du noch für Kanäle genutzt?

R2: Es gab ein paar Artikel in Lokalzeitungen im ((location)). Es gibt einen Flyer, der auch im ((location)) liegt, das auf die ((location)) fährt. Der ((function)) sollte auch die Leute aufmerksam machen. Dann gibt es Plakate. Am ((location)) gibt leider noch nichts. Es gab eine Vorstellung für die Presse im letzten Juli. Man muss vielleicht nächstes Jahr, wenn die Saison wieder anfängt, Werbung machen. Auch lokal muss sich das ein bisschen herumsprechen. ((partner)) hat auch eine Liste von solchen ((public outreach activity)). Die machen auch dauernd Werbung, denke ich.

Kategorie 4: Research quality

OK: Sind wissenschaftliche Erkenntnisse gewonnen worden, die ohne CCES nicht gefunden hätten werden können?

R2: Ja, ich denke wir haben durch diesen multidisziplinären Approach etwas gemacht, das wir nicht hätten machen können. Wir konnten die Sachen von mehreren Seiten anschauen, was sonst

einfach nicht passiert. Es braucht auch eine Zeit, bis die Leute lernen zusammen zu kommunizieren. Das ist einigermassen gelungen, denke ich. Wir hätten eine zweite Phase sicherlich gebrauchen können. Wenn wir in einer weiteren Phase weitergearbeitet hätten, wäre es wahrscheinlich besser gelungen, dort weiterzugehen. Das Problem ist, dass ein paar Leute weggegangen sind, die wichtig waren, andere hatten keine Zeit mehr. Es hat sich ein bisschen verlaufen, und ich hatte nicht mehr die Zeit und Energie um ein zweites Vollprojekt einzureichen. Ich war auch im ((project)). Ich denke aber, man hätte vielleicht in einer zweiten Phase mehr rausholen können. Aber für mich war es ein gänzlich neuer Approach und das ist etwas, was jetzt in den nächsten Jahren boomen wird, mit den ((project)), und da haben wir eine gute Contribution gegeben in dieser Startphase, was man machen soll.

OK: Es gibt allein durch die Koordination mit anderen Stellen und Institution einen Mehraufwand. Hat sich der Mehraufwand gelohnt angesichts der Forschungsergebnisse?

R2: Ich glaube schon. Und ich muss sagen, ich finde das CCES eine sehr schlanke Struktur hat, verglichen mit anderen ist CCES viel einfacher ist in Sachen Administration. Was wir machen mussten war relativ wenig, im Vergleich mit einem EU Projekt, Nichts! Der Mehraufwand war nicht so gross und die Resultate können sich sehen lassen.

OK: Was hat CCES bzw. ((project)) für Deine eigene Forschung bedeutet? Oder: hat Dir ((project)) einen neuen Spin gegeben? Haben sich neue Forschungsfelder ergeben, ein neuer Schwerpunkt aufgetan?

R2: Eine Sache, die ich entwickelt habe, ist ((research)). Das haben wir im Prinzip erreichen können durch ((project)), weil ich damit einen Postdoc hatte. Und die Zusammenarbeit mit dem ((organization)). Das ist etwas, das ich jetzt auch brauche für andere Projekte und das hat meine Forschung sicherlich positiv beeinflusst.

OK: Die Teilnahme am CCES hat sicherlich positive Aspekte wie negative Aspekte gehabt? Was ist aus Sicht eines Forschers Deine Ansicht?

R2: Ich habe nicht viel Negatives. Für mich war es ein neues Feld. Ich habe viele spannende Leute kennengelernt, was mir neue Projekte eröffnet hat. Ich habe eigentlich sehr wenige Probleme gehabt im Projekt. Es war eigentlich eine Freude mit so vielen motivierten Leuten zu arbeiten. Ich habe eigentlich keine negativen Punkte.

OK: Würdest Du sagen, dass der neue Approach dazu beigetragen hat, dass die ETH Domain international sichtbarer geworden ist?

R2: Ja, die Präsenz in der ((research field)), zum Beispiel, die jetzt in die zweite Phase geht in ((location)). Dort sind 15 Millionen von der EU investiert worden. Unsere Anwesenheit ist dort klar. Wir sind ein Teil. Ich wurde eingeladen vom ((organization)) als Reviewer für das Programm um seine Zukunft zu diskutieren. Das hängt sicherlich mit meiner gesteigerten Visibility zusammen.

Allgemeine Fragen und Feedback:

OK: Würdest Du sagen, dass CCES rückblickend ein wertvolles Forschungsinstrument war?

R2: Ja. Es hat mir die Möglichkeit gegeben, etwas zu machen, das ich sonst nicht hätte machen können. Es hat neue Zusammenarbeiten ergeben und neue Kontakte.

OK: Wenn Du entscheiden müsstest ob es nach wie vor derartige Projektunterstützung geben soll, auf welche Aspekte würdest Du besonders Wert legen?

R2: Eine Sache ist: Wenn man wirklich so über Disziplinen arbeiten will braucht es Zeit. Es müssten unbedingt längerfristige Projekte sein. Vier Jahre sind nicht genug, acht oder zehn sind sicher besser. Weil erst dann bildet sich eine gewisse Community. Für mich war es wirklich eine Möglichkeit, etwas neues zu machen. Für gewisse Leute war es nicht so. Es war einfach eine andere Geldquelle. Jeder macht es ein bisschen seiner Art. Wenn man die Leute ein bisschen pusht zusammenzuarbeiten, verschiedene Leute in einer Gruppe, kommen sicher Sachen raus, die sonst nicht passieren würden. Es ist vielleicht ein bisschen top-down, aber an sich ein gutes Instrument. Viele Doktoranden und Postdocs haben es auch gesehen. „Du musst in Deiner eigenen Spezialität stark sein, du musst dich aber auch öffnen für andere sein“ So eine Kultur kann man in so einem Forschungsinstrument versuchen zu stimulieren. Gerade in der Umweltforschung braucht man auch Leute, die ein bisschen querschauen und nicht super spezialisiert sind.

OK: Wenn man jetzt konkret Education finanzieren wollte? Wo würdest bei Dialog und Outreach ansetzen?

R2: Für Doktoranden sind Summer Schools sicher nützlich. Aber auch ein ganzer Studiengang, den gibt es ja schon in den Umweltnaturwissenschaften. Auf Masterniveau wäre es sicherlich auch interessant. Bei den Schulen: ich denke man muss sehr gute Materialien liefern. Meine Erfahrung ist, dass Schulen schon volle Programme haben. Warum jetzt noch mehr Materialen produzieren? Ich habe den Überblick nicht. Aber ich sehe es von meinen Kindern, die haben schon recht gute Sachen. ((partner)) und ich sind ab und zu in der Schule. Und das haben die Schulen sehr gerne. Führungen im ((name)) Museum. Vom CCES für die Schulen, ich weiss nicht. Was die ((organization)) für Schulen haben ist super. Da und dort kann man das ein bisschen ergänzen, aber jetzt etwas grosses Neues zu machen ist überflüssig.

OK: Abschliessend, würdest Du es wiedermachen?

R2: Ja. Ich habe viel gelernt, es war eine gute Erfahrung.

Transcription of the expert interview with Respondent 3 (R3)

The expert interview was held on 3 December 2013 between 16:00 hrs and 18:00 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: Was war Deine Motivation am CCES mitzumachen?

R3: Es war eine gute Chance das Netzwerk etwas auszuweiten. Nicht nur über den Atlantik und in Europa, sondern einfach mal lokal. Möglichst lokal die Synergien bündeln.

OK: Hat sich das positiv entwickelt?

R3: Auf alle Fälle. Es hat sich auch bewahrheitet. Dazu kommt noch, dass ich, als das CCES aufgesetzt wurde, zufällig noch ein gutes Thema hatte. Diese ((research theme)) war damals relativ neu hier an der ((institution)) und das war einfach ein super Topf für uns, um das zu versorgen und dort zu platzieren.

<u>Kategorie 1: Structuring effect</u>

OK: Wie stark waren diese Kontakte mit Partnern an der ((institution)) und ausserhalb?

R3: Hier an der ((institution)) hatten wir gerade mit dem Thema ((research theme)) begonnen. Wir hatten ein SNF Projekt eingegeben, das dann aber abgelehnt wurde. In diesem Sinne hat sich das voll ausbezahlt für mich. Ich konnte gut mit der Forschungseinheit ((unit)) zusammenarbeiten und das ist jetzt wirklich gut etabliert. Obwohl ((partner)) ja hat abspringen müssen wegen der ((position)) und ich jetzt meist mit ((partner)) arbeite. Aber das ist ein sehr guter und verbindlicher Kontakt.

OK: Was meinst Du woran das liegt?

R3: Ich denke, dass die ((institution)) Leute sind sehr viel mehr fokussiert, auf ein Thema. Hier an der ((institution)) sind wir einfach sehr breit ausgelegt.

OK: Hast Du auch mit Leuten ausserhalb deines Projektes etwas zu tun gehabt?

R3: Besonders am Anfang habe ich mich mit ((partner)) getroffen um Erfahrungen auszutauschen, wie es läuft, was man erwarten kann. Man will ja Synergien. Aber man kann die Leute auch nicht zwingen etwas zu produzieren. Ich wusste nicht wie man damit umgehen sollte, aber es hat sich dann eigentlich gut eingespielt.

OK: Es hat schon ein bisschen Zeit gebraucht?

R3: Ja. Ich denke jetzt wären wir so richtig gut etabliert. Jetzt können wir das Ganze auch in Wert setzen, auch mit der Kommunikation, die sind ganz begeistert. Vielleicht mit ((media outlet)), die machen dieses ((research field)), wo man mit ((research method)) ansetzen kann. Dann könnte die Moderatorin durch ((location)) schleichen. Aber es hat alles seine Zeit gebraucht, bis man sieht, erstens, es klappt, und zweitens, die Leute bleiben dabei. Das ist ein Thema, das uns noch 5-10 Jahre beschäftigen kann. Und dann ist die Motivation auch da.

OK: Sind denn auch gänzlich neue Kontakte entstanden durch CCES?

R3: ((institution)) intern ist der Schwerpunkt der Kontakte, die ich etablieren und vertiefen konnte. Und sonst habe ich viel von der ((institution)) erfahren und auch von den ((institution)) Leuten habe ich viel gesehen. Die haben schon Tonnen von Projekten an der ((institution)). In ihrem relativ engen Fachgebiet. Die ((institution)) und vor allem auch die ((institution)), die haben ihre Professuren, ihre Themen, und off we go! Hier an der ((institution)) probieren wir immer ein bisschen breiter zu sein, so ist mein Gefühl.

OK: Falls neue Kontakte entstanden sind, wie hoch ist die Chance, dass diese aufrecht erhalten werden?

R3: Ich denke schon. Sicher in-house an der ((institution)).

OK: Inwiefern würdest Du sagen, dass CCES, konkret auch Deiner Projekte, zur Entwicklung der Community beigetragen haben in dem Feld?

R3: Viel. Für die ((research field)) war CCES der Zünder. Für uns an der ((institution)), und ich glaube nicht, dass sehr viele Leute ((research field)) arbeiten. Es kommen neue Arbeitsgruppen, z.B. ((institution)), ((partner)), hat dort ein Projekt, an dem ich mitmachen kann, also Proposal schreiben.

OK: Und dieser Kontakt ist entstanden…?

R3: Dadurch, dass ich CCES Projekte gemanaged habe, war ich eben präsent.

OK: Durch das Projekt und die Zusammenarbeit ist die Assoziation zwischen ((research field)) und ((institution)) hergestellt worden?

R3: Absolut, auf alle Fälle.

OK: Meinst Du, dass Du mit den Leuten, mit denen Du zusammengearbeitet hast, dass sich da eine Art Workflow eingelebt hat, die sich zum Beispiel in Sachen Grant-Seeking-Capability äussern?

R3: Ja. Wenn man einander kennt, wie man arbeitet, dann geht das sehr viel einfacher.

OK: Inwiefern hat sich die Teilnahme am CCES auf Deine Karriere und Mobilitätsentwicklung ausgewirkt?

R3: Ich konnte mal PI sein. Und das war sehr gut. Und ich konnte mal ein bisschen steuern, lenken, die Proposals zusammensetzen, ein grösseres Ganzes entwickeln, was mir sehr liegt und was ich gerne mache. Ich denke, in dem Sinne war das ein voller Erfolg für mich. In-house habe ich auch an Visibility gewonnen. Was es für ausserhalb bewirkt kann ich nicht so sagen. Was mir auch grosse Freude macht ist die Zusammenarbeit mit der Praxis. Vor allem im ((project)) hat sich das wahnsinnig gut angegangen. Wenn laufend kleinere neue Projekte reinkommen. Dann müssen wir rumstressen und deren Finanzierung gewährleisten. Es ist irgendwie so ein Basisvertrauen geschaffen worden, auch mit gewissen Leuten aus der Praxis. Da kann man sicher immer wieder anklopfen und fragen „Hast Du was?“ Das ist für mich eigentlich das Zentrale: zusammen mehr erreichen. Und ich denke von dem her war das super für mich.

OK: Wie ist es mit der Mobilität? Bei Doktoranden oder Postdocs?

R3: Nein, aber durch das CCES konnte ich das Thema ((research field)) auch international platzieren, mit Symposien dieses Jahr. ((year)) werde ich wieder in ((location)) sein. Für mich ist es so eine tolle Sache.

OK: Hat sich denn auch Dein Forschungsschwerpunkt ein bisschen dadurch definiert?

R3: Es hat mich gezwungen, zu fokussieren auf zwei Themen. ((research field)) und ((research field)) war ein Thema und dann die ((research field)) als das andere. Ich bin ja so ein ((unit)), ich habe keine Gruppe hinter mir. Und ich denke es geht recht gut so. Die ((research field)) teile ich mir natürlich a priori mit ((partner)). ((partner)) ist die ((research field)) und ich die ((research field)). Und das eine geht nicht ohne das andere. Das ist mit ((partner)) sehr gut handlebar und ich kann mir vorstellen mit anderen Leuten geht das nicht so einfach. Wenn man sich da quasi als Datenlieferant vorkommt. ((partner)) ist die ((research field)) und ich die ((research field)). Wo ist dann die Wissenschaft? Es ist tricky aber wir haben das mit ((partner)) voll etabliert.

<u>Kategorie 2: Education</u>

OK: Haben Leute von Dir an einer CCES Winter School teilgenommen? Und wenn ja, wo siehst Du den added value?

R3: Ja. ((student)) hat teilgenommen. ((student)) war einerseits begeistert ob der Vielfalt aber es ist schon so, dass ((research field)) und ((research field)) völlig anders kommunizieren. Das war teilweise ein bisschen zu weit gegangen, das ((research field)). Sie ist ((research field)). Und ich glaube nicht, dass sie jemals irgendwie mit ((research field)) zusammengearbeitet hat. Das war für sie sehr fremd. Aber es war sicherlich eine Horizonterweiterung.

OK: Hast Du sie darauf angesprochen, oder sie motiviert?

R3: Ich habe gesagt, sie müsse. Ich denke es gut mal in diesen Betrieb reinzuschauen und wir haben ja auch ((research field)) drin, im ((project)) und so. Dieses Gespür entwickeln.

OK: Wie ist es mit CCES@School?

R3: Da wäre ich schon interessiert aber ich verstehe nicht genau was hier der Hintergrund ist. Ich habe heute noch mit ((research management)) geredet. Es gibt irgendwie 10000 Franken und dafür kann man vielleicht einen Praktikanten 2-3 Monate finanzieren, einen Postdoc vielleicht 1.5 Monate. Und dann hat man noch längstens kein Lehrmittel gemacht. Mir ist nicht klar ob wir als Berater dabei sein sollen und die Lehrer machen Materialien selber? Aber wie wir es machen sollen, dann wird es schwierig. Denn es ist überhaupt nicht in unserem Fokus, die Mittelschulen bzw. Gymnasien. Wir sollen Master und aufwärts ausbilden. Bachelor, wenn es nicht anders geht, das ist die Weisung von oben. Schule ist für uns nur ein Thema bei Zukunftstagen und wenn man mal eine Führung macht. Ich wäre sehr interessiert und bin überzeugt, dass die ((research field)) viel beitragen kann, aber das muss dann auch gut gemacht sein. Ich hoffe, dass ich am ((event)) mehr erfahre.

