Evaluation and Program Planning 43 (2014) 105–117

Contents lists available at ScienceDirect

Evaluation and Program Planning

journal homepage: www.elsevier.com/locate/evalprogplan

Developing a methodology to assess the impact of research grant funding: A mixed methods approach

Carter Bloch *, Mads P. Sørensen, Ebbe K. Graversen, Jesper W. Schneider, Evanthia Kalpazidou Schmidt, Kaare Aagaard, Niels Mejlgaard

Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University, Bartholins Allé 7, DK-8000 Aarhus C., Denmark

ARTICLE INFO

Article history:
Received 7 March 2013
Received in revised form 14 October 2013
Accepted 19 December 2013

Keywords:
Mixed methods
Research policy
Grants
Additionality
Impact analysis

ABSTRACT

This paper discusses the development of a mixed methods approach to analyse research funding. Research policy has taken on an increasingly prominent role in the broader political scene, where research is seen as a critical factor in maintaining and improving growth, welfare and international competitiveness. This has motivated growing emphasis on the impacts of science funding, and how funding can best be designed to promote socio-economic progress. Meeting these demands for impact assessment involves a number of complex issues that are difficult to fully address in a single study or in the design of a single methodology. However, they point to some general principles that can be explored in methodological design. We draw on a recent evaluation of the impacts of research grant funding, discussing both key issues in developing a methodology for the analysis and subsequent results. The case of research grant funding, involving a complex mix of direct and intermediate effects that contribute to the overall impact of funding on research performance, illustrates the value of a mixed methods approach to provide a more robust and complete analysis of policy impacts. Reflections on the strengths and weaknesses of the methodology are used to examine refinements for future work.

1. Introduction

Research policy has taken on an increasingly prominent role in the broader political scene. The driving force behind this change is the belief that research is a critical factor in maintaining and improving growth, welfare and international competitiveness. This increased focus on the promotion of research[1] has not just led to a greater allocation of resources to the area; it has also led to a rethinking of the ways in which research can benefit the economy and society.

In terms of goals, there is an increasing emphasis on the impacts of science funding, and how funding can best be designed to promote economic and social progress (OECD, 2010). Examples here are questions of how to fund research in order to better encourage scientific breakthroughs (National Research Council, 2012), supporting the development of new areas that emerge at the boundaries of existing disciplines (European Commission, 2005), and how funding programmes can take into account the way that the overall science and innovation system functions and evolves in spreading and developing new knowledge (Feller, 2007). Feller (2007) points out that many of these are ex ante questions that are more focused on informing future decisions as opposed to an ex post assessment of what worked and what did not.[2] In terms of measurement, there is an increasing demand for improved quantitative evidence on the impacts of research funding and to establish the causal relations between funded projects and results (Lane, 2009; Lane & Bertuzzi, 2011; Salter & Martin, 2001). Governments face a number of competing demands for public funding, pushing efforts to seek more efficient allocation of resources. At the same time, econometric analyses face a number of challenges in providing the information that is needed (Jaffe, 2002; Macilwain, 2010; Salter & Martin, 2001). In particular, data limitations may necessitate assumptions that are not fully realistic or restrict analyses to specific issues that do not provide the full picture (Feller, 2007).

Meeting these demands for impact assessment is a tall order and one that involves a number of complex issues that are difficult to fully address in a single study or in the design of a single methodology. However, they point to some general principles that

* Corresponding author. Tel.: +45 87165901.
E-mail address: carter.bloch@cfa.au.dk (C. Bloch).

[1] See for example, the America COMPETES act (U.S. Department of Commerce, 2012) and the EU 2020 initiative (EU Commission, 2011).

[2] See also Georghiou and Roessner (2000).

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http://dx.doi.org/10.1016/j.evalprogplan.2013.12.005

can be explored in methodological design and have also been used to guide the study examined in this paper. First, studies of research funding should be forward looking and explorative, analysing how results can inform future measures and thus measuring both intended and unintended outcomes. Second, given a focus on informing future use, the questions of why and how the impacts were achieved are as equally important as the question of what the impact itself was. Third, a systems view is important towards understanding funding impacts and putting them into a broader context.

This paper discusses the development of a mixed methods approach to analyse research funding. We outline and critically assess an approach recently developed for a study of the effects of research grants for the Danish Council for Independent Research over the period 2001–2008. In all, approximately 2600 small to medium sized grants to a total of around $600 million[3] were awarded to 1600 different principle investigators covering all main fields of science.[4]

The main objective of the study was to gain a comprehensive view of the impacts of research project grants for research output, the researchers themselves and their related research environments. In addition, the study examined the role of the application process and how it may have an important influence on the impact of the funding programme, both through grant recipients and those that have been declined. Key focus areas for the study were the role of grant size, the influence of grants on risk-taking behaviour within research, and characterizing differences across research fields.

Our design of research method is driven by a desire to capture the full impact of research funding grants, by data availability and by the limitations of feasible quantitative approaches based on existing sources of objective data; all of which argue for a mixed methods approach employing both quantitative and qualitative analyses. A survey-based approach is needed to capture a number of effects that are not possible to examine based on quantitative analysis of existing data sources. Combining the survey approach with studies based on bibliometric data and register-based data on careers provides hard objective evidence on the impacts of funding grants, which is crucial both for understanding the actual effects of the grants and for their justification. Finally, in order to better understand how these effects take place, in depth qualitative analysis is also needed. Qualitative interviews both provide illustrative examples that greatly strengthen the quantitative results, and allow us to examine in depth issues or elaborate on the results raised in the other analyses. A key focus in the paper is in how the different types of analyses can be used to complement and validate their respective results, thereby improving the robustness of the measures. An additional focus is on the need for both quantitative and qualitative analyses in order to provide a better understanding of not just what the impacts are, but how and why they occur.

The study of research grants provides a detailed illustration of the strengths of our implemented mixed methods approach. However, it is equally useful in identifying limitations due to data, timing and method. Hence, the paper will critically examine our approach and discuss how it could be strengthened.

The remainder of the paper is organized as follows. The next section contains a brief overview of the mixed methods literature used to frame our study design. The subsequent section outlines the mixed methods design that was developed and implemented in the study of research project grants. Thereafter, results of the study are presented in order to illustrate the strengths and limitations of the mixed methods approach used. This section is followed by a critical assessment of the approach and implications for future design. The final section concludes.

2. Mixed methods research – an overview

Mixed methods research can be defined as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language in a single study" (Johnson & Onwuegbuzie, 2004, p. 17). Mixed methods research represents a pragmatic combination of methodological approaches and their underlying rationales. This combination however raises epistemological issues which some view as implying that qualitative and quantitative approaches are incompatible (Howe, 1988; Lincoln, 1990). Quantitative approaches are typically linked to positivistic views that social phenomena can be analysed objectively in much the same way as physical phenomena, by making context-free generalizations that can be tested. Qualitative approaches are typically based on an interpretivistic view that social phenomena must be seen from the point of view of the subject, that behaviour can only be understood in the context of meaning systems employed by a particular group or society.

Mixed methods takes a pragmatic stance between these "purist approaches" (Johnson & Onwuegbuzie, 2004), for example that while context is important, some degree of generalization is also possible. Furthermore, qualitative and quantitative methods often cannot be directly linked to a specific epistemological stance. For example, surveys are not necessarily based on positivistic assumptions (Brannen, 2005) and qualitative approaches may often make 'quasi-generalizations' (Bryman, 1984). The value of mixed methods is seen in its ability to address problems from a number of angles to provide a more comprehensive analysis. "Audiences such as policy makers, practitioners, and others in applied areas need multiple forms of evidence to document and inform the research problems. A call for increased sophistication of evidence leads to a collection of both quantitative and qualitative data" (Creswell, 2006, p. 13).

