Understanding societal impact through productive interactions: ICT research as a case

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Abstract

Universities are increasingly expected to fulfill a third mission in addition to those of research and education. Universities must demonstrate engagement with society through the application and exploitation of knowledge. As societal impact of research is uncertain, long term and always dependent on other factors, we argue here that evaluation should focus on the conditions under which societal impact is generated rather than on the impact itself. Here we focus on a specific set of those conditions: the interactions between academic researchers and societal actors. Instead of speculating about potential impacts of research, we argue that *current* productive interactions of researchers with societal stakeholders improve the probability that *future* societal impact will occur. This paper supports this idea by examining in detail several, mainly retrospective examples. As productive interactions are field specific, we restrict ourselves to 'professional adhocracy fields', especially to ICT research. We address the patterns of productive interactions that result in societal impact within this field and we discuss whether differences are observed in contrast to other fields, such as social sciences and humanities (fragmented adhocracies). We end by discussing the implications that these patterns have for societal impact assessment. Shifting the focus to interactions allows assessment of short-term knowledge transfer and other collaborative efforts with stakeholders that contribute to long-term societal impact.

Introduction

Beyond education and research, universities are increasingly expected to realise their 'third mission'. These 'third mission' activities of universities are meant to stimulate the application and exploitation of knowledge for the benefit of the social, cultural and economic development of society. They shape the interaction between universities and academic research with the wider society (Pålsson et al. 2009; Tran 2009). Several concepts have been suggested for this interaction in the academic literature including 'Mode 2 knowledge production' and the 'Triple Helix of university-industry-government relations' (Gibbons et al. 1994; Etzkowitz and Leydesdorff 1998; Hessels and Van Lente 2008). However, these remain at a rather general level and do not help to *assess* societal impact at the level of individual research projects and programs. For this, a range of methods have been proposed, developed and sometimes tested (Davies, et al. 2005; De Jong et al 2011; Spaapen & Van Drooge 2011; Donovan & Hanney, 2011; Bozeman & Sarewitz, 2011). Inspired by these concepts and methods, science policy makers and funding agencies have introduced a variety of instruments to stimulate relationships between science and society, including European Framework Programs, the Dutch Bsik-FES programs, and the UK Economic and Social Research Council's Science in Society Program.

Simultaneously, (experimental) indicators for societal impact are increasingly included in national research evaluation exercises. The swift conversion of societal impact assessment from craftsmanship to standard and routinised activity in research evaluation and by funding agencies leads Ben Martin (2011) to fear that *'…we may be in danger of creating a Frankenstein monster*' as it remains unclear what impact exactly is and how it can be stringently and soundly evaluated. A wide range of definitions exist for the concept of societal impact (Bornmann 2013). He identifies three main strands of defining societal impact that have been developed in research evaluations since the 1990s. These strands seem to represent three subsequent stages in the process of research having impact:

1. Societal impact as *a product*: Knowledge with a potential societal value is embodied in a product that may or may not be used by societal audiences (Boekholt, Meijer and Vullings 2007). Among these products, one may distinguish between information, products, tools and instruments, methods, and models. An example is the summary for policy makers of the report 'Managing the risks of extreme events and disasters to advance climate change adaption' issued by the IPCC (2012);
2. Societal impact as knowledge *use*: Interaction processes between researchers and societal stakeholders may result in the adoption of knowledge by the latter (Moffat et al. 2000; Roessner et al. 2006; Castro Martinez et al., 2008). Knowledge use may be facilitated by a product (the use of a policy report by civil servants) or a person (researchers as consultants);

3. Societal impact as societal *benefits*: the effects of the use of research results is the meaning here. Within this category, many notions of societal impact can be found. The focus can be on policy, professional practice, business or on wider impacts, such as the impact on culture, media and community. Impact can have the form of jobs and education (Library House 2006), or network building, trust, and community formation (Walter, Helgenberger, Wiek and Scholz 2007).[1]

There is no clear one answer yet as to how to evaluate social impact. In research evaluation differences between fields create challenges for comparison (Donovan 2007; Martin et al., 2010, Lane 2010) and this holds true for the evaluation of societal impact (De Jong et al., 2011). Furthermore, many proposed societal impact indicators focus on economic impact (for example, Health Economics Research Group, Office of Health Economics and RAND Europe 2008) or health impact (Bensing et al., 2004), which suggests that other fields require additional indicators for measuring their societal impact.

Scholarly output indicators at most result in a picture of *potential* impact and it is well-known that the links between scholarly output, use and benefits are generally indirect and time-lagged. These problems are related to temporality and attribution; it often takes a long time for societal impact to come about and impact often is mediated and moderated by a variety of actors and events, both scientifically and societally. This would imply that evaluating societal impact can only be done through in-depth case studies – a rather time and resource consuming procedure as currently adopted by e.g., the UK *Research Excellence Framework (REF)*.

Process indicators can overcome the problems of temporality and attribution, and at the same time solve the problem of resource intensive research assessment. If we know what process characteristics correlate with (often only long-term) impact in terms of use and benefits, these process characteristics can be used as a proxy for societal impact. They actually show the *smart* efforts made by researchers to contribute to societal impact. For example, the type and intensity of interactions between researchers and stakeholders may be a reliable predictor of societal outcomes in the long run.

To date, however, process indicators are less well researched. Societal impact process indicators should be based on an improved understanding of the complex interactions between academic researchers and societal stakeholders. What is known about which interactions are important, or even required, for research to have impact?