OK: Public Admin Dialog?

R3: Ich habe grundsätzlich Interesse und würde gerne mehr darüber erfahren. ((partner)), ((partner)) und ich haben ja einen Blockkurs zum Thema ((research field)) aufgesetzt, der hier an der ((institution)) durchgeführt wird. Es ist schon noch ein wichtiger Teil unserer Arbeit.

<u>Kategorie 3: Implementation</u>

OK: Was waren Deine Erwartungen, Outreach-Aktivitäten durchzuführen?

R3: Outreach habe ich vorher noch nie gemacht und in diesem Sinne hatte ich eigentlich keine klare Vorstellungen. Ich hatte es mir eher so vorgestellt, dass man irgendwelche Artikel schreibt für ((media outlet)) und so, die kleineren Sachen. Aber jetzt hat sich das eigentlich sehr gut angegangen, dass man auch durchaus etwas Grösseres machen kann. Wir hatten da eine Pressemitteilung mit dem ((project)) gegen Ende und jetzt vielleicht ((media outlet)) und so, also ich denke es geht sich sehr gut an. Es braucht sehr viel. Man muss einerseits Ergebnisse haben, vor allem bei Fernsehen und Radio, und trotzdem etwas am Laufen haben, das sehr aktuell ist. Man kann es also nicht in den ersten zwei, drei Jahren machen sondern muss warten bis der erste Batch Doktoranden durch ist und dann kann man darauf aufbauen. Ich denke, diese Outreach Sachen, die kommt einfach mit der Zeit. Wenn man dann ein bisschen reinschaut dann kennt man auch mehr Leute. Die sagen dann „Könntest Du nicht noch und so?“ Ich habe mich auch sehr bemüht. Schon wichtig, dass es in Wert gesetzt wird.

OK: Angesichts der Opportunitätskosten. Hat es sich gelohnt?

R3: Für mich schon. Mich interessiert es auch. Ich bin auch PI, ich habe eine feste Anstellung. Es kommt auch immer ein bisschen darauf an, wer es macht. Man kann es nicht von den Doktorierenden erwarten, von den Postdocs auch nicht. Es müssen die Leute, die ein bisschen Senior sind, machen. Und ich denke, die, die es interessiert, machen es auch.

OK: Wann siehst Du diese Aktivitäten als Erfolge?

R3: Wenn es auf kein Interesse stösst, dann ist es ein Misserfolg. Erfolg ist es, sobald es rauskommt. Wir konnten nichts in der NZZ positionieren, dafür aber im 20 Minuten. Die Sache mit den ((research field)). Es ist zwar nicht hochqualitative journalistische Arbeit, aber es erreicht die Leute.

OK: Hat Dich der CCES-Rahmen zu den Aktivitäten motiviert?

R3: Auch, ja. Aber ich habe auch gemerkt, dass man weiterkommt, wenn man die Leute, die die Umsetzung machen müssen, auch direkt fragt und deswegen konnten wir ja beim ((project)) quasi eine Blackbox beantragen. Der Stakeholder Workshop hat ja eigentlich erst begonnen, als das Projekt begonnen hat, wo wir gefragt haben, was wir eigentlich machen sollen. Das, denke ich, war eine super Gelegenheit.

OK: Wie findest Du könnte CCES dazu beitragen, dass diese Aktivitäten unterstützt werden, oder noch erfolgreicher werden?

R3: Ich denke, was schön für uns wäre, wenn das CCES nicht abgeschafft würde, 2016. Weil jetzt haben wir alle, vor allem das CCES Management, hat sehr viel Energie reingesteckt, und jetzt läuft es, und jetzt will man wieder was anderes. Ich finde das einfach tragisch. Aber Unterstützung habe ich eigentlich immer gut bekommen, kann man sich nicht beklagen. Höchstens vielleicht die Finanzierung ist ein bisschen anspruchsvoll. Diese 1/3, 1/3, 1/3, das setzt ja voraus, dass man Geld wie Heu hat. Das Drittmittel-Drittel war für mich besonders schwer zu erreichen. Und es war auch, relativ wenig Geld für das, was dann immer gewollt wurde.

OK: Die Berichte?

R3: Nein, Wissenschaft UND Outreach UND man-könnte-doch. Es kommen immer gute Ideen, aber das stimmt dann irgendwann nicht mehr so. Und die Leute kosten viel Geld.

OK: Man hat ja mindestens einmal im Jahr die Gelegenheit, Feedback zu geben. Hättest Du Dir mehr Feedbackmöglichkeiten gewünscht?

R3: Als wir mal wirklich eine Krise hatten, konnten wir gut reden, mit ((research management)), und das war auch sehr erfolgreich. Es hat ein bisschen gestört, dass dieses Budget gekürzt wurde, und dann konnten wir zweijährige 70 Prozent Postdocs anstellen und dann kommt man einfach

nirgends hin. Zwei Jahre ist schon mal super, aber 70 Prozent? Das Geld ist einfach wirklich schwierig zusammenzubekommen.

OK: Hat CCES aktiv oder passiv dazu beigetragen, dass die Kommunikation zwischen Wissenschaft und Praxis im allgemeinen verstärkt ist?

R3: Im Allgemeinen weiss ich es nicht. Hier, 100 prozentig, ja. Ich habe auch Leute begeistern können für die Umsetzung, die vorher sehr skeptisch waren.

<u>Kategorie 4: Research quality</u>

OK: Sind denn aus Deiner Sicht wissenschaftliche Erkenntnisse gewonnen worden, die sonst nicht hätten gewonnen werden können?

R3: 100 prozentig.

OK: Und wenn ja, welche Eigenschaften von CCES haben diesen Gewinn ermöglicht?

R3: Einmal das Vertrauen, das uns entgegengebracht wurde. Nicht nur immer die Top-5 Prozent der Leute, sondern eben auch ein bisschen Durchschnitt. Dass man mich da als PI akzeptiert hat. Dann konnten wir eben so Dinge experimentieren, wie z.B. der Stakeholder Workshop. Das hätte der SNF nie bewilligt. Ich kenne kein Gefäss, das so was bewilligt hätte. Dass man zuerst das Projekt beantragt und man weiss noch gar nicht so recht was man eigentlich untersucht. Und, einfach, man konnte so ein bisschen narrenfreie Projekt entwerfen. Wir hatten tolle Experimente in ((research field)), im ((project)), mit ((partner)). Wir konnten ganz verschiedene Habitate untersuchen weil ja die Konsortien gefragt waren von der ((institution)), ((institution)), ((institution)) Leute mit ganz verschiedenen Hintergründen auf ein Thema ansetzen. Das ist schon sehr lehrreich.

OK: Hat die Eigenschaft, dass CCES interdisziplinär war oder institutionen-übergreifend ist, geholfen? War dieser Austausch besonders inspirierend?

R3: Wir haben ((research field)). Die ((stakeholder)) müssen 7 Prozent der ((unit)) beiseitelegen. Dann bekommen sie ((resources)) und die ((stakeholder)) haben mit ((method)) gearbeitet um zu schauen, ob das auf die Konnektivität einen Einfluss hat. Ob die strukturellen Massnahmen, die wir machen, was nützen. ((partner)) mit ihren ((experiment)) hat geschaut, wie weit geht überhaupt so eine ((unit)), wenn man die ((research object)) in irgendeinem räumlichen Muster anordnet. Es waren einfach gute gemeinsame Themen und ganz verschiedene Approaches. Natürlich, ((partner)) hat dann in der ((location)) geschaut, ob ((unit)) irgendwas zur Konnektivität beitragen.

OK: Also hat sich der Mehraufwand gelohnt?

R3: Ja, auf alle Fälle. Man hat eben nicht so viel reisen müssen. Sonst, diese EU Projekte, da muss man alle drei Monate weit weg. Hier sind alle relativ lokal. Vielleicht mal ((location)). Da ist man

einfach da. Und man kann einen halben Tag an der ((institution)) verbringen oder sonst wo und dann wieder zurück und braucht nicht so viel Zeit für Reisen und sonstige Reibungsenergien, die da verloren gehen. Es war sehr optimiert vom räumlichen her und trotzdem, die Kompetenzen waren alle da. Als wären wir irgendwo nach ((location)) gereist. Und vielleicht sogar noch mehr, weil das Verständnis für die Systeme, die sind einfach da, wenn alle in der Schweiz arbeiten.

OK: Ich war gestern bei einem Ex-PI in ((location)). Der hat andere Ansichten gehabt, weil es ein bisschen weiter weg ist.

R3: ((location)) ist ja einige andere Geschichte. Und die wollten halt teilweise auch nicht. Die wollten einfach das Geld. Und machen damit was auch immer. Das ist dort weniger angekommen. Die ((location)) haben, das stimmt, nicht so viel davon gehabt.

OK: Was hat die Teilnahme am CCES für Deine Forschung bedeutet? Haben sich gänzlich neue Forschungsfelder aufgetan?

R3: ((research field)), die Kontakte, das Netzwerk, die Visibility. Es hat mich mit Inhalt gefüllt.

OK: Aus Sicht einer ((researcher)), welche Vorteile hatte die Teilnahme am CCES? Nachteile?

R3: Vorteile: Kompetenzen in der Schweiz lokal gebündelt. Man muss nicht weit reisen. Man hat Zugriff zu den Leute, sofort, gleiche Zeitzone. Netzwerk, Visibility. Nachteile: Das mit dem Lohn, dass man als Postdoc schlecht finanziert ist, und wenig Chancen auf Zusatzfinanzierung. Weil, wer gibt schon Geld für Nichts, sondern nur zum Aufstocken. Aber das nicht unbedingt CCES-spezifisch. Dass die Konsortien relativ lokal sind, und für einen Doktoranden, der halt raus will, könnte vielleicht etwas nachteilig sein, weil das internationale Konsortium fehlt. Andererseits haben wir alle Betreuer, die die grosse Welt kennen.

OK: Hat CCES dazu beigetragen, dass der ETH Bereich eine führende Präsenz in diesem Forschungsgebiet hat? Oder Nachhaltigkeitsforschung?

R3: Die ((institution)) hat das sowieso. Ich denke CCES hat das einfach massiv verstärkt. Als ((institution)) haben wir viele von diesen CCES Projekten. Und die Masse macht natürlich recht viel aus.

OK: Wenn also eine Konferenz veranstaltet würde, und es würde um Landschaftsgenetik gehen, wäre es schon überraschend, wenn sie nicht an Euch herantreten würden?

R3: Ja, das sehen wir ja im Januar ((year)). Wir machend dann eine Konferenz.

Abschliessend: Allgemeine Fragen:

OK: War CCES rückblickend ein sinnvolles Forschungsinstrument?

R3: Ja, und ich finde es total unsinnvoll, das jetzt einfach abzuwürgen. Das sollte man dem ETH-Rat verdeutlichen.

OK: Sollte die Forschung im Stile von CCES auch nach 2016 weitergeführt werden?

R3: Aber sicher doch.

OK: Was genau? Eher Personal, oder eher Infrastruktur, oder Education? Wo siehst Du da Prioritäten?

R3: Das Zusammenspiel von allem. Das ist interessant.

OK: Du hast jetzt mehrfach die 70 Prozent Postdoc Stelle erwähnt?

R3: Es sind ja nicht nur die Postdocs. Wenn man als PI involviert ist, dann kann man so viel Mehrwert draus ziehen, gerade weil CCES ein Tummelfeld ist für vielmehr als nur Paper machen.

OK: Würdest Du empfehlen, dass man auch nach 2016 noch in Education, Teaching und Outreach Aktivitäten investiert? Und wenn ja, warum?

R3: Jetzt habe ich so viel aufgleisen können und jetzt würde ich das gerne noch ein bisschen mehr ernten. Gerade mit diesem ((partner)), ((partner)), ((partner)), Praxis-Forschung Spannungsfeld. Die Education, da muss irgendwie noch etwas spezifiziert werden. Vielleicht auch schon von Anfang an, was genau Möglichkeiten sind, wie sie finanziert werden sollen. Es ist wahnsinnig spannend.

OK: Würdest Du es nochmal machen?

R3: Ja, sicher. Ich möchte es auch nochmal machen.

OK: Möchtest Du noch etwas Allgemeines loswerden?

R3: Ich finde es sehr angenehm mit dem CCES Management zu arbeiten. Die Reporting, die sie verlangen (müssen), sind so kurzgehalten, prägnant. Man hat unheimliche Geduld mit diesen Finanztabellen. Es ist eine gute Stimmung. Nicht auf Konfrontation, sondern eine gute Stimmung. Es ist ja auch nicht einfach. Wir werden auch nicht überbeansprucht. Die Meetings sind immer sehr klar und prägnant.

Transcription of the expert interview with Respondent 4 (R4)

The expert interview was held on 5 December 2013 between 13:00 hrs and 15:00 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: Was war den Deine persönliche Motivation?

R4: Das war sehr einfach, weil ich dadurch meine Forschung finanzieren konnte. Da bin ich reingerollt. Schlussendlich war ich ja PI, aber ich habe ja nicht die Initiative für das Projekt genommen. Die Leute haben gesagt: Wir hatten keine Lust, oder keine Kapazität, um das zu leiten, und dann bin ich reingerollt. Und dann Geld für zwei Doktoranden bekommen. Und das auch gut funktioniert.

OK: War es besonders reizvoll, dass es Institutionen-übergreifend war?

R4: Es war schon reizvoll um diese Gruppe, mit der wir zusammenarbeiten konnten. Von der ((institution)), ((name)), ((name)), ((name)) und so. Das war eine gute Möglichkeit.

<u>Kategorie 1: Structuring effect</u>

OK: Im Rahmen deiner Arbeit im ((project)). Wie stark waren die durch das Projekt initiierten Projekte innerhalb der ((institution)) aber auch nach aussen?

R4: Innerhalb der ((institution)) waren die Kontakte innerhalb der Abteilung. Die Kontakte gab es vorher auch schon. Die Kontakte mit dem Rest der ((institution)), ein bisschen durch Zusammenarbeiten im ((project)) (was ja auch eine Art von Spin-off vom CCES war), aber sonst hatten wir nur die jährlichen Meetings gehabt.

OK: Gab es denn Kontakte zu Leuten auch ausserhalb deines Projektes?

R4: Nein. Wir haben zwei oder drei Mal mit allen PIs und dort habe ich die Leute mal getroffen und das war es.

OK: Mit anderen CCES Partner an der ((institution))?

R4: Am Anfang ein bisschen über Logistik, wie die ihre Webpage aufgesetzt haben. Aber das war es.

OK: Hat sich das über die Jahre geändert?

R4: Ich habe schon die Leute an der ((institution)) dadurch besser kennengelernt. Das merke ich jetzt auch. Jetzt spielen wieder verschiedene Sachen mit ((project)) eine Rolle. Ich habe einen guten Draht zu ((name)), zu ((name)). Da habe ich von profitiert, sicherlich. Auch dadurch, dass ((project)) ein solche grosses Projekt war habe ich doch das ein oder andere gelernt über

Management Strukturen auf der ((institution)) Ebene, das ist auch nicht schlecht für einen Abteilungsleiter um sich so zu vernetzen. Das hat sicher mitgewirkt, zum Positiven. Das alles wurde ja für einige Jahre von ((partner)) geleitet, der hatte ja seien Wurzeln an der ((institution)), das war auch gut. Auch ((management)) ist im SB, auch dort sind die Kontakte immer gut gewesen.

OK: Haben sich denn durch die Arbeit im ((project)) gänzlich neue Kontakte entwickelt?
R4: Kaum würde ich sagen.

