The Impact of Research on EU Agriculture
impresa

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Research Impact Pathways – Comparative case study analysis

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IMPRESA Project WP3 Final Report D 3.3 - Partners

Research Impact Pathways – Comparative case study analysis

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Preface

This synthesis report, which provides a comparative analysis of individual case studies of science-based agricultural innovation, is a deliverable of the IMPRESA (the IMPact of RESearch on EU Agriculture) project. It compares and contrasts the impact pathways from agricultural research through the causal framework of case-specific individual research-based innovations.

The synthesis is based on comprehensive and detailed case study reports prepared by research teams of six of the partner institutions working on the project. These are: FiBL, Research Institute of Organic Agriculture, Frick Switzerland; Aberystwyth University, Wales (UK, overall project coordination); IfLS, Frankfurt a. M., Germany; Sofia University, Bulgaria; University of Pisa, Italy; FAO, Rome, Italy.

As Workpackage leader, I want to thank all the research teams involved for their tremendous and very interesting work on the case studies as well as for their excellent collaboration. I also want to thank the many stakeholders (researchers, advisors, experts, farmers, etc.) who contributed with active participation in interviews and workshops. Their participation was essential for successfully testing methodology for participatory research impact assessment. The content of the report is also based on a specific workshop with contributions from representatives from all case studies and additional experts, held in Bologna in February 2016. Their input is also gratefully acknowledged.

A special thanks goes to the main co-authors of the report Sylvain Quiédeville (major inputs in chapters 2, 3 and 6), Simone Sterly (major inputs in chapters 5, 7 and 8.2) and Dominique Barjolle (major inputs in chapters 2.2, 4.1, 5, 7 and 8), who invested much time to contribute to a synthesis from so many quite specific cases in different national contexts.

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Finally, we acknowledge the strong support of the overall coordinator of the IMPRESA project, Peter Midmore from Aberystwyth University in Wales, who provided the final content and made also the language editing of this report.

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Content

Executive Summary

Goals and objectives of case study analysis and synthesis

This synthesis report provides a comparative analysis of six individual case studies of science-based agricultural innovation. It is a deliverable of the IMPRESA (the IMPact of RESearch on EU Agriculture) project, which aimed to 'measure, assess and comprehend the impacts of all forms of European SRA (Scientific Research on Agriculture) on key agricultural policy goals, including farm level productivity but also environmental enhancement and the efficiency of agri-food supply chains.

The specific objective of the case study approach was to develop and test a methodological framework for assessing the impacts of scientific research on agriculture (SRA). The approach was adopted to analyse innovations and research projects/programmes in depth and explore the complex processes that occur along related impact pathways. The case studies were selected for their agro-ecological and (as far as possible) their socio-economic diversity.

Theoretical background

The development of the methodological framework for measuring, monitoring and assessing scientific research on agriculture (SRA) and its impacts is based on state-of-art knowledge on innovation, theories of change as well as quantitative, qualitative and mixed evaluation methods of research programmes.

The theoretical framework is based on an Impact Pathway Analysis (IPA), which was adopted in this study. Conventionally, IPA has been used in an ex-ante manner prior to the research programme being implemented. In this manner, it has been developed as a causal model summarising the way the innovation pathway is intended to, or should occur; from the implementation of research activities to achieved outputs, outcomes and impacts. However, in the IMPRESA case studies, the goal was to evaluate the impacts and role of the research ex post.

A more participatory approach than IPA was used in order to get stakeholders more involved in the evaluation process; and to increase the likelihood that those stakeholders will use the evaluation results by improving the way research programmes are implemented (both currently and in the future). The Participatory Impact Pathway Analysis (PIPA) (Douthwaite et al., 2007) was used with the organization of participatory stakeholders' workshops to enable reconstruction of the innovation pathway.

This approach was complemented by some additional methods. These adapted the IPA approach to the requirements of an *ex post* impact assessment (using Outcome Harvesting), improved consideration of the role of the actor network (using either Social Network Analysis or Stakeholder Mapping) and triangulated information collected from different sources in the course of the evaluation process (using both Process Tracing and asking counterfactual questions in semi-structured interviews with actors).

