# A model for evaluating Food and Agricultural Research Projects: A Danish application

**Pedersen S.M. [a*] Boesen M.V. [a] Baker D. [a, b], Larsen A. [a]**

[a] *Institute of Food and Resource Economics, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg C, Denmark*
[b] *Present address: International Livestock Research Institute, Box 30709, 00100 Nairobi, Kenya.*
[*]*Corresponding author. Tel.: +45 35 3368 82; fax: +45 35 33 68 01. E-mail address:Marcus@foi.dk*

## Abstract
In this study the usefulness and scientific quality of research projects is addressed, and a pilot study is executed for 3 Danish food and agricultural research programs. The method developed and implemented addresses these concerns, particularly by employing simple measures and by complementing quantitative analysis with qualitative exercises featuring structured stakeholder interviews. The results of the pilot indicate substantial variation between projects within programmes, and some evidence of size-performance relationships.

*Keywords: Evaluation methods; Agricultural Research; Cost effectiveness; Research performance*

## Introduction
Recent enthusiasm for evaluation of research is due to a variety of factors, including increased fiscal accountability, perceived needs for research to demonstrate its relevance to society, competition for research funding, and the quantification of research organisations' merit. The current paper arises from a Danish government agency's request for development of an evaluation methodology applicable to research projects in a long-standing programme of support to agricultural research. Evaluation of agricultural research has mainly been focussing on the scientific impact whereas the impact on the related industry and society has been of less importance.

The objective is to provide a motivation for evaluation of research projects and to develop and transfer a workable methodology where the impact to industry, society and research organizations is evaluated.

Research evaluation shares with research itself the characteristics that its costs and benefits can be difficult to isolate and attribute. The "scientific" quality criterion is often distinguished from "societal" quality (Merkx et al., 2006), with the former being associated with peer review and the latter with context. In particular, bibliometrics is advocated as a quantitative supplement to peer review. Bibliometrics is, however, a special case of a broad range of methods that seek to measure impact by means of tracking them through networks of stakeholders.

OECD (1997) identifies five "levels" as targets for evaluation: individual researchers; research groups (typically a laboratory or institute); entire disciplines; government programmes or agencies; and entire national research bases. This list is notable in two senses. First, the levels that it identifies all from part of the context described above. Second, it excludes the focus of the current study: the individual project. Arnold (2005) also questions evaluation at the level of research projects because it gives insufficient consideration of context, and Maredia et al. (2007) express doubts about the practicality of evaluation at project level due to the difficulty of attribution of impacts and resource use. These authors also question its appropriateness as research programmes are typically portfolios of activities that include failures as well as successes. The issue of what constitutes research failure is not addressed by their work.

Consideration of the level at which evaluation occurs must also reflect funding realities. In most countries, funding streams take two general forms: institutional funds and project support (Lepori et al., 2007). The former is the support provided to organisations involved with research, which includes universities, and others, that provide products and services additional to research (such as teaching). The latter is more commonly associated with policy-relevant research, and tends to be administered by purpose-specific agencies that select projects and are responsible for aspects of their management.

**Method**

The evaluation exercise presented here is targeted at the project level, with the purpose of measuring the quality of each project. The evaluation is based upon discussions in Larsen and Pedersen (2007) and Pedersen et al. (2005) and descriptions in Baker et. al. (submitted 2008). The user of the evaluation is a government agency charged with administering a funded programme of research with competitive allocations to projects. The main interests of the user are the quality of the research in terms of its short term outputs, the internal consistency and effectiveness of the projects in delivering those outputs, and the value for money generated by the research projects. Particular significance was placed on simplicity of operation, standardisation of procedures and measures, use of easily-accessible and non-disruptive data collection, and ease of interpretation. These attributes of the evaluation particularly address the issue of scientific competence, in that the client's project portfolio spans a substantial range of advanced disciplines. In addition, the ex-post nature of the evaluations mean that a short time frame (2 years) was preferred by the user.