OK: Kanntest Du die Leute alle schon? Über welche Kanäle ist das entstanden?
R4: Die Idee war ja von ((partner)) oder so. Der hatte die Idee, vielleicht zusammen mit ((partner)). ((partner)) sagt auch immer, dass er dabei am Anfang gestanden hat, aber ich weiss es nicht. Die hatten dann die Idee, die Leute, die im Bereich der ((research field)) forschen im ETH Bereich, zusammenzubringen. Aber man hat nicht gesagt, dass man ein Forschungsprogramm in diesem Themengebieten schreiben würde. Man hat einfach gesagt: „Es gibt uns, wir sind gut, und wir wollen Geld für Doktoranden und Postdocs, die dann bestimmen, welche Forschung gemacht wird“. Das ist dann passiert und man hat gesagt, im Prinzip sei das okay. Man würde das Geld reservieren, erwarte aber noch einen Workplan. Dann haben diese Leute ihre eigene Forschung reingeschrieben, und vor allem die Dinge, die sie ohnehin schon gemacht haben. Und so ist dann das Geld vom CCES verteilt worden, und wir haben auch nie Sachen versprechen müssen. In Sachen Education, da haben wir dann auch nie etwas gemacht. Denn wir haben uns nie dazu verpflichtet gefühlt. Von oben ist das immer wieder etwas gekommen. Aber dann: „Machen wir nicht, warum sollten wir das machen? Wir haben uns doch nie dazu verpflichtet“. Es hat uns auch keiner nachweisen können. Dort sind wir einen ziemlich eigenen Weg gegangen und ich konnte auch als Koordinator nichts weiter machen weil die ((institution)) Professoren haben sich einfach geweigert. So ist das nicht gegangen. Fragen darüber, die kannst Du eigentlich überspringen, denn es ist kaum etwas passiert. Nie eine Summer School oder etwas passiert, nicht in diesem Rahmen.

OK: Kannst Du mir nochmal kurz erklären, wo Du den Grund siehst, warum das nicht passiert ist?
R4: Weil die Leute schon sehr verpflichtet waren. Es war für sie einfach ein zusätzliches Projekt, womit sie noch ein bisschen Geld für ein extra Postdoc bekommen haben. Für mich war es essentiell in dieser Zeit. Es war für mich mehr als die Hälfte von meinem Funding, auch für die Leute an der ((institution)). Aber nicht für die Hauptträger, die Professoren an der ((institution)), auf deren Initiative das zustande gekommen ist. Die haben dann ein klein bisschen Geld bekommen, denn sie brauchten es ja eigentlich nicht. Denn sie werden alle gross finanziert, ERCs und solche Sachen. Die brauchten das eigentlich kaum und haben sich danach auch nicht weiter verpflichtet gefühlt. Haben die Publikationenliste abgeschickt wenn es nötig war, und haben dann einen kleinen Text schreiben lassen für den Jahresbericht. Bei Evaluationen mit Peers von draussen, da haben sie sich ja dann quer gestellt.

OK: Hat sich den ein Gruppenbildungseffekt ergeben? Oder ein Lerneffekt.

R4: Sicher schon. Ich war aber nicht Partei davon. Insbesondere ((partner)) und ((partner)) und ((partner)), das waren die Leute gegen dieses bürokratische Gebilde von CCES, die eigentlich hatten das Gefühl die machen unsere Forschung schwieriger als einfacher. Aber die Gruppe gab es sowieso schon.

OK: Inwiefern kannst Du sagen, dass CCES auch dazu beigetragen hat, dass z.B. Karriereentscheidungen getroffen worden sind. Haben z.B. deine Doktoranden einen Mehrwert gehabt?

R4: Ich denke schon. Meine eine Doktorandin arbeitet jetzt bei einem ehemaligen Projektpartner an der ((institution)). Gewisse Individuen haben, ausser Frage, davon profitiert. Das ist sicher so.

OK: Hat denn ((project)) Deinen Forschungsschwerpunkt bzw. den der Gruppe irgendwie beeinflusst?

R4: Ich denke schon. Ich hatte vorher eine Doktorandin, die auf ((research field)) gearbeitet hat. Durch ((project)) sind dann zwei dazu gekommen und das hat die Sache schon bestätigt, oder vertieft oder jetzt ist das einfach einer meiner Forschungsschwerpunkt, die nicht mehr wegzudenken sind. Ich habe im Moment wieder zusammen mit ((name)) (meine ehemalige Doktorandin), sie ist jetzt Assistenzprofessorin in ((location)), da haben wir über ((funding organization)) und ((funding organization)) ein gemeinsames Projekt und überlegen jetzt schon wie das Nachfolgeprojekt aussehen könnte. Dadurch hat sich das eigentlich gesettlet. Für mich persönlich hat das schon dazu beigetragen, dass ich diesen Teil meiner Forschung etablieren konnte. Und das war auch ein Vorteil für mich: Dass die anderen mich das haben machen lassen. Einerseits haben sie das gemacht, weil ich dann die „Drecksarbeit“ habe machen müssen. Ich musste dann für die Berichte sorgen, die Meetings koordinieren, und musste in die allgemeinen Sitzungen gehen. Von der anderen Seite habe ich dann noch ein bisschen Extrageld bekommen. Ich war ja wissenschaftlich jünger als die anderen bzw. weniger etabliert. Das hat dazu beigetragen.

OK: Treffen denn da zwei Kulturen aufeinander zwischen ((institution)) und ((institution)), ((institution))? Andere Vorstellungen, andere Bedürfnisse? Warum gab es dieses Ungleichgewicht?

R4: Es ist nicht ((institution)) und ((institution)), weil ((partner)) ist ja an der ((institution)). Es ist eher soweit die Kultur, dass man sagt, auf der einen Seite gibt es die ((institution)) Full Professors, und auf der anderen Seiten die anderen PIs. Es gibt da Privatdozenten, Titularprofessoren etc. Das hat schon ein bisschen eine Rolle gespielt.

OK: Liegt es also auch an den Ressourcen?

R4: Die Full Professors haben sich doch wenigstens so verhalten: uns kann man doch nichts machen! Wir sind selbständig und bestimmen selbst was wir machen. Punkt.

Kategorie 2: Education

OK: Ist Dir die die CCES Winter School ein Begriff?

R4: Ich weiss, dass es das gegeben hat, aber mehr auch nicht.

OK: CCES@School?

R4: Natürlich. Ich war ja auf den Sitzungen.

OK: Wie schätzt Du diese Aktivitäten ein? Kannst Du das einschätzen?

R4: Unser Projekt hat keiner an solchen Dingen teilgenommen hat. Wir haben immer, wenn es um Education geht, haben wir gesagt, wir bilden Doktoranden aus.

OK: Public Admin Dialog, neue Platform für praxisorientierte Masterarbeiten…?

R4: In diesem Projekt, der Punkt ist, dass die die führenden Personen diesem Projekt sind eigentlich nur ausgewählt aufgrund ihrer scientific excellency. Die sind in ((research field)), aber das sind nicht die Leute, die die praxisgerechte ((research field)) machen. Das sind andere Abteilungen. Das sind Wissenschaftler mit Herzblut und die wollen ihre Zeit investieren. Ob man es gut oder falsch findet: man hat den Leuten am Anfang einen Freibrief gegeben. Und daher ist das Projekt gelaufen, wie es gelaufen ist, und hat sich demnach anders entwickelt als die anderen Projekte.

OK: Es liegt wohl an der Konstellation der Personen?

R4: Ja.

Kategorie 3: Implementation

OK: Implementation…

R4: Wenn wir einen Artikel gut veröffentlichen konnten, dann wird wie überall an der ((institution)), eine Medienmitteilung gemacht und dann kommt es in die Zeitung oder dann wird man interviewt und so. Aber das ist für mich bei diesem Projekt eigentlich kaum passiert. Die Sachen, mit denen ich in die Zeitungen gekommen bin, waren eigentlich andere Geschichten. z.B. ((project)), wo sich die ((stakeholder)) beklagt haben. Das ist mein zweites Standbein. Dort haben wir nicht viel gemacht. Wir haben in erster Linie wissenschaftlich publiziert.

OK: Das heisst die Aktivitäten sind auch so Teil von deiner Arbeit, unabhängig von CCES? Es gibt z.B. Leute, die machen nur wegen CCES…

R4: Nein. Ich leite diese Abteilung und jetzt hat wieder ein Gruppenmitglied ein ((journal)) Paper publiziert und das kommt dann in zwei bis drei Wochen raus. Jetzt diskutieren wir miteinander und der Medienabteilung, ob es Kapazitäten gibt, dort etwas zu machen. Und wir sind auch aktiv natürlich wenn es um gewisse Themen geht. Wir versuchen an der ((institution)) die publike Meinung zu beeinflussen. Im schlimmsten Fall: das ist aber bisher erst einmal passiert, auch im Parlament etwas zu bewirken. Wenn dann die Frage war: sollten wir den ((location)) düngen? Sollten wir die ((research infrastructure)) lockerer stellen und dann hat ((institution)) gesagt, das geht zu weit. Wir haben jetzt 40 Jahre am ((research field)) arbeitet und wir sind an der Basis gewesen davon. Dann mussten wir auf unserer Homepage doch klar sagen, wie wir dazu stehen. Natürlich, aufgrund unserer wissenschaftlichen Daten und Hintergrund, natürlich darf die Politik wenn sie das alles abwägen etwas anders entscheiden, es ist ja so. So ist es ja hier in der Schweiz, in jeder Demokratie, ist ja okay. Aber trotzdem.

OK: Was war Dein Highlight in Sachen Outreach?

R4: Mein Highlight war, dass dieses Jahr, dieser Herbst. ((politician)) hat im Nationalrat meine Forschung zitiert. Hat natürlich jemand anderes für sie geschrieben: „Forscher an der ((institution))…“

OK: Hat der CCES Rahmen geholfen solche Praxiskontakte herzustellen? Wenn ja, wie kann man so was erreichen?

R4: Indirekt natürlich schon. Durch Die Mittelverteilung. Aber da meine ich, dass wir uns an der ((institution)) solche ein PR Abteilung leisten können. Aber die Leute, die etwas Vergleichbares an der ((institution)) machen, da habe ich keine Erfahrung, keine Kontakte. Wenn schon, dann wird es über meine Leute. Die Leute hier sind sehr gut vernetzt. Kennen Nationalräte und so. Wenn wir dann unsere, einmal pro Jahr z.B. haben wir ((institution)) Infotag, Leute kommen oder letztes Jahr kam die Umweltkommission vom Ständerat. Mit diesen Leuten kann man dann wirklich reden und sich auch über andere Sachen unterhalten. Das ist natürlich toll, dass es solche Möglichkeiten gibt. Alles was ich dort gemacht habe ist durch die ((institution)) Abteilung passiert. Nie etwas gespürt von der ((institution)). Ich bin ja auch kein ((institution)) Mitarbeiter.

<u>Kategorie 4: Research quality</u>

OK: Sind denn aus deiner Sicht wissenschaftliche Erkenntnisse gewonnen worden, die ohne CCES nicht möglich gewesen wären?

R4: Ich denke für mich selbst schon. Ob was im ((project)) erreicht worden ist, im Grossen, das denke ich nicht. Die achievements, die gemacht wurden, waren ohne ((project)). Die ((institution)) Professoren waren alle gut genug finanziert, Sie hatten diese gute Person auch sonst anstellen

und finanzieren können. Es ist nicht so als wären diese Leute ohne ((project)) für den ETH Bereich verloren gegangen. Das ist vielleicht am ((project)) und für die ((project)) Mitglieder anders gewesen. Für mich war das ein ziemlich signifikanter Teil meiner Arbeit.

OK: CCES ist in seiner Natur institutionen-übergreifend. Hat es durch den Charakter von CCES besondere Erkenntnisse gegeben?

R4: Wenn ich ehrlich sein muss, sage ich nein.

OK: Hat sich denn trotzdem der Mehraufwand, der damit verbunden war, gelohnt?

R4: Keine Frage.

OK: Für alle?

R4: Für alle. Weil die anderen haben ja kaum administrative Arbeit gehabt. Für sie hat es sich sehr gelohnt. Sie haben sich schon sehr beschwert und es war auch ab und zu nicht so günstig. Weil dann auch ausserhalb von Jahresberichten quantitative Daten beigebracht werden mussten. Das hat sie dann auch am meisten irritiert.

OK: Haben sich denn über ((project)) neue Forschungsfelder aufgetan?

R4: Auch nicht so stark, aber schon ein bisschen. Die Leute von der ((institution)) und der ((institution)) konnten durch den Prozess besser anknüpfen können an unsere Partner an der ((institution)). Daraus haben wir mehr Möglichkeiten bekommen.

OK: Hat der ETH Bereich durch CCES mehr Sichtbarkeit bekommen?

R4: Die einzelnen Professoren sicher. Es war ja während das Projekt lief, dass ((researcher)) und ((researcher)) ihr ERC bekommen haben. Sie waren sicher sichtbar. Sonst hätten sie das ja nicht bekommen. Das ist ja klar. Und vielleicht hat CCES da ein klein bisschen mitgeholfen. Aber das war sicher nicht der ausschlaggebende Punkt. CCES hat geholfen, diese Leader Position, die wir haben, das zu bestätigen. Sicher.

OK: Es war also klar, schon vor CCES, dass diese Arbeit, in ((location)) sehr gut war?

R4: Ja, im diesem Gebiet.

OK: CCES hat also dazu beigetragen, dass das Niveau beibehalten wurde?

R4: Sicher.

OK: Es wäre auch ohne CCES gut gelaufen?

R4: Für die Schweiz sicher. Für mich persönlich ist es durch CCES viel besser gelaufen, ich habe davon sehr viel profitieren können. Das gilt auch sicher für die Leute an der ((institution)). CCES

hat uns, den Leuten von ((institution)), doch geholfen, uns besser durch die Kontakte mit der ((institution)) etablieren zu können und unserer Forschung einen Schub zu geben.

Abschluss:

OK: CCES geht 2016 zuende, und derzeit ist noch nicht hundertprozentig klar, was aus CCES wird? Aus Deiner Sicht, würdest Du sagen, es würde Sinn machen, weiterhin auch CCES-artige Forschung zu finanzieren, die institutionenübergreifend ist, die ganze Schweiz abdeckt. Siehst Du da einen Vorteil?

R4: Nein, persönlich hätte ich lieber, dass wir unseren Teil vom Geld an die ((institution)) überwiesen würden. Oder dass das Geld zum ((funding organization)) geht. Natürlich, wir haben mitgemacht weil es eine Möglichkeit war, an Geld zu kommen. Aber wenn man schaut, was die Verwaltung, und die Strukturen, die es dafür gebraucht hat, dann denke ich, man könnte es ja auch gezielt an Institutionen geben und sagen: Wir wollen, dass ihr das und das mit dem Geld macht. Zum Beispiel gibt es vom ((funding organization)) die ((funding scheme)) und so. Man könnte das Geld auch an den ((funding organization)) geben und sagen: Es gibt einen Call für umweltrelevante Forschung, dafür reservieren wir 45 Millionen für X Jahre und dann wird über diese Struktur ausgegeben und verwaltet. Und dann weiss auch jeder wie die Spielregeln sind. Man weiss beim ((funding organization)) wie man rapportieren muss und es gibt auch keine Überraschungen. Vielleicht übertreibe ich ein bisschen, aber ich habe doch das Gefühl, dass es auch anders geht. Natürlich ist es das gute Recht des ETH Rats, dass sie nicht nur Grundlagenforschung, sondern auch Angewandtes oder in Schulen gehen wollen. Vielleicht geht das schwieriger über den ((funding organization)). Vielleicht kann man das Geld an eine Institution geben, und sagen: Du bekommst das Geld nur, wenn du es da und dafür verwendest und das musst du dann am Ende des Jahres nachweisen. Das ginge ja auch, denke ich.

OK: Du findest also Education und Teaching Aktivitäten wichtig. Denkst Du, dass diese Dinge freiwillig passieren? Wie kann man gewährleisten, dass wenn man so etwas unterstützen möchte, das so etwas auch unterstützt wird?

