Navigating the impact-innovation double hurdle: The case of a climate change fund

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Abstract

This paper analyses how the funding for research grants was allocated from a specific research fund which aimed to support innovative research projects with the potential to have research impact by reducing carbon emissions. The fund received a total of 106 proposals, of which 27 were successful at obtaining financial support. Our aims were to test which factors influenced the funding decision and to discover whether or not and to what extent the fund met its intended objectives through the allocation of monies. The allocation process and its outcomes were analysed using correlation, logistical and linear regression to test our research hypotheses. Using this research funding process as a single study, we found that trying to clear the impact-innovation double hurdle in a single funding initiative ultimately compromises both goals. This paper therefore contributes to our understanding of innovation management within the context of carbon emission reduction and explains which factors influenced success in securing research monies through the funding process.

Keywords: research funding, carbon emissions reduction, innovation, research impact

1. Introduction

Scientific research has been positively associated with technological change (Dasgupta and David, 1994; Diamond, 1986; Gerschenkron, 1962; Jaffe, 1989), which in turn affects economic growth in Western economies (Schumpeter, 1934; 1943). For some time, Western societies have been evolving towards the need for public research to generate useful outcomes for increasingly diverse and competing stakeholder demands and interests (Braun, 1988; Cole et al, 1981; Moore and Garnsey, 1992; Viner et al., 2004; Wenneras and Wold, 1997). There is also increased need for research that can be put to practical application in the private sector for the delivery of more diffusion-oriented policies which encourage knowledge adoption, as opposed to mission-oriented policies which create new knowledge (Ergas, 1987). This is resulting in a changing institutional order that is becoming increasingly pre-occupied with demonstrating the impact of research investments through considerations of commercial potential and beneficial societal outcomes (Sarewitz and Pielke, 2007). Not surprisingly, this has led to tensions between various constituencies (researchers, institutions, funding bodies) and has raised questions about whether or not pursuing research and commercialisation activities are actually competing or complementary endeavours (Archibald and Finifter, 2002; Goldfarb, 2008; Perkmann and Walsh, 2008).

Benner and Sandström (2000) analysed the institutional regulation of research and revealed that funding reforms across different countries, whilst continuing to recognise scientific merit, were also emphasising utility and the future commercial potential and societal benefits. Etzkowitz and Leydesdorff (1996) introduced the construct of the ‘triple helix’ to illustrate that in addition to academic interests, industrial and political interests were progressively being considered in the evaluation, organisation and performance of university research. This amalgamation seeks to better service the new knowledge based economy which promotes technology and market driven economic renewal. Inevitably evaluation criteria for academic work are being redirected towards commercial application and matters of wider beneficial social outcomes, rendering user- and industry-university collaboration as paramount to achieve better reconciliation between the ‘supply’ of information and knowledge and the ‘demand’ function that seeks to apply it to meet societal goals (Sarewitz and Pielke, 2007).

Funding agencies clearly influence the new institutional order by designing and re-designing the standards by which research is evaluated and the granting actions that proceed (Benner and Sandström, p293 2000). “*All researchers submitting proposals therefore, must structure their research practice according to the exigencies coming from the administrative logic of the funding agency*” (Braun, 1998, p810). Naturally, this has led to changes in the way research proposals for monetary funds are expressed, constructed, negotiated and re-negotiated through an often lengthy peer review process where researchers must express their research in terms of external problems and where funding agencies have to reconcile the demands of both scientific and political actors (Braun, 1998). The pursuit of funding for many scientific actors, or so called Principal Investigators, often marks the start of a successful academic career leading to full tenure in academic establishments (Baruch and Hall, 2004). Other research illustrates the importance of attracting funds for researchers in their early and formative years, if they are to continue with successful academic careers (Melin and Danell, 2006; Jacob and Lefgren, 2011).

Human-induced climate change is increasingly being recognised as a key external problem that should be addressed by researchers from multiple disciplines (Goodall, 2008). In response to this, funding agencies are making explicit calls for research that addresses climate change and inviting proposals from academics in many different disciplinary fields. Although previous studies have examined how research funds are allocated, much of this work has focused on generic programmes and examined how the peer review system protects existing networks and paradigms (Walsh, 1975; Travis and Collins, 1998). Further articulating the inadequacies of the peer review system Grant and Allen (1999) suggest that it is “*inherently conservative and biased*” (p.201) against more innovative and fundamental research propositions and they call for novel evaluations techniques to be introduced. Heinze (2008) espouses the warning that a scientific exploration of novel research frontiers will inevitably result in more risky and ground-breaking research proposals entering the review process, and will demand a break from tradition and the creation of new assessment structures.

Other previous work has also considered whether or not the distribution of research funds is meritocratic and whether or not gender plays a part in the distribution of funds (Wenneras and Wold, 1997; Viner et al, 2004). Interestingly, Langfeldt (2001) observes a general lack of clear norms for peer review assessment practice and variations in the criteria that different reviewers emphasise, illustrating the subjective and interpretive nature of such processes. Furthermore, although there has been research on which disciplines are tackling climate change issues and are publishing academic papers on the topic (Goodall, 2008), there is a dearth of research on how funds for climate change research projects are being distributed. This research makes a step towards addressing this gap, by focusing on one specific climate change funding initiative.