The primary output of research (as defined by OECD, 1997) is the creation of knowledge, and this is the main focus of the evaluation exercise. Also addressed are key research outcomes, such as linkages to industry and to training, regeneration of research capacity and the appearance of new products. Research context is embraced in this exercise by inclusion of stakeholders in the analytical process, and by questionnaire design that addresses stakeholder concerns as well as environmental and social issues.

The evaluation follows a dual path:

1) a quantitative summation of research outputs based on a number of indicators to which weights are assigned; and
2) a qualitative evaluation based on interviews with project leaders and relevant stakeholders from the research community (basic research and applied research), food industry and the surrounding society.

Because traditional bibliometric and peer review studies tend to deliver output/results that are either "multidimensional" (in the sense that each project generates several outputs) or "one-dimensional" (due to a focus on one type of output such as articles in peer reviewed international journals), cost effectiveness analysis is also used. Notably, the outcomes from research projects are often multidimensional, including: research articles and papers, teaching activities, capacity building, posters, patents, PhD-supervision, popular papers, press interviews etc, making it difficult to compare outputs across projects. Moreover, bibliometry and peer review do not involve estimation of financial budgets or costs of carrying out the project: such variables are readily compared across projects.

Following Alston et al. (1995), weighted output indicators are used. In addition to their simplicity and low cost, the weighting procedure offers two other desirable features of the evaluation: the capacity for involvement of stakeholders (research organisations, institutions, farmers, and decision makers) in assigning weights; and the capacity for informing researchers and project managers ahead of time about the priorities attached to evaluation of future research projects.

To these ends each output has been prioritised and been given individual weights by an indicator board (commission) with 4 members. The indicator board comprises members/stakeholders that have various interests in research policy from four perspectives: applied research; basic research; food/agro-business; and the surrounding society. The indicator board is located in the middle of the project cycle described in figure 1. The indicator board decided that a peer reviewed journal article should be the benchmark/reference indicator for other outputs. In this matter, a peer reviewed journal article with a journal impact factor (JIF) above 2.0 was assigned 100 points. A peer reviewed article with a JIF below 2.0 was assigned 80 points. Similarly a peer reviewed conference paper was assigned 20 points, and a poster presentation paper 10 points.

In the current application, three impacts of applied research projects were considered (all scores assigned are presented within these impacts - see table 1):

1. scientific effect/ impact: outputs and outcomes from the research project that are directly related to scientific dissemination, including scientific peer reviewed journals, conference papers, etc;
2. embedment of knowledge: outcomes from the research project that are related to the education of current and future researchers (e.g. Ph.D students, master students, and production of patents); and

3. impact on industries and society, including outcomes such as popular articles, homepages, newsletters, press interviews, etc.

*Table 1: Indicator list*

| Indicator | Score assigned (points per output) |
|---|---|
| **Scientific effect** | |
| *Publications* | |
| Scientific paper with JIF>4 | 120 |
| Scientific paper with 4>JIF>2 | 100 |
| Scientific paper with JIF<2 | 80 |
| Scientific paper without JIF | 30 |
| Danish-language paper without JIF | 20 |
| Books (chapters) | 40 |
| Proceedings and working papers | 20 |
| Research report | 20 |
| Conference presentation (with peer review) | 20 |
| Conference presentation (without peer review) | 15 |
| Poster presentations | 10 |
| Total score scientific effect | (totals) |
| **Embedment of knowledge** | |
| *Education* | |
| Researchers (ph.d. and post doc.) | 300 |
| Master students (supervision) | 50 |
| Supplementary training (education) 20 points pr. Course | 20 |
| Bachelor (supervision) | 20 |
| Guest lectures | 10 |
| *Technical* | |
| Patents extermination of novelty | 20 |
| Patents application | 100 |
| Patents approval | 40 |
| Development of strategic methods | 100 |
| Other sort of comer commercialize | 100 |
| Software programs | 100 |
| Total score embedment of knowledge | (totals) |
| **Industries and society** | |
| *Publications* | |
| Publication in subject-specific journal | 50 |
| Publication in subject-specific newspaper | 50 |
| Larger account >50 pages | 80 |
| Smaller account <50 pages | 20 |
| Procedure for authorities | 100 |
| Lecture | 20 |
| Feature article, newspaper article, discussion article | 20 |
| Interviews to nationwide radio or television | 20 |
| Subject publications in relation to the project | 20 |
| Subject meeting / workshop | 20 |
| Newsletter | 10 |
| Homepage | 10 |
| Total score for industries and society | (totals) |

In addition, separate interviews were conducted with research leaders and research stakeholders, within an overall scheme presented in figure 1. Below the evaluation procedure illustrated in figure 1 is explained.