The impact pathway model used in IMPRESA for assessing the impacts and role of the research represents not only the inputs, outputs, outcomes and impacts but also the way in which they interact with feedback loops and interactions between different technical, commercial and institutional spheres.

Methodological approach applied in the selected case studies

The approach consisted of seven steps, which are summarised in Figure 1 and elaborated further in detail below.

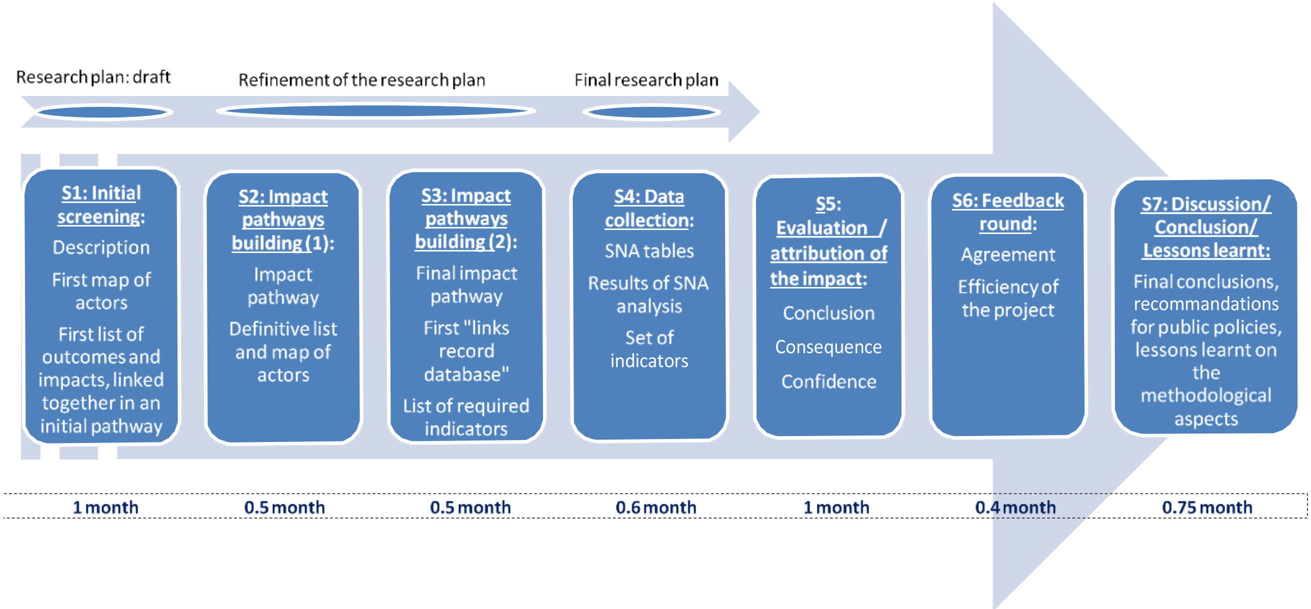

Figure 1: Steps in IMPRESA Case Study Research

Selection and brief description of case studies

The relatively small number of six case studies, in five different countries, was chosen in order to allow detailed and in-depth comparison. They cover a wide range of agro-climatic, socio-economic and sectoral conditions. We selected highly diversified cases within agricultural sectors: Dairy cow fertility index in the United Kingdom, an optical crop sensor for arable farming in Germany, Integrated Pest Management in olive farming and on-farm biogas in Italy, organic arable production in Camargue/France (conducted by the Swiss team), and a Varroa control product for beekeeping in Bulgaria.

Highlights from the impact pathway analysis

The research evaluated in the case studies was generally oriented towards improving the economic performance of farming, or towards solving environmental issues related to farming practices, or, in the case of the UK, ensuring the survival of the industry. Objectives outlined in the research proposals related to expected outputs and outcomes, but there was minimal if any information on expected impacts. Nevertheless, in most cases expected impacts can be derived from these objectives as plausible consequences.

In the six case studies, the diversity in activities, outputs, outcomes and impacts of agricultural scientific research is very large. Nevertheless, all provided evidence that their intended impacts were met, at least to some extent. The level of impacts were in all cases both at farm level and territory level.