Mark, Henry, and Julnes (1999) argue that an integrative framework that takes into account both types of inquiry and evaluation purposes creates a common ground that can accommodate both qualitative and quantitative paradigms. They identify four types of purposes, each of which to a certain degree influences choice of approach: assessment of merit and worth, oversight and compliance, programme and organizational improvement, and knowledge development.

The use of a combination of quantitative and qualitative approaches, mixed methods research, has increased considerably over the last couple of decades (Creswell, 2006; Teddlie & Tashakkori, 2009). The field of mixed methods research accordingly has moved beyond quantitative versus qualitative arguments and recognizes the value of both paradigms in order to maximize the strengths and minimize the weaknesses of each other (Johnson & Onwuegbuzie, 2004; Maxcy, 2003; Morgan, 2007).

Despite its value "there are many unresolved issues to address before a more matured mixed methods research area can emerge" (Teddlie & Tashakkori, 2003, p. 3). Conducting mixed methods research implies challenges to method design, such as whether both the methods are given equal priority, whether to conduct the qualitative and quantitative stages concurrently or sequentially, where the mixing of the methods will occur, and how the methods interact. Furthermore, in order to mix approaches in an effective way, researchers need to have a profound knowledge of both the quantitative and qualitative methodologies and consider all

[3] For simplicity, throughout the paper we use an approximate exchange rate 1 USD = 6 DKK.

[4] The Research Council consists of five individual councils responsible for awarding funding within their field: Natural Sciences, Medical Sciences, Technology and Production Sciences, Social Sciences and Humanities.

the relevant characteristics of the two research approaches (Johnson & Onwuegbuzie, 2004).

Attempting to address challenges and the different types of mixed method design, authors have developed typologies or classification systems of mixed methods (cf. Caracelli & Greene, 1997; Creswell & Plano Clark, 2007; Creswell, Plano Clark, Gutmann, & Hanson, 2003; Greene, Caracelli, & Graham, 1989; Johnson & Onwuegbuzie, 2004; Leech & Onwuegbuzie, 2009; Morse, 2003; Patton, 1990; Tashakkori & Creswell, 2007; Teddlie & Tashakkori, 2006). A key problem for mixed methods design is that there is a plethora of typologies, which either are too complicated, too simplistic with neglect of important criteria, or do not represent a consistent system. In the following a recent typology developed by Leech and Onwuegbuzie (2009) will be outlined and discussed in relation to the design chosen in the study presented here.

According to Leech and Onwuegbuzie (2009) mixed methods research falls on a continuum from not mixed, monomethod design using either qualitative or quantitative techniques, to partially mixed designs and fully mixed methods. The latter represent the highest degree of mixing of methods and paradigm characteristics. For partially mixed designs, qualitative and quantitative phases are carried out independently, with mixing primarily taking place at the data analysis stage. In fully mixed methods, on the other hand, mixing occurs in either one or more of the following components in a study: the research objective, type of data and operations, type of analysis, or type of inference.

Leech and Onwuegbuzie (2009) use three criteria to develop a three-dimensional typology of mixed methods design: (i) the level of mixing (partially mixed versus fully mixed), (ii) time orientation (concurrent or sequential) and (iii) emphasis of approaches (equal status versus dominant status of one approach). By crossing the three criteria, an eight mixed method typology was developed (see Leech & Onwuegbuzie, 2009).

There are however, a number of additional aspects concerned with how individual analyses are interconnected. Greene et al. (1989) identifies five types of interactions between analyses. Triangulation is the use of different methods in order to validate results, so that they are "different from one another with respect to their inherent strengths and limitations/biases and that both method types be used to assess the same phenomenon" (Greene et al., 1989, p. 266). Complementarity seeks to elaborate specific results while expansion supplements by examining a broader range of results. Development refers to the sequentiality of analyses in order to build on results, while initiation uses different methods to further explore contradictions or unexpected results. While our study is not able to encompass all these "purposes", we will draw on these in both the design of our method and ex post assessment of its outcome.

An important issue in the design of a mixed methods approach is how qualitative and quantitative approaches should be related, or which of these types of interactions should be given priority (Kelle, 2005). A focus on triangulation requires that different approaches are aligned to validate results. This essentially implies that qualitative are subordinate to quantitative approaches, with the main purpose of validating and illustrating quantitative results. Alternative focus on complementarity and supplementarity places less importance on cross validation and more on capturing the different insights that each approach can generate. While quantitative approaches are directed towards identifying effects of phenomena, qualitative approaches seek to understand how those effects come about.

In this paper we present and discuss our research design that seeks to address our research objectives, purposes and questions, drawing both on the issues and classifications mentioned above, and on the experiences from the study. As we illustrate below, both the considerations involved in designing an actual study that seeks to combine econometric analyses with both quantitative survey data and qualitative interviews, and ex post assessments of the results offer a number of insights for mixed methods design.

3. Designing a methodology to assess the impact of research grant funding

This section outlines the mixed methods design that was developed and implemented in the study of research project grants.[5] Our primary focus is on the overall design and the interaction between individual analyses in the study. However, the design of individual studies is also important, both in themselves, and also because considerations for individual analyses (and in particular potential strengths and limitations) have an important influence on overall design. In essence, design must take account of both individual and overall design, and interactions at the same time. Hence this section will begin in particular by discussing many of the challenges for individual qualitative and quantitative analyses before moving on to discussing the overall structure and interactions between each actual analysis.

In terms of the typology proposed by Leech and Onwuegbuzie (2009), our study is *fully mixed* as the methods were designed together and there was significant degree of integration of analyses. Though, as was alluded to above, fully mixed can have many meanings, with important tradeoffs in terms of *how* the methods are mixed. While the timing of the study was slightly sequential, in practice the sequencing was not enough to take advantage of initial results. Hence, the study should essentially be considered to be *concurrent*. Finally, in terms of the relative status of quantitative and qualitative methods, the basic principle behind the overall design of the analysis was to rely on quantitative analysis to the furthest degree possible, and use qualitative analysis both to supplement and complement the three different quantitative analyses and to assess their validity. In relation to the tradeoff of "triangulation versus complementarity" described above, our approach pursues a middle path, choosing to cover the same basic topics (effects), but seeking in-depth descriptions of how and why the grant mattered. We discuss this in greater detail below.

3.1. Classifying effects of funding grants

We begin first by identifying what types of effects should be considered for research grant funding. The mission of the Danish Council for Independent Research is to support research based on researchers' own initiatives. The Council has the responsibility to develop the level of research in Denmark and to ensure opportunities for breakthroughs in research in coordination with other funds within the Danish public research system. In essence, the goal of research funding is quite singular in nature; to promote research performance. Arguably, research performance is something that can be measured quantitatively through the use of bibliometric measures that take account of the impact of research articles through a variety of indicators.[6] Indeed, this has been the approach taken by a number of analyses of the impact of research grants (e.g. Benavente, Crespi, Garone, & Maffioli, 2012; Chudnovsky, Lopez, Rossi, & Ubfal, 2008; Furman, Murray, & Stern, 2012; Jacob & Lefgren, 2011; Ubfal & Maffioli, 2011). However, under the surface is a complex mix of direct and intermediate effects of funding that contribute to the subsequent impact of funding on research performance, and which require a broad set of instruments to capture them. Hence, many of these effects also

[5] Bloch et al. (2011).

[6] There are however, some issues concerning the ability of bibliometric indicators to measure research performance. These are discussed below.

provide information on how funding impacts research performance.