In this paper, we explore how one research fund, with an explicit dual innovation and research impact agenda, distributed its funds across 27 projects. The fund received a total of 106 applications, all claiming to reduce carbon emissions. The research fund had the overall aim to fund projects that could demonstrate carbon emission reduction, that were innovative and that could demonstrate the application of knowledge and future commercialisation of the research. A detailed description of the call for proposals and aims of the funding programme is given in section 2.1. By comparing the successful and unsuccessful research proposals, we aim to identify which factors influenced the decision making process for allocating the research funds. In particular, we wanted to assess whether or not this particular research fund achieved its potentially competing aims of impact and innovation. In this paper, first we develop the research hypotheses that guided the analyses and then we describe how the research proposals were analysed and the statistical tests employed to compare successful and unsuccessful projects and test our research model. We then present the results and finally discuss these to arrive at our conclusions and implications for future research, policy and practice.

2. Hypotheses Development

Based on the aim and goals of the research fund, and supported by a thorough review of the literature, eight research hypotheses were developed.

2.1. Description of the Research Fund

We had access to the evaluation and the decision making process involved with the provision of research grants in a specific programme relating to carbon emission reduction. This fund totalled over three million British Pounds (£3,000,000), and was distributed following a formal and open procedure of bidding.

The stated aim of the programme was: "*to give support to innovative projects which involve the application of knowledge generated in a higher education institution into a 'live' context, with the overarching theme of achieving carbon savings and reducing carbon emissions*". The programme had two stated key goals. The first was to achieve measured carbon savings. Projects supported by the fund would need "*to demonstrate the potential to achieve carbon emissions reduction and outline the possible impacts if widely applied*". The second goal was innovation. It was stated that the projects funded should "*introduce something new, in addition to achieving the objective of facilitating carbon emissions reduction*". It was anticipated that "*the proposed innovative change would vary from substantial and radical to incremental and progressive*". The innovation could relate to "*the technology that is being worked on, the systems that are being applied, or the working practices that are being established*". The criteria for the assessment of innovation were that the project should be "*substantially breaking new ground and have the aim of collecting evidence to endorse the further adoption of the technologies and techniques under review.*" The programme was particularly interested in supporting "*projects which focus on undertaking trials, gathering evidence and/or developing an existing proposition to achieve product/process credibility in the marketplace.*"

Other conditions for successful funding include that the project must be led by a UK university. The university should also be working with at least one non-university partner to ensure that the project team can integrate both knowledge generation and application activities within a live commercial context. The guidelines for applicants advised an upper threshold of £100,000 for projects, but higher amounts would be considered, where "*critical to project success*".

2.2. Carbon Reduction Predictions

The 2008 United Kingdom (UK) Climate Change Act (UK Parliament, 2008) states that "*It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least 80% lower than the 1990 baseline*" (p1). It is also now widely acknowledged that human-induced climate change is a result of the production and consumption patterns that have emerged to meet society's evolving needs (Unruh, 2000; Foxon and Pearson, 2006) and that these need to be addressed by switching from fossil fuel based systems to more efficient and non-fossil fuel sources of energy. However, it is broadly recognised that industrialised economies have become locked-in to fossil fuel based technological systems and processes and it would be difficult to make the required changes (Unruh, 2000; Foxon, 2002).

In response to the climate change issues, research funding for climate change programmes is increasing. For example, the UK Research Councils now have commissioned funding initiatives that target climate change and carbon emission reduction projects. In addition, specific funds, such as the one evaluated in this research, have also emerged in response to growing concerns about the environment and the implications of a changing climate. We would therefore expect that a fund that explicitly has carbon reduction as a stated aim would be more likely to fund projects with greater carbon emission reduction predictions. However, often the research projects that could potentially achieve the greatest carbon emission reductions are those more likely to be associated with greater risks, which may subsequently position them as less likely to attract funding. Nonetheless, if the pressing issue of climate change is to be successfully tackled in relatively short timescales, there is a need to pursue projects with a larger potential for carbon reduction. We therefore developed the first set of hypotheses:

$H1_a$. Projects with higher predicted carbon reduction figures are more likely to be funded.
$H1_b$. Projects with higher predicted carbon reduction figures are more likely to achieve higher levels of funding.

2.3. Commercial Maturity

As stated in the introduction, there is an increasing trend towards funding research projects that can also demonstrate commercial viability and industrial application (Ergas, 1987; Braun, 1998; Buenstorf, 2009), albeit with concerns that an increased focus on commercialisation will favour knowledge application and diffusion at the expense of knowledge creation (Archibald and Finifter, 2002; Perkmann and Walsh, 2008). However, there has generally been a trend towards research funds which explicitly call for the diffusion and application of knowledge generated through the research process. Due to the utilitarian nature of the fund under study and its stated objective for the application of knowledge and research impact, we would expect to find that the more commercially mature the project, the more likely it is to be funded and funded to a higher level. Thus, we hypothesise:

$H2_a$. Projects that are more commercially mature are more likely to be funded.
$H2_b$. Projects that are more commercially mature are more likely to be funded to higher levels.