R4: Ich würde das sehr klar kommunizieren, über den ((funding organization)): Du bekommst nur Geld, wenn Du auch solche Aktivitäten machst. Es muss auch im Budget sichtbar sein, nachweisbar. Jetzt muss man nur ein lay summary schreiben. Das könnte man natürlich riesig ausbauen. Dass man nachweisbar an eine Schule etc. gehen muss. Dann ist es für jeden möglich, sich ins Zeug zu legen, damit die Forschung an die Leute gebracht wird. z.B. Seniorenuniversität, Naturschutzverein und so weiter. Das kann man ja auflisten, aber ich habe nicht den Eindruck, dass das im Moment eine Rolle spielt, ob man beim nächsten Mal Geld bekommt oder nicht. Eher Publikationen und Impactfaktor. Ich denke wir haben die Struktur dafür, wir haben auch die Möglichkeiten. Die Leute sind erfahren um Indikatoren zu messen. Das brauchen wir, denke ich. Und dann hat man es für die ganze Schweiz abgedeckt. Die ((institution)) ist gross genug, und

wenn sie das wollen, um das zu bewirken. Sie decken einen grossen Teil der Schweizer Forschungslandschaft ab. Sie werden gehört, wenn sie sich beim ((funding organization)) melden.

Transcription of the expert interview with Respondent 5 (R5)

The expert interview was held on 6 December 2013 between 10:00 hrs and 12:00 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: Du hast ja in zwei Projekten mitgemacht, ((project)) und ((project)). Was war denn Deine Motivation?

R5: Das erste war ((project)). Und da war ja die Idee, dass alle vom ((unit)) da mitmachen. Von daher war das bis zu einem bestimmten Grad vorgegeben. Bis zu einem bestimmten Grad war hier die Motivation, dass es da Geld gab. Beim zweiten Projekt, ((project)) war es so, dass die ((researcher)) auf uns zukamen und fragten, ob wir als ((researcher)) da mit machen wollten weil es auch klar war, dass gewisse Gelder von der Industrie ausgesprochen würden, also auch in ((research field)) Fragestellungen investiert würde. Weil es allen Beteiligen klar war, dass, wenn es um ((research question)) geht, früher oder später Akzeptanzprobleme aufkommen würden, musste das relativ früh berücksichtigt werden. Wir fanden es spannend, weil es dazu schon Forschungsarbeiten gab, es war aber ein sehr neues Thema und deswegen fanden wir es spannend, da mitzuarbeiten. ((research question)), das war ein Thema, das wir nicht gesucht hätten. Aber in dieser Konstellation war es für uns interessant weil wir auch gewisses Wissen erhielten. Wir konnten den ((researcher)) Fragen stellen. Bei einem Paper ist jetzt auch ein ((researcher)) mit dabei, von der ((institution)), der eben auch im CCES war. Also da würde ich sagen kam es zu Kooperationen, zu Arbeiten, die wir nicht gemacht hätten, wenn es CCES nicht gegeben hätte.

<u>Kategorie 1: Structuring effect</u>

OK: Wie stark waren Deine Kontakte mit Projektpartnern an der ETH, und ausserhalb der ETH?

R5: Beim ((project)) haben wir uns ohnehin getroffen. ((project)) war kein überzeugendes Projekt, aber deshalb weil es am Schluss zu heterogen war. Man hat immer das Problem bei diesem Top-Down Initiativen, dass man dann am Schluss, die Forschung macht, die man sowieso macht und versucht auch noch Geld dafür zu bekommen. Und versucht möglichst wenig an der Struktur zu ändern. Da bin ich eher skeptisch. Bei ((project)), da gab es natürlich ein Folgeprojekt. Die ((industry)) hat ja die Forschungsgelder gepoolt und die wurden von einer Einheit vergeben. Und da hatten wir eine zweite Doktorandin dann finanziert zu diesem zweiten Projekt, das ein Folgeproject vom CCES war. Das hätte sich wahrscheinlich nicht ergeben ohne das CCES.

OK: Wo liefen denn die meisten Kontakte?

R5: ((institution)) war da. Leute von der ((institution)), von den ((institution)) und auch von der ((institution)).

OK: Hast Du auch Kontakt gehabt mit Leuten ausserhalb Deiner eigenen Projekte?

R5: Nein. Mit ((project)) gab es gewisse Kooperationen weil es sehr ähnlich zum Teil auch die gleichen Leute.

OK: Wie haben denn ((project)) und ((project)) sich ausgetauscht?

R5: So genau weiss ich das jetzt auch nicht um ehrlich zu sein. Ich bin der Meinung, es kamen gewisse Leute, die bei ((project)) dabei waren, dann auch zu den ((project)) Projekten. Wir hatten aber keinen intensiven Austausch mit denen.

OK: Wie hat sich das über die Zeit geändert? Stärker geworden, gleich geblieben?

R5: Es ist einfach so lange das Projekt läuft. Wenn das Projekt nicht mehr läuft, dann gibt es auch keinen Grund, da gross zu kooperieren, aus meiner Sicht. Aber das kann sich natürlich auch wieder ändern, wenn es gewisse neue Projekte gibt, weil man die Leute kennt, die Leute kennen einen. Die Wahrscheinlichkeit nimmt dann natürlich schon zu, dass man auch in Zukunft was macht.

OK: Hast Du auch gänzlich neue Kontakte herstellen können? Wenn ja, wie ist die Wahrscheinlichkeit, dass die Kontakte weitergeführt werden?

R5: Bei ((project)) waren die Kontakte alle neu. Wir sind ja von der Forschung her ein bisschen anders als die ((researcher)). Bei uns macht die Kooperation nur Sinn, wenn es uns ermöglicht, unsere Fragestellungen einzubringen. Es hängt am Schluss nicht von uns ab, weil wir gehen nicht zu ihnen, sondern eher umgekehrt. Sie müssen sagen: Wir haben ein zusätzliches Forschungsgebiet, würdet ihr mitmachen? Daher ist es für mich schwierig abzuschätzen.

OK: Hat es denn neue Allianzen ergeben, einen Gruppenbildungseffekt?

R5: Das denke ich, hat es schon gegeben.

OK: Und auch ein gewisser Workflow?

R5: Wie gesagt, das ist natürlich, die Gruppe ((researcher)) ist vielleicht ein bisschen anders. Die machen auf einer Ebene Forschung, die überhaupt nichts mit der zu tun hat, was wir machen. Es würde gar keinen Sinn machen, zusammen zu arbeiten, ausser eben man hat, und das war bei einem Paper durchaus der Fall, die Frage: Wie wird eigentlich das ((research field)) Wissen kommuniziert? Wie sollte man es kommunizieren, was wäre richtig? Dann hat man dann zusammen dieses Paper geschrieben. Bei diesem Projekt muss der Input von der anderen Seite ausgehen. Dass die anderen sagen: Wir haben jetzt ein Projekt eingegeben und es braucht auch ((research question)). Dann würden sie auf und zukommen. Umgekehrt macht es keinen Sinn.

OK: Hat denn die Teilnahme am CCES, für Dich oder Deine Projektpartner, Auswirkungen auf Karriereentscheidungen oder Entwicklungen gehabt?

R5: Es ist die Forschung, die wir gemacht haben. Aber da ist ((project)) in dem Sinne relevant. Ich finde wir haben gute Artikel publiziert. Einer der Doktoranden ist jetzt in der ((institution)) und der hat diese Stelle natürlich nicht zuletzt bekommen, weil er sich mit dieser Fragestellung auseinandergesetzt hat, weil es in ((location)) auch eine Frage ist. Er hat dort Projekte bearbeitet, aber das war inhaltlich. Wenn die Frage ist: Hat ((project)) dazu geführt, dass eine Doktorand Forschung machen konnte, die es ihm erlaubt hat sich jetzt erfolgreich auf eine Stelle zu bewerben, dann ist die Antwort „Ja“. Wenn die Frage ist: War es jetzt wichtig für die, dass das Projekt im ((project)) war oder im CCES, dann ist die Antwort „Nein“.

OK: Inwiefern haben den ((project)) oder ((project)) deine Forschungsschwerpunkte oder Ausrichtungen beeinflusst?

R5: Den Forschungsschwerpunkt kann es garnicht beeinflusst haben weil wir hier von CHF 100.000 bei ((project)) und ein bisschen mehr bei ((project)) sprechen. Weil die Industrie uns ein bisschen mehr zur Verfügung gestellt hat. Somit hatten wir die zweite Doktorandenstelle fast zu 90 Prozent finanziert. Aber sonst hätte ich wahrscheinlich nicht gemacht weil das wäre mir jetzt zu mühsam gewesen da zusätzliche Gelder zu akquirieren weil es ja nicht der Kernbereich ist unserer Forschung. Bei diesem Projekt von den ((research area)), bei denen das zentrale Forschungsprojekt war, von daher, wir hätten die Forschung im ((research field)) Bereich nicht gemacht, ohne das ((project)) Projekt. Aber sie passt natürlich gut in unser Forschungsportfolio rein weil es um ((research field)) und ((research field)) geht. Wir machen ((research field)) im Bereich ((research field)), ((research field)). Da haben wir schon ähnliche Methoden benutzt um zu überprüfen: Wie könnte die Akzeptanz aussehen, wenn es um die ((research field)) geht. Es hätte also schon gepasst. Wir hätten aber nicht ein Proposal beim ((funding organization)) geschrieben um ((research field)). Ich hätte ein anders Thema geschrieben.

<u>Kategorie 2: Education</u>

OK: Haben Leute von Dir an der CCES-Winterschool teilgenommen?

R5: Nein. Wenn Leute Summer und Winter Schools besuchen, dann nur wenn die ihnen etwas für die Dissertation direkt bringt, sei es Methoden, da haben die Leute von mir nicht direkt einen Nutzen offenbart gesehen, daran teilzunehmen.

OK: CCES@School?

R5: Ich fände es falsch, wenn wir das machen würden. Da müssen wir immer kämpfen mit den Leuten. Als die Leute gesagt haben: „Ihr seid die ((research field)), macht ihr doch das“. Ich sage „Nein, das müsst ihr doch machen“. Es macht keinen Sinn, dass wir den Schülern zu erklären versuchen, wie ((research theme)) funktioniert. Das müssen die ((researcher)) machen. Aber das

Thema ((research field)) ist nicht wirklich das Thema, was sich hier anbietet, für das Gymnasium. Ich denke, dass es wichtiger ist, dass sie die Grundlagen haben.

OK: Warum sind denn Leute nicht proaktiv und investieren Zeit in Themen wie diese?

R5: Es ist brutal aufwändig. Zum einen gibt es aus meiner Sicht schon fast zu viele solche Dinge. ((public outreach format)), ((public outreach format)), ((public outreach format)), ((public outreach format)), ((public outreach format)). Also Du hast so viele Gefässe schon und wir machen hin und wieder mit, aber nicht jedes Mal weil es einfach brutal aufwändig ist. Du brauchst extrem viel Zeit, und Manpower. Müssen die Leute dann hingehen. Es muss den Leuten auch Spass machen, dort hinzugehen und von daher verstehe ich das, dass nicht alle bei neuen Vorschlägen ausflippen und sagen: ich mache das. Es gibt schon so viele Gefässe, dass man sich die Frage stellt will ich das jetzt auch noch machen? Lohnt sich das?

OK: Hängt es auch damit zusammen, dass man sowas nicht quantifizieren kann?

R5: Richtig. Ich habe schon genug Vorlesungen an der ((institution)), dass ich beim allem, was zusätzlich kommt sage: mache ich nicht. Ausser das sind jetzt Vorträge, die ich aus der Schublade holen kann. Aber neue Module aufzubauen, da fehlt mir schlicht die Zeit. Ich glaube auch nicht, dass wir die Zielgruppe wären. Unsere Fächer werden ja eigentlich nicht abgedeckt in Gymnasien. Nur Teilweise. Es bietet sich also nicht wirklich an für uns.

OK: Public Admin Dialog? Oder anders: was war denn die Motivation beim ((non CCES project)) mitzumachen?

R5: Nur, dass wir Daten bekommen. Es gibt zwei Gründe weshalb man interessiert ist und das glaube ich sind meisten Kollegen, wenn sie ehrlich sind: erstens, Finanzen, um Forschung zu realisieren und zweitens, dass man Daten bekommt, die man sonst nicht bekommt. Das wäre interessant. Von der ((institution)) eben, ((data)), ((data)) etc. Wir versuchen die Forschung, die wie ohnehin machen, mit Masterarbeiten zu kombinieren. Daher bin ich sehr vorsichtig bei Masterarbeiten, die von aussen herangetragen werden. Die passen oftmals nicht so gut rein. Das ist dann für ein ((stakeholder)) vielleicht relevant, für uns aber forschungsmässig nicht so relevant. Leider nicht selten der Fall, dass das so passiert. Und deshalb sind wir da eher zurückhaltend und wir wollen eigentlich die Themen für die Masterarbeiten festlegen, die wir dann entsprechend betreuen. Für uns war das da interessant bei dem ((non CCES project)), dass es da die Möglichkeiten gibt, Daten zu bekommen.

<u>Kategorie 3: Implementation</u>

OK: Mit welchen Erwartungen plant man solche Aktivitäten?

R5: Bin ich nicht sicher, ob ich die richtige Ansprechperson bin dafür. Outreach ist wie gesagt bei den anderen zentraler. Jetzt bei den ((research field)) Teilen dieses Projekt. Bei uns ging es eher

darum, wenn man kommuniziert. Wir haben uns mit der Frage beschäftigt: was für mentale Modelle haben die Leute wenn es um ((research question)) geht und was für Missverständnisse, auch Lücken, die Leute haben, die ein Problem darstellen können wenn man nachher gewisse Informationen kommuniziert. Da heisst, und das macht jetzt keinen Sinn damit Outreach zu machen. Welchen Sinn macht ist den Leuten, die dann entsprechend sich mit den Laien beschäftigen, oder wenn mit Informationsmaterial zusammenstellt, das man diese Erkenntnis, die wir gesammelt haben, auch entsprechend berücksichtigt. Es macht aber wenig Sinn jetzt zu sagen, wir wollen Stakeholder einladen und denen sagen, was wichtig ist, bei der Kommunikation. Wenn sie nicht kommunizieren, ist es ohnehin irrelevant. Das müsste man relativ spezifisch den Leute geben. Das ist ja alles publiziert und verfügbar.

OK: Habt ihr euch in Sachen Kommunikation stark mit den ((researchers)) ausgetauscht?

R5: Wir hatten mindestens zwei Sitzungen pro Jahr, da hat man entsprechend dann die Dinge präsentiert, war auch immer so, dass sie immer sehr auf Interesse gestossen sind, dass es immer grosse Diskussionen gab, war natürlich bei unseren Dingen alle mitreden können, dass Gefühl haben, sie hätten noch einen Beitrag dazu.

OK: Inwiefern ist denn Outreach in welcher Form auch immer, sonst auch relevant für Deine Arbeit?

R5: Kommt darauf an, was Outreach bedeutet. Ich habe den Begriff nicht so gerne. Ich (a) hasse ich den Begriff, weil man dann das Gefühl hat, die ((research field)) sei verantwortlich für die Outreach-Komponente. (b) Ich halte relativ viele Vorträge zur Forschung, die wir machen. Zum Teil auch Beratungsaufträge, also von daher fliesst das Wissen schon die Praxis. Wenn jetzt die Frage ist: ob ich anfangs Jahr hinsetze, was könnte ich unternehmen um mein Wissen breiter zu streuen, nein das mache ich nicht. Das ist eine ad-hoc Basis. Wenn Leute interessiert sind, dann bin ich bereit mitzumachen. Aber auch da finde ich ist das Level an Vorträgen, an Interviews, an Presseanfragen, das genügt für mich im Moment. Da habe ich kein Bedürfnis, das noch anzuschauen.

OK: Zusammenfassend für diesen Teil: Haben denn die Projekte im CCES-Rahmen dazu beigetragen, dass der Kontakt zwischen Wissenschaft und Praxis verstärkt worden ist?

R5: Im Prinzip kann ich das nicht herunterbrechen auf eine Doktorandenstelle und auf die Papers, die daraus resultiert sind weil es am Schluss ja nicht, weisst Du ja nicht warum Dich die Leute anfragen. War das etwas Bestimmtes? Ein Artikel? Es ist also schwierig zu sagen. Von daher glaube ich, dass man so ein funding scheme nicht zu ernst nehmen sollte, weil ich glaube nicht, dass die Welt jetzt völlig anders ist mit oder ohne CCES. Es gibt einfach Möglichkeiten, noch zusätzliche Forschung zu machen, aber es ist ja nicht, dass man sonst keine Interviews geben würde, keine Vorträge halten würde.