1. Two types of interactions can be distinguished in the literature: direct and indirect interactions. Direct interactions by academic researchers with stakeholders during and after the research

[1] The things that are regarded as benefits very much depend on the perspective of the relevant actor, for example creating new jobs may be the objective of a politician, but the reduction in the number of jobs may be the aim of an entrepreneur who deploys new knowledge to rationalise work processes.

process. These interactions may generate relevant research questions, may improve access to financial and material resources, and may support knowledge diffusion (Bozeman and Coker 1992; Molas-Gallart et al., 1999; Cowan and Patel 2002; Molas-Gallart and Tang 2007; Academy of Finland 2009). In the process of stakeholder involvement, personal interaction between researchers and stakeholders may accelerate research uptake (Meagher et al. 2008; Brousselle, Contandriopoulos and Lemire 2009). The involvement of key persons, such as high level civil servants, have been found to increase success chances (Molas-Gallart and Tang 2007; Kennedy, Seymour, Almack and Cox 2009; Krücken, Meier and Müller 2009). Alternatively, malfunctioning personal interaction hampers research achieving societal impact (Kingsley, Bozeman and Coker 1996).

Indirect interactions are mediated through information carriers. For instance, this can be in the form of texts (Molas-Gallart, Tang et al. 1999; Molas-Gallart and Tang 2007; Health Economics Research Group, Office of Health Economics et al. 2008; Prins 2008) and of technological artifacts (Kingsley, Bozeman et al. 1996; Kingsley and Farmer 1997).

2. Interaction processes with stakeholders are subject to field specific dynamics. Different fields are characterised by different research dynamics, based on internal factors as well as on contextual factors. Research dynamics are fundamentally related to the organisational characteristics of a field. For example, if in a certain field researchers depend less on peer recognition for careers and funding, they have more freedom to address a large variety of audiences. If there is no clear hierarchy between these audiences and these audiences also have different objectives, dependence of scientists upon any single audience is lower than in the case of a strict hierarchy between audiences. In cancer research, for instance, patients have different objectives than peers. This offers other practices and aims than purely scientific ones, such as funding by patient organisations next to funding councils (Whitley 2000). Verbree *et al.* (2011) indeed found that medical research groups have a wide variety of funding sources, indicating a wider variety of audiences.
3. Interactions can be rather complex. The network configuration, the actors (researchers, intermediaries and stakeholders), research fields, and societal sectors involved may all influence societal impact and the way it is, or isn't, generated (Molas-Gallart, Tang et al. 1999; Krücken, Meier et al. 2009). There is an urgent need for more in-depth study of these interaction processes. Cozzens et al (2002) suggest the challenge in measuring societal impact is due to a paucity of well-developed models explaining the processes leading from innovation to impact. In a report about the value of medical research, the Health Economics Research Group *et al.,* (2008) stated that there is consensus in the academic literature about the existence of societal impact of academic research, but that it is less clear how different processes of knowledge transfer contribute to it. In their study of the impact of a German university on its geographic region, Krücken *et al*., (2009) argue that there is a need for

additional studies to completely grasp the fundamental dynamics of knowledge transfer. Jensen, et al. (2008) pleaded for more qualitative research on the interaction mechanisms deployed by academic researchers.

To summarise, (i) previous research has resulted in limited knowledge on how field specific interactions between academic researchers and societal actors relate to the societal impact of academic research, and (ii) evaluation methods generally have neglected these interactions so far. In the SIAMPI project[2] we investigated how information about *interaction processes between academic researchers and their stakeholders* can be made productive for evaluation purposes. Molas-Gallart and Tang (2011) applied the approach to social sciences and humanities (SSH) cases. Their conclusion is that it offers a way to deal with attribution problems that are widespread in the evaluation of these fields, as SSH research dynamics are intertwined with social and political developments. Moreover, mapping productive interactions helped researchers to reflect on their engagement with users and society.

In this paper we extend the SIAMPI approach to other fields than social sciences and humanities (Molas & Tang 2011; De Jong et al 2011). We focus on the class of fields labeled 'professional adhocracies' (Whitley 2000), which includes engineering, artificial intelligence and bio-medical sciences. These fields are different as they combine standardised research methods with a wide variety of audiences. Other fields either have highly varied audiences but low standardisation of research procedures, for example the social sciences (fragmented adhocracies) and humanities (polycentric oligarchies), or have highly standardised research procedures but a small variation in audiences (technologically integrated bureaucracies), such as chemistry.

Despite the variety of audiences, in professional adhocracies performance standards are mainly set within the peer community. Other audiences have less influence on evaluation criteria (Whitley 2000). Consequently, on the one hand serving highly varied audiences is intrinsic to these fields, while in evaluations emphasis is on the academic audience. This creates a tension in adhering to standards set by the peer community on the one hand and being relevant to varied audiences on the other hand. Furthermore, professional adhocracies display a high variation of research topics within each field. If commercial applications exist, the variety increases even more (Whitley 2000). Mapping productive interactions in one of these fields has to take into account a wide variety of research dynamics and thereby serves as a serious test for the method.

In this way we hope to contribute to a better understanding of how societal impact is produced in a variety of research fields and also contribute to improving research evaluation of these fields. The questions we will answer about 'professional adhocracy' fields are: (a) Can we relate societal impact to (past) productive interactions? (b) If so, what are the implications for societal impact assessment of

[2] Social Impact Assessment Methods for research and funding instruments through the study of 'Productive Interactions' (SIAMPI), a European FP7 project grant number 230330

these fields? To answer these questions, we will present four examples of ICT research that were analysed using the SIAMPI method.

The following section explains the method, data and discusses the selection of the cases. The subsequent section describes four examples in terms of the observed productive interactions and the observed societal impact. The fourth section presents a comparative analysis of the examples, leading to impact indicators presented in section five. The concluding section reflects on the value of the SIAMPI approach for the evaluation of societal impact.