2.4. End-of-Pipe or Cleaner Production Approach

There is still a considerable debate over how to tackle the problem of climate change. However, there is some agreement that there are two main approaches. The first approach is usually referred to as ‘end-of-pipe’ (EoP) and means that the overall system remains unchanged but emissions are treated (Unruh, 2002) and pollution is controlled by trapping, storing, treating and disposing of emissions and effluents (Hart, 1995). The second is usually referred to as ‘cleaner production’ (CP) and involves changing the overall system (Unruh, 2002), whereby emissions are reduced, changed or prevented through better housekeeping, material substitution, recycling or process innovation (Hart, 1995).

The most common path has been to adopt EoP approaches. Hartje and Lurie (1984) estimate that these have accounted for about 75% of pollution control activities and investment in industrialised countries (cited in Unruh, 2002) and Hart (1995) also notes a reliance on expensive EoP solutions. The resistance to adopting CP approaches has been attributed to society and organisation’s lock-in to existing technologies and systems (Unruh, 2000). Technological lock-in is efficient at maintaining the status quo and competitiveness of incumbent organisations and often affirms the dominant design (Utterback and Abernathy, 1975; Suarez, 2003), as well as creating R&D inertia

(Arthur, 1989; Narula, 2001). Since the mid-1990s, there have been increasing calls for a shift to more CP approaches, which are argued to deliver higher benefits to the organisations implementing them as well as having a bigger impact on reducing emissions (Hart, 1995; Berkhout, 2002). As this fund has the aim to achieve significant carbon emission reductions, we would expect the decision makers to favour projects taking cleaner production over end-of-pipe approaches, leading to our third hypothesis:

$H3_a$. Projects with cleaner production approaches are more likely to be funded than end-of-pipe approaches.
$H3_b$. Projects with cleaner production approaches are more likely to achieve higher levels of funding than end-of-pipe approaches.

2.5. Level of Innovation

Solutions that leave as much as possible of the overall system architecture unchanged are termed incremental or modular innovations. In contrast, those that change the overall systems architecture are termed architectural or radical innovations (Henderson and Clark, 1990). EoP solutions will tend to leave the system unchanged; however, some may have an impact on the system. Unruh (2002) also recognises this distinction within CP solutions. He terms CP solutions that maintain the overall system architecture as continuity approaches and those that significantly change or replace the system are discontinuity approaches. An incremental or continuity approach is more likely to be funded and implemented as it is less disruptive to the existing systems, less costly and more likely to make a rapid impact. However, in the longer term, it is the radical, architectural or discontinuity approaches that might achieve more substantial carbon reductions, but face resistance due to existing technological lock-in and the inability to reverse existing technology trajectories (Dosi, 1982) and path dependence (David, 1985; Tushman and Anderson, 1986; Arthur, 1989; Anderson and Tushman, 1990). We therefore hypothesise:

$H4_a$. *Projects with innovation approaches requiring less change to the system are more likely to be funded.*
$H4_b$. Projects with innovation approaches requiring less change to the system are more likely to be funded to a higher level.

2.6. Level of Creation versus Diffusion

There has been increasing research interest in how quickly new products are adopted by consumers, which has been termed the diffusion of innovation (Rogers, 1976). Although there has been some debate about the true shape of these diffusion curves and whether or not they are different for policy induced innovations (Jaffe et al., 2002; Diaz-Rainey and Ashton, 2008), there is a consensus that the rate of diffusion can be influenced to some extent by marketing activities (Rogers, 2003) and policy directives (Jaffe et al., 2002). Because of the utilitarian nature of the research fund investigated in this paper, and the need to demonstrate carbon reduction impact, we would expect that projects that aimed to more widely diffuse existing solutions (whether they be architectural innovations or incremental and whether they be cleaner production or end-of-pipe solutions) would be more likely to be funded than those projects that require the development of new solutions. This leads to our fifth set of hypotheses:

$H5_a$. Projects requiring the diffusion of existing innovations rather than the creation of new innovations are more likely to be funded.
$H5_b$. Projects requiring the diffusion of existing innovations rather than the creation of new innovations are more likely to be funded to a higher level.

2.7. Level of Technology

Cultural and domestication studies argue that consumption is more than simple adoption or buying patterns, especially for more radical innovations (Geels, 2004). Du Gay et al (1997) argue that the cultural appropriation of technologies is an important part of consumption, whereby users need to integrate new technologies into their practices, organisations and routines. Adoption is seen as an active process requiring adaptations and innovations within the user context. There is therefore an argument for an increased focus on technological solutions that also consider the social and behavioural aspects of technology adoption and use, rather than just focusing on the development of new technologies in isolation (Charbonnier-Voirin et al, 2010). We would therefore expect that the more complex and socio-technical the solution, the less likely it is to receive funding compared to simpler technology-only solutions, even though the subsequent implementation of these technologies could require significant cultural appropriation (Berkhout, 2002). In addition, this research fund had the explicit goal to fund one-third non-technology (or socio-behavioural) projects. We therefore would expect that more technology based projects would be funded overall, but that the ratio would be close to two-thirds technology projects and one third non-technology research projects. This leads us to hypothesise the following:

$H6_a$. Technology projects are more likely to be funded than non-technology projects.
$H6_b$. Technology projects are more likely to be funded to higher levels than non-technology projects.