OK: Die Frage ist: hat es das mehr stimuliert? Mehr Sichtbarkeit? Netzwerke?
R5: Das kommt natürlich immer wieder vor. Aber wie gesagt, ob das jetzt CCES war oder nicht, das könnte ich nicht zuordnen. Aber es kommt natürlich immer vor, dass man dann sagt, und dass man weiter verwiesen wird. Wir haben auch mit ((stakeholder)) arbeiten können, in verschiedenen Projekten, und mit ((stakeholder)). ((project)) war also nicht das einzige Projekt, bei dem wir mit ((researchers)) zusammengearbeitet haben. Von daher ist es schwierig zu sagen.

Kategorie 4: Research quality

OK: Sind denn aus Deiner Sicht wissenschaftliche Erkenntnisse gewonnen worden, die ohne CCES nicht möglich gewesen wären?
R5: Publikationen. Am Schluss waren es zwei in ((project)) und eine in ((project)). Drei Doktorandeninnen und Doktoranden, die Artikel wurden in guten Journals publiziert und die haben auch gute Visibilität, bis jetzt. Da, denke ich, konnten wir gerade im ((research field)) Bereich relativ viel Gutes publizieren.

OK: Dass diese Publikationen besonders visibel sind, liegt woran? Dass sie interdisziplinären Charakter haben? Welche Eigenschaft von CCES hat das bewirkt?
R5: Wir hätten das ohne CCES nicht gemacht.

OK: Aber dass man sagt, ((project)) war interdisziplinär und Institutionen-übergreifend, was dazu geführt hat, dass der Erkenntnisgewinn ein anderer ist, und dass die Publikationen in besseren Journals veröffentlicht wurden? Könnte man das so sagen?
R5: Das wäre vielleicht ein wenig übertrieben. Was man sagen kann, wir hätten die Forschung nicht gemacht ohne CCES. Ob wir das losgelöst gemacht hätten?

OK: Gab es einen grossen Mehraufwand?
R5: Es sind zwei Dinge. Zum einen gab es relativ viele Sitzungen. Zum Teil an zwei Tagen, das fand ich an der Schmerzgrenze. Vom Nutzen, den wir daraus ziehen konnten. Und dann fand ich das financial reporting. Ich habe noch nie sowas Mühsames erlebt, wie beim CCES. Wir waren immer überfordert. Manchmal kam es auch drei Mal zurück jeweils. Es lag aber nicht nur an uns, denn bei anderen funding agencies sind wir in der Lage das zu machen. Beim CCES liegt es auch daran, 1/3, 1/3, 1/3, bei dem man am Anfang willkürliche Zahlen einsetzen muss weil man ja noch nicht weiss was anderes noch kommt, weil zum Teil ja die Drittmittelfinanzierung gar noch nicht klar ist. Das heisst, ich finde da den administrativen Aufwand mehr als übertrieben. Weil am Schluss sprechen wir hier von wenig Geld, wir sprechen von CHF 100.000. Ich finde hier Aufwand und Ertrag ging in keinem Verhältnis. Da kriege bei einem ((funding organization)) CHF 150.000 mit weniger Aufwand als bei CCES. Ich fand, bei ((project)), da war es etwas anders weil es auch das Folgeprojekt gab, bei dem wir relativ gut finanziell über die Runden kamen weil die ((industry))

((research field)) Forschung finanzieren wollte und daher war das relativ einfach das Geld zu bekommen.

OK: Haben sich denn durch das Projekt neue Forschungsfelder aufgetan, die jetzt verfolgt werden?

R5: Neue Forschungsfelder, ((research field)) hat sich aufgetan. Ob wir da weiterforschen, das kann ich im Moment nicht sagen. Es gibt keine konkreten Pläne, es kann durchaus sein. ((project)) hatten wir eigentlich vorher spezifisch nichts gemacht. Da hatten wir eine Doktorandin, die auf dem aufbaut. Das ist durchaus weitergeführt. Da hat es durchaus einen Effekt gehabt.

OK: Hat es denn auch einen Effekt gehabt, dass man sagt, in dem Bereich, ist die ((institution)) jetzt besonders stark? Oder die Partner, die daran teilgenommen habe, sind besonders visibel, global oder national?

R5: Für uns ist es vollkommen irrelevant, weil es interessiert niemanden in der Community. Die schauen das Paper an und das wird akzeptiert oder nicht akzeptiert. Ob ((partner)) der Leader ist oder nicht, ist irrelevant. Man hat ja seine Community und da ändert das CCES nichts dran. Ich bin in der ((research field)) Community, bin dort aktiv, die kennen mich, und das hat keinen Einfluss.

<u>Abschliessend: allgemeine Fragen</u>

OK: CCES wird 2016 zuende gehen. Wo sollte, wenn überhaupt, in Zukunft Mittel bereitgestellt werden? In Forschungsprojekte, in Outreach Aktivitäten, oder Education?

R5: Ich finde den Begriff Outreach so etwas von bescheuert, weil man muss ja Ziele haben. Die Frage ist: Will ich eine Technologie, von der ich überzeugt bin? Will ich, dass die Gesellschaft sie akzeptiert? Sollen die Leute, die jetzt in der Nuklearforschung tätig sind, die Schweizer Bevölkerung überzeugen, dass nukleare Energie eine vernünftige Technologie ist, um Strom zu erzeugen, mit CO_2? Meint man das mit Outreach? Meint man mit Outreach, man soll den Leuten erklären, wie eine bestimmte Technologie funktioniert? Was ist eigentlich das Ziel von Outreach? Nur Praxisrelevanz kann ich auch sonst erreichen. Oder will man sicherstellen, dass die ((institution)) auch in Zukunft unterstützt wird uns deshalb machen wir so Events, bei denen die Bevölkerung mit Forschern in Kontakt kommt. Aber bevor man nicht definiert hat, was man will, sollte man verbieten, das Wort Outreach in den Mund zu nehmen. Es ist wie bei EU Projekten die „dissemination activities“. Man weiss, man muss das machen, aber die Ziele sind unklar.

OK: Ich denke zwei Dinge sind in dem Bereich massgeblich: einerseits der Bevölkerung Informationen geben, auf deren Grundlage sie sich eine Meinung bilden können und die andere Sache ist, Entscheidungsträgern wissenschaftlichen Unterbau geben für Entscheidungen, die sie treffen müssen. Denkst Du, dass es wichtig ist, und wenn ja, über welche Kanäle sollte man das machen?

R5: Wir haben ja gesehen, dass man ohne jegliche Grundlage weitreichende Entscheidungen fällen kann. Schau nur mal die ((political decision)) an. ((politician)) macht eine Entscheidung nur, damit sie und ihre Partei wieder gewählt wird. Und dann liefert die ((institution)) im Nachhinein die Entscheidungsgrundlage post-hoc, damit man nicht ganz blöd dasteht mit den Entscheid. Man braucht sehr häufig gar kein Wissen um Entscheidungen fällen zu können wenn man in der Politik tätig ist. Und auch da stellt sich die Frage, da geht es um die Interessen: man sagt ja nicht „Ich will wertneutral der Politik Wissen zur Verfügung stellen". Sondern es gibt Leute, die überzeugt sind, dass eine bestimmte Technologie jetzt wichtig ist und dann weibeln sie, oder Du hast Leute wie ((researcher)), die sind jetzt davon überzeugt, dass es wichtig ist, dass wir möglichst viele ((data)) sammeln und er hält überall Vorträge um die Leute davon zu überzeugen. Die Leute, die Outreach machen, wollen gewisse Ziele erreichen. Dass man jetzt wertneutral auch sagt, wir erzählen wertneutral damit sie sich entscheiden können, da machen wir uns nichts vor, das wird niemand so machen. Da sind immer Vertreter einer bestimmen Technologie, die diese Technologe durchsetzen möchten. Deshalb machen sie das, was dann am Ende als Outreach bezeichnet wird. Soll man jetzt noch alle davon überzeugen, die Politiker. Ich weiss garnicht ob dieser Outreach notwendig ist. Häufig ist es ja PR, was die Leute da machen.

OK: Nachhaltigkeitsforschung ist ein Gebiet, das man interdisziplinär anschauen muss. Denkst Du, dass es nach wie vor wichtig ist, so etwas zu finanzieren? Diese Frage hat ja mehrere Aspekte. Ich habe auch mit Leuten von ((institution)) und ((institution)) gesprochen. In Sachen Funding ist ((institution)) sicherlich viel stärker. Meiner Ansicht nach ist so etwas wie CCES eine Möglichkeit, Leuten die sonst nicht im Rampenlicht stehen, auch mal substantiellere Finanzen zu geben aber auch ein Forum, eine Plattform, Verantwortung zu geben. Ist es das wert?

R5: Wie gesagt, ich fand den Aufwand für das Geld, das ich bekomme, sehr gross. Ich fand diesen Aufwand zum Teil alibimässig. Wir müssen das jetzt noch machen. Diese Outreach Aktivitäten im ((project)), zum Beispiel. Mir war unklar, was will man jetzt erreichen? Will man jetzt die Politik überzeugen, dass Klimawandel schlecht ist? Will man mit den Leuten, die da kommen, zusammen jammern, dass es immer noch Leute gibt, die finden, es sei kein Problem. Das Ziel war mir vor der Veranstaltung nicht klar und auch danach nicht klar.

OK: Fühlte es sich an wie eine Top-Down Bestimmung? Nach dem Motto: ihr müsst Outreach machen!

R5: ((researcher)) musste dann wahrscheinlich was organisieren, weil es hiess, sie müsste auch noch Outreach machen. Was am Ende dann aber nicht so berauschend war.

OK: Der Dialog zwischen Wissenschaft und Praxis bzw. Wissenschaft und Öffentlichkeit ist ja eigentlich wichtig. Er kommt leider nicht so initiativ aus der Wissenschaft, weil er nicht quantifiziert werden kann? Wie könnte man Anreize schaffen? Kulturwandel?

R5: Nein, das sollte man nicht machen. Ich glaube das hängt sehr stark vom Fach ab wie einfach das ist. Es gibt Gebiete, in denen es nun mal einfach schwierig ist, die Leute für das Fach zu interessieren. Schlicht und einfach weil es nicht ein Gebiet ist, dass die Leute vom Stuhl haut. Und das sehe ich ja bei unserer Forschung auch. Alles was mit ((research theme)) zu tun hat, da hast Du Leute, die sind interessiert und da könntest Du jede Woche einen Vortrag halten, weil die Leute einen Bezug haben. Es betrifft sie selbst. Sie sind daran interessiert. Und da ist es sehr einfach, Forschung zu vermitteln. Und über die Forschung zu sprechen. Und dann gibt es andere Gebiete, da ist es vielleicht etwas abstrakt. Da ist es schwieriger, die Leute dafür zu begeistern und direkt auch was zu erzählen. Man wählt ja auch Themen, bei denen man weiss, dass sie auf ein gewisses Interesse stossen. Und dann ist es ja nicht gegeben, die Forschung den Leuten in einer verständlichen Form zu präsentieren. Es gibt Leute, die null Begabung haben, das zu machen. Das ist kontraproduktiv. Es muss ja eine Nachfrage geben nach diese Aktivitäten. Wird die nicht gedeckt? Gibt es eine ungedeckte Nachfrage? Das ist immer die Annahme. Ob es hier ein Bedürfnis gibt, das im Moment nicht gestillt wird, da bin ich mir garnicht so sicher. Wie jedes Institut auch noch einen Newsletter macht, der von niemandem gelesen wird. Und da habe ich mich Jahre eingesetzt, im ((institution)), dass der Newsletter abgeschafft wird. Das ist krank. Die Arbeit, die wir verbraten, dass zum Schluss 200 Leute den bekommen, und wir dann feststellen, er wird von 50 gelesen. Das macht dann CHF 1000 pro Leser, den Du aufwendest. Und das kann es nicht sein. Von daher würde ich jetzt zum einen wirklich dafür plädieren, dass man sich überlegt: was für Bedürfnisse gibt es in der Gesellschaft, die nicht gestillt sind? Was wollen wir erreichen mit solchen Aktivitäten? Geht es um Beeinflussung bezüglich bestimmter Entscheidungen? Geht es darum, Fördermittel sicherzustellen? Geht es darum, politische Entscheidungen zu beeinflussen? Das muss man sich im Klaren sein, weil einfach Kommunikation zu machen, das ist Blödsinn, aus meiner Sicht. Macht nur Sinn wenn man diese Ziele definiert hat. Dann weiss ich auch, und ich sehe das, es macht Sinn, dass wir sagen, wie ((public outreach format)), dass man sagt, es geht darum, der interessierten Öffentlichkeit die Möglichkeit zu geben, sich mal mit der Forschung an der ((institution)) vertraut zu machen. Da weiss man: Zielpublikum: nicht Wissenschaft, nicht Politiker, sondern wirklich ein Querschnitt der Bevölkerung, die Sonntagvormittag um 10 Uhr sich die Mühe macht auf ((location)) zu kommen, 45 Minuten zuhören und dann weiss man ungefähr, was einen erwartet und was das Ziel ist. Es geht nicht darum, Geld zu akquirieren, nicht darum, dass sie anderen Entscheidungen fällen, sondern darum, in einer unterhaltsamen Art und Weise gewisse Forschungsergebnisse zu vermitteln damit die Leute etwas lernen. Und da ist es klar. Aber einfach zu sagen: ihr müsst mehr Outreach machen, das finde ich nicht zielführend. Was ist denn Outreach?

Transcription of the expert interview with Respondent 6 (R6)

The expert interview was held on 12 December 2013 between 9:30 hrs and 11:30 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: Was war denn Deine Motivation am CCES teilzunehmen?

R6: Persönliche Motivation, insofern, dass die Forschung, die wir gemacht haben, oder machen wollten, dass das ganz genau in Richtung dieses CCES Projektes ((project)) gegangen ist und für mich, weil ich neu an der ((institution)) war, in 2008, war das ein sehr guter Aufhänger, meine Projekte auch in diese Richtung auszurichten und die Infrastruktur von ((project)) auch mit zu nutzen. Aufgrund dessen habe ich dann versucht, eigene Projekt einzuwerben, die dann auch direkt in das ((project)) reingepasst haben.

OK: Hat sich das auch so bestätigt?

R6: Es war insofern massgeschneidert, weil sich die ((research field)) zu diesem Zeitpunkt, 2008, etwas wegbewegt hat von rein ((research field)), mehr in Richtung ((research field)), ((research field)) und das ist ja ein Kernpunkt von ((project)) gewesen, in Bezug auf die ((research field)). Aber das ((project)) ist ja noch viel umfassender gewesen. Und genau da passt das rein. Das bedeutet, die Forschung war reif dafür. Wir mussten eigentlich in diese Richtung gehen und da konnte ich natürlich die Erfahrung von vorher, aus dem ((institution)), hier wunderbar mit einbringen.

OK: ((project)) war der Beweis dafür, dass ((project)) gut gelaufen ist?

R6: Wenn man das so sagen möchte, dann ja. Das ((project)) war auf zwei Standorte fokussiert. Wobei allerdings schon während dieses Projekts haben wir uns mit dem weiteren Standort innerhalb des ((location)) beschäftigt. Und dort ging unser Prozessverständnis mit ((research question)), ((research field)), wie sich das auswirken wird mit irgendwelchen ((research field)), die über die ((research field)) eingebracht werden. ((research field)) und auch ((research field)) und solche Sachen. Und als wir dann evaluiert worden sind, als ((project)) Projekt, und das eigentlich sehr gut lief, wurde uns dann vom Advisory Board gesagt, wenn das in die zweite Phase gehen würde, müssten wir uns auf das ((location)) konzentrieren, und nicht nur auf die ((location)), die wir ausgebaut hatten, und auf diesem Weg sind wir ja schon gewesen. Ich hatte schon ein grösseres Projekt, eingeworben über den ((funding organization)), wo es dann darum ging zu schauen, was das ((research field)) macht und die ((research field)) im gesamten ((location)) zu verbessern. Genau das hat im Prinzip das Advisory Board gesehen und sozusagen als Auftrag gegeben und auf diesem Weg waren wir schon, insofern hat das wunderbar zusammengepasst. Forschung ist ja nicht losgelöst. Sie entwickelt sich ja. Man kann auch mal querdenken und Leute sind nicht mit einem auf dem Weg. Oft ist es aber so, dass viel in eine Richtung zeigt und das man es dann aufnehmen muss.