Method and cases

To answer our research questions, we co-developed the SIAMPI approach (Spaapen and Van Drooge 2011), which is based on the earlier ERiC project (De Jong et al 2011). At the core of the approach is the notion of productive interactions. Productive interactions are defined as encounters between researchers and stakeholders in which both academically sound and socially valuable knowledge is developed and used. The method distinguishes direct interactions from indirect interactions, as described above. Within these interactions, different carriers may be distinguished, amongst others, that of funding. Knowledge production and transfer are considered interactions and not impact themselves. Interactions are also characterised by their duration and the resources involved. Examples of resources are IPR agreements, financial contributions and societal or economic use of research equipment (Horlings et al, 2012). Impact is regarded as the consequences of knowledge applications research that has impact if stakeholders changed their attitudes, opinions, and behavior based on the research outcomes. Stakeholders are broadly defined as all the actors involved in the process that leads to societal impact. This includes societal actors such as governments, NGOs, industry and consultancy firms and also researchers from other fields that take up knowledge and further develop it.

In order to identify the interactions that relate to (later) impact, we adopted an exploratory case study approach. At the same time the study had to show how it might be used in evaluation procedures and therefore it had to be restricted in terms of resources used and time. In other words, the function of the case studies is a proof of (impact evaluation) concept. In the concluding section we discuss   additional research that is needed to further underpin the evaluation approach.

From the *professional adhocracies* fields we selected ICT research because we expected to find a large variety of productive interactions in this field. ICT has a wide range of applications that permeate society throughout the various sectors including the commercial sector, applications within government and in research and education. We selected two cases in two different evaluation contexts - a university department and a research program. The second is a society-oriented multi-university research program with multiple stakeholders involved from the outset; the first is a single university research department with no pre-determined stakeholder audiences.

The UK digital economies research[3] program is funded by four UK Research Councils, and has a broad societal aim: to bring about the transformational impact of ICT for all aspects of business, society and government. Within the program, we selected a project in which two universities cooperate with a variety of societal stakeholders. These are multinationals in the ICT and electronics sector; local organizations including patient and government organisations and some 3000 volunteers from the region, including people from a range of age groups and with a variety of disabilities. Under these circumstances, we expected to find many productive interactions between ICT researchers and their stakeholders. The computer science department is located in a Netherlands university. It has an excellent scientific reputation, including a broad range of both theoretical and applied computer science. Research undertaken by the group is heavily funded through EU and national research programs. In addition there was evidence of interdisciplinary collaboration by computer science staff with economists and social science researchers. Within the department we have selected one basic and two more applied research groups.

Data collection is mainly based on in-depth interviewing, since interactions often are not recorded in documents (Spaapen & Van Drooge, 2011). Separate interview protocols were developed for researchers and stakeholders. The researcher protocol includes the following item categories: interviewee profile; research context in terms of users; mechanisms of interaction and outcomes/impacts. The stakeholder interview includes items on: interviewee profile; knowledge context in terms of use of academic knowledge; mechanisms of interaction with the academic researchers on the one hand and their own stakeholders on the other hand and outcomes/impacts for/on their organization. [4]

From a wide variety of examples resulting from the interviews in the two cases, we selected four to illustrate the diversity of interaction patterns and impacts we found in ICT research. Three examples were taken from the department and one from the program. The examples differ in several dimensions: type of research (basic versus applied); stakeholders known from outset or not; inclusion of stakeholders in research or not; and whether impact was achieved or not (yet).

In the first project, it took ten years from basic academic knowledge to societal impact. Here, a potential audience was not identified at the outset of the project. The second project also involves basic research, but a potential audience was identified and targeted from the onset. However, at the time the case study was undertaken there was no societal impact yet identified. The third project is again about basic knowledge, but in this instance there is a chain of academic researchers from

[3] http://www.rcuk.ac.uk/research/xrcprogrammes/Digital/Pages/home.aspx

[4] In this study, stakeholders are broadly defined as beneficiaries of the ICT researchers that have been interviewed. NGO's, funding agencies, governments and private companies, other scientific researchers, such as biologists and medical scientists are included.

different fields who all have contributed to the current impact. The fourth project deals with applied research in which a target audience was not only identified from the outside of the project, but also included in the project from the beginning. An additional reason to select these four projects is that they could be reconstructed into sufficient detail to allow analysis.

Data were primarily obtained through one to two hour semi-structured interviews, following the SIAMPI interview protocols, which we adapted to the ICT field. In the case of the computer science department, we interviewed four researchers, the leaders of the selected projects and the head of department, and five dominant stakeholders. For the UK research program, we conducted eighteen researcher interviews and three stakeholder interviews. They were selected because of the breadth of activity undertaken in the case study.

The interviews were recorded and fully transcribed. The interviews protocols were color coded, in order to identify the various types of productive interactions, as well as the outcomes and social impacts. Alongside the interviews, texts such as websites, annual reports, policy documents and evaluation reports were used to obtain contextual information. The second interviewer checked the transcripts and the coding. The interviewed researchers and stakeholders checked the descriptions of the projects, and they gave feedback to correct factual mistakes. Researchers and stakeholders draw their own pictures, but they proved to be consistent with each other. The overall analysis of the department case was presented to and discussed with the head of the department.

The program is a multi activity example and for the purposes of this paper one activity was selected on which to focus our analysis. The SIAMPI team interviewed four researchers and three stakeholders involved in the Ambient Kitchen project, next to a large number of researchers and stakeholders active in other activities of the program. The project website and publicly available outputs that were available were consulted. Feedback from the relevant departmental head highlighted the early stage analysis of the SIAMPI productive interactions work, which reflected the ambitions of the project at that time. A more detailed analysis at the current time could identify a range of interactions that took place during the project and beyond.

Findings

This section presents a selection of four projects, which are representative of our findings. For each case, productive interactions and impacts are described, together with factors that influenced the interactions and impacts of the research.

Project 1: Applying semantic technologies in the development of forensic software

A professor of a Dutch research group in knowledge representation and reasoning was involved in a ten year research effort during the 1990s that resulted in a standard language for ontologies for the World Wide Web. The language developed facilitates software applications *'that need to process the content of information instead of just presenting information to humans'*[5]. The research undertaken resulted in new standards for the semantic web and in one of the best-cited (and awarded) papers in the field. The impact on the development of the semantic web is also an obvious societal outcome of the research.