2.8. Level of Risk

Allocating research funds is generally recognised as a ‘risky enterprise’ because it is difficult to predict the outcomes of research. Nevertheless there is an expectation that some of the funds awarded will provide a return on investment (Braun, 1998). However, funding administrators and peer reviewers are often asked to demonstrate the success of the fund in delivering the expected benefits. Research by Mitroff and Chubin (1979) and Walsh (1975) found that funders therefore tend to be risk adverse and promote established research groups and proposals rather than backing more risky path-breaking proposals. Lettice and Thomond (2008) found that when portfolios of new product development projects were analysed, the organisations favoured and funded those projects with a higher technical risk than those with a higher market or commercial risk. As this research fund wants to be able to show success in reducing carbon emissions, we would expect that the funders would generally support projects with a lower risk assessment. Within the call for proposals, four types of risk were proposed: technical, commercial, environmental and societal, which are defined in Table 1.

Table 1: Definitions of risk (taken from the funder’s Call for Proposals)

Type of Risk	**Definition**
Technical Risk	Including failure to deliver follow-on impacts where completion is contingent on achieving technical milestones early in the project lifetime
Commercial Risk	May include cost overruns, emergence of competing technologies or initiatives, changing commodity prices
Environmental Risk	May include a lower than expected reduction in CO2 impact
Societal Risk	May include changes in legislation/regulatory framework and in market drivers/conditions

Based on Lettice and Thomond's (2008) findings and the technology focus of the funding body, we would also expect that there would be greater tolerance for technical risk than for environmental, commercial or societal risk. Thus our hypotheses for risk are:

$H7_a$. Projects with lower risk are more likely to be funded.
$H7_b$. Projects with lower risk are more likely to be funded to higher levels.
$H7_c$. Projects with higher technical risk are more likely to be funded than those with higher environmental, societal and commercial risk.
$H7_d$. Projects with higher technical risk are more likely to be funded to higher levels than those with higher environmental, societal and commercial risk.

2.9. Other Factors Hypotheses

Goldfarb (2008) predicted that high-ability researchers would tend to prefer to pursue funding opportunities which lead to academically valuable results, rather than pursuing those funds which emphasise utility. Based on his study of NASA funded research, a funder that favours non-academic outputs, he found that this utilitarian fund did not attract proposals from high level academics, measured by their publications and citations over time and those that pursued such funds reduced their publication output by 25%. Viner et al (2004) used the UK Research Assessment Exercise (RAE) scores to indicate the research standing of the academic's host department for researchers who submitted proposals to the Engineering and Physical Sciences Research Council (EPSRC). Although not supporting the meritocratic view, they did find a positive correlation between the RAE rating of the academic's home department and the success of the grant being funded. They also found an under-representation of women in those that were successful in securing research funding. However, following the view that research is funded based on the merit of the proposal; we would expect to find no relationship between gender or RAE score in successfully funded projects. For this research fund, there was no limit on page numbers, so we also included a count of pages for each proposal submitted to the fund. We would not expect this to influence the outcome of the funding decisions. We also counted how many partners (universities or industrial collaborators) were involved in each proposed project and would not expect this to influence the funding decision. This leads to our final hypotheses:

$H8_{a,b}$. Department RAE score should have no impact on (a) project success and (b) project funding levels.
$H8_{c,d}$. Gender of proposer should have no impact on (c) project success and (d) project funding levels.
$H8_{e,f}$. Number of partners in research proposal should have no impact on (e) project success and (f) project funding levels.
$H8_{g,h}$. Page length of proposal submission should have no impact on (g) project success and (h) project funding levels.

3. Method

The fund, which was described in detail in Section 2.1, aimed to provide research grants to proposers whose projects could demonstrate carbon emission reduction, provide an innovative solution and that were relatively close to commercialisation. The fund received a total of 106 applications during the period of the Call for Proposals, of which 27 were funded. For the purposes of analysis, 4 of the 106 proposals were removed from the sample as they contained insufficient data for the majority of variables being considered in this research, making the sample size 102 proposals. The 4 proposals removed from the sample had all been unsuccessful in receiving funds.

Each proposal was reviewed and categorised by two researchers independently (e.g. Huutoniemi et al, 2009; Scandura and Williams, 2000). Tracy (2010) recommends the use of more than one researcher to provide investigator triangulation and a more complex and in-depth understanding of the issue. Where there was disagreement in the categorisations, these were re-visited and discussed until the disagreement was resolved. The final ratings were also discussed and agreed with the fund manager. Two types of coding were used: manifest coding and latent coding (Neuman, 2006). Manifest coding involved coding the surface content in the proposals, such as the amount of funding requested, the predicted carbon emissions reduction, and the host department and university submitting the proposal. Latent coding was used by the researchers to assess the subjective meaning within the proposals and to classify them by, for example, level of innovation, diffusion of existing or creation of new solutions, and cleaner production or end-of-pipe approaches. This information was not explicitly written in the proposal, but could be assessed by the researchers by interpreting the content of the proposals against standard definitions for types of innovation. This coding process is described below and summarised in Table 2. Table 2 shows the identification, type (e.g. Stevens, 1946) and coding used (i.e. whether manifest or latent coding) for all of the variables used in the statistical analysis.