OK: Wie stark waren Deine Kontakte mit Projektpartnern an der ((institution)) und darüber hinaus? Wie hat sich das entwickelt, über Zeit?

R6: Im März ((year)) habe ich begonnen. Schon im Februar ((year)) war das erste Kickoff Meeting, es wurde damals „PhD Retreat“ genannt. Da haben alle Doktoranden vorgetragen. Da waren auch die allermeisten PIs mit dabei. Bevor ich begonnen habe, habe ich am Retreat teilgenommen und habe dort schon alle Leute kennengelernt und war sehr begeistert von der gesamten Projektstruktur. Sowas gibt es nicht so oft, dass so viele Leute zusammenarbeiten. Und damit war ich im Prinzip eigentlich von vorneherein mit dabei. Ich konnte dort schon die ganzen Leute kennenlernen wobei ich dort in einer anderen Kapazität aufgetreten bin. Ich hatte auch noch keine Leute. Ich musste erstmal in den ersten zwei Jahren Anträge schreiben, dass ich überhaupt Doktoranden einwerben kann, oder Masterstudenten anstellen. Das muss sich erst entwickeln. Nach ein paar Monaten war dann klar, dass ((partner)) gehen wird. Und da kannte ich auch die Leute schon und wurde eben dann gewählt zum PI. Und innerhalb der ((institution)) musste ich mich ohnehin vernetzen und das war natürlich die ideale Plattform. Aber auch nach aussen haben wir, bevor ich hergekommen bin, wurde am ((institution)) auch schon versucht, ich war in einem interdisziplinären Bereich gewesen, den dem man versucht hat, Departement-übergreifend die Arbeit zu organisieren, und später gab es dann eine sogenannte programmorientierte Forschung. In der Arbeitsgemeinschaft, wo wir als Departementsleiter auch versuchen mussten, interdisziplinär zu denken. Da war unsere Aufgabe, mit ((research theme) beschäftigt. Was wir im ersten Teil des ((project)) noch etwas ausgeklammert haben. Aber diese Struktur, wie man die Leute zusammenbringen kann, da hatte ich schon etwas mehr Erfahrung, das hat natürlich geholfen.

OK: Wie ist es denn mit Projektpartnern ausserhalb der ((institution)) gewesen?

R6: Das läuft eigentlich genauso wie innerhalb der ((institution)). Gerade als PI, wir hatten einen Postdoc, der geholfen hat, zu managen: ((research)). Wobei er nur zur Hälfte von ((project)) beschäftigt war. Die andere Hälfte war eher das Datenmanagement, bei ((project)). Darüber ist auch die halbe Stelle finanziert worden. Und in der zweiten Phase bei ((project)) haben wir einen Manager eingestellt: den Postdoc ((researcher)). Und so eine Stelle ist natürlich essentiell. Das kann man nicht alleine machen, weil es da viel zu organisieren gibt, in Bezug auf die Feldarbeit, Datenmanagement, Laborarbeiten usw. Und das haben wir versucht über die gesamte Zeit, mit den Projektpartnern zu machen und da sind ja vor allen Dingen auch ((institution)), ((institution)) und ((institution)), die Projektpartner, die dort eingebunden sind, und das handhaben wir ob es „next door“ ist, oder anrufen, oder treffen, oder im Feld treffen um etwas zu koordinieren, das ist eigentlich zweitrangig.

OK: Haben sich diese Kontakte über Zeit gefestigt?

R6: Sicherlich festigen sich natürlich die Kooperationen. Es sind einige Partner dann auch ausgegangen aus dem Projekt, weil sie Professorenstellen an Unis, die nicht im ETH Bereich sind,

bekommen haben, z.B. mit der ((institution)) haben wir einen sehr guten Partner. Mit denen versuchen wir trotzdem Kontakt zu halten. Aber ausserhalb vom offiziellen ((project)).

OK: Durch das CCES Projekt sind ja offensichtlich neue Projekte entstanden. Aber wie gross ist denn tatsächlich die Chance, dass diese erhalten werden? Hat sich z.B. ein Work-Flow ergeben? Siehst Du da auch in Zukunft, auch nach CCES, dass es da noch weiterhin Kooperationen geben könnte, zwischen Dir und den Leuten, mit denen Du im Rahmen von ((project)) zusammengearbeitet hast?

R6: Sicher. Dann macht man es über gemeinsame ((funding organization)), oder ((funding organization)) Projekte, wo man zusammenarbeiten kann. Wobei bei ((funding organization)) Projekten dürfen es ja nicht sehr viele Schweizerische Partner sein. Aber genau so macht man das halt. Es gibt Forscher, mit denen man mal zusammengearbeitet hat, man kennt Stärken und Schwächen. Mit denen Arbeitet man dann später zusammen.

OK: In dem Kontext fällt ja auch der Begriff der „wissenschaftlichen Community"? Würdest Du sagen, dass durch deine Projekte eine Art Community entstanden ist, auf die Du aufbauen könntest?

R6: Ja, für mich sowieso. Als Projektleiter hat man diese extra Expense von der ganzen Administration usw. Und in ((location)) ist die Administration noch viel grösser, schlimmer. Das, was ich im CCES leisten muss, bringt mich nicht um. Das mache ich nebenbei mit. Als ((project)) PI hat es mir eine ganze Menge geebnet hier in der Schweiz. Wenn man neu ins Land kommt, muss man das erstmal aufbauen. Als Gruppenleiter hier habe ich ja mit mir alleine angefangen. Das hat mir schon geholfen. Ich denke aber auch, die Doktoranden und die PIs, die mitgearbeitet haben, dass sie auch das dieses ((project)) Gefühl entwickelt haben. Wir hatten zum Beispiel am Ende eine Doktorarbeit zu finanzieren, denen konnte ich helfen, 1-2 Monate weiter zu finanzieren.

OK: Kannst Du einschätzen, ob die Teilnahme für Doktoranden am ((project)) Projekt, ihre persönliche Karriere, Karriereentscheidung oder Mobilität beeinflusst hat? Vielleicht sogar im akademischen Sinne?

R6: Für Professorenstellen ist es etwas zu zeitig. Im Prinzip sind die ersten Doktoranden 2011/2012 fertiggeworden. Viele haben auch erst jetzt angefangen. Das muss sich erst noch entwickeln. Aber dass die Leute an interessante Stellen als Postdoc oder in der Industrie gekommen sind, das ist auf jeden Fall gegeben. Wir haben jetzt schon die erste Anfrage. Ein Doktorand, der bei ((partner)) gearbeitet hat, in der ((institution)), der ist jetzt zu einer ((industry)) gegangen. Die wollen sich in Richtung ((research field)) engagieren. Das ist er unsere Schnittstelle und eine super Möglichkeit, einen Fuss mit in die Tür zu bekommen.

OK: Liegt es an der wissenschaftlichen Expertise? An der Visibilität? Kannst Du einschätzen, warum jetzt solche Dinge passieren?

R6: Ich könnte jetzt stolz sagen: „Ja, es stimmt“. Aber das kann ich nicht wirklich einschätzen. Wobei natürlich solche Leute wie ((researcher)), den ich gerade gemeint habe, dass eben Leute über ihren CV… die sehen dort sofort: er hat nicht nur als ((researcher)) gearbeitet, sondern er musste mit ((researcher)) zusammen arbeiten, er musste wissen, wann ((research problem)) passieren, musste mit ((researcher)) zusammen arbeiten usw. Insofern denke ich schon, dass es ihm geholfen hat, wenn er so einen CV vorlegt. Dass er in eine solche Position kommt, in der er diese Schnittstelle bedienen kann, zwischen ((industry)) und Wissenschaft. Wobei man noch sehen muss was da rauskommt, wieviel die wirklich investieren wollen.

Kategorie 2: Education

OK: Haben denn Leute von Dir an der CCES Winter School teilgenommen?

R6: Ja, alle meine Doktoranden haben teilgenommen. Ich bin nicht direkt bei der Ausbildung involviert, aber beim Verteilen. Ich glaube, dass CCES PIs das machen sollten. Mit dem ((partner)) habe ich natürlich sehr eng zusammengearbeitet. Über CCES habe ich ((researcher)) kennengelernt. Beim ersten Teil waren die ((researchers)) ausgeklammert. Aber beim zweiten Teil, weil es ums gesamte ((location)) geht, auch zwischen Sachen, wie nehmen Leute diese ((research field)) an, muss man unbedingt ((researcher)) mit im Boot haben. Nicht nur deshalb, nach aussen, sondern auch nach innen, die Projekte strukturieren, weil das doch sehr komplexer war als im erster Teil vom Projekt. Und da bin ich sehr froh, dass ((researcher)) bei uns mit eingestiegen ist und zusätzlich ist ((researcher)) ja auch jemand, der die Winter School vorantreibt. Eigentlich von Anfang an.

OK: Was ist denn Deine Einschätzung? Was war das Feedback Deiner Doktoranden?

R6: Durchweg positiv. So etwas ist so schwierig zu machen, weil gerade die ((researchers)) haben das Problem, dass es sehr lokal ist. Deutsch, weil die Stakeholder natürlich auch Deutsch reden, meistens nur Deutsch verstehen, und dann ja doch eine ganze Menge, die nur Englisch sprechen, bedienen müssen. Was ich aber sehr wichtig finde ich, dass es schon als ich beim ((institution)) gearbeitet habe, dachte ich man müsse in diese Richtung gehen. Nur wenn man als ((researcher)) mit ((researcher)) zusammen arbeitet, kommt man an die Gesellschaft. Das ist ein ganz anderes Hintergrundwissen. Ganz anders wie man mit den Leuten umgeht, wie man z.B. ((research output)) entwickelt, die dann nie angewendet worden sind, und heute weiss ich ,wenn ich noch mal 15 Jahre zurückgehen könnte, dann würde ich das anders angehen. Ich würde von vornherein die Leute ins Boot holen und die ((researcher)) mitnehmen. Diese Brücke haben wir bereits am ((institution)) versucht, wo wir ein sehr starkes ((research field)) Departement hatten. Schon diese Zusammenarbeit hat mir geholfen. Wenn man hierher kommt, muss man das machen. Da ist natürlich CCES die absolut beste Plattform dafür, die man sich vorstellen kann.

OK: CCES@School: Ihr habt auch sehr aktiv mitgemacht, und die Unterrichtsmaterialen für ((research field)) erstellt. Das ist ja wirklich sehr interessant, sehr vorbildlich. Was war denn für dich der Mehrwert angesichts der hohen Opportunitätskosten? Was war Deine Motivation?

R6: Wer, wenn nicht wir? Ich musste in der ersten Zeit schauen, dass ich hier Fuss fasse. Aber als ich dann gemerkt habe, das läuft hier gut, dann sind solche Leute wie ich natürlich prädestiniert, diesen Extraschritt zu gehen. Was sich oft ein Postdoc noch nicht leisten kann, den Schritte auf die ((researcher)) zuzugehen, von der Erfahrung her, vom Standing her, vielleicht. Ganz einfach auch weil die vorankommen und eine feste Stelle kriegen müssen. Das ist bei mir natürlich alles gegeben. Insofern sage ich mir: wenn ich nicht diesen Extraschritt gehe, welcher Wissenschaftler soll das machen? Und CCES@School, auch deshalb, habe ich gedacht, ich kann das sowieso nicht alles selber machen, aber wenn ich jemanden hier habe, wie ((doctoral student)), hat das dann übernommen. Wenn ich dort eine gewisse Finanzierung für ((doctoral student)) bekomme, und in der Zeit einen Projektantrag schreibe, und ich sie als Doktorandin anstellen könnte, dann können wir diesen Extraschritt gehen. Und zusätzlich war es auch noch, weil ((personal reason)). Dann kann ich erstmal testen. Verstehen die das? Die sind noch begeistert am Standort. ((personal detail)). Was ist denn eine ((research field)). Und ich denke, das muss auch ein grosser Teil der wissenschaftlichen Arbeit sein, dass die Leute verstehen, was wir machen. Weil nur dann ist die Bereitschaft der Gesellschaft da, uns dafür Geld zu geben.

OK: Oft höre ich das Argument, das sowas nicht quantifiziert werden kann.

R6: Genau das ist das Problem in der Wissenschaft. Wenn mir jemand sagt: „Das hast du umsonst getan. Du bist mit Deiner Karriere nicht weitergekommen." Ich habe so eine schöne Karriere bekommen als Wissenschaftler, mehr kann ich mir eigentlich nicht wünschen. Und insofern ob ich jetzt 8 oder 10 Paper im Jahr habe, das wird vielleicht… Wenn jemand diese Erbsen zählt, dann stört das den oder die, mich aber nicht.

OK: Ist das an einer Institution wie der ((institution)) einfach zu realisieren? Oder ist das die Sache des Wissenschaftlers, das hinzukriegen?

R6: Wahrscheinlich ist man durch die Struktur ((institution)) prädestiniert sowas zu machen. Weil eben viele keine Lehre haben. Ich bin in ((institution)) an der Lehre angebunden, bin dort ((position)), damit ich meine Leute promovieren kann. Aber das ist ja bei der ((institution)) das gleiche. „Ich habe keine Zeit", ich kann das nicht mehr hören. Für mich ist das einfach unehrlich. Es gibt Prioritäten und wenn man diese setzt hat man immer Zeit für sowas. Das ist so.

OK: Wie bist du zu dieser Einstellung gekommen?

R6: Vielleicht bin ich ein gebranntes Kind. Ich habe eine sehr schwierige Sektion übernommen, damals am ((institution)). Wir haben damals eine sogenannte ((project)) Forschung gemacht. Es ging dort um ((research field)). Und da haben wir wirklich interessante ((methods)) entwickelt,

naturnah. Und da haben wir sogar eine Methode soweit gebracht, dass sie anwendungsbereit ist. Mit Patent und so. Wir haben sogar mitgeboten, als Betrieb, nicht als ((institution)). Wir waren sogar die Preiswertesten und es wurde trotzdem nicht genommen. Und da wussten wir: wir haben da fundamental was falsch gemacht. Wir haben die Leute von Anfang an nicht mit ins Boot geholt, ((researcher)) nicht eingebunden, die den Prozess mitbegleitet hätten. Und als ich das gemerkt habe, habe ich gewusst: wenn wir wirklich was ändern wollen, und nicht nur Grundlagenforschung machen wollen, was auch wichtig ist, wenn wir aber wollen, dass es in die angewandte Richtung geht, wie z.B. ((research field)), dann müssen wir andere Schritte gehen. Und das schaffen wir nur zusammen, wenn wir über die Wissenschaftsgrenzen hinausdenken.

OK: Ist CCES@School eine Möglichkeit, junge Leute für Nachhaltigkeitsthemen zu sensibilisieren?

R6: Genau. Wenn Du Leute haben willst, die später über den Tellerrand hinausblicken, dann müssen die wissen: was läuft in der Gesellschaft, was in der Wissenschaft, wie macht man das? Und was wird sich in den nächsten Jahre kolossal ändern. Wir werden sonst nicht weiterkommen. Auch wenn das jetzt nicht zähl- oder messbar ist. Ich hoffe, dass die Doktoranden, die hier fertig werden, dieses Wissen mitnehmen. Dass sie wissen: ich bin zwar ((researcher)), aber ich weiss was der ((researcher)) macht, oder was der ((researcher)) macht. Dass ich mit den Leuten reden, und sie fragen muss: was gefällt euch, was stört euch? Oft ist es nur das Problem, dass man nicht miteinander redet und manche Sachen einfach nicht angenommen werden.

<u>Kategorie 3: Implementation</u>

OK: Was waren denn Deine Erwartungen an Outreach-Aktivitäten?