Furthermore, the research resulted in a spin-off company, which is the focus of the first case. Over the years the company employed many former Masters and Doctoral students of the group. In 2009 after ten years of research and development, the company launched a software product for forensic research, which allows intelligent investigation of large numbers of e-mails and data files. The product became a success. Four phases of interactions can be distinguished in the process from academic research to product launch.

(i) Between 1998 and 2001 academic knowledge was being *developed into technology*. The leader of the academic research project took part-time leave from the university in order to be involved in the new spin-off company, which was founded by a former classmate and personal friend of his. Engineers were hired from a polytechnic where the owner of the company had been employed. In this phase, his most important role was demonstrating the *potential value* of the technology. The professor and the company signed an IPR agreement stating that all IPR will rest with the company. In this phase, the professor and employees of the company co-authored a number of scientific papers, which were presented at academic conferences.

(ii) From 2001 to 2005 the company was involved in projects to demonstrate the *viability* of the technology. The goal was to translate the academically developed technology into a practical tool for use outside the university. The owner of the company financed the R&D. Pilot projects were undertaken in the building industry and in the education sector amongst others. The company also participated in EC funded projects with various academic institutes and large firms, large telecom and insurance companies. Every three months meetings were held with the professor, in which he had two main roles. He firstly served as the company's antenna in academia, for example by highlighting upcoming new standards and formats to take into account. He secondly brought in his network. The university based research group provided the company with skilled employees and interns, who served as an additional interaction mechanism between himself and the company.

[5] http://www.w3.org/TR/owl-features/ (accessed online date)

(iii) The phase of *product development* began in 2006 and ended in 2008. In this phase the goal was to slim down the tool to its essential core. The role of novel academic knowledge became less prominent and meetings with the professor were held only twice a year. His role shifted towards providing complementary knowledge rather than providing state of the art advice. The company shifted its focus towards the market.

> *'We* [the company] *said: 'we will make it a success', so we could not stay in our ivory development tower, we had to go into the field and talk to police departments, we had to give presentations…'*

In this phase, the need for knowledge on marketing and software engineering grew. Knowledge on licensing and financial investments was obtained externally.

(iv) From 2009 onwards the focus has been completely on *marketing*. The relation between the university and the company now is maintained through the scientific board of the company, of which the professor became a member. A joint venture with a software vendor with market knowledge was created to enter the market. Within nine months a worldwide sales organisation was established to distribute the software. The product is marketed in combination with training on how to use it and has already been sold to police departments in the Netherlands, China and the USA, and to international accountancy companies. It is used to investigate digital information in the fight against crime and fraud.

In terms of the three approaches to impact, this case is an example of impact as a *societal benefit.* More specific, the research resulted in economic and safety impacts.

Project 2: Using knowledge representation for analyzing the consistency of medical protocols

When asked for his best recent paper, a Dutch researcher in knowledge representation and reasoning mentioned a paper in which he and his colleagues demonstrated that medical knowledge could be represented using reasoning tools based on mathematical logics. They were the first researchers to achieve this. The project was funded by the European Commission through a FET-open grant; a grant for blue-sky research in future and emerging technologies in ICT[6]. The test case in this project was a medical protocol for breast cancer treatment. Initially, medical researchers thought that it would be impossible to capture medical knowledge into logics because it would be too complicated. Experts from logics, on the other hand, thought that it would be impossible because medical knowledge would not be precise enough to do so. After a few years of research in an international consortium, the approach was successfully applied on the case of a protocol for the treatment of breast cancer. The stakeholder involved in this project is an institute responsible for improvement of quality in health

[6] http://cordis.europa.eu/fp7/ict/programme/fet_en.html

care, including medical protocols. The researchers collaborated intensively with the institute but not with medical researchers themselves. One of the results of the project was that existing treatment recommendations proved to be inconsistent.

Regardless of the success of the method and its obvious potential value for medical practice, the societal impact of this research has remained only limited to present date. The researcher explained that apart from financial investments outweighing quality improvement, the method was too far ahead of its time to be incorporated into medical practice at the time. Applying the method requires skills, which are hardly available and the deployment of formal reasoning in medical practice would require substantial changes in existing routines and in existing culture. Absorptive capacity to deploy the method is lacking at the level of the every-day medical practice. Therefore, IPR agreements have never been made, since from the beginning it was clear the project would not result in a marketable tool. Nevertheless, because of the study, an institute responsible for improvement of quality in health care realised it should improve its internal quality procedures.

Unlike the previous case, the principle investigator is not investing any additional effort into stimulating societal application for the method as he does not consider it to be his responsibility and there is a lack of incentive to be involved in third mission activities. *'Do we try to keep it in the spotlight so…no…that is unrealistic. Knowledge transfer…to say it bluntly…I'm neither paid nor rewarded for knowledge transfer or directed towards it...to be honest…I did not become a scientist to do those things.'*

This does not mean the efforts invested into developing the method were not of any use. The research is being taken further by the same principal investigator in a new project that aims to integrate static data in personal health records into the dynamic data of the protocols. Integrating static and dynamic data is a scientific challenge in computer sciences, with potential societal benefits. Knowledge on formalizing dynamic data gathered in the previous project is used in this project. In terms of the interaction types, the uptake of the method by other societal relevant projects may lead to *indirect* societal benefits.

To summarise in terms of the impact concepts distinguished in the introduction, the knowledge developed in the project described here clearly resulted in a product in which value was clearly acknowledged by societal stakeholders. However, the sectors' absorptive capacity is simply not large enough to use this type of innovation at this moment and turn it into a societal benefit, as it is not compatible with existing practice and skills. The approach developed in this project may turn out to be a necessary contribution to changes in practice but in isolation it is not sufficient for change.