While the funding grants themselves are hoped to produce high quality research, arguably an important channel is through the careers of funded researchers, with subsequent impacts on both their own research and potentially the research of others. Effects of funding grants may thus run through the funded researchers to impact the researcher's own later research, the researcher's host institution, attraction of international talent, and research leadership that benefits more junior researchers. Another channel through which funding may affect performance is through networking; that processes of collaboration, international exposure and other interaction result in better research. Funding can also be considered a performance measure in itself, and recognition that it brings may positively impact research.

In classifying effects of funding, we utilize the concept of additionality. The concept of additionality was originally developed for evaluation of the effects of public support for business R&D (Buisseret, Cameron, & Georghiou, 1995; Georghiou, 1994). Georghiou (1994) identified three types of additionality: input additionality, output additionality and behavioural additionality. Input additionality is the extent to which public support leads to an increase in firms' own expenditures on R&D, output additionality is funding effects on end results of R&D, and behavioural additionality is changes to the behaviour of the firm.

We apply the additionality concept to evaluation of the effects of public funding on academic research. We both set input, output and behavioural additionality in an academic research context and expand the notion to include two additional types of additionality: career additionality and institutional additionality. Career additionality captures funding impacts on the important role of mobility and career progress for research performance and the development of new knowledge, while institutional additionality recognizes the individual researchers' work may have impacts for their associated research environments.

The effects of funding grants are thus classified into 5 groups:

- *Effects on the research itself (Input additionality)* – did the grant facilitate research activities that would not otherwise have been possible?
- *Effects on the scientific production and other outputs (Output additionality)* – this includes both scientific outputs such as publications, patents, new products or services, and the development of new knowledge or skills. Citations provide an indirect measure of output, by indicating the quality of output by virtue of its recognition and use by other researchers.
- *Effects on research behaviour (Behavioural additionality)* – the degree to which grants have facilitated changes in the character of the grantees research or the way research activities are conducted; choice of research topic/area, size of research projects, publishing strategy, risk-level in research, international collaboration, research dissemination, research management, and fund-raising.
- *Effects on career structure (Career additionality)*–these include changes in research position, mobility and workplace, work-home balance and unconventional career paths.
- *Effects on associated research environments (Institutional additionality)* – the degree to which grants have impacted host institutions and other connected research environments.

3.2. Key issues for evaluation design

Hence, a key challenge of the study design is to capture this broad range of effects and better understand how they come about. However, at the same time, it is equally important that individual quantitative analyses are as reliable as possible. Quantitative impact policy evaluation studies cut across several disciplinary boundaries, making use of social psychology (Campbell & Stanley, 1963), political science (Mohr, 1999), economics (Heckman, 1979, 2001), and statistics (Rubin, 1974). There has been considerable discussion concerning the merits of *experimental* approaches, based on random assignment of those receiving assistance (treatment group) and those that do not (control group), versus the *non-experimental* approaches. With respect to the analysis discussed here, an experimental approach is not feasible, as we are not able to randomly choose those that receive grants.[7] In non-experimental approaches, the counterfactual condition is used to assess the impact of an intervention by comparing outcomes for groups that have participated in the programme with similar outcomes for groups that have not participated. Sampling bias for non-experimental approaches (Heckman, 1979) becomes an econometric problem as well as a problem for evaluating research and innovation policy because treated agents differ from the non-treated agents, which often leads to a misleading and often an incorrect estimation of the policy instruments.

In order to address these issues, our approach involves a combination of two approaches, Propensity Score Matching (PSM) and Differences-in-Differences (DID). DID enables the estimation of treatment effects while eliminating individual time-invariant effects and time effects, however the method neither controls for unobserved temporary individual-specific components nor for differential impacts of macro-effects across the groups of comparison. Matching approaches, such as Propensity Score Matching[8] (PSM), are non-parametric approaches that match treated and non-treated individuals based on observable characteristics. The method eliminates selection on observables, thus ensuring comparability between individuals. Conditional DID combines the two approaches, providing scope for unobserved determinants of participation as long as it lies on separable individual and/or time-specific components of the error term (Blundell & Costa Dias, 2002). The combination of the two methods provides more reliable results, as argued by e.g. Heckman, Ichimura, Smith, and Todd (1998), Dehejia and Wahba (1999, 2002), and Smith and Todd (2005).

An additional issue that has great influence on our research design is the type and quality of (quantitative, unobtrusive) data available for the analysis. The data consists of all grant recipients and rejected applicants over the period in question. This is a strength for the analysis that we can use rejected applicants as a control group, which avoids selection bias based on possible differences according to whether individuals seek funding grants or not. We can also see if individuals have received more than one grant as principle investigator over the period in question or if they have received a grant earlier. However, we do not have data on grants from other funding sources. Furthermore, we are only able to identify the principle investigator for each application or grant. This both means that we are unable to examine impacts for all participants in the grants and that we do not know if the other participants have been involved in additional council grants. These issues influence in particular the design of the quantitative analyses of scientific publication and career outcomes, though they also have an important indirect influence on the survey and interview analyses.

An additional issue is potential differences in how research is conducted across fields. This was addressed in all analyses, typically by examining results both for the sample as a whole and for individual fields.

[7] Heckman (2005) also provides arguments that the experimental approach may not be the best research design to evaluate research policy.

[8] Rosenbaum and Rubin (1983).

3.3. Bibliometric data and analysis

The bibliometric analysis examines the impact of research grants by comparing publication activity for a subset of the sample, consisting of 208 applicants in all (21 grant recipients and 21 rejected applicants in each of the 5 main fields of science). Only a subset was selected due to resource constraints, as collection and preparation of bibliometric data is costly and time consuming. Generally, the social sciences and humanities are not included in bibliometric analyses, because data coverage in the available citation databases is generally low. However, the choice was made here to collect data on all 5 areas in order to maintain correspondence with the other analyses in the study. An additional motivating factor here was a desire to explore the feasibility of analysing the social sciences and humanities using bibliometric data. We discuss the validity of this choice in more detail below. Applicants for the period 2002–2004 were selected for the sample and publications and citations were measured in the four years prior to application and four years afterwards, beginning two years following the application year.[9] The two groups were chosen using the PSM matching procedure, based on a range of characteristics.[10] The aim of this procedure is to isolate effects of the grant by ensuring that selected grant awardees and rejected applicants are comparable in all other respects than the receipt of the grant, so that eventual differences in publication activity are not due to differences in academic position, research experience, etc. The sample consisted of pairs of grantees and rejected applicants with the best match on all criteria. Given that the bibliometric data was collected after sample selection, it was however not possible to include prior publications and citations as matching criteria. We attempt to address this and any remaining differences in initial conditions through the use of DID, focusing on changes over the analysis period as opposed to absolute levels. Publication counts are a simple measure of research production, whereas citations are considered as a proxy for short term research impact, not research quality per se. There are several modalities in the use of citation data, one which is important in evaluation contexts is that citation analysis can only be performed on publications after a number of years. This time lag is needed for publications to be able to accrue citations. An important aspect of bibliometric data (and for that matter, register-based data) in the context of mixed-methods is their role as unobtrusive supplementary measures that do not involve direct elicitation of data from the research subjects, which can be compared with data collected within the study. Measures based on bibliometric data typically need a context within which to be interpreted, such as that provided by data from the survey and qualitative interviews.

3.4. Register data analysis

The analysis of career progression is based on register-based employment and funding data for a broad based sample including all grant recipients and applicants over the period 2001–2008. The analysis compares the probabilities of obtaining a professorship and of obtaining a higher academic position three years after grant application. As with the bibliometric analysis, grant recipients and rejected applicants are matched according to the above mentioned characteristics in order to ensure comparability of the two groups. Both the bibliometric and career analyses examine impacts only for the principle investigators of grants and applications.