R6: Auf der einen Seite natürlich, dass wir zeigen wollten, auch stolz zeigen wollten, was wir geschafft haben mit dem ((project)) Projekt. Wir haben z.B. einen Workshop gemacht für das ((location)). Wir arbeiten am engsten mit dem ((political entity)) zusammen, neben ((location)), den ((political entity)). Und die geben uns natürlich auch unheimlich viele Daten. Die haben das auch organsiert. Und wenn dann eben dort 60 Leute kommen, die sich das anhören wollen, dann ist das auch für die eine ziemlich gute Plattform, auch innerhalb des ((political entity)), wie innerhalb vom Feld gerne hin und hergeschoben werden dorthin, wo am meisten rauskommt. Auch deshalb haben wir das gemacht. Die Sichtbarkeit zu bekommen, aber auch wenn dann zu viele Leute dort sitzen, hat man sicherlich auch bei ((management)) bessere Karten, wenn es darum geht, mal CHF 20000 mehr zu bekommen, für ((logistics)), die wir brauchen, um ((data)) zu bekommen oder irgendwelche zusätzlichen ((methods)), die eingebaut werden, die man nicht über CCES finanzieren kann. Und auch nur die Zeit, die die Leute investieren. Jetzt kommt mal einer einen Tag an die ((institution)) für den Workshop.

OK: Ich habe von Leuten gehört: Outreach mach ich auch sowieso. Andere sagen: ich habe es nur wegen CCES gemacht, weil es verlangt war? Wie war es denn bei Dir?

R6: Ich mache nichts, weil es gemacht werden muss. Es ist die Überzeugung, dass man es machen muss. Das einzige was mich stört ist, dass es dann gezählt werden muss. Und dann sehen muss ob ich das alles zusammenkriege. Und der Appendix. Das ist dann schon Arbeit. Aber für uns als Wissenschaftler ist es ja auch gut, wenn wir sichtbar werden.

OK: Ich finde den Begriff Überzeugung ganz treffend hier. Ich bin auch der Überzeugung, dass Wissenschaft in der Pflicht steht, gesellschaftliche Beiträge zu leisten. Überzeugung kann man den Leuten aber nicht aufzwingen. Wie kann man das Leuten schmackhaft machen?

R6: Ich denke, es ist schon ein Systemproblem. Wenn man z.B. messen würde, wie glücklich die Doktoranden sind, die hier fertig werden und in die Gesellschaft gehen, wenn es dafür eine Messgrösse gäbe, würden sich die Betreuer viel mehr Mühe geben, dass ihre Leute glückliche, gefestigte, gute Wissenschaftler „gute Menschen" sind, die der Gesellschaft was geben. Wenn es aber nur gemessen wird, wie viele Paper die Doktoranden geschrieben haben, dann wird man sicherlich oft in Kauf nehmen, dass sie 3 oder 4 Paper geschrieben haben, aber durch das System durchgepeitscht wurden. Dass man sagt, vielleicht sind auch 2 ausreichend, neben der Thesis. Die Leute haben aber eine gute Zeit gehabt, und denken gut daran zurück, was sie hier gelernt haben. Deswegen ist für mich auch wichtig, dass sie zu solchen Aktivitäten wie die CCES Winter School gehen. Ich habe von Kollegen gehört, „Es kommt für mich überhaupt nicht in Frage, dass sie dort hingehen". Aber ich finde genau dort lernt man, sich auseinanderzusetzen mit anderen Sachen, die ich ihnen sozusagen hier als ((supervisor)) nicht geben kann, weil wir uns damit einfach nicht beschäftigen.

<u>Kategorie 4: Research quality</u>

OK: Sind denn aus Deiner Sicht wissenschaftliche Kenntnisse gewonnen worden, im Rahmen Deines Projektes, die ohne diesen CCES Charakter, nicht hätten gewonnen werden können?

R6: Prinzipiell schon. Wissenschaft wird sich immer entwickeln. Die Frage ist, wie schnell man es machen kann und ich denke, durch diesen CCES Rahmen haben wir vieles schneller entwickeln können. Ich würde nicht so weit gehen und sagen: „Wir hätten es nie geschafft, wenn CCES nicht da gewesen wäre". Aber diese Synergien, die man erzeugt, zwischen den Doktoranden, die Datensätze ausgetauscht werden. Die ((institution)) Gruppe zum Beispiel schaut sich die ((data)) an, was den anderen genauso mithilft. Das sind alles Sachen, die das unheimlich beschleunigen. Und deswegen ist das natürlich sehr gut. Und auf der anderen Seite hilft es, wenn man jetzt schon einen Projektrahmen hat. Ich habe jetzt schon ((methods)). Dann kann ich auch schon einen ganz anderen Antrag gegenüber ((funding organization)) schreiben uns sagen, ich brauche „nur" das

Geld vom Doktoranden und Reisegelder und vielleicht ((research infrastructure)), und brauche nicht noch eine halbe Million für irgendwelche Ausrüstung, wo ich dann erst noch den Doktoranden rausschicken muss um das einzubauen. Das sind alles Synergien, die ohne CCES nicht einfach gegeben sind.

OK: Was ist denn Deiner Ansicht nach die besondere Eigenschaft von CCES, die das ermöglicht hat?

R6: Weil man eben ein übergreifendes Management hat. Das ist eigentlich das Entscheidende. Zum Beispiel, wenn jetzt an einem unserer Standorte irgendwelche Daten gebraucht werden, oder einfach Genehmigungen, dass man ((research actitivity)) darf, wenn wir dann mit den ((political entity)) schon, das schon drei Mal beantragt haben schon an anderen Stellen, dann ist das für sie sofort unterschrieben, und da braucht dann nicht jeder einzelne für sein eigenes ((funding organization)) Projekt loszugehen und dann rauszufinden, wer dort dafür verantwortlich ist. Und das sind alles Sachen, die so eine Plattform eines grossen, übergreifenden Projekts, bieten kann.

OK: Würdest Du sagen, dass es einen grossen Mehraufwand gegeben im Gegensatz zu konventioneller Forschung?

R6: Ja, schon.

OK: Hat es sich dennoch gelohnt?

R6: Ja, ich komme zurück auf das, was ich am Anfang gesagt habe. Ich wollte kein PI mehr sein, im zweiten Teil, ich wollte einfach mitmachen, als einer der PIs, aber es hat sich niemand gefunden. Deswegen habe ich am Anfang gesagt: in ((location)) ist das mit der Administration viel schlimmer. Insofern ist das, was ich jetzt extra reinstecken muss, bin ich einer von den Prädestinierten, die das machen müssen. Also insofern, ja, wer, wenn nicht wir?

OK: Was hat denn ((project)) für Deine Forschung bedeutet? War es ein substantieller Teil Deiner Forschung? Haben sich neue Gebiete aufgetan? Neue Forschungsfelder?

R6: Neues Feld insofern als wir ((project)) gemacht haben, mit den beiden relativ lokalen Standorten. Habe ich eigentlich gemerkt, dass wir uns eigentlich auf das ((research field)) konzentrieren sollten. Und wir haben uns dann überlegt, hat meine Forschung überhaupt Impact, oder habe ich immer das Richtige gemacht in der vorangegangen Jahren? Ein paar Dinge, die muss man machen, wie die Übernahme der Sektionsleitung. Oder man macht es halt anders. Aber ob dann sozusagen, ich meinen wissenschaftlichen Output in die Gesellschaft, ob das wirklich fundamental was ändern kann, war ich mir zu dem Zeitpunkt nicht so sicher. Und dann hatte ich eine grössere Konferenz an der ((institution)), und habe ich mir überlegt, wir als ((researcher)) haben ein riesen Problem: auf der einen Seite haben wir manchmal zu viel ((research object)), und manchmal zu wenig ((research object)). Und eigentlich ist es nur ein ((research problem)). Und da habe ich gedacht: diese grosse Aufgabe müssen wir angehen. Es heisst, ((research problem)) so

abzuschwächen, und das ((research object)) zu diesem Zeitpunkt nehmen, und woanders hin transportieren, und auch ((research object)) mit zu nutzen, um dieses ((research object)) zwischenzulagern. Hat unheimliche viele Hürden, die man dann nehmen müsste. Ist die ((research object)) gut genutzt? Beschmutze ich ((research object))? Nicht nur ((research field)), sondern auch ((research question)) Probleme. Sachen, die man mit ((research field)) angehen muss. Mit wem muss ich reden? Denn das ((research object)), was im ((research object)), wird viel besser gereinigt, als es im ((research object)) möglich ist, weil es ((research object)). Wenn man das angehen will, dann braucht man einen grossen Rahmen. Das war ((year)). Da lief das ((project)) Projekt. Als wir dann die Chance bekommen haben, das im ((project)) aufzugreifen und zur Haupthypothese gemacht. Insofern hat mir das unheimlich viel geholfen. Das wird es nicht lösen, in den nächsten 5 oder 10 Jahren, oder in diesem CCES Projekt, das ist mir völlig klar. Aber angehen müssen wir das. Und die Leute in der Praxis, die denken schon darüber nach, im ((political entity)) grosse Gebiete so zu ((method)), dass wenn grosse ((research field)) kommen, über einem bestimmten ((research field)), kann man das berechnen, wie viel ((research field)), dann wären dort über die nächsten Jahre oder Jahrzehnte sogar, werden dort ((research field)) zur Verfügung gestellt, die jetzt ((research question)). Also Leute in er Praxis machen sich schon Gedanken. Aber genau dort kommt ((project)) mit rein. Man kann auch, wenn ich hierherkomme, als Gruppenleiter ((research field)), dann bin ich eine Person und kann Doktoranden einwerben. Aber alle Doktoranden, die jetzt bei mir arbeiten, da habe ich natürlich Projekte so geschrieben, dass die alle reinpassen, in ((project)). Das war meine Vision. Per Definition müssen die eigentlich da rein passen.

OK: Wieviel Prozent Deiner Arbeit war ((project)) ungefähr?

R6: Ich weiss nicht ob man das so in Prozentzahlen nennen kann. Im Prinzip habe ich Doktoranden, die arbeiten, und die passen alle dort rein. Insofern zählt das alles für ((project)). Obwohl ich sicherlich auch viele von denen eingeworben hätte, wenn ich das ((project)) jetzt nicht gehabt hätte. Insofern kann man das schlecht sagen. ((project)) ist schon ein grosser Prozentsatz meiner Arbeit, aber auch weil das alle mit reinpasst.

OK: Würdest Du sagen, dass durch ((project)), dass sich eine Visibilität ergeben hat? Schweizweit, Europaweit? Ist die ((institution)) sichtbarer geworden, in diesem Gebiet?

R6: Wahrscheinlich müssen das andere einschätzen. Ich meine, ich höre oft : „Achja, ((project)); das habe ich schon gehört“, und dann denke ich, wir haben Einiges richtig gemacht. Das ist immer so eine Frage. Ich meine so wie wir es machen, so wie die ((infrastructure)) ausgebaut sind, gibt es eigentlich nicht nochmals bei ((research field)). Wobei jetzt viele in diese Richtung arbeiten, weil ((research question)) und ((research question)) sehr gut erkannt werden, gerade die ((researcher)) und ((researcher)), die arbeiten jetzt viel enger zusammen. Da haben die ((researcher)) nur für sich gearbeitet, und die ((researcher)) fast nur in der ((research field)) gearbeitet. Es kommt also jetzt zusammen, weil es zusammengehört. Aber insofern, ich denke, wir sind schon sehr sichtbar. Aber

das ist natürlich der ETH Bereich, die Mittel, die hier zur Verfügung stehen, da träumen andere davon. Selbst in ((location)) ist es so und wenn wir dann nicht sichtbar werden, dann machen wir was falsch.

Abschliessende Fragen:

OK: CCES geht 2016 zuende. Macht es Deiner Meinung nach Sinn auch in Zukunft in Projekte zu investieren, die CCES Charakter aufweisen?

R6: Unbedingt. Es ist der Vorteil von solchen Projekten, wenn man die Leute findet, die gewillt sind, diesen Extraschritt zu gehen. Es gibt wenige Förderinstrumente, die sowas ermöglichen. Was in die gleiche Richtung geht sind EU Projekte, die aber in aller Regel ganz themenspezifisch sind, die vorher über Jahre mit viel Lobbyarbeit mit verschiedensten Enden werden diese Themen lanciert und damit sind sie auch sehr restriktiv. Man kommt auch sehr schwer rein und die Chance dort Gelder zu bekommen, aber das wenn man da relativ flexibel ist und so Sachen. Dass das was wir hier in der Schweiz brauchen, dass das mit solchen Projekten gefördert wird, ist das, was wir brauchen.

OK: Es ist also nicht nur ein Trend, sondern eine Notwendigkeit.

R6: Absolut. Ich ärgere mich jedes Mal darüber, wenn jemand sagt: „Ich habe keine Zeit, ich kann das nicht machen“, weil sie unheimlich viel Mittel zur Verfügung haben. Das sind sicherlich Koryphäen, die werden überall hin eingeladen. Und haben ein sehr gutes Standing. Am Ende aber frage ich mich, hat es was gebracht? Habe ich etwas weiterentwickelt? Das sind Leute, die, sobald sie in den Ruhestand gehen, weg sind. Wenn Du aber versucht, das eher zusammenzubringen, wirst Du sicherlich auch später noch gefragt werden.

OK: Und der Bereich, Education; Teaching, Outreach? Wie wichtig ist das in der Zukunft, und warum?

R6: Die Leute, die wir heute hier ausbilden, die übernehmen später die Führung. Mit Schrecken stelle ich fest, dass ich nur noch ((years)) habe, wenn es so bleibt, bis zum Ruhestand. Ich hoffe, dass ich noch viel länger arbeiten kann. Aber ich weiss, dass meine Doktoranden jetzt, die sind ((year)) Jahre junger oder mehr, das sind die Leute, die später mal die Probleme lösen sollen. Für mich sind meine Doktoranden mit das allerwichtigste. Nicht dass die einen Arbeitsplatz haben für 3-4 Jahre haben, sondern dass sie lernen, Probleme zu lösen.

OK: Und dass sie eine Erfahrung wie ((project)) mitgemacht haben, prägt das die Leute auf lange Sicht? Dass sie dann sagen: „Es fällt mir leicht und ich bin der Überzeugung, mit anderen Disziplinen zusammenzuarbeiten“?

R6: Hoffentlich, das ist meine grosse Hoffnung. Das musst Du mal Doktoranden fragen.

OK: Hättest Du noch fragen, Rückmeldungen, Bitten, Wünsche?

R6: Das einzige, diese Tabellen, ich denke, dass die schon wichtig sind. Aber jetzt ist der Aufwand nochmal grösser geworden, weil man dies ganzen Sachen nochmal als Appendix. Das ist schon ein riesen Aufwand. Wenn es was bringt, dass das CCES mehr sichtbar wird, dann ist okay, aber einfach nur wegen Buchführung ist es ganz schön Aufwand. Wir zählen ja schon ehrlich unsere Publikationen. Aber wenn es dann darum geht: jeder Abstrakt. Und ich muss dann jeden meiner Doktoranden bitten, mir die Daten zuschicken. Oder wenn wir im ((media outlet)) erscheinen, dann muss ich das hier reinschreiben, das ist dann schon eher viel Arbeit. Wenn wir da schon weniger machen müssten, das wäre schon gut. Ich meine, es sieht gut aus, aber ob es jemals jemand liest?

Transcription of the expert interview with Respondent 7 (R7)

The expert interview was held on 18 December 2013 between 14:00 hrs and 16:00 hrs at the interviewee's office. It was conducted in German by Omar Kassab (OK). Information that would allow drawing conclusions on the identity of the interviewee was coded and indicated accordingly "((detail))".

OK: You were engaged in more than one project. Looking back, what would you say was your motivation to participate in CCES?

R7: Well, I suppose, my motivation, like all academics, was that it was a big funding opportunity. But also, I liked very much the focus it put on sustainability and bringing disciplines together to try and answer some of the bigger environmental problems.

OK: Within your projects, you had contact to people within ((institution)), but also with people outside. How strong were these contacts?

R7: During the projects, there were really quite strong. For example, the ((project)) project, we went down to run field projects and workshops in ((location)) and you really work very closely with people from other institutions. I got to know them very well, and that was clearly one of the main benefits of the research center, that we got to know colleagues with related interests in different institutions. But I also think that as soon as the funding or the project stopped, those links became dormant. So, I am doubtful that it had any very long term structuring effects. And to be honest, I don't think one should have expected it to. As you make an institutional change, these kinds of relationships function very well for the course of the project and then they more or less stop.