Significant unintended direct impacts occurred in several case studies (e.g. market changes, change of policy support, etc.). The case studies also revealed a number of unexpected indirect impacts, many of which were either negative or ambiguous (e.g. black market for resale of the subsidized Varroa control product, contribution to intensification of dairy systems, etc.).

Most case studies contain at least elements of scaling-up. Typically, the scaling-up was linked to capacity building and to the research done, in raising awareness, to the setting up of lobbying and marketing organizations, to changes in the regulatory framework and to developing convenient uses of the new product/technology.

In every case analysed, the role of research in the innovation process was embedded in a set of preceding, related, or subsequent innovations of a different nature. These included changes in governance, in market conditions, in the legal framework, and in financial support.

Enabling and disabling factors were analysed related to human and social capital, the relation between actors, resource and economic prospects, institutional and policy frameworks and to advisory services. A variety of social factors, linked to capacities of the key actors, were found to foster the innovation process. Most importantly, these included trust among actors that fostered networks and collaboration, as well as contributing to development of the skills of beneficiaries. Economic factors also often play a prominent role.

In the research and development phase, factors that held back innovation development included a lack of public funds (Varroa control product); lack of awareness of a problem (dairy cow fertility index) and general conservatism of the farming community towards adopting new products/technologies. In the adoption phase (were diffusion is part), poor economic performance (biogas), high investment costs or product prices (optical crop sensor, Varroa control product), and absence of support from the public advisory system (organic production Camargue, optical crop sensor) hindered or slowed the uptake of an innovation.

In each of the case studies, the role of public advisory services was either limited or non-existent.

Experience of and learning from the PIPA application

While the original case study manual provided a menu of options for the conduct of individual evaluations of impact, experience of its use indicates a greater need for flexibility to cope with the very wide range of cases that can occur. The IMPRESA project is developing an updated PIPA case study manual, which can be recommended for general use, based on the experience reported here. More emphasis is given to the geographical scope, the data availability, more precise definitions of the concepts of outcomes and impacts, Process Tracing and testing the reliability of alternative explanations.

Conclusions from the comparative analysis of case studies

Participation of actors and other stakeholders at case study level was a final objective of the study described in this report. The ex post nature of the case studies made this difficult in some instances, especially where the original research took place many years previously and key actors or stakeholders had retired or had moved to different positions. The involvement in the case study work was highly valued by research actors, although it was sometimes difficult to convince other relevant stakeholders of the potential benefits of their participation, given the complexity and abstract level of the research.

The need for expertise in participatory methods and facilitation skills was emphasised, as there was a need to cope with dominance of some stakeholders in discussions and to manage conflicts between participants. Given the importance placed on capacity building along the innovation process, subsequent recommendations recognise a need to incorporate relevant social scientists and professional facilitators when designing research projects.

Recommendations for researchers

It is important to embed a culture of impact across the entire applied research process. Thus, these specific recommendations relate to research design and planning; to the process of research itself; to the analysis of performance to influence subsequent projects and programmes after completion; and to the overall institutional context in which research takes place. Of these, recommendations relating to the initial pre-research phase of activity are of paramount importance. This is because, if established without some participation from stakeholders other than scientists or policymakers, it is much harder to incorporate these perspectives once the research is under way, and the possibility of mis-targeting or minor relevance is much more likely to occur. Nevertheless, the other recommendations for interim review and effective impact monitoring should not be neglected; otherwise, stakeholder engagement could lapse into symbolic lip service, with minimal enhancement of impacts.

Here are the main recommendations for researchers:

For ex ante research impact assessment:

- Plan for impact at outset of the research design.
- Involve key stakeholders (including private sector) at early stage in the research.

For maintaining impact focus within project implementation:

- Consider impacts mid-term project reviews.
- Provide project resources for ‘soft factors’.

For ex post impact evaluation:

- Enrol researchers into a new ‘culture of impact’.
- Where appropriate, conduct ex post Participatory Impact Pathway Assessment.

For managing research calls and funding frameworks:

- Build flexibility into calls for projects to allow for new stakeholder perspectives.
- Design funding frameworks to gain early involvement of the private sector.
- Monitor research output with data collection tools and protocols at early stage.