Table 2: Identification, type, and coding process used for the variables in the research

Variable	**Description**	**Details**	**Type**	**Coding Process**
Success	Whether the proposed project was funded or not	1 = funded/successful, 0= not funded/unsuccessful	Nominal	Manifest
Amount funded	How much funding the successful project received	0 = not funded, if funded, amount awarded in British Pounds	Scale	Manifest
Claimed CO2 reduction	How much CO_2 reduction the project expected to deliver	Amount of CO_2 reduction claimed in tonnes of CO_2 per annum	Scale	Manifest
Commercial maturity	How close the proposers are to bringing the solution to market	1= early concept, 2= business case, 3= development, 4 = demonstration, 5 = pre-commercial, 6 = supported commercial	6-point scale	Manifest
End of pipe vs. clean production	The approach taken to reduce CO_2	1 = cleaner production, 2 = end of pipe approach	Nominal	Latent
Level of innovation	The level of change required to the system by the proposed innovation	1 = component substitution/improvement within existing system architecture, 2 = full upgrade of existing system, 3 = replace system with an alternative architecture used elsewhere, 4 = significantly change system architecture, 5 = totally new system architecture	5-point scale	Latent
Diffusion or creation	Whether the project will diffuse existing innovations or create new innovations	1 = diffusion of existing innovation within a sector, 2 = transfer of existing innovation from one sector to others, 3 = incremental improvement of existing innovations, 4 = combination of several existing innovations to create a new innovation, 5 = breakthrough or radical innovation	5-point scale	Latent
Level of technology	Whether the project is a technology or non-technology project	1 = non-technology, 2 = technology project	Nominal	Latent

Technical risk	Technical risk assessment of the project – see Table 1 for definition	1 = low risk, 2 = medium risk, 3 = high risk	3-point scale	Manifest
Environmental risk	Environmental risk assessment of the project – see Table 1 for definition	1 = low risk, 2 = medium risk, 3 = high risk	3-point scale	Manifest
Societal risk	Societal risk assessment of the project – see Table 1 for definition	1 = low risk, 2 = medium risk, 3 = high risk	3-point scale	Manifest
Commercial risk	Commercial risk assessment of the project – see Table 1 for definition	1 = low risk, 2 = medium risk, 3 = high risk	3-point scale	Manifest
Department RAE	UK Research Assessment Exercise (RAE) score of the department of the Principal Investigator	0 = unranked, 1 = 1*, 2 = 2*, 3 = 3b, 4 = 3a, 5 = 4*, 6 = 5/5*	Scale	Manifest
PI Gender	Gender of the Principal Investigator of the proposal	1 = Male, 2 = Female	Nominal	Manifest
Number of partners	How many partners (academic and non-academic) are involved in the project	Number of partners specified and confirmed in the proposal	Scale	Manifest
Proposal page length	How many pages the proposal has	Number of pages	Scale	Manifest

NOTE: All variables from the proposal were kept in their original form.

Each proposal was initially categorised as having been funded or not. The monetary value of funds requested by each proposer was also recorded as was the funding amount which the successful projects received. The actual figure claimed for predicted carbon emissions reduction was also recorded from each proposal. The host department and university of the lead academic investigator were noted. In addition, the gender of the principal investigator and the RAE score for their department were recorded against each proposal. The number of pages for each proposal was also noted as was the number of partners involved, which included both other universities and industrial partners. The proposals were then read to evaluate what the proposed solutions were and their self-assessed closeness to market (Commercial Maturity on a scale of 1 to 6). The proposals were also classified into either cleaner production (1) or end-of-pipe (2) approaches. They were classified as being technology or non-technology solutions predominantly and they were classified as being innovations that required systems change or those that did not (Level of Innovation on a scale of 1 to 5). They were also classified as to whether they were projects that required the diffusion of existing solutions or the development of new solutions (Diffusion vs. Creation on a scale of 1 to 5). The proposers were also asked in the call to assess the levels of technical, environmental, societal and commercial risk associated with their projects. These self-assessed risks were also classified on a scale of 1 to 3 for low, medium and high risk assessments respectively for each type of risk. All scales developed by the researchers are 1 to 5 in range. For self-assessed risk and closeness to market, the pre-existing scales from the call for proposals were used as we determined that reclassification could lead to greater bias.

Once the data were coded into the required format, a three step process was followed in the data analysis:

1. Assess the data for the presence of multicollinearity;
2. Binary logistic regression on the full sample (*n*=102) using funding success as the dependent variable to explore the significance of the independent variables on success;
3. Linear regression on the funded sample (*n*=27) using funding amount to explore the significance of the independent variables on the funding amount awarded.

4. Results

This section presents the results of our study. We first present the descriptive statistics of the research proposals, followed by the results of the correlation, logistic regression, and linear regression to test the research hypotheses.

4.1 Descriptive statistics

Of the 102 proposals analysed, 27 projects were funded, resulting in a success rate of 26%. The total amount of funding given to these 27 successful proposals was £3,047,110 (British pounds). Although for subsequent analysis, the 4 proposals were removed from the sample, for the funding requested, data was available for all 106 project proposals. The funding limit was advised at £100K. Thirty five of the 106 proposals (33%) were above this, with 12% (13 applications) over £150K. Forty percent of those projects funded were over £100K (11 of 27), where 15% were above £150K (4 of 27). 51% (54 of 106) of all applications were in the £75,000-100,000 range. 52% of funded applications (14 of 27) were in this range. Table 3 shows the descriptive statistics (variable, mean and standard deviation) for all (*n*=102) of the proposals and the funded subset of the proposals (*n*=27). The descriptive statistics indicate that the mean amount funded for the 27 proposals was £112,856.