Project 3: Using imaging technology to increase diagnostic efficiency

In 2003 the Dutch government funded nearly 40 new research programs at a total cost of 802 million euro. The overarching goal of these four to eight year programs was to strengthen the future national knowledge base[7]. One of the aims of the programs was the translation of basic knowledge into new products, processes or societal concepts. Consequently, the program leaders also have a responsibility for knowledge transfer and dissemination.

Among the programs was the Virtual Laboratory e-science program (VL-e). It aimed to improve e-sciences by developing facilities and methodologies. Within the Medical Subprogram, the Medical Diagnosis and Imaging Project focused on recognition of digital images. This project resulted in a software tool that is now widely used within a university medical center. The tool is expected to contribute to finding a cure for Alzheimer's disease at a much faster rate than had the tool not been developed.

The software tool is based upon the work of a research group on high performance distributed computing. The group develops methods for the recognition of digital images. One of the results is a generic software platform for distributed computing.

The software platform was further developed within the VL-e program. There, collaboration emerged between researchers from the ICT research group and a senior researcher in medical informatics at a university medical center. The goal of the latter researcher was to improve the ICT environment within the center. After a few meetings the senior researcher started to adapt the generic software to the environment of the center.

The senior researcher in medical informatics needed a test case for further development of the software. At the medical center he approached a radiologist who was studying brain images to identify biomarkers of Alzheimer's disease. Pharmaceutical companies used these markers in clinical trials. The software he used to study the images was rather slow and it took half a year to analyse the thousands of images resulting from his research. The radiologist, however, was reluctant to use the newly developed software tool, since he was not able to see its value. By coincidence, the radiologist happened to play field hockey with an employee of an ICT support organisation who had supported the senior researcher in his research.

> *'But also it turns out that the medical doctor, the radiologist, who doesn't know much about computers but is a very good radiologist, understands shrinking brains, happens to play field hockey with the ICT support person at […] that I was dealing with. So they talked.'*

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[7] http://www.agentschapnl.nl/programmas-regelingen/besluit-subsidies-investeringen-kennisinfrastructuur-bsik (6-12-2011)

The ICT support person convinced the radiologist to try the software tool. From that moment on, the radiologist and the senior researcher had many conversations about what ICT had to offer and about the radiologists' needs.

Despite the fact that the distributed computing researchers had to continue working at the forefront of their own field, they remained involved in the development of the software. The senior researcher in medical informatics served as a translator between the distributed computing group and the radiologist. The computer researchers preferred to provide academic support through e-mail and over 700 e-mails in total were sent back and forth. Ultimately, a software tool was developed to study brain images 300 times faster than before. An analysis that previously took half a year to complete could now be done overnight. In terms of impact definition, in this case there is a clear change in practice because of knowledge use by stakeholders. The change in practice has resulted in a *societal benefit of ICT research,* if medical researchers are considered stakeholders of ICT researchers.

In spite of the cooperation in the project, no joint publications of the computer scientists and the researchers in the medical center were produced because of disciplinary boundaries. What is frontier research in the medical imaging field is considered applied research in ICT research. Therefore, the ICT researchers did not invest in a joint research paper, as they expected publication in the core journals of their field to be problematic.

Project 4: Developing technologies to assist domestic living

The Digital Economy Programme[8] is a nationally focused cross-research council program from the UK. It is aimed at providing capability in the early adoption of information technologies by business, government and society and focuses on the transformational effect that these technologies can have. One of three UK research hubs funded through the Digital Economy program is the Social Inclusion through Digital Economy (SiDE) hub, a collaboration between two universities that have worked together on previous projects within ageing, assisted living and technologies. The hub addresses some key strategic and applied research questions, which aim to yield innovations across the fields of technology, social science, business and user engagement in research.

One of the projects in the hub is the Ambient Kitchen. This is a lab-based project through which the research team explored the use of pervasive computing for assisted living. In brief, The Ambient Kitchen embeds sensors in the kitchen environment, for example in the floor, cupboards, kettles and food containers that allow the kitchen to be aware of how food and utensils are being used. Tags integrated in food items and appliances, together with sensors integrated into the bench and cupboards, allow the location and changes in location of objects to be monitored and a pressure sensitive floor

[8] http://www.rcuk.ac.uk/research/xrcprogrammes/Digital/Pages/home.aspx

allows people in the kitchen to be tracked.[9] The project team are particularly interested in supporting the elderly and those with dementia.

The Ambient Kitchen is a research platform and the software is in a constant stage of development and re-development. The Ambient Kitchen is a collaborative university led research project involving significant numbers of users in several different 'groups'. Interactions between researchers, volunteers and stakeholders are structured from the outset into the Digital Hub project. It includes regular demonstrations for a variety of groups such as university students, representatives from other universities, members of the public, city council members, company visitors and the media by researchers of the technologies developed from the Ambient Kitchen work being undertaken. The concept of delivering demonstrations to a variety of groups was planned but the type of audience is subject to opportunities emerging during the timescale of the project.

The project aims to work with volunteers, including people from a range of age groups and with a variety of disabilities. Recruiting to the volunteer pool has been carried out through local governmental departments and local charities including Years Ahead, the Regional Forum on Ageing and The Alzheimer Society. The panel of volunteers is contributing to the formulation of research strategy and the evaluation of the research outputs, as well as being engaged in participatory design, co-design and evaluation activities to ensure that the outputs of the research program are both meaningful and usable.

Other interactions factored into the planning of the project included membership by the Digital Hub researchers of various charities which were engaged in the research to help recruit users. Being involved with the charities helps the research teams to maintain strong links with the user community and to develop the applications. The involvement of the research may be personal but is a link that can be exploited and has benefits for the research activity and in principal for the charity's community.