Recommendations for policy makers:

Innovation theory (e.g. Saviotti, 2001) suggests that, while impacts of the research and the innovation cannot entirely be directed by policies and regulations, they play a crucial role in creating a suitably enabling environment for innovation, in contributing to capacity building and in facilitating access to funding. Recommendations to policy makers at the European and national government levels are focused on four key areas that have arisen from this comparative case study analysis.

Strengthening agricultural innovation support:

- Strengthen agricultural extension and advisory services as educators, knowledge hubs and innovation facilitators.
- Engage key actors in research and innovation and experiment with their potential roles.
- Coordinate and improve effectiveness of support instruments for capacity building, networking and funding of innovation brokers.

Engaging with the private sector:

- Develop a code of practice for public-private partnerships in research and innovation systems.
- Identify 'honest innovation brokers' to ensure that relationships function in the public interest.

Strengthening and coordinating research and innovation policy:

- Integrate research and innovation support instruments.
- Coordinate innovation support instruments with agricultural policies.
- Include stakeholders in research programming and evaluation.

Availability and access to research data:

- Strengthen availability and open access to research data and results for assessment of impacts and for general interest.

To conclude, the impact pathway approach taken in this comparative case study analysis of applied agricultural research has helped to understand the role of research in achieving impacts, and has provided insights into enabling and hindering factors in the social, economic and institutional dimensions, and particularly the role of capacity building in brokering and diffusion of innovation.

In summary, the recommendations all require greater acknowledgement of the important role of 'soft' factors in promoting applied research impact, and widening the role of all stakeholders in the innovation system. It must be acknowledged that this approach constitutes a challenge to existing power relationships and existing innate conservatism associated with the dominant log-frame approach of evaluation. It also affects wider issues concerning the collaboration between public and commercial interests and the equitable sharing of benefits between them.

1. Introduction

The overall aim of the EU-funded IMPRESA research project was to 'measure, assess and comprehend the impacts of all forms of European SRA (Scientific Research on Agriculture) on key agricultural policy goals, including farm level productivity but also environmental enhancement and the efficiency of agri-food supply chains'[1].

Specific objectives of the project were as follows:

(1) To describe the contemporary evolution of traditional public and private agricultural research, particularly as its boundaries with food processing, biotechnology and bio economy activities (e.g. renewable energy) are becoming increasingly blurred, and its objectives are broadening, using on-going structured interaction with an expert stakeholder panel.

(2) To survey the trends, sources and objectives of agricultural research in EU and EEA countries and Switzerland, providing a scoping survey, which provides a preliminary view of the range and integration of activities, and to design a framework, compatible with the OECD Frascati manual (2015), to assess the volume and effectiveness of research.

(3) To carry out econometric analysis and input-output modelling on the effect of research on agricultural productivity, including lag modelling, as the call specifically requires this, but with a view to acknowledging the importance of additional objectives for research; limited to a small number of country studies, to include small, medium and large countries, which also reflect geographic diversity.

(4) To investigate the overall causal framework of case-specific individual research-based innovations (in six regional case studies), using active searching for disconfirming evidence as a validation criterion.

(5) To innovatively and effectively communicate the major results of the project workpackages to national governments and other stakeholders, through a variety of dissemination channels (webinars, policy briefs, as well as traditional reports and conference presentations).

The fourth objective specifically relates to this synthesis report. Case studies were conducted (in **Workpackage 3)** in IMPRESA project to elaborate and test a methodological framework for assessing the impacts of scientific research on agriculture (SRA). The case study approach was adopted to analyse innovations and research projects/programmes in depth and explore the complex processes that occur along related impact pathways. The case studies were selected for their agro-ecological and (as far as possible) their socio-economic diversity.

[1] Further information can be found here: http://www.impresa-project.eu.

In more specific terms, the **objectives** of the **Workpackage 3** were as follows:

- To elaborate a methodological framework for measuring, monitoring and assessing scientific research on agriculture (SRA) and its impacts.
- To pilot the methodological framework in a set of carefully selected case studies, and actually assess the whole range of SRA impacts in each case study.
- To identify factors, which enable and/or foster, or limit, the effectiveness and performance of research in terms of desired changes, and present the results of the analysis to relevant audiences in a Research Brief and a Policy Brief;
- To offer insights for the scaling-up of quantitative assessment approaches in WP4;
- To provide a platform for bottom-up interaction with key actors and stakeholders at case-study level and to create an opportunity for their involvement in the IMPRESA project.