3.5. Questionnaire survey

A survey was also conducted among both grant recipients and rejected applicants.[11] The main objectives of the survey were to supplement the bibliometric and career analyses by collecting quantitative data on research projects as a whole and to examine the full range of effects listed above. The survey sample included all grant recipients (1546 with a response rate of 53%) and a random sample of rejected applicants (512 with a response rate of 39%). All individuals in the bibliometric analysis were included in the survey, but responses were obtained for only around half of them. Given the small size of the bibliometric sample, this precluded analysis of bibliometric and survey data combined.

3.6. Qualitative analysis

The final analysis in the study is a qualitative, case study analysis. In depth qualitative interviews were conducted to explore individual experiences and perceptions with both principle investigators from granted projects and with council members that are responsible for assessing grant applications. In all, 20 principle investigators and 10 council members participated in semi-structured interviews. The objective of the interviews with principle investigators was to gain more in-depth information concerning the same five thematic topics covered in the quantitative analyses, in particular those from the questionnaire survey, and to validate and deepen on these survey results. The objective of the interviews with the council members was to gain a broader systems view concerning grant evaluation practice over the period and within different fields, and general considerations concerning prioritization and grant outcomes.[12]

The principal investigators were selected randomly according to main field, gender, application year, and application size, while the council members were selected to cover main fields and gender. Semi-structured interviews were chosen to achieve a balance between open responses and a harmonization of interview material for comparison with the quantitative data. The case interviews were transcribed, coded and thematically analysed. The categories used in the analysis reflected a semi-structured coding process at where initial categories were chosen according to the interview guide and thereafter refined over the course of analysis (Gibbs, 2002). The coding procedure thus includes an inductive research strategy with open coding, allowing one to maintain an explorative approach with its basis in the empirical material (Charmaz, 2006; Glaser, 1998). This grounded theory strategy, involving the refinement and interrelationship of categories of information (Corbin & Strauss, 2008), helped support the development of emerging categories and themes which were subsequently held up against results from the other analyses. A description of the categories that emerged from the analysis of interviews with principle investigators can be found in the appendix.

Both the number of interviews and the sample selection process have implications for the analysis. The sampling process seeks both

[9] While the evaluation covers the period 2001–2008, the bibliometric analysis was restricted to 2002–2004 precisely due to this need to establish a 'window' of publication activity both before and after the grant period. See Mortensen, Thomsen, and Kruuse (2011) and Bloch et al. (2011).

[10] Field, application year, gender, age, academic position, research experience (years since Ph.D.) and receipt of council grants prior to 2001.

[11] Separate questionnaires were used for granted and rejected projects. The questionnaire for rejected projects was much shorter, excluding in particular questions on the importance of the grant. As with the other parts of the study, only principle investigators were included in the survey.

[12] Much of the interviews with council members delve into specific issues concerning specific funding rules, the Council's relation to other funding organizations, and other country specific issues. A detailed analysis of these aspects is beyond the scope of this paper; hence analysis of the interviews with council members is only discussed briefly in this paper.

to capture potential differences across fields and project size, and also to allow some degree of generalizability. However, and in particular due to the total number of interviews, this comes at the cost of a less in-depth understanding of the mechanisms behind many of the impacts, given that we do not have a large number of interviews with any particular type of respondent. An alternative approach would have been to strategically select cases in order to highlight different types of mechanisms, such as the role of increased recognition or networking and collaboration, or cases where critical mass is viewed as crucial for project success. Such an approach would potentially have facilitated more in-depth analysis of how funding impacts research, though prior knowledge of the principle investigators would have been necessary for selection. This was not feasible at the onset of the evaluation, but this type of interview sample selection could likely have been implemented using preliminary results from the survey. We discuss sequential design in greater detail below.

3.7. Combining the analyses – mixed methods design

A central aspect in the mixed methods design is how the four analyses are interconnected in terms of complementarity and validation for common factors and how they supplement each other with aspects that are not covered in the other analyses.

The career and bibliometric analyses supplement each other by covering two different aspects of research performance. Though, there is also a validation element here: do the results point in the same direction? If not, why? Can we identify possible factors behind eventual differences in results for the two analyses?

The questionnaire survey examines to a certain degree all types of effects in the study, with particular focus on the effects not covered in the career and bibliometric analyses, such as effects on collaboration, teaching, subsequent financing, and more subjective effects such as recognition among colleagues and risk taking or level of ambitions for the project. The survey also supplements the above analyses by providing information on the project as a whole, both basic project characteristics (number of participants, inclusion of PhDs and Postdocs, and whether the project is collaborative among different departments or institutions) and project impacts. The latter includes the importance of the grant for the hosting university department and the number and type of publications produced for the project as a whole. Results for publications can then be compared with those from the bibliometric analysis, though the many differences between the two measures greatly limit the potential for validation. In contrast, subjective questions concerning impacts on research and career progression were explicitly designed to facilitate comparison with results from the bibliometric and career analyses.

Survey data on rejected applicants are used to help characterize the control group, examining basic characteristics of the project, whether it was possible to secure funding for the project by other means and the impacts of not receiving a grant.

The qualitative interviews provide both complementary and supplementary information on the impacts of grants. They go beyond the quantitative analyses by examining not only whether grants had an impact or not, but on how and why they mattered. This gives us a much better understanding of what lies behind stated impacts. For example, general questions on impact may be quite helpful in identifying what were the most important impacts of the grants. The interviews with grant recipients serve an additional purpose in validating quantitative results, in particular those from the survey. However, as we noted above, there is a certain tradeoff between attempts to serve both purposes of validation and in-depth understanding.

Interviews with council members seek to put the results into a broader context, examining funding practice concerning key issues of the study, such as which factors or effects are given highest priority in practice, project size, project risk profiles, and how funding practices may influence project outcomes. This work can be linked with the background work or desk research that is typically needed for the development of any study. This work included both a detailed examination of the complete funding database for the council and of the practices used both in the application process and in awarding grants, supplemented by interviews with council members. This work covered a number of items such as laws, rules, co-finance and admission demands, system items such as institutions, councils, key persons, announcement of research funding programmes, selection rules, demands to applicants, and policy priority items such as strategic priorities, financial constraints or policy targeted programmes in specific fields. Together with the interviews, this background work was important in framing the study. However, an important point here is that this framing analysis is not exclusively ex ante; both interviews and desk research were ongoing throughout the study to allow adjustment to initial outcome assessments.

4. Results from the use of a mixed methods based evaluation

This mixed methods approach to impact evaluation of research grant funding thus seeks to utilize the best available data sources in a way that gives robust and comprehensive answers. However, a number of constraints, such as time, resources and respondent burden raise the need for pragmatic compromises in an evaluation. This was also the case in this particular evaluation.

Table 1 lists the five different types of effects that were addressed in the evaluation and the sources used to examine them. For the interviews and the survey, the table includes actual questions that were used in the evaluation.[13] As can be seen, all five types of effects were identified using more than one data source. In the following we first present selected key results of the analysis in order to illustrate how our approach functioned in practice, and thereafter critically analyse the approach. As we have alluded to above, many of these effects are difficult to investigate in full, either due to data or statistical limitations or to the fact that the concept itself if fuzzy and can be understood and examined in many ways, though often only partly so. We present the results through three different examples concerning funding effects.

4.1. Example 1: career impact measures

The first example is the effect grants have on recipients' careers. Here the use of a mix of three methods – analysis of register-based data (career analysis), survey and interviews – clearly provided us with a more comprehensive understanding of the effects than a single method approach would have done. The characteristics of groups of grant recipients and rejected applicants are fairly similar in terms of age and gender, but there are significant differences in academic position. Around 86% of grant recipients had a tenured position at the time of application, of these 30% with professorships. In comparison, 65% of rejected applicants had a tenured position, with 14% as professors. These differences in qualifications at the time of application illustrate the importance of using matching methods in order to 'level the field' when making comparisons.