1. When a new research programme is launched a selected group of stakeholders from the relevant field define targets and formulate project calls. Prior to that an indicator board (also selected among stakeholders) defines the weighted indicators for each research outcome. These indicators may be of general use for different project calls within a scientific area.
2. The next step is that individual research groups submit their project proposals to a funding Board. The funding Board is represented by different stakeholders within the scientific community and agro-food industry.
3. The proposals are then evaluated (ex ante) by the funding Board and the best or most relevant proposals are selected. The non-selected projects exit the project cycle, to seek funding elsewhere or await future project calls.
4. The selected research groups complete their projects and the results are disseminated to the funding Board and evaluated according to the weighted indicators. In addition, qualitative interviews are made with relevant project leaders and project stakeholders (see indicator list in table 1).
5. The projects are evaluated (ex post) with the procedure described in this paper. Based on these evaluations the funding Board identifies the best performers, which may receive additional funding.
6. The cycle starts over again and all project groups may enter.

It should be emphasised that individual stakeholders represented on the funding Board must not necessarily be members of the indicator Board (and vice versa), but they should represent the same field of interest within the scientific (basic and applied research) community, agri-food industry and society in general.

By using a board (with multiple interests in research) to make the weighted indicators, we ensure that the evaluation of the research projects meets the requirements from not only the scientific community but also the food- and agro industry as well as the surrounding society. The board performs a vital task in choosing the indicators for different research output, weight them and prioritise among them. Based on this outcome, the chosen indicators provide an incentive for researchers to prioritise their research effort according to these criteria and to follow a path where they perform well.