Table 3: Descriptive statistics for the variables used in the research

	All (*n*=102)		Funded (*n*=27)	
Variable	**Mean**	**SD**	**Mean**	**SD**
Success	0.265	0.443	1.000	0.000
Amount funded	29873.628	53772.365	112855.930	38820.092
Claimed CO2 reduction	103.652	869.314	33.205	118.777
Commercial maturity	2.647	1.087	2.963	0.650
End of pipe vs. clean production	1.608	0.491	1.444	0.507
Level of innovation	3.520	1.533	3.296	1.636
Diffusion or creation	2.176	1.367	2.778	1.450
Level of technology	1.676	0.470	1.852	0.362
Technical risk	1.696	0.742	1.741	0.813
Environmental risk	1.637	0.541	1.630	0.565
Societal risk	1.598	0.567	1.704	0.542
Commercial risk	1.422	0.667	1.704	0.823
Department RAE	3.980	1.610	4.260	1.631
PI Gender	1.098	0.498	1.185	0.396
Number of partners	2.961	3.515	1.963	1.091
Proposal page length	14.657	5.034	16.111	5.780

To assess whether there was multicollinearity within the data, a correlation analysis was performed, the results of which are shown in Table 4.

From Table 4, it can be determined that there are a number of variables where there are correlations, but there is only one correlation that exceeds the threshold of 0.8 (Hutcheson and Sofreniou, 1999) indicating multicollinearity: success – amount funded. This is acceptable, as success (a binary variable) and amount funded are used as the dependent variables in the next stages of our analyses and are therefore not regressed against each other.

Table 4: Correlation table of the variables

	Success	**Amount funded**	**Claimed CO_2 redn.**	**Commercial Maturity**	**EP vs. CP**	**Level of innovation**	**Diffusion vs. creation**	**Level of technology**	**Technical Risk**	**Environmental Risk**	**Societal Risk**	**Commercial Risk**	**Department RAE**	**PI Gender**	**Number of partners**	**Proposal page length**
Success	1															
Amount funded	.931**	1														
Claimed CO_2 redn.	-.049	-.053	1													
Commercial Maturity	.175	.168	.022	1												
EP vs. CP	-.201*	-.143	-.118	-.114	1											
Level of innovation	-.088	-.106	.099	.064	.208*	1										
Diffusion vs. creation	.265**	.276**	.123	.136	-.545**	-.129	1									
Level of technology	.225*	.202*	.052	.065	-.513**	-.314**	.583**	1								
Technical Risk	.036	.037	.168	.124	-.167	-.086	.122	.084	1							
Environmental Risk	-.008	-.077	.051	.167	-.056	-.021	.047	.040	.389**	1						
Societal Risk	.112	.102	.066	.281**	-.181	.026	.054	-.047	.342**	.584**	1					
Commercial Risk	.255**	.284**	-.075	.098	-.125	-.197*	.102	.029	.402**	.209*	.426**	1				
Department RAE	.104	.140	-.072	.075	-.022	-.108	.069	.188	.086	.094	.089	-.011	1			
PI Gender	.106	.085	-.039	.156	.118	.127	-.026	-.075	.108	.060	.001	-.006	.336**	1		
Number of partners	-.171	-.162	-.063	-.100	.157	-.048	-.120	-.241*	-.046	-.008	-.082	-.056	.049	.098	1	
Proposal page length	.174	.227*	.189	.103	-.171	.048	.110	-.035	.253*	.103	.104	.209*	.044	.014	.011	1

Notes

EP vs. CP: Denotes End of pipe vs. Clean Production solutions

*: Correlation is significant at α= 0.05 (two-tailed)

**: Correlation is significant at α= 0.01 (two-tailed)

4.2 Analysis of success

To analyse the variables that influenced proposal success, a binary logistic regression was conducted. Table 5 shows the results of this test.

Table 5: Results for the logistic regression of project success

Variable	β	**Std. Error**	**Wald statistic**	α
Constant	-0.179	0.811	0.049	0.836
Claimed CO_2 reduction	0.000	0.000	0.477	0.490
Commercial maturity	0.274	0.268	1.047	0.306
End of pipe vs. clean production	0.032	0.668	0.002	0.962
Level of innovation	0.033	0.201	0.028	0.867
Diffusion or creation	0.255	0.251	1.037	0.308
Level of technology	-1.276	0.946	1.821	0.177
Technical risk	-0.525	0.444	1.399	0.237
Environmental risk	0.053	0.643	0.007	0.934
Societal risk	0.338	0.632	0.287	0.592
Commercial risk	0.837	0.469	3.183	0.074*
Department RAE	0.132	0.196	0.454	0.500
PI Gender	-1.313	0.817	2.580	0.108
Number of partners	-0.454	0.224	4.105	0.043**
Proposal page length	0.123	0.062	3.857	0.050**
Cox and Snell R^2	0.236			
Nagelkerke R^2	0.344			