If we first look at the career analysis results, we found that, among non-tenured researchers and associate professors, grant recipients had a substantially higher probability of becoming professors within three years after grant application compared with rejected applicants. The career analysis of the evaluation thus

[13] This does not cover all questions used in either of these analyses. The full survey questionnaire and interview guides can be obtained from the authors on request.

Table 1
Types of effects and how they are addressed in the study.

Research effects (input additionality)
Interviews
Did the grant make possible research that you otherwise would not have been able to perform?
In your view, of what importance was the size of the grant for your career, research, etc.?
Survey
The grant gave the opportunity to produce novel results within my field.[a]
Output effects (output additionality)
Bibliometric analysis: publications and citations
Interviews
What came out of the grant? More publications, collaborations, additional grants, other?
Survey
Please provide the number of scientific publications that were directly the result of the funded project (list of types of publications).
Have received awards based on research within the grant.[a]
Behavioural effects (behavioural additionality)
Interviews
What was your experience of receiving a grant from the Danish Council?
What did the grant mean for your research management competences and what types of expertise did you gain from the grant?
Survey
The grant led to other applications or grants.[a]
Formal collaboration with Danish/International research environments.[b]
Management of a research project.[b]
Management of a permanent research group.[b]
Participation in a large, international research project.[b]
Participation in international councils or boards.[b]
Career effects (career additionality)
Career analysis: vertical and horizontal mobility, income effects.
Interviews
What did the grant mean for your career?
In your view, of what importance was the size of the grant for your career, research, etc.?
Survey
The grant was important for the continuation of my academic career.[a]
Research environment effects (institutional additionality)
Interviews
Did the grant allow you to employ younger researchers (PhD, postdoc), and if yes, what did they get out of the grant?
Has the grant has any importance for your integration in relevant research environments?
Survey
The grant has strengthened the department's recognition in relevant national and international research environments.[a]
Work and results under the grant gave the department better ability to attract research talents within relevant fields.[a]

[a] Respondents asked to what extent they agree with the statement (5-point scale from "completely agree" to "completely disagree").
[b] Respondents asked whether they participated in the activity before the grant and after the grant.

showed that there is a positive difference between grant recipients and rejected applicants when it comes to securing a professorship (Bloch, Graversen, & Pedersen, 2014). Grant recipients have a 7% point higher probability of becoming a professor in the period after the grant reception than rejected applicants (16% compared to 9%), and the effect is highly significant (p-value = 0.003). We find a similar result for the likelihood of career advancement in general (advancement either from a non-tenured to tenured position or from associate to full professor), 23% for grant recipients compared to 15% for rejected applicants. This difference is also significant with a p-value of 0.011. The career effects for associate professors and non-tenured researchers may be different, but due to the small share of non-tenured researchers, we are forced to combine them, and are thus not able to estimate effects for early career researchers separately. However, both interviews and the survey allow us to examine this issue in greater detail, where grants appear to be particularly important for researchers early in their careers (see below).

The survey results both supplement the register-based analysis by covering a broader range of effects ("elaboration" in terms of Greene et al., 1989), complement them by examining career impacts from different perspectives, and to a lesser degree can also be used to validate the above results.

To illustrate, some survey results concerning the importance of the grant for the principle investigator can be highlighted. Three out of four recipients said that the grant had led to other project applications or grants, and approximately 60% believed that the grant was essential for their careers. About 90% said that the grant allowed them to produce new research. About 6% said that the grant led to the formation of a new company, while 23% received awards or distinctions on the basis of their research. In general, shares do not vary much by academic position (non-tenured, associate professor, professor), though with the exception of importance for continuing their research careers. Shares for associate professors and non-tenured researchers are 67% and 59%, compared to 45% for professors.

Career effects can also be measured in terms of research based competences, such as research management and international collaboration. Fig. 1 shows the share of respondents that have participated in research based activities before and after grant receipt, by academic position at time of application. The figure indicates that it is to a very large degree the non-tenured researchers and associate professors that acquire new competences through the grants, not professors (who often already have them). In terms of own assessment of the importance of the grants for these competences, there is however very little difference in the shares across the three groups.

Qualitative interviews corroborate these results and further complement the picture by examining how and why grants have impacted academic careers. Several of the interviewed grant recipients said that the grant had had a positive impact on their career. One recipient stated: "The grant has without doubt meant a lot to my career. I got a position as a professor, and my recognition and competence were also raised within the research environment." (Grant recipient within the Humanities, translation by the authors). Another recipient put it quite similarly, though also stressed the positive effect the grant had on her research environment: "It was really nice to get the grant. It also led to a more attractive position (as a professor, ed.). And it allowed us to establish a whole new research area." (Grant recipient within the Medical Sciences, translation by the authors).

In addition to this, several of the interviewed grant recipients said that the grant had had a "snowball effect" in relation to their career. They had experienced an increase in invitations to participate in conferences, to give lectures and to become reviewers. Some of the informants also experienced being offered exciting tasks as members of research boards or to become chairmen of a major programme committee.

The interviews furthermore made it clear that receiving a grant is associated with prestige and recognition which, as alluded to above, has a positive impact on their research. If an application leads to a grant, it is described as an endorsement of the researcher's research. This means that the grant recipient "moves up in the recognition hierarchy", as one interviewee put it. To have success in obtaining external research funding is seen as particularly important for universities in the future, and in the scientific community there is an awareness of the fact that the success rate of applicants for Council grants is low (average of 24% for the period as a whole). Therefore the applicants who manage to get a grant experience greater respect for their work. One of the interviewees stated: "One's prestige and competences are highlighted within the research environment. For me it has to a large extent meant that I have gone from a lower level in research on to a higher position in my field. It has meant a lot."

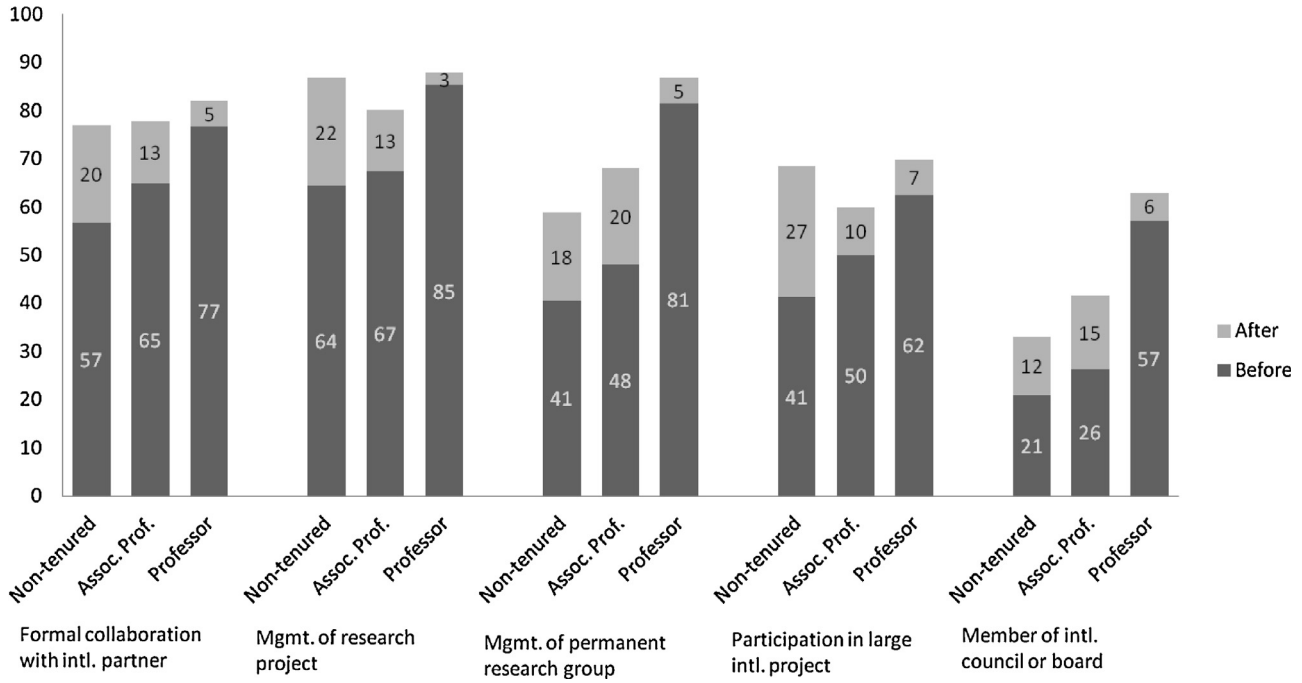

Fig. 1. Research-based competences before and after grant receipt, 2001–2008.
Source: Bloch et al. (2011). *Note*: "Before" and "After" show the share of grant recipients that had participated (during their academic career) in the activity before and the additional share that had participated in the activity after completion of the grant project.