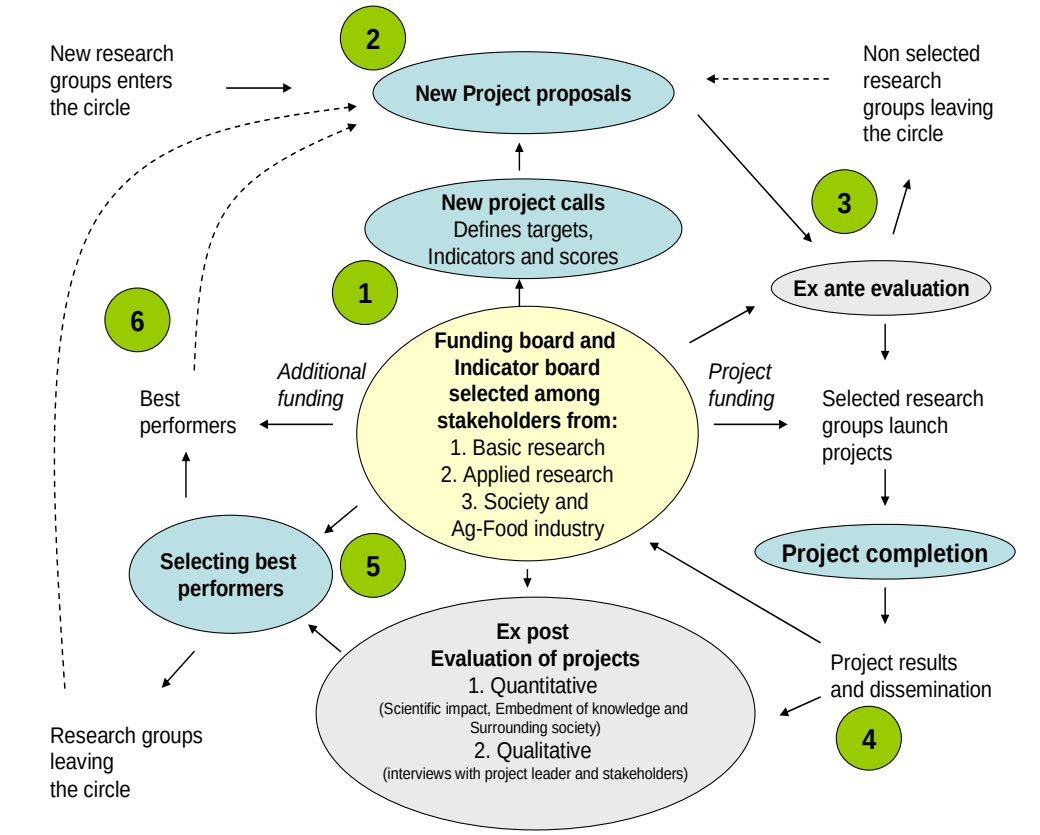



*Figure 1: Evaluation within the research project cycle*

Three readily-available data sources were used: reports and other official project life cycle documents; interviews with senior research staff; and interviews with selected industry or related stakeholders. To a significant degree, the latter source was used to both complement and supplement the former two, in particular to allow checking of details. These sources were used to generate a quantitative analysis based on (i) bibliometry with scores assigned to specified categories of professional output and (ii) training and technical issues with scores assigned to specified outcomes. Qualitative analysis employs the results of the two interview procedures in terms of the extent to which research objectives are fulfilled, the newness and uniqueness of methods employed and results generated, and context in terms of involvement with industry, existence of industrial and consumer applications of research outcomes, and the role of the project in the research organisation and the broader industry.

The methodology is piloted on three research programmes funded by the Danish Ministry of Food, Agriculture and Fisheries: “Food quality with focus on food security”; “Biotechnology and applied genetics in plant breeding”; and “Interdisciplinary animal science”. Each of these programmes entail 5-10 research projects. In total, the three programmes enabled the evaluation of 24 research

projects (listed in table 2) during 2006-2008. The three programmes are evaluated in: Boesen et al. (2008a), Boesen et al. (2008b) and Larsen et al. (2006).

*Table 2: Projects evaluated in pilot exercise*

| |
|---|
| **Biotechnology and applied genetics in plant breeding** |
| Danish Functional Genomics Research Initiative for Improving Feed Quality and Disease Resistance in Grasses and Cereals (DAFGRI) (a series of work packages) |
| WP1: Database and technology platform |
| WP2: Nitrogen utilization and amino acid composition in the developing barley grain |
| WP3: Phosphate metabolism in the developing barley grain |
| WP4: Disease resistance in barley |
| WP5: Biosynthesis of the phytate in barley grain |
| WP6: Nutrient utilization and forage quality in ryegrass |
| **Interdisciplinary animal science** |
| Robust dairy cows |
| Facility for adaption in dairy cows |
| Feeding strategies for dairy cows |
| Basic automatic registering of data |
| Liver abscesses in beef calves |
| Robust pigs |
| Fertility in dairy cows |
| Robust broilers |
| High yielding mink |
| Physiological unbalance in dairy cows |
| **Food quality with focus on food safety** |
| Prevention of fungal growth |
| Microbial pest control |
| Control of listeria monocytogenes |
| Food borne bacterial infections |
| Human diarrhoeagenic |
| Wildlife source salmonella |
| Combinary effect plasticisers |
| Quantitative and qualitative analysis of campylobacter |
| Food hypersensitivity |