This synthesis report draws together results from each case study, mapping and assessing the individual research impact pathways, and provides an assessment of both the appropriateness of the methodological framework and also the strengths and weaknesses of the approach.

2. Theoretical background

The development of the methodological framework for measuring, monitoring and assessing scientific research on agriculture (SRA) and its impacts is based on state-of-art knowledge on innovation, theories of change as well as quantitative, qualitative and mixed evaluation methods of research programmes. While agricultural science is our focus we have also taken into account more widely applied evaluation methods from social sciences. The first part of this chapter outlines the theoretical background that informed the choice of the analytical tools and mix of qualitative methods to be applied to the IMPRESA case studies. The second part explains some aspects of innovation system theory in the context of *ex post* evaluation of research programmes, and relates it to the theoretical framework based on an **Impact Pathway Analysis (IPA)**, which is adopted in this study.

2.1 Theoretical background of the analysis

In the IMPRESA case studies, the tools of evaluation analysis were based on the theory of change applied to either a research project or programme. IPA draws on programme-theory, also often referred to as theory of change, to make explicit the mechanisms along the innovation pathway. The IPA approach provided the starting point of our reflections.

The rationale for this focus on impact pathways was the strong critique (Douthwaite et al., 2003; Springer-Heinze et al., 2003) of the 'logical framework', or log-frame, still used extensively as a monitoring and evaluation tool for project management. The underlying causal model of the logical framework is quite straightforward: inputs to the research process lead to activities that produce outputs, which in turn generate outcomes that ultimately lead to impacts. This simple unidirectional and sequential view of innovation processes is, however, problematic, contrasting with more recent conceptions that understand innovation as resulting from complex interactions and learning processes. Moreover, the log-frame's simple causal chains automatically attributes the entire impact to the intervention, thus not taking into account alternative causes in the impact pathway. As Godin and Doré (2004) have noted, in the context of measuring the multidimensional impacts of science, the challenges involved in identifying the underlying mechanisms along the process including discriminating conceptually between outputs, outcomes and impact; unambiguously identifying these transfer mechanisms; and developing appropriate and reliable instruments and indicators. The development of impact pathways with general validity thus represents a challenge, but is also a significant step in the impact assessment process. The IPA method intends to answer these challenges.

Conventionally, IPA has been used in an *ex-ante* manner prior to the research programme being implemented. In this manner, it has been developed as a causal model summarising the way the innovation pathway is intended to, or should occur; from the implementation of research activities to achieved outputs, outcomes and impacts. However, in the IMPRESA case studies, the goal was to evaluate the impacts and role of the research *ex post*. Furthermore, we wished to follow a more **participatory approach** than IPA in order to get stakeholders[2] more involved in the evaluation process; and to increase the likelihood that those **stakeholders will use the evaluation results** by improving the way research programmes are implemented (both currently and in the future).

Participatory Impact Pathway Analysis (PIPA) (Douthwaite et al., 2007) suggests that organization of participatory **stakeholders' workshops** could enable **reconstruction of the innovation pathway**. The aim is to visualize, collaboratively, the **causal model** of the change with the various stakeholders who are, or who will be, involved in the research programme. These **stakeholders** can be funders, researchers, institutions (either public or private), extension services, and beneficiaries (such as farmers). However, the PIPA method does not include a clear template that is applicable for *ex post* evaluations. Further limitations of the PIPA approach are that some stakeholders may influence discussions in workshops and thereby introduce bias into the results; moreover, the role played by the innovation network is not extensively reflected within the PIPA, even though this issue has become increasingly important in the agricultural sector.

To bypass these limitations we have enriched the PIPA approach with four complementary methods:

- **Outcome Harvesting[3]** (Wilson-Grau and Britt, 2012) provides a framework for *ex post* reconstruction of the innovation pathway. It reverses the conventional sequence of impact assessment in that it identifies outcomes first and then works back to outputs and subsequently activities. It also suggests supplementing information from stakeholders' workshops (as in the PIPA approach) with semi-structured interviews of actors, as well as with secondary analysis based on project's documentation.