(Grant recipient within the Humanities, translation by the authors).

The combination of the three research methods into a mixed method approach perhaps did not change the overall positive picture of the career effects that was first shown in the register based analysis. However, the combination of the three methods – including combining quantitative and qualitative methods – achieved a more comprehensive understanding of the effect a grant has on the applicant's career in terms of position but also in terms of prestige, research independence and other qualitative effects. For example, the survey supplements the register-based analysis with a broader set of effects, which are important in helping explain how and why grants have an impact on careers. The interviews go further along these lines with more detailed analysis of how the positive effects are achieved, which is very valuable for future design. Finally, both the interviews and the survey function as a validation tool for quantitative results, and appear to confirm that grants are important towards becoming a professor.

4.2. Example 2: output and impact measured by publications and citations

Another illustrative example of the strength of the chosen mixed methods design relates to the analysis of the output and impact of the research grants. In this part of the evaluation, bibliometric data and survey data were used to evaluate scientific output from research grants in form of publications and citations and the results were validated against survey results and impressions collected among the key interviewees from research councils and universities and ex ante desk research results found elsewhere. Effects on article production and impact for project research grant receivers were analysed by "matching"[14] grant recipients with rejected applicants using the procedure described above.

[14] A "similar" researcher matches on characteristics such as age, scientific field, years since Ph.D., gender etc., and distinguishes only on grant receiving.

Table 2 below presents the main bibliometric results. Preliminary examination of the data for all five fields showed that a number of researchers within the social sciences and particularly within the humanities did not have any registered articles in either the before or after periods, which suggests that coverage of publication activity for these fields in the bibliometric data may not be adequate for the analysis. For this reason, we have restricted the analysis of results shown here to the natural, medical and technical sciences. The strict matching process, combined with multiple indicators calculated before and after the "treatment" and analysed with difference-in-difference, offers in our view a reliable approach to examine the impacts of grants on research performance. However, bibliometric data is typically heavily skewed, with a small share of researchers producing a large share of publications and receiving the majority of citations. This complicates the use of standard statistical tests, as the data does not follow a normal distribution. Furthermore, the small size of the sample used for the bibliometric analysis, also suggests that the results of the actual analysis here should be treated with some caution.

Given the skewness of the bibliometric data, we use non-parametric statistics to compare grant recipients with rejected applicants. The Mann–Whitney test compares the distributions of the two samples and tests whether the two populations are the same or if one tends to have larger values than the other. Table 2 shows results for number publications, number publications fractionalized by number of authors and field normalized citation scores. For each indicator, mean and median values are shown, and *p*-values from the Mann–Whitney test.

In general, both groups of researchers have experienced increases in their scientific production over time; hence, the analysis of grant impacts needs to evaluate whether the grant receivers had a larger increase compared to the "matched" researchers. The results found were that grant receivers both initially and afterwards were more productive and their articles on average had a larger impact. Both for the total number publications and fractionalized publications (which account for number

Table 2
Results from the bibliometric analyses.

		Difference in publication and citation activity between grant receivers and rejected applicants *before* the application (4 year period before application)		Difference in publication and citation activity between grant receivers and rejected applicants *after* the application (2–5 year period after application)		"Difference-in-difference" in the development of publication and citation activity between grant receivers and rejected applicants	
		Mean	Median	Mean	Median	Mean	Median
Number of publications	Grantees	18.67	13.00	21.35	15.00	2.68	1.00
	Rejected	13.57	9.00	14.43	12.00	0.86	1.00
	p-Value	0.016	0.122	0.907			
Number of fractionalized publications	Grantees	8.54	7.32	9.34	7.11	0.81	0.40
	Rejected	6.09	3.59	5.65	4.15	−0.44	−0.10
	p-Value	0.006	0.013	0.431			
Field normalized citation scores	Grantees	1.36	1.22	1.41	1.19	0.04	0.00
	Rejected	1.19	0.96	1.19	1.03	0.00	−0.02
	p-Value	0.092	0.368	0.749			

Data source: Scopus publication and citation database.
p-Value of Mann–Whitney test of whether distributions differ between grant recipients and rejected applicants. Results based on a matched sample of grantee and rejected applicants within the natural, medical and technical sciences for 2002–2004. Total number of observations: 63 grantee and 63 rejected applicants (21 within each field).

co-authors) the differences between grant recipients and rejected applicants before the grant period are statistically significant. Differences in the distribution for field normalized citation scores are weakly significant at the 10% level. After the grant period, differences in mean values are somewhat larger than before the grant period, however median values are slightly smaller. Test results show that differences in distributions after the grant period are only significant for fractionalized publications.

In terms of measuring whether grants have had a positive impact on research performance, the main question is whether differences between the two groups are larger post-grant than they were before grant application. Here we do not find a statistically significant effect for any of the measures. In comparison of differences before and after, it can be seen that differences are indeed larger after the grant period, but the "difference in difference" measure is not statistically significant for any of the three performance measures examined. We also conducted the analysis excluding the lowest and highest five percentiles for each measure, to examine potential influences of extreme observations. For all three measures, differences between grantees and rejected applicants both before and after increased in size, though with no qualitative change to the difference in difference measures.

The survey collected data on the number of publications for the project as a whole which were the direct result of the grant. This data provides valuable, albeit less objective, data on the total research output of project grants, though it cannot be used to validate the above bibliometric results for principle investigators. We discuss below how this data can be used to examine the impact for different types of projects.

While the survey is perhaps less suited to validate the bibliometric results, it allows us to better characterize how grants influence researcher behaviour and how they impact research performance. For example, 91% stated that the grant gave them the opportunity to produce very novel research results within their area, and 65% stated that the grant had resulted in unexpected results of great importance for their field. In addition, 25% stated that they had received awards for their grant project work. Finally, 50% stated that their granted research project was more ambitious than their research work in general. Hence, the survey results suggest that research grants may affect research performance both by providing the opportunity and the motivation to advance their research more than otherwise would have been the case.

Unsurprisingly, all interviewed grant recipients were very pleased to have been awarded the grant and stated that it had a positive influence on their research. While some did not feel that the grant was crucial to their research performance, many attached significant importance of the grant to their research, both within the project and afterwards. For example, one interviewee states: "It was possibly even more promising than expected. We got a lot out of the grant, and it (the project research) really has paid off in our later work. It was very important, what we achieved (in the project)" (Grant recipient within the Natural Sciences, translation by the authors). However, it is also worth noting that, while some interviewees describe grant impacts in terms of research results, the far majority focuses instead on the impact the grant has had on their research through career advancement.