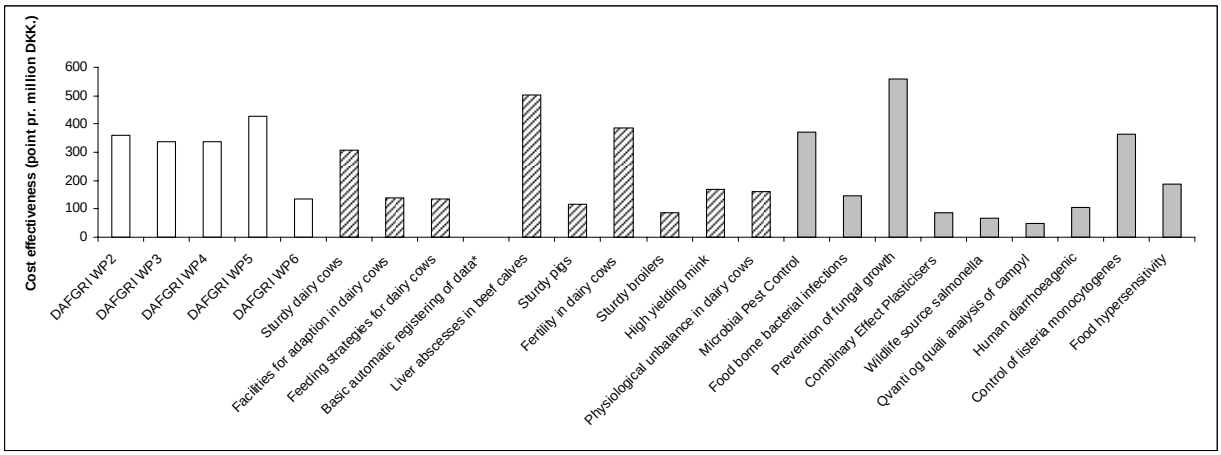
## Results

The programme “Biotechnology and applied genetics in plant breeding” received a total funding of 20 million DKK from the Ministry and the 5 projects in the programme achieved a total of 4,965 points in the quantitative analysis. The budget of the “Interdisciplinary animal science” programme was 70 million DKK funded by the Ministry (50%), Industry (25%) and the institute’s own co-funding (25%). The 10 projects in the programme earned 10,500 points in total in the quantitative analysis. The budget in the “Food quality with focus on food safety” programme was 50 million DKK funded primarily by the Ministry, but with some co-funding for some projects (total 10 million DKK). The 9 projects in the programme earned 8,550 points in the quantitative analysis.

Figure 2 presents estimates of cost effectiveness for all 24 projects evaluated in the pilot exercise. The average cost effectiveness for the "biotechnology and applied genetics in plant breeding" programme was 248 points per million DKK, 170 points per million DKK for the "Food quality with focus on food security" programme, and 150 points per million DKK for the "Interdisciplinary animal science". The average outcome for all projects is 171 points per million DKK.

For the programmes "Food quality with focus on food security" and "Interdisciplinary animal science" there is a large variation amongst projects: in the latter cost effectiveness ranges from 88 to 502 points per million DKK and 50-550 points for the former. In comparison, "Biotechnology and applied genetics in plant breeding" displays a narrower range: 136-428 points. The observation that variation in cost effectiveness is greater within programmes, than between programmes, indicates that cost effectiveness of programmes is not only associated with the subject of the programme, but also with other factors.

*Figure 2: Cost effectiveness results*




*The project "Basic automatic registering of data" didn't receive any points due to its nature as a support project for the new automatic research cowshed.

Figure 3 shows the focus of research effort: all three programmes have placed emphasis on scientific effect/impact. For the programmes "Food quality with focus on food security" and "Biotechnology and applied genetics in plant breeding" the distribution of results amongst the three categories is somewhat similar. About 65% of the research outputs are related to the category "scientific effect" 25% to "embedment of knowledge" and 10% to "industry and society". Rather different results are apparent for the "Interdisciplinary animal science". In that case about 50% of research outputs are related to "scientific effect", 15% to "embedment of knowledge" and 35% to "industry and society". For this programme, the emphasis on "industries and society" seems a logical consequence of the large share of funding (25%) from Industry. Moreover, this programme was carried out in close contact with the agri-food industry (farmers, farm consultants and slaughterhouses).