*: significant at $\alpha \leq 0.10$
**: significant at $\alpha \leq 0.05$

Table 5 indicates that for the logistic regression model the Cox and Snell R^2 is 0.236 and the Nagelkerke R^2 is 0.344. These results indicate that the variables included in the model explain 23.6% and 34.4% (dependent on method) of funding success. Given the nascent nature of the phenomena we are examining, these are acceptable values. Table 5 also indicates that there are only three variables which have a statistically significant (at $\alpha \leq 0.10$) effect upon proposal success. These are commercial risk (β=0.837, α=0.074), number of partners (β=-0.454, α=0.043), and proposal page length (β=0.123, α=0.050). These results indicate that as commercial risk increases so does funding success, whilst a reduction in the number of project partners also has a statistically significant impact on funding success. Moreover, more pages in the project proposal leads to a statistically significant impact on funding success. These results indicate that only three hypotheses were supported. These were $H7_a$: an increase in the risk of the project would lead to greater funding success, but of the four types of risk, only commercial risk had an impact. Two of the control hypotheses ($H8_a$ and $H8_c$) were supported. This indicates that Department RAE score and Principal Investigator gender had no impact on funding success. Conversely, $H8_e$ and $H8_g$

were unsupported indicating that the number of project partners and proposal length does affect funding success.

4.3 Analysis of funding amount

To analyse the variables that influenced the amount funded, linear regression was employed using funding amount awarded as the dependent variable. Table 6 shows the results of this test.

Table 6: Results for the linear regression of amount funded

	Unstandardized coefficients		*Standardized coefficients*		
Variable	***β***	**Std. Error**	***β***	***t***	***α***
Constant	145288.358	40184.869	-	3.615	0.004**
Claimed CO_2 reduction	-215.759	78.643	-0.660	-2.744	0.018*
Commercial maturity	-2543.263	15055.587	-0.043	-0.169	0.869
End of pipe vs. clean production	15110.139	10158.021	0.394	1.488	0.163
Level of innovation	1134.954	6251.719	0.048	0.182	0.859
Diffusion or creation	8383.353	7122.295	0.313	1.177	0.262
Level of technology	-28603.622	33766.146	-0.272	-0.847	0.414
Technical risk	4481.200	12070.641	0.094	0.371	0.717
Environmental risk	-31907.472	19482.444	-0.464	-1.638	0.127
Societal risk	25435.475	22506.813	0.355	1.130	0.281
Commercial risk	-5997.464	14001.863	-0.127	-0.428	0.676
Department RAE	4022.736	5513.188	0.169	0.730	0.480
PI Gender	-32945.911	25909.362	-0.336	-1.272	0.228
Number of partners	727.601	8218.297	0.020	0.089	0.931
Proposal page length	1661.438	1563.612	0.247	1.063	0.309
F	1.318				
R^2	0.606				
R^2 adjusted	0.146				

*: significant at $\alpha \leq 0.05$
**: significant at $\alpha \leq 0.01$

Table 6 indicates that for the regression model the *F* value is 1.318, the R^2 value is 0.606, and the R^2_{adj} is 0.146. Whilst the *F* value and R^2 values are acceptable, the R^2_{adj} value suggests that the model has been overfitted (i.e. through the addition of non-significant variables). Whilst the parsimony of the model could have been increased through the deletion of non-significant independent variables, this would not have allowed us to show whether the hypotheses were supported or unsupported. Table 6 shows that there is only one variable which has a statistically significant (at $\alpha \leq 0.05$) effect upon funding amount. This is the Claimed CO_2 reduction (β=-215.759, *Standardized* β= -0.660, α=0.074). This finding indicates that whilst Claimed CO_2

reduction had a significant impact upon amount funded, it has a negative sign, indicating that as claimed CO_2 reduction increased so the amount funded reduced. Thus $H1_b$ is not supported. Table 6 also shows that the constant within the regression model is significant (α=0.004), indicating the presence of other variables which were not operationalised within our model.

Some of the control hypotheses ($H8_b$, $H8_d$, $H8_f$ and $H8_h$) were supported. This indicates that although the number of project partners and proposal length did affect funding success; RAE score, PI gender, number of project partners and proposal length did not affect the amount of funding awarded.

5. Discussion and Conclusions

The research fund that we studied represents a relatively small proportion of the total UK climate change research funding and the results may not be representative of how other funding bodies have distributed their funds.

We draw certain interesting conclusions from our research. The first is that funding agency actions do not always match their original intentions and expectations. In our case, the funders set out to fund projects that would achieve carbon savings and reduce carbon emissions. Our analysis shows that this did not occur, as this variable did not influence the success of the proposal. In fact, of the projects funded, projects with lower claimed carbon reductions were more likely to receive higher funding amounts. This may have been because other funding criteria were more important within the process to determine which proposals were to be granted funds. However, from the analysis, we can see that the funding decisions in general did not match the other criteria specified in the programme's aims. This means that many of the hypotheses for this research, predominantly derived from the aims and goals of the research fund and supported with extant literature, were rejected. Unsupported hypotheses indicate where the theory base needs refinement or extension, as can be seen in other research (e.g. Clayson et al, 2006; Bozeman and Gaughan, 2011). We suggest that our unsupported hypotheses indicate the following:

a) The programme related goals were not adhered to in the decision making process, and;
b) The extant theory base does not 'hold' in this context and will require further research to adapt it to the new context.

This fund is classified as a utilitarian or diffusion-oriented fund (Ergas, 1987), where the aim is to fund more commercially viable and mature projects that could be implemented swiftly to make a shorter term impact in terms of carbon reduction savings. Within our results, there was no indication that the more commercially mature the project, the more likely it was to get funded and funded to higher levels, which further indicates that the impact criterion was not strongly guiding the funding decisions within this programme.