4.3. Example 3: comparing the benefits of small versus large grants

The role of grant size for funding effects will function as the last example of our mixed methods approach. An important focus of this study has been a comparison of the benefits of funding small versus large grants. The question is particularly relevant given general international trends towards the funding of larger and larger projects.[15] A central argument behind the concentration of resources in centres or larger projects is that it creates a critical mass that is needed to promote scientific excellence. The concentration of funds in a smaller number of hands though has distributional consequences that motivate a number of questions, in particular concerning the effects of increased competition for funds and declining acceptance rates and the extent to which a focus on excellence comes at the expense of equity.

Knowledge on the relative benefits and effects of small and large grants can thus be used to assess this trend and whether there are any negative consequences of a shift away from the funding of smaller projects. This example is very instructive in demonstrating the benefits of a mixed methods approach, which allows us to characterize trade-offs in terms of grant size.

The research project grants evaluated here are typically small to medium size, though with large increases in the average size of grants over the period, from $163,000 in 2001 to $300,000 in 2008 (both in 2001 prices).

The most striking result concerning grant size is the survey results from the estimation of total project publications produced;

[15] This study is no exception. In 2001, 65% of all project grants were under $165,000, with 19% greater than $250,000. By 2009, the share of small projects had decreased from 65% to 16% and the share of projects over $250,000 had increased from 19% to 70%.

the average number of peer-reviewed articles per $100,000 granted was found to be substantially higher for small grants (under $160,000), more than double that for large grants in 4 of the 5 fields.[16] Though, it should also be noted that it is likely more difficult to accurately account for all publications for larger grants, which may lead to their underestimation.

One qualitative aspect that is worth highlighting, and one that was mentioned in part above, is that virtually all interviewees stressed the importance for their subsequent careers, and hence also the quality of their research, of simply having been awarded a project grant of any size from the Council. Small projects were often cited by interviewees as 'kick-starting' research careers, leading to larger projects and important research results. On the other hand, some interviewees complained that grants that were too small limited what they were able to do, and the need for funding from other sources could result in a loss of continuity in research work. Larger projects also hold a potential for 'second generation effects' for the young researchers involved in the project. And, according to both survey and interview results, small and large projects were given equal importance in establishing collaborative relationships with other researchers. Finally, the career analysis also contributes to this issue; both small and large projects were found to increase the probability of career progression. Though, the probability is slightly higher for large projects, potentially indicating the effects of leadership and fundraising of a large grant.

It is important to note that the role of grant size may vary greatly across fields.[17] We have examined this both through the comparison of small and large grants within each individual field and also through comparison across fields. The need for equipment, labs and other 'non-labor' expenses is clearly greater in general for the natural, medical and technical sciences, and among those respondents that argued that their project would not have been at all possible without external funding, the far majority are from these more technical areas. However, beyond this, there is no clear cut difference concerning the role of project size across fields. Average grant size for the humanities (310,000 USD in 2008) and social sciences (217,000 USD) are comparable to those for natural sciences (243,000 USD) and medical sciences (175,000 USD). In contrast, average grant size is much larger within the technical sciences, at 690,000 USD. In terms of project publication output, we have noted above that the number of articles per 100,000 USD is much higher for small grants within four out of five fields (the exception here is the natural sciences). Interview responses are also fairly similar across fields in this respect; with both examples of interviewees emphasizing the importance of small grants (or grants of any size) and examples that a certain critical mass is best for project performance.

These combined results are far from conclusive, but they indeed motivate further consideration of common perceptions that research funding in the form of large project grants or centres are most beneficial, and motivate further analysis into this question.

[16] Differences were statistically significant, with p-values under 0.01 for the full sample, technical sciences, social sciences and humanities, and a p-value of 0.03 for the medical sciences. Within the natural sciences, the average number articles per $100,000 was higher for small grants, but the difference was not statistically significant (p-value = 0.30).

[17] It should also be noted here that our data is for grant size for funding from the Council, which may not reflect the full size of the project if there are other funding sources. We do not have data on total project budgets, but do have data on application size which may provide an indication of overall project size. The shares of applied amounts that were granted vary across fields (around two thirds for the natural sciences, social sciences and humanities, under 50% for medical sciences and around 90% for technical sciences) but there is little difference in the percentage awarded for small compared to large grants.

5. Discussion and implications for future design

We discussed above the potential strengths and limitations of the mixed methods approach that we developed and implemented for this study. An ex post assessment of the results allows us to validate many of our expectations on how the method functions, but it also presents some new insights. We examine first each of the analyses individually and then turn to the interaction between them.

Consider first the bibliometric analysis and its connection to the other analyses. While a larger sample would have improved the results' reliability, the approach used here provides an effective way to measure the effects of grants on research performance. Though, while this analysis utilizes objective data, it still must contend with a number of measurement challenges. For example, the timing and precise reference to the evaluation object was not identified. We must also reckon with some non-classical measurement errors in publication and citations measures because of false positives in the matching of bibliometric data with the author names in the bibliographic database. Further, the data only covers the principal investigator and does not include additional project participants and output.

Despite a lack of full coverage, this approach is still able to produce useful results on the impact of grants. The principle investigator is typically both the leader and key researcher behind the project, and thus has the most to contribute and the most to gain from the grant. Hence, in a number of ways, a focus on impacts for the principle investigator makes good sense. And for some parts of the analysis, such as the survey, it would also seem to be the most sensible procedure as it is the principle investigator that is the most knowledgeable on the project as a whole. However, the results of this study point to a number of relevant areas that cannot be covered through this type of approach. First, survey results showed that a large share of grants (43%) included either PhD students or postdocs, motivating the important question of what were the effects of the grant for these early career researchers. Second, results showed that the actual involvement of PIs varied greatly, from being the main driving force behind research work to a marginal, administrative role. This complicates efforts to translate results for PIs to impacts for the projects as a whole. Third, there is clearly a political interest in mapping the full effects of the funding resources invested in grants. Finally, a large share of grants involved collaborations between different institutions and likely also often included additional collaboration with external partners. Being able to map this networking activity would provide valuable insights on the broader effects of funding grants.

An additional issue is the interaction between the qualitative and quantitative studies. As mentioned above, a risk with the design of the interview study here was that it would mainly illustrate effects as opposed to examining in-depth how the effects came about. Our assessment is that the interview approach used here went beyond a mere illustration, and was useful in describing the various mechanisms in play and to some degree their relative importance. It is important to note that many intermediate effects are essentially elements in the eventual impacts of funding on research performance. Examples here are descriptions of the roles of increased recognition and networking. However, the interviews may still have been more beneficial if a more narrow focus was placed on these mechanisms.