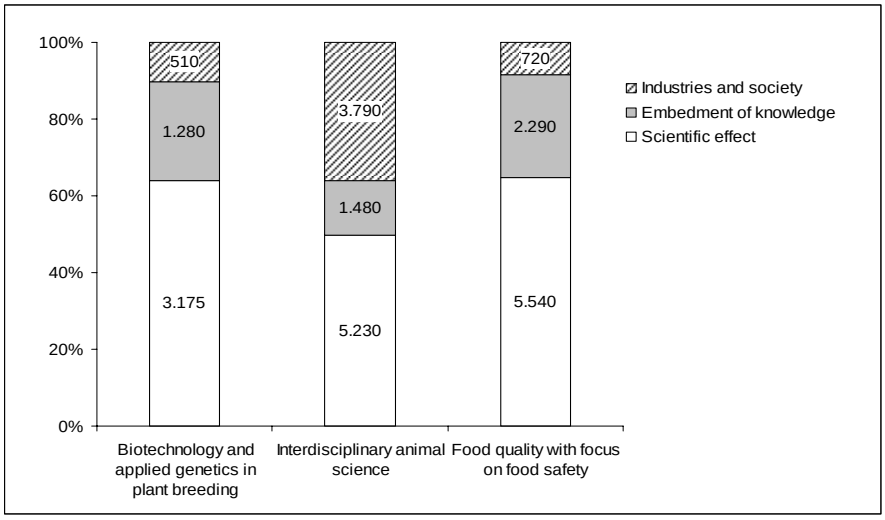



*Figure 3: Programmes' distribution of research impacts*

A general impression is that cost effectiveness declines with project size. Although this result is not investigated further here, some justification is available. It may be, for example, that smaller projects (by funding) address smaller, well defined, subject areas, making the research more focused and the results less diffuse. This hypothesis received some support in the current study, as some leaders of the larger projects identified the challenge of running the larger projects with many people involved.

Regardless of the cause of the negative relationship between cost effectiveness and project size, the inference must be drawn that cost effectiveness is a problematic indicator for the comparison of projects. This is especially so when comparing projects across scientific disciplines, or when certain inherently expensive activities (such as experimentation on valuable animals) are featured in some projects but not others.

**Qualitative results**

Each interview with project leaders and representatives from Industry and Society followed an interview protocol, grouped into relevant themes inspired by Kvale (2004). Each theme was first explored by use of open-ended questions which were then narrowed down to very specific questions related to output and impact. The open-ended questions ensured that the interviewed person was allowed to present his or her own perceptions of the project and main outcome. By using this approach outcomes can be presented that are not captured in the quantitative analysis.

The same themes were pursued with each person interviewed, entailing questions such as:

- Which central new knowledge and possibilities has the project resulted in?
- Which research breakthrough has the project contributed to (if any)?

- Have there been additional outputs in addition to those mentioned in the objective?

Aside from enhanced understanding of the outcome and impact of the research project being evaluated, interviews relate outcomes to specific goals of the project. In principle, a project cannot be considered successful if it does not fulfil its purpose. A high score in the quantitative analysis would, in such a case, not be an indicator of success.

The analysis from the interviews is presented in written statements (see examples below) relevant to each project. These describe all relevant outcomes of the project.

**Examples of statements from analyses of interviews:**

| **Project: Robust broilers** | **Project: Liver abscesses in beef calves** | **Project: Facility for adaptation in dairy cows** |
|---|---|---|
| Statement from interview with project leader<br>*"an important result of the project is that the collaboration between the disciplines (animal behaviour, animal physiology) has been strengthened, both intern on DJF and between the research institutes."*<br><br>This statement show how a project is leading to better contact between scientist and research institutions.<br>Statement from the industry (Danish poultry Council with knowledge about the project was interviewed.)<br><br>The Council emphasize:*" that it has resulted in a knowledge pool about poultry and chicken production has been established. Two new important subjects have been knowledge about diseases (foot pad dermatitis and hock burn) and the differences between old and new types of poultry. The new knowledge about foot pad dermatitis and hock burn will have a direct economic effect for producers and an increased welfare for the chickens.* | Statement from the interview with the project leader.<br>*"During the project there was a close and continuous contact with industry e.g. the project leader has informed Danish Crown (a Danish slaughterhouse firm) about the knowledge gained, assisting them in developing strategies for farmers to avoid liver abscesses in their beef calves. Moreover, interest in the results has been expressed by the beef trade and the project leader is in weekly contact with producers, responding to questions about raising of calves. Direct contact with industry is, in the project leader's view, an important breakthrough in this project. Additionally the project leader has been involved in lectures and supplementary training of stakeholders, further strengthening contact with the industry."*<br><br>This is a strong statement that the project was important to stakeholders and that the research is directly usable in the industry. | From interview with the project leader<br>*"According to the project leader the objective of the project was only fulfilled for two of the three parts of the project. The objective for part three was not fulfilled because more time was used for part one than had been expected. This was caused by malfunction in the equipment for automatic blood sampling and therefore time was used to develop such a device."*<br><br>*"According to the project leader, development of the automatic blood sampling device is the most important result from the project. The device makes it possible to take blood samplings from cows in loose-housing systems which are unique and necessary (e.g. if stress hormones in the blood have to be measured). The development of the device was essential to fulfil part one of the project and has resulted in a new method to implement blood sampling."*<br><br>This statement gives an explanation where although the objective of the project was not fulfilled, valuable research outputs were still achieved. |