Our results show that there was no significant preference from the funders towards either cleaner production or end-of-pipe solutions. This demonstrates that within this programme a shift away from the more expensive treatment of emissions, towards the more environmentally and economically viable cleaner production solutions (Frondel et al, 2004), was not evident. If we then look at whether or not architectural projects are funded over more incremental innovations, we see again that there was no obvious preference for these types of projects. We also evaluated whether or not the proposals were focused on creating new innovations or diffusing existing innovations. In doing so, we found that the reviewers and funders did not favour proposals that were creating new knowledge over those that were diffusing existing knowledge. This suggests that their aim to support more innovative projects was not met and was not a dominant criterion within the decision making process. In other words, our results show no evidence of a funding shift from continuity to discontinuity approaches or towards the creation of new innovations and solutions for carbon reduction (Unruh, 2002). Consequently, systemic technological lock-in problems (Unruh, 2000) are not being aggressively addressed by this particular fund. Thus, the projects funded may not contribute significantly to ameliorate the problems associated with such a pressing and complex issue as climate change.

Although the fund had the aim of using one third of the monies for non-technology projects, it fell short of this by funding about one-fifth of projects in this category. However, technology was not a significant variable within the funding decisions or the amount of funding awarded. This is reassuring, as non-technology projects are likely to be more complex, given they tend to address behavioural and social issues. They are therefore often perceived to be more difficult to implement and to provide less certainty about how they will achieve a clearly measurable impact when compared to their technological counterparts.

Our findings on risk are perhaps the most intriguing. Because of the utilitarian nature of the research fund, we expected that lower risk proposals would be more likely to receive grants, but this was not the case. For technical, commercial and societal risks, the decision makers favoured those projects which categorised their risks as higher and this was statistically significant for commercial risk. This seems counterintuitive for a fund that has an explicit aim to support projects that can demonstrate carbon reduction savings.

The success of a proposal was based on merit more than on departmental research standing (as measured by UK Research Assessment Exercise (RAE) scores) or principal investigator gender. This result contradicts other researchers' findings where gender and RAE score have affected funding outcomes (Viner et al, 2004). The number of partners involved in the project was a significant factor in whether or not the proposal was funded, where fewer partners were preferable. This may be because of the additional costs and co-ordination efforts required when too many partners are involved. Guidance on the length of proposal was not specified in this call. Nevertheless, we did find that it was advantageous to submit a longer proposal, which we suggest enabled a more detailed description and justification of the project's potential value.

In conclusion, this fund had the stated aim of achieving impact through carbon reduction savings. However, it was also a research fund with the explicit aim of funding innovation. For this particular fund, neither hurdle was cleared as the funders showed no preference for any particular type of proposal. The findings from this research are indicative of a compromise. This may be because it was not possible to find sufficient individual projects that met both the innovation and impact criteria. Also, it may not have been possible for the reviewers and funders to understand enough about innovation to make appropriate decisions against each criterion. As a result, the decision making led to neither the innovation nor impact criteria being met within the overall programme. We therefore find support for Langfeldt's (2001) findings that there are variations in the different criteria that reviewers emphasise. The decision making processes associated with funding activities are therefore to some degree inherently capricious, subjective and interpretative.

We draw general implications for the funding of research, as well as more specific implications for the funding of climate change research. In doing so, we have found that the subjective and interpretative nature of the funding process may threaten the ability of such research to ultimately overcome technological lock-in and R&D inertia, which are barriers to many carbon emissions reduction solutions (Unruh, 2002). Based on our findings, we are proposing that for climate change research at the programme level, it would be beneficial for the funders to consider each project in relation to the other projects being funded. This approach would help to ensure that a balanced portfolio is achieved and that the overall goals of the programme are met across multiple projects. For the most important criteria a stronger emphasis, or weighting and operationalisation of these criteria, may also help to ensure that specific goals of the programme are satisfied. This would assist in identifying where there are potentially conflicting goals and decisions regarding which of these should then take priority. Programme managers would thus be able to obtain an overview to help them to better understand and more consistently prioritise the most important goal (in this case, whether or not it should be impact or innovation) when allocating research funds.

At the multiple programme level, policy makers should aim to ensure a balance of impact and innovation across the range of climate change research funding agencies and initiatives. This demands the use of mechanisms that allow for a meta-view to be comprehended and made accessible to different funding agencies trying to meet the common and often competing goals of innovation and impact. Trying to clear the impact-innovation double hurdle in a single funding initiative may ultimately compromise both goals. This balanced approach across the entire portfolio would see some funds working within existing architectures, whilst others pursue more discontinuous and systemic solutions to address the problems associated with climate change. Some funds would focus on how to better diffuse existing solutions whilst others pursue the creation of new knowledge. Finally, some funds would focus on short term impact and carbon reduction savings, whilst others would pursue research which cannot yet demonstrate impact or where savings would be less immediate.

Further research should focus on more studies of other funders and comparisons should also be drawn across and between different funds and their administration processes. Research and debate are needed that allow for more sophisticated funding processes that are better able to accommodate complex research challenges. Future research could also ascertain how successful the funded projects in this study were at meeting their aims and whether or not they did achieve the intended level of innovation and carbon reduction impact.

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