Studies of this kind are typically subject to restrictions both in time and resources, which often means, as was the case here, that all analyses need to be conducted parallel to each other. We outlined many of these potential limitations in the previous section. Our general assessment is however, that the careful design of the different analyses can ensure that they are well integrated, with the results building on each other despite the analyses being conducted at the same time. For example, the interviews were able to probe into issues uncovered in the survey, even though they

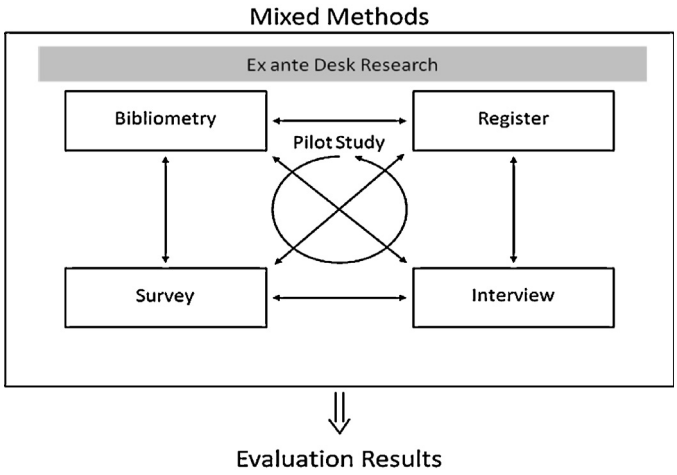

Fig. 2. A model of mixed methods dynamics, interactions and use in an evaluation of project research grants.

were conducted with little time lag. However, a clear advantage to a more sequential design is that, for example, interviews can explore unexpected results. A case in point here is the survey result that smaller projects appear to generate in relative terms a larger number of publications. Furthermore, with a sequential design, initial survey results could be used to better target the selection of interview cases towards key issues regarding the mechanisms of funding effects. A further advantage of a sequential approach would have been to collect bibliometric data in advance of the other analyses. While the matching process used in this study was successful in eliminating differences between grant recipients and rejected applicants concerning a number of characteristics, publication history could have further augmented quality in other parts of the evaluation. In addition, both matching criteria and subsequent analysis using bibliometric data have to contend with the general skewness in science. Instead of matching in terms of number of publications or focusing on average effects, we should for example match in terms of citation rates and measure impact in terms of the production of 'excellent' (highly cited) publications.

Hence, while a primarily concurrent design was chosen here due to time considerations, there are a number of arguments for a more dynamic, sequential design, that enhances the interactive element of the analyses, allowing for larger and more inclusive feedback loops in the data collections process, i.e. mixing data from different sources in new interconnected, imbedded data sources, cf. Creswell and Plano Clark (2007). However, at the same time we should be careful not to exaggerate the possibilities for greater sequencing in practice. Typically, time and resource constraints will not allow full sequencing where one analysis is fully completed before the next is started. What we are proposing here is moderately increasing the sequencing compared to our analysis, but at the same time more careful planning as to how intermediate results can be used across analyses. Fig. 2 provides a simple illustration of the model with both data source interactions and feedback possibilities.

In addition, coverage of the many types of effects can potentially be further augmented to include issues not covered in the study here or to increase the number of analyses that cover them in order to better validate and complement results. We have argued above that a larger bibliometric sample is needed in order to obtain more reliable results, and that data should seek to cover all participants in grants. However, bibliometric data can also be used to analyse other aspects than the effect of grants on individual researcher performance. Both publication co-authorship and citations can be used to examine collaboration and networking patterns among researchers, and citations can also be used to construct indicators of the broader societal impacts of grants. To a lesser extent, interviews and surveys can also be used to gauge the broader impacts of research funding.

6. Conclusion

Evaluating complex and multidimensional issues such as the effects of research funding is a methodological, theoretical and practical challenge. Solid and comprehensive conclusions can not be reached with the singular, quantitative focus on research output – even though such measures often have been used alone – but requires the application of a number of both quantitative and qualitative methods as well as deep multidisciplinary knowledge of the issues at stake.

From this point of departure this paper has presented and discussed an attempt to develop a mixed methods approach to analyse research funding. In our discussion of the study design and its results, we have in particular focused on the interaction between the four applied sub-analyses in terms of validation, complementarity and how they supplement each other in covering the broad range of potential impacts of research grants. The paper has accordingly illustrated the value of a mixed methods approach to provide a robust and complete analysis of complex policy impacts, not least due to the inclusion of qualitative methods to complement and validate quantitative results.

Reflections on the strengths and weaknesses of the methodology has however also been used to propose refinements of the approach for future work. Both our ex ante discussion and the ex post assessment of the study results suggest a number of directions that can be pursued in future work. An example here relates to the sequentiality of the study. Even better results could be achieved with greater focus on sequential design that enhances the interactive effects of the individual elements over the course of the study, allowing for larger and more inclusive feedback loops.

Acknowledgements

Financial support from Aarhus University's Senior Management Strategic Funds for the project 'Contextualizing and Measuring Research Performance' (CoRe) is gratefully acknowledged. We thank Peter S. Mortensen for his work in collecting data and developing the indicators that were used in the bibliometric analysis in this paper, and Stine T. Faber, Lise Degn and Tine Ravn for their work in conducting and analysing the qualitative interviews with grant recipients. This paper has also benefited greatly from the comments by four anonymous reviewers.

Appendix

See Table A.1.

Table A.1
Master headings and subheadings that emerged from qualitative interviews with 20 principle investigators.

After grant
• Additional effects, Reporting
Before grant
• Action areas, Career starting point, Motivation for applying, Considerations regarding size of grant, Application process
Attitudes towards The Danish Council for Independent Research (DFF)
• The importance of free research, Criticisms - proposals for improvement, Small versus large grants
Risk assessment
• Level of ambition, Completed as planned, Achievement of objectives, Results as expected, Risk
Benefits of a grant
• Second generation effects, Recruitment of junior researchers, Establishing a research career, Freedom, Integration, Leadership skills, Enabled research, Prestige issues, Publications, Cooperation and networking, Overall assessment, Side effects, Meaning of grant size, Time, Educational meaning

Source: Degn, Thidemann Faber, and Ravn (2011).

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Carter Bloch is research director at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government at Aarhus University in Denmark. His research focuses on impacts of funding on research careers and performance, innovation measurement, knowledge spillovers, and the relationship between R&D, innovation and economic performance. He has led a number of international and national projects concerning research evaluation, development of innovation indicators, the measurement of innovation in public sector organizations, and micro-based data analysis. He holds a Ph.D. degree in economics from Aarhus University.

Mads P. Sørensen, Ph.D., is Senior Researcher at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. He is author and co-author of several books, journal articles and book chapters. His latest publications include *Ulrich Beck. An Introduction to the Theory of Second Modernity and the Risk Society*, Routledge 2012 (paperback 2014).

Ebbe Krogh Graversen, Ph.D., is Associate Professor and Research Director at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. His research is in impact and effect measuring and incentive structures and has been concentrated on knowledge relations and innovation capacity, programme evaluation, indicator development, ranking, benchmark and impact of policy initiatives. He has also analysed industry – science relations, impact of research management and best practice in research environments.

Jesper W. Schneider is Associate Professor at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. He holds a PhD in Information Science and is former Head of Department at the Royal School of Library and Information Science, Denmark. He has performed numerous evaluations in Denmark concerning research performance. His areas of interest include scientometrics, bibliometrics, research evaluation, scholarly communication, sociology of science and statistics. His current research focuses on contextualizing

excellent research performance; problems relating to the understanding and misuse of statistical significance tests; and applications of Bayesian statistics.

Evanthia Kalpazidou Schmidt is Associate Professor and Research director at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. Her main fields of specialization are S&T evaluation and policy, higher education policy, organizational development, efficiency and productivity in a comparative perspective, S&T and gender issues. Her activities include evaluations in the European Research Area and numerous EU research projects. She has since 2003 been the Danish expert member of the European RTD Evaluation Network. She is frequently engaged by the EC as expert in the evaluations of FP6 and FP7 proposals, and on ex-ante impact assessments of Horizon 2020 in the area of environment.

Kaare Aagaard, Ph.D., Postdoc at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. He works with Danish and International Higher Education-, Research- and Innovation Policy applying both quantitative and qualitative methods and has great experience with evaluations and knowledge exchange in various forms. Issues of public research funding and the effects of different allocation mechanisms have been at the centre of his academic work.

Niels Mejlgaard is M.Sc. (Political Science) and Ph.D. (Development and Planning). He is Director at the Danish Centre for Studies in Research and Research Policy, Department of Political Science and Government, Aarhus University. His research interests include science and technology policy, science governance, and public engagement in science and controversial technologies. He has published in on these issues in leading broad and specialized journals including Science and Public Policy, Public Understanding of Science, Science as Culture, and Nature Biotechnology.