In contrast to the quantitative analysis, the qualitative analysis describes what the research has achieved, and how the results can be used in a broader setting (i.e. in the context). Furthermore, the interviews with the stakeholders provide an important alternative view of the results, indicating their actual importance to the stakeholder involved. For example the "Robust Broiler project" was characterised by being costly (11.3 million DKK), and was assigned relatively few points (1,000 points). In comparison with other projects this result seems low but the statement from industry indicates that its results have been important and relevant.

**Discussion and conclusions**

The current paper addresses the task of evaluation of research projects' usefulness and scientific quality. It recognises the difficulty inherent in individual projects' generating highly specific knowledge that is only accessible to, and used by, a few people. In addition, it addresses difficulties in distinguishing amongst the activities, funding, outcomes and impact of a number of projects. The paper presents reviews of literature and of practical experience, and applies this in an empirical evaluation exercise requested by the Danish government.

By using a board (with multiple interests in research) to make the weighted indicators for research outputs we ensure that the evaluation of the research projects meets the requirements from not only the scientific community but also the food and agricultural industries as well as the surrounding society. The board performed a vital task in choosing the indicators for different research outputs, weighting and assigning priorities among them. Based on this outcome, the chosen indicators provide an incentive for researchers to prioritise their research effort according to these criteria and to follow a path where they perform well.

The approach taken enabled:

- a consistent (i.e. fair) and reasonably accurate evaluation of a research project at a cost that is not disproportionate to the cost of the actual research project.
- feedback to policymakers about the use of research funding.
- feedback to the research institutions in order to improve the management of research projects
- reflection of incentives for individual researchers in the evaluation criteria used.
- provision of a tool for researchers that "visualises" the outcome from research to the surrounding society – especially outcome that goes beyond peer reviewed articles.

The experience of the pilot evaluation is that the method provides a useful estimation of the distribution of impact amongst “Scientific impact”, “Embedment of knowledge” and “Impact on industry and society”. Of the programmes evaluated, most have their main impact focus on “scientific outcome” and “embedment of knowledge”. Impact on “Industry and surrounding society” receives far less emphasis. The same is true for the individual projects.

The pilot exercise also indicates that the quantitative evaluation is usefully complemented by a qualitative assessment in order to identify the impact on society and other research groups independently from the weighted indicators. Cases were found, for example, of projects’ obtaining a low score in the quantitative evaluation but having outstanding results in the qualitative evaluation (in the current case, based on stakeholder interviews).

Finally, it is important that an evaluation approach as presented here receives general support from scientist and the surrounding society before it is implemented. It is vital that the scores, and evaluation approach is regarded as fair and transparent among researchers. Creating negative incentives could occur when researchers focus too much on the total score or cost effectiveness of the projects. This could create a dichotomy of incentives: easy points rather than relevant points.

As a final comment, there are always two parts to an evaluation - those who evaluate and those who are being evaluated. Our approach aims to bring those two groups closer together and to ensure that the evaluation process is both operational (easy to use and easy to understand) and at the same time fair and acceptable to researchers.

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**Presenter info:** Søren Marcus Pedersen is a senior researcher with 12 years of experience in production economics and technology assessment. He has participated as a researcher and project manager in several national and European research projects. His Ph.D.focus on technology assessment and impact analysis in the agricultural sector.