The aim was to do field tests before considering commercialisation. As the project is ongoing, the full impact has not been realised yet. It is however clear that work on the Ambient Kitchen includes many different productive interactions between scientists and societal actors in the form of publications, awareness raising and liaising with stakeholder groups. The latter will help in articulating user needs and in generating feedback on new products and services.

In terms of the types of impact, and the interaction types, this case is an example of societal impact as knowledge *use*: Interaction processes between researchers and societal stakeholders results in adoption of knowledge by the latter.

[9] http://culturelab.ncl.ac.uk/ambientkitchen/

Comparative analysis

The previous section described four different examples of research projects (within a department and within a program) with their specific audiences, productive interactions, and types of impacts – as summarised in table 1. This section aims to analyse the cases and collect the building blocks for indicators to assess professional adhocracies based on an understanding of their research dynamics.

ICT research, as expected, has a *wide variety of stakeholder* audiences (table 1). In some cases, such as the Ambient Kitchen, quite a few direct stakeholders are involved, such as volunteer groups, charities and city council members. In other cases, such as the forensic software, only one stakeholder was involved. In the knowledge representation example, one direct stakeholder was involved and a large set of indirect stakeholders.

Table 1: Overview of the findings

Case	*Impact*		*Stakeholders of researcher*		*Productive Interaction types*		*Interaction characteristics*	
	Scholarly	**Societal***	**Direct**	**Indirect**	**Direct**	**Indirect**	**Resources (Human, financial, technical, legal)**	**Time lag between outcome and impact**
1 Basic	Highly cited paper	SOCIETAL BENEFIT Spinoff-company. Successful product. New standards for the semantic web.	Spin-off company	Building industry. Education sector. Police departments. Accountancy firms.	Professor participated in company in different roles over time. Coauthoring papers. Presentations at scientific conferences. Advice by PI. Hiring employees with additional skills.	Internships. Graduates of involved group. Scientific papers.	IPR Agreement. Company funding. EC funding. Joint venture. Sales contracts.	Long, from knowledge development to product introduction (1998-present)
2 Basic	Proof that representing knowledge in logics is possible	OUTCOME Potential impact on medical treatment guidelines (project showed inconsistency of current guideline	Organisation for improvement of quality in health care	Health care sector (medical doctors, nurses, hospitals) and patients	Face to face meetings with stakeholder. Formal project meetings with research consortium.	Take up of results by other research project – which may have societal impact.	EC funding through FET-open; medical protocols	Not relevant (no use or societal outcomes)
3 Basic	Generic software tool for distributed computing	SOCIETAL BENEFIT Software tool for medical imaging resulting in 300 times faster image analyses	Senior researcher medical informatics	Radiologist and other medical researchers the university medical centre	Formal meetings Informal meetings	Software tool E-mail Intermediary person	Government funding through VL-e	Long period of knowledge development, development of tool (2003-present)
4 Applied	Academic conference articles and position papers	USE OF KNOWLEDGE Ambient kitchen incorporating prototype system	Charities, City Council, Volunteers in user groups, People with Dementia, Carers, University Students, Representatives from other Universities, Members of the Public, Company Visitors, Media.	Broader Community. This project promotes Community Cohesion	Volunteer panel Conference disseminations Demonstrations Membership of Charities	On-line forums Prototypes feedback forms newsletters, project website newspaper/ magazine articles	Commercial company Council and Charity representatives working within the project	Long period of knowledge co-development, (2007-present)

*Type of impact as distinguished in the introduction

We have found a *variety of productive interactions* between ICT researchers and their stakeholders (table 1). There are direct interactions, including demonstrations in the Ambient Kitchen, indirect interactions such as the software in the medical imaging project where hundreds of email were exchanged and financial interactions, for example the investments in the forensic software project. In some instances interactions are straightforward, as in the forensic software project, or complex as in the medical image case and the medical guidelines case.

What does seem to be important for the creation of social impact are interactions that take place *after the research* has been completed, as a comparison between the forensic software case with impact and the medical protocol case without impact demonstrate. Both technologies were promising and in the medical protocol case stakeholders acknowledged the value of the research. In the first case the investigator was committed to further development of the knowledge, since the owner of the company was a personal friend and many employees were his former masters and doctoral students. It is not (mainly) the incentives of the research system, but the social network of the involved researcher that seems to be an important factor. In the latter case, without such network relations, the researcher was not committed to further development of the technology.

Comparing the cases, productive interactions can occur in basic research as well as in applied research. There does, however, seem to be an important difference between *basic and applied research configuration*. In basic research projects, it is not clear from the outset what end-users might benefit from the research, which makes it difficult to include them directly. As a result the impact of basic research is often dependent on more or less complex ‘knowledge production chains’ with many interactions in each link. A stakeholder in one link can be the researcher in the next. This type of configuration may yield generic basic research results with a wide range of potential applications. The knowledge production chain can have different branches resulting in different applications of the same generic research results. An example is the medical imaging project. In applied projects the end-user is more likely to be known and therefore can be included in the project from the start, as we have seen in the Ambient Kitchen case. In that case, research is conducted in a ‘beehive’ configuration, where researchers from multiple fields and stakeholders from different backgrounds can interact simultaneously to achieve a common goal. This type of research configuration leads to more specific application-oriented outcomes.