OK: And when looking only at the project period, would you say they have developed further?

R7: The thing I remember most of all, I must say: we had to put those projects together in great speed. We had three or four weeks to come up with an idea. We all summoned together on a Saturday morning to discuss the structure of the project and the thing that struck me was how little people from different institutions knew each other. People were, although they all work together in a similar field, even in ((location)), they were meeting each other for the first time, maybe they knew the person's name. And so that was a big big plus, no doubt about it. People from ((institution)), from ((institution)), from different departments of the ((institution)). Actually understood what other groups were doing for the first time. So that was undoubtedly a big plus. Or, within ((institution)), in ((research field)) and ((research field)). The fact that we went on to merge was undoubtedly partly possible because we had been working together. So undoubtedly, there was a big benefit in getting to know each other. And then of course, the projects were defined as, as always, you find colleagues that you really relate to, so tight partnerships developed that would not have developed otherwise. And I was involved in four of these projects and they were organized in different ways. And the best of them, this really functioned well, you were in a small group with colleagues from

other intuitions, and you worked together very well. So I think the first getting to know each other, and then ordinary business of running a project together, was a very good experience.

OK: Do you think that among these contacts, that were established, there are contacts that are sustained beyond the project or as you say, the moment the funding is over, the whole thing fell asleep? Do you think people will go back and use their CCES networks?

R7: For PIs and the senior scientists, it is certainly true that some of the new contacts will have developed and gone on and so on. I am sure that is the case. And then, of course, there are the doctoral students and the post docs, and those people, who worked in a larger environment, and they will have built quite important networks. Actually I think that this is one of the most important benefits. It is less how the PIs get to know each other, but the fact that the doctoral students and post docs, who are sort of "entering" scientific community and building up their network, do that in a rather rich environment, where they learn about the importance of other disciplines and that other institutions work in other ways, and that I am sure will all affect their future careers.

OK: Do you already know of anyone that benefited from the CCES context in terms of the career path? Or is it too early to say that.

R7: I am sure I do know. But I cannot think of an example. I believe it is true. One of the really important things in this project, it gives them some coordination responsibility. As the traditional ((research field)) PhD student you are very often by yourself, or you got one colleague sitting next to you. And one of the good things about these larger, interdisciplinary projects is that if you are in a relatively junior position, you have to take some responsibility. Whether it is to manage some data base, sort out a method or something. You have to take a group responsibility. And I think some people are good at that and they discover that this is something they can do and undoubtedly it affects their chances of getting the next job. You know, more and more, there are these big EU projects, and these big interdisciplinary projects, and the one thing we really lack is scientific administrators. People that can do this coordination. And so doctoral students who proved to be good at this undoubtedly do go on to those kinds of jobs.

OK: Would you say that this interaction and responsibility they gain at an early stage in their academic career, influences their research agenda? That they e.g. get to know a topic only because they work together with e.g. a geophysicist?

R7: Yes, I am sure but desperately trying to find an example. Going back to that ((project)) project. My PhD student was looking at the ((research field)). ((doctoral student)) was working on the field with people that were looking at ((research field)) and with ((research field)) and undoubtedly, some of the questions ((doctoral student)) went on to answer were only possible because ((doctoral student)) got an insight into the different methodologies that the groups used. So I am sure that this must be case. And I think it will have changed, in ((doctoral student)) case, it certainly changed the content of ((doctoral student)) PhD thesis. If I had been supervising in isolation, two of ((doctoral

student)) chapters would have been quite different, ((research field)). So that certainly affected ((doctoral student)) view of things.

OK: Were your PhD students co-supervised from a different discipline?

R7: One of them was ((project)), supervised by us, but had very close contact with the group. Not supervised by someone else. The projects are quite complex so we decided very early on that, we decided it would be better to be a post doc than a doctoral student. This ability to interact with other disciplines and so on is something you have to learn and if at the same time, you just learn the basics of how to be a ((researcher)), so in fact, although we applied for doctoral students before we actually implemented the project, we converted them to post docs. And the thing about the post docs, they need much less supervision. We had post docs in ((project)) and in ((project)). In ((project)) we also had a post doc. It was true, we only had one doctoral student working in the context of this. All others we very rapidly upgraded to post docs. The ((project)) post doc was jointly with me and ((partner)). Supervision is not really the right word but undoubtedly, he benefitted enormously from the access of the technique and the exchange with the groups. And I think that is one of the things that got him his next job. He holds a research position in ((location)). I have no doubt about it. When these projects are running well. And it doesn't matter if it is a formal supervision arrangement. When they are working well and you got close links between different groups, the people doing this research are in a richer environment and they are clearly benefitting from other groups. Sometimes it is very difficult to quantify. But it is certainly the case.

Category 2: Education

OK: Have any of your students/post docs participated in the CCES Winter School?

R7: It was one doctoral student and three post docs and I don't think any of them did. And I was sorry about that. People know very well what is evaluated and the primacy of publications and things and I always found it quite difficult to have doctoral students, going off to do these other activities, when they feel they should be concentrated on writing the best papers they can. So I don't think any of my group went to these events, which I regret because I think they were very good. There was actually a general problem with ((institution)). When these Winter Schools started they got lots of applications from all around the world and surprisingly few from ((institution)). There were various interpretations. One is that ((institution)) students are expected to perform well in the conventional well and they simply didn't regard this as core business and the other is, maybe ((institution)) offers so many possibilities, it is not as if the Winter School is a "must do" because there are other things you could be doing.

Category 3: Implementation

OK: How important do you think are these (outreach) events and what are the opportunity costs?

R7: They clearly are. And in this world where the best possible publication is actually the only thing which counts on an academic CV people regard these opportunity costs as too high. And I have now been in many of these projects where delivering this kind of activities has been one of the goals and it is just evident that it always takes lower priority. And I think, in general, we are not really good at this. We don't quite know how to go about it and we are not sure which of the activities has the greatest impact. So publications to outside the scientific community, that I think, from my experience, we have been relatively successful at, there are several journals or forestry and agriculture, which go to farmers and foresters and so on and we write so called popular articles, intended for them. And I think most of my doctoral students have done one of those. Press articles, sometimes we have done one or two of those: I am not sure what impact they have. I think the former is a more effective thing to do. Courses, seminars, workshops from stakeholders from outside the scientific community: in that respect, the outstanding project was the ((project)), where we were working with various stakeholders in ((location)). I think we were really effective in explaining the significance of these results, maybe changing their thinking a little bit. Public information events for local authorities and residents, I don't personally remember doing any of that, but they probably went on with some of our projects. At schools: again, I think we didn't do that. Other events, patents. Just to sum it up: the two things were probably fairly effective was publications in the so called professional literature outside the scientific community and in workshops and seminars for stakeholders outside the community, for example in the ((project)) project we worked with ((stakeholders)) and so on, and I think that was quite well received.

OK: One of my interview partners said: "If you want people to do Outreach, you have to impose it on them, top-down". What do you think about this?

R7: Well, that is probably true. I mean and that has been my experience, not just here, even in EU projects, someone saying: "where is your outreach?". The kind of incentive system in academia at the moment is that people will not do this voluntarily. If they got to do it, they will, unless they find a way to avoid it.

OK: Do you think a framework like CCES can promote something like this?

R7: This is really the big big question. And it goes right back to this whole evaluation process. Because doctoral students talk to each other, they know exactly what the criteria are by which you stay on the academic ladder. And consciously or unconsciously, they do the sensible things like spend their time writing for these journals and showing themselves and presenting at scientific conferences and so on and they give much less priority to some of these other outreach activities. So, can something like CCES help? I suppose it can in as much as it can make the process easier.

If it was to take rough drafts for articles, and if there was a writer to turn them into better articles. Basically, taking some of the work away. But the real change that has to happen is in the incentive system. You know, slowly and somehow, the academics have to realize that part of their future career prospect does depend on being effective in outreach, and funnily enough we are much worse in this than in the USA. I have spoken to many people in American universities where having an impact in the community is very clearly part of your appraisal system. But it is not here, so to answer your question, I think CCES can help by having professional expertise and to some extent making the job somewhat simpler but they cannot change the incentive system. So I think it is impact would always be rather limited.

OK: How did this cultural dynamic come about in the US? Why is it more central in the US as compared to here?

R7: I don't know in detail but I think one of the reasons is that in the US, in particular the state universities, are much more dependent upon diverse sources of funding. And therefore, for a university president, it is extremely important that he can show politics, industry and charities that they are doing a useful job. Whereas here, almost all of the money comes from the government and therefore we don't have to justify our existence quite so much.

OK: Would you say, nevertheless, that over the course of the years, the projects in CCES have strengthened the dialog between science and practice?

R7: I am sure they have. Not dramatically, I don't think it has been a dramatic effect, but it was one of the things we were expected to do and I think the difference that CCES projects have done it, with different degrees of success. In the ((number)) that I have been involved in, I think the ((project)) project did a great job in the context of ((location)). The ((project)) project was quite effective. I think the ((project)) and the (project) were good projects, but rather "academic speaking to academic". I don't think they had very much of an outreach.

<u>Category 4: Research quality</u>

OK: Do you think that scientific results have been generated that wouldn't have been possible without CCES?

R7: Oh yes, definitely. In all ((number)) projects I was in, we had a level of resources which allowed us to have an experimental design or an infrastructure that one could not have had individually. ((project)), for example, we have this wonderful series of ((infrastructure)), ((number)) of them altogether, and no individual group could have done that. It was a big deal to negotiate these ((infrastructure)) and fence them and so on. And that was a great thing. In the case of the ((project)), again, the logistical problems of doing that project would not be possible at a smaller scale. So, I think, undoubtedly, that it allowed us to do things we could not otherwise had done, and obviously, that is reflected in some of the papers that were published.

OK: This is more pointed towards funding for infrastructure and logistics. In terms of scientific outputs, did the interinstitutional and interdisciplinary setup of CCES promote the generation of scientific results that would have not been possible without this context?

R7: Well, to different degrees. The ((project)) was very interesting but it was relatively narrow in terms of disciplinarity. I mean the individual projects could have been done within professorships. The ((project)) was much more interdisciplinary. The ((project)) was quite interdisciplinary. When you look at the papers and I guess the ((project)) was strongly interdisciplinary as it brought together a huge range of techniques which didn't belong to one individual group. So undoubtedly, the proportion of the papers reflects this interdisciplinary character. A majority, I suspect, are relatively disciplinary. But there are a few where you really benefitted from several disciplines working together.

OK: Now this obviously entailed extra costs in terms of coordination. Was it worth it in light of the scientific results?

R7: Well, I think so but opinions differ about this. Many people are absolutely happy to work in their own disciplines. They know their methods and they can do great things and can have great h-factors. But for people who are genuinely interested in some of these big and more complicated questions, it is very much worth it. It is a matter of individual perspective.

OK: What did participating in these projects mean for your personal research?

R7: I guess this familiarity with colleagues and their techniques and basic things, what kind of equipment they have and so on, it must have broadened the horizons. I am sure it is the case that in other projects, unrelated to CCES, we would use techniques that we used for the first time in CCES because we knew that there was an expert. So I am sure that is true that is was a broadening experience it opened up the range of possibilities.

OK: From your viewpoint, did CCES and its projects help the ETH Domain and its individual institutions to gain more visibility in this field of Environment and Sustainability?

R7: I am sure it did. It is always very difficult to say. How would have things been different in the absence of CCES? I am sure it did but whether in a way that you can demonstrate was due to CCES? Before CCES came along, the really extraordinary thing were very first meetings, where people simply didn't know each other. And after a couple of years in CCES, there was a group of people, particular in ((institution)), ((institution)) and ((institution)) who knew each other much better even within my ((institution)), I think it was the CCES that kind of turned us into environmental scientists, to some extent. Before that, we have been ecologists, and bio geochemists, and so son, but you could really say, for the very first time, we stopped being a collection of disciplines, and that was big effect. And it clearly must have influenced how people see environmental science at ((institution)). One consequence, relatively painlessly, it became possible for ((discipline)) for merge with ((discipline)). And that would have not been possible if we hadn't known each other,

what others do and understand what the others think. So that is an indirect effect of CCES. That wouldn't have been possible otherwise. But, I have to say that when the CCES funding stops, I think we sort of sink back, partly to the condition we were in beforehand, for example, these new NCCR have just been announced, and I would have thought that after these CHF 45 Million of real interdisciplinary environmental research, you would have thought that there was so much momentum in environmental research, that one of the NCCR would have been environmental in nature. And, to be honest, I am rather shocked, there was no sign of all of this, has somehow changed the research landscape.

OK: The NCCR DRIFES didn't make it, unfortunately.

R7: And certainly it is true that some of the people that put that together were very active in CCES. My feeling is that CCES was great for the ((discipline)) because for the first time we were doing environmental research rather than our own little niche of research. It definitely improved contacts amongst the institutions and within ((institution)) very strongly. But I am afraid it didn't really have the sort of Tsunami effect of reshaping the environmental research area.

OK: Do you think that a reason is that it is was constrained time-wise? Do you think that, if you have some kind of institutionalized structure, people would commit more?

R7: I do think that. And obviously, it was essentially, more than anything, a fund so that people for a period of five years, could apply to do this according to certain rules. But it wasn't really an institution, I mean, correctly, probably, it was sort of the minimum staff in the administration of it, and as much money as possible going into the projects. But when the projects end, so does a lot of, but this is the classic problem. When I first came to Switzerland, I was involved in this ((research field)) of the ((funding organization)), and very similarly, big projects, good management, strong emphasis on outreach and interdisciplinarity, but then, funding stopped, and then, there were personal links and so on, abut essentially they simply went back to their departments. And that is the case with EU projects, and NCCRs. None of these projects develop a life beyond the funding period.

OK: Why do you think that NCCRs continue to be the main source of non-institutional funding in this country?

R7: It is clear that the SNF wants to use them as an instrument to change the research landscape and they built in all kinds of conditions, about influencing your professorial planning and so on, so they specifically intended to have a long term effect but I think it is just not real politics. Clearly, this is a sort of funding, there are lots of other initiatives, and one funded activity for a five year period is naïve to expect this to change things thereafter. And I think that, for me, had some very clear benefits and indirect consequences which we can see to this day. The other thing which I must say was a huge lost opportunity, was that CCES and CCEM were not part of the same program. Because so many of these environmental problems have technical or engineering solutions, and

from the outset to separate from the engineering from the environment, I think it was a terrible lost opportunity. And so we have the situation in ((institution)) now that we have an ((unit)) which has far too little contact and engagement with the engineering and architecture. And that was a great lost opportunity. If basically the funding of CCES and CCEM had been put in the same pot and there had been some rules about fostering collaboration with environmental science and engineering and so on, things could be very different now. I think this was a real lost opportunity.

OK: CCES, in 2016, will close down its doors. From what I hear, it was worthwhile supporting such projects in your opinion. If you were to decide, where would you place the focus for future funding? Projects, education, post docs, doctoral students, outreach? Where do you think is the big need?

R7: I think the big need is to do research which is problem-oriented, in other words, aimed at improving a perceived social problem. In a context which is policy relevant. And I think institutions are quite important. The real high leverage thing we do is not outreach, to be quite honest. The really high leverage thing is when we train doctoral students who have a skill set and an attitude which is different from ours. I saw this at the ((project)), where there were a few students that had to work on a problem related to sustainability and they had to work part of their time in ((location)), and some in ((institution)), and part of the time in ((location)), and then you look to see what happens to these people, a few years later, many have gone into extremely interesting, forward-looking professorships, leaders in their field, and I am sure it is not a coincidence. Those people got their early training in a very stimulating environment, and I think that is the highest leverage activity we can do, to provide the actual students with an environment that is different than that of their professors, where they work across the disciplines on more complex problems. You still have to train people as whatever they are, but the environment they are in is different, and CCES did that to some extent, but because it wasn't a permanent institution, it was limited in this effect, and that is where the ((organization)) is a good idea. That we actually create an environment where the doctoral students at least are totally familiar with the engineers, the architects, the natural scientists, the policy issues, even though they have their particular field, so I think the best thing we can do is to try and provide research environment, multidisciplinary, problem-oriented research.