Apart from the issue of not (yet) known end-users there is also the issue of the *complexity of the (potential) stakeholder network*. In the case of the medical protocols, the potential users were well known (the doctors in the field) and therefore, this is a basic research project with known potential users. However, the development from the prototype into usable and used tools requires many different additional innovations and organisational changes in the health care system, in order to have the technology implemented. The stakeholder environment is in this case large, diverse, and highly institutionalised. The researcher did not have the position, instruments, or intention to influence this system. In the image analysis case, the users were not yet known and potentially there are many. Nevertheless, a relatively simple chain of actors enabled the development into a specific application for a specific user type. In project 2, the context was much more complex than in project 3 (and project 1). Furthermore, the involved researchers and the organisation for quality improvement in health care were not connected to the main players. This may explain the different outcomes in terms of use. To have a tool adopted by a group of medical researchers is much easier and requires less socio-technical systems innovation than to have a tool used by the medical profession, which is strongly institutionalised, regulated and dominated by huge interests. Basic research often leads to specific (essential) inventions and the development into an innovation requires a follow up trajectory that depends on the complexity of the stakeholder context. Applied research, in contrast, often includes from the onset an analysis and development of the whole socio-technical system in which innovations would be used and not only one (albeit crucial) component.

Table 2: Type of research, complexity of the stakeholder community, and obtained impact

Research type	*Project*	*Complexity*	*Impact Strategy*	*Impact*
Basic	2	High	No	Outcome with potential impact
Basic	1, 3	Low	Yes	Societal Benefits
Applied	4	High	Yes	Use of Knowledge

Figure 1 illustrates in brief the interaction networks. Where the researcher collaborates with a stakeholder who is well integrated in the use environment and has a significant interest in ‘selling the product’, societal relevance changes into deployment of the innovation in society.

By tracing productive interactions, we found *a number of impact types* of ICT research (table 1). It can have health and safety impacts, exemplified by the potential improvement of medical protocols. It can have commercial impacts, such as the forensic software (which could also be considered a safety impact). It can have an impact on the quality of life, as the Ambient Kitchen and medical imaging cases show. In all cases, ICT research was one of the contributors to the impact. The knowledge it produced had to be further developed, as in the forensic software case, or it facilitates the advancement and impact of other disciplines. ICT research contributed to the resulting impacts, rather than bringing them about by itself. Two consequences of this facilitating role can be seen in the cases. First, it takes time for ICT research to have impact; it took ten years from an academic web language to a commercial forensic software tool. Second, impact also depends on the stakeholder. If a stakeholder acknowledges societal relevance of research outcomes, but lacks, for example, resources or absorptive capacity, there will be no societal impact. The medical protocol case is a clear example of such a situation.

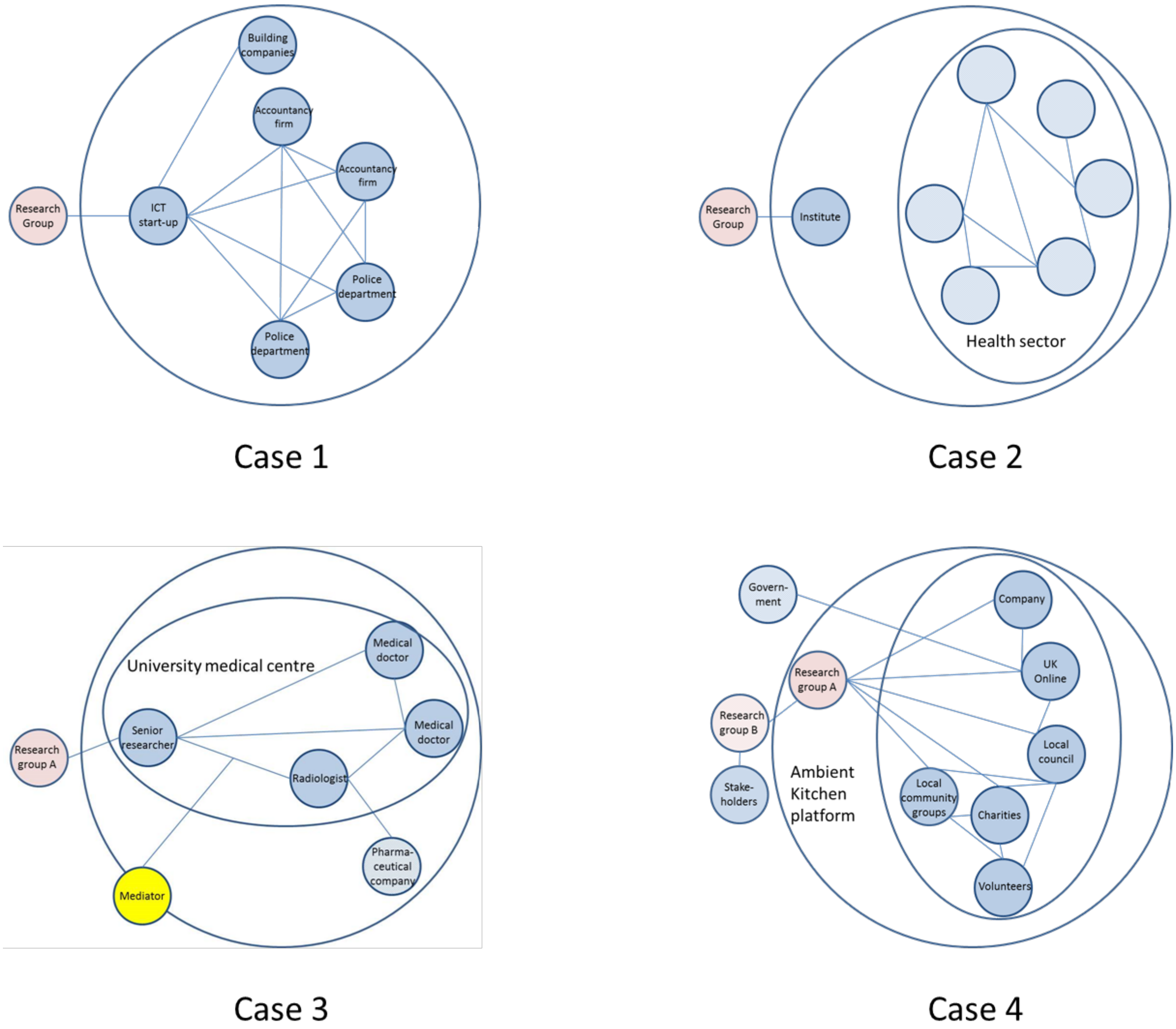

Figure 1: Network diagrams of the cases

Discussion

The SIAMPI approach

Our study aimed to test the value of the concept of productive interactions for ICT research, which is a representative case of *professional adhocracies*. We have shown a variety of interactions that were beneficial for the generation of impact, suggesting that process characteristics can be used as a proxy for future impact in the 'professional adhocracy fields. Molas-Gallart and Tang (2011) applied the SIAMPI approach in the social sciences (*fragmented adhocracies)* and also found that productive interactions are crucial for impact. Similarly to our project 3, they explained that by focusing on the interactions and processes, impacts previously unknown could be identified. They found that the approach helped social scientists to legitimise their significant efforts in engaging with society. We did not find this for ICT researchers, as esteem resulting from societal impact seemed to be less important to them. Obviously, fragmented adhocracies are more dependent on reputation gained in non-scholarly audiences than professional adhocracies, who are more dependent on peer recognition (Whitley 2000).

The SIAMPI approach might seem to be labour intensive because of the case study style approach with document analysis and interviews. This is also the criticism on the social impact approach in the UK Research Excellence Framework. We believe this is not necessarily the case, as data collection can be guided by two questions: 1) who - and how - do you interact with in your research and who do they interact with about your research results – now and in the past? and 2) what has your contribution been to their opinions and activities? Answering these questions facilitates self-reflection in preparing research evaluations. Our examples show that few interviews are required to answer these questions.

Lessons for research evaluation

This study shows that using *process indicators* does help to anticipate societal impact that may not yet have occurred at the moment of evaluating. This finding is consistent with other studies showing that interactions with practice are an important predictor of impact (Bercovitz and Feldman, 2011; Lövbrand, 2011; De Jong et al, forthcoming).

In this way, the classical problem of *time lags in evaluation* can be solved. It is well known, as some of our cases also demonstrate, that there is a considerable time lag between research and impact. By shifting focus to the quality of interactions and knowledge transfer efforts, the likelihood of future contributions to societal impact can be assessed.

Our approach also helps solve the second classical problem of *attribution*. Attributing impacts to individual researchers or single research groups is problematic because usually more parties, scholarly as well as societal, are involved in knowledge production and application. The focus on interactions in the network of researchers and societal stakeholders, and on the mechanisms that moderate and modulate societal impact allows it to become clear how knowledge directly or indirectly contributed to observed impact. The advantage of the approach is that it may reveal impacts the researchers were unaware of, as became clear in several of the SIAMPI cases (Molas-Gallart and Tang 2011)

Evaluating through tracing productive interactions should not be mistaken for a *linear model*. Interaction networks may be complex, changing over time, with information and influence disseminating in many directions (e.g. Molas-Gallart and Tang, 2007), as our examples show. It is exactly these interactive processes that are captured by the SIAMPI approach. Four aspects are especially relevant:

First, our cases illustrate that it is insufficient to focus only on direct contacts that researchers have with societal stakeholders when evaluating their societal impact. In addition to having its own direct societal impacts, ICT research also contributes to societal impact of other research fields (Khan et al, 2013) through the tools made available. In other words, when assessing societal impact, researchers in other research fields may be the relevant direct stakeholders, who may then interact with societal stakeholders. Sometimes these indirect relations can be detected through co-authorships, citations, or acknowledgements. In other instances, it may require interview-based studies as in this paper. Not only can the knowledge production network be complex, the same may hold for the stakeholder network in which knowledge is received and used. That societal relevant knowledge may not reach the impact stage, as that may depend on characteristics of the use-networks that are far beyond the influence of researchers (e.g., project two). In other words, one should always look at the position of the research in the larger interaction network between research and its often-complex audiences.

Second, not only did we find various successful interaction configurations but also differences in types of output. Both interaction patterns and relevant outputs differ between fields (De Jong et al, 2010; Martinelli et al, 2008; Mutz, 2013). This implies that we cannot generalise our findings, since they are based on just four examples. In follow-up research we will investigate the production of societal impact in other fields, such as climate science. This may lead to a more complete picture of how societal impact is generated and should be evaluated in different fields. In the end this should lead to general (theoretical) understanding about the mechanisms behind the production of societal impact.

Third, post-research support - ranging from support through e-mail conversations to being employed by a spin-off company - to stakeholders seems to have promoted societal impact in our cases. Murray (2004) also found that the involvement of academic inventors in entrepreneurial firms beyond academic invention were beneficial to the firms. This leads to an additional societal impact indicator for evaluating research institutes or programs: are incentives present for post-research support to societal stakeholders? Incentives should cover more than financial rewards, as researchers differ in their motivations for research commercialisation (Lam, 2011).

Finally, we feel that our approach also may inform ex-ante assessment of research proposals. Increasingly research funders require applicants to explain how they plan to realise societal impact. Reviewers of proposals may assess these plans in terms of (i) how well applicants are able to describe the network of required productive interactions, and (ii) how adequate their plans are to create and exploit these relations.

This paper explored some of the interactions that relate to impact. Although we cover only ICT research, the following preliminary implications for research evaluation can be formulated that should be subjected to further research. When assessing societal impacts, emphasis should be on (i) *contributions* of research to societal impact instead of *attributing* societal impact to specific research and (ii) *efforts* instead of *results* which does not exclude acknowledging short term results, as successful innovation is not the standard outcome. Here *post-research support* plays a role. Furthermore, (iii) it should be taken into account how well the efforts are embedded in an understanding of the knowledge production and knowledge use in the networks of the research group, project of program. Through such an approach we may avoid Martin's *Frankenstein's evaluation monster* that may do more harm than good to the science system and to societal benefits it brings.

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