- **Process tracing** (Bennett, 2010; Mahoney, 2012; George and Bennett, 2004) triangulates and validates the information collected by evaluating whether the different components of the hypothesized links (such as an event 'A' leading to an event 'B') actually existed. The rationale is that, due to the participatory nature of the PIPA approach, results could potentially be biased. The aim is to identify the **necessary conditions** for the links to occur. Particularly, these conditions include the presence of **underlying mechanisms** along the different linkages of the innovation pathway. The information about those mechanisms may be collected from face-to-face interviews or can be based on publicly available documents (coherently with the Outcome Harvesting method). Exploring possible alternative explanations contributes to the verification of the underlying mechanisms.

- Following on from this latter point, the **counterfactual approach** (Collins et al., 2004) was also considered of interest in order i) to permit identification and elimination of

[2] Definition of stakeholders: see Glossary in the Annex of this report.

[3] The Outcome Harvesting approach has been developed in order to overcome the limitations of "Outcome Mapping "(Earl, Carden and Smutylo, 2001) for *ex post* programme evaluation. Outcome mapping assists project evaluation by developing an *ex-ante* causal pathway model.

links in case where a second event occurred, regardless of occurrence of the first event; and ii) to identify the links where a second event would not have occurred even if the first event had not happened. This second aspect consequently allows the essential events in the pathway to be identified and thus assess whether, and to what extent, the research has played a major role.

- Finally, **Social Network Analysis (SNA)** (Scott, 2000) can improve understanding of the role of different stakeholders at different phases of the innovation process, and what that this entails. SNA is a tool to analyse how actors[4] interact within networks, and offers multiple ways for characterizing network structures through various indices of network clustering, actor centrality or prestige (Borgatti et al., 2002). Particularly interesting is the concept of 'betweenness' of actors, which can be recognised in terms of a '**knowledge broker**' function (Haythornthwaite, 1996).

2.2 Relevant aspects of innovation system theory

This section starts by providing the definition of innovation that was considered for the IMPRESA case studies, explaining the rationale of its choice in relation to the theoretical background. The section goes on by briefly summarizing the theoretical perspectives around the role that research can play in agricultural innovation processes.

Innovation concept in the context of EU agriculture

The IMPRESA project has investigated innovation in the agricultural sector. Here innovation is defined as the implementation of a new or significantly improved product (good), service or process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations (OECD, 2005).

However, the IMPRESA project did not investigate merely the generation of innovation alone, but the 'Innovation System'; this can be defined as a set of components, which by mutual interactions affect the introduction and development of different types of innovation at a given spatial level: local, regional, national and institutional (Esparcia, 2014). The innovation system turned to be the focus of the IMPRESA project because the agricultural sector, in many respects, is more complex than other sectors investigated by the mainstream innovation literature. This complexity is because new products and techniques, and also their adoption, do not result exclusively from the outputs or outcomes of research activities but also from other activities. The characteristics of the agricultural sector have important influences on this difference; they include the large number of relatively small farm businesses; a dependence on the primary resources of land, soil, water; the nature of the goods that are produced; some complex interactions within socio-ecological systems; and the strategic and geopolitical dimension of food. Thus, complex innovation processes occur in the agriculture sector (Bockelmann et al. 2012).

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[4] Definition of actors: see Glossary in the Annex of this report.

Furthermore, there is wide divergence between the individual innovation capacities of farmers. Some farmers demonstrate exceptional capacity in developing innovative solutions in production and marketing, whereas others have difficulties in adapting the structure and performance of their activities, particularly when it comes to commercialisation.

This suggests that there is a need for sharing information, capacity building, training, self-experimentation, and learning from advisors or peers through multi-way exchanges. This includes assessing new markets, creating channels for selling new products and supporting policy lobbying as well as for implementing better practices, e.g. more sustainable farming systems.

More than two decades ago, Gibbons et al. (1994) challenged the classical linear conception of knowledge transfer (which they named mode 1) in favour of more multidimensional and complex innovation processes (named mode 2). This paradigm shift has been subsequently adopted widely in the literature, especially in relation to the role of research and extension in the agricultural knowledge and innovation system, or AKIS[5] (Leeuwis and Van den Ban, 2004; EU SCAR, 2012). The impact pathway model used in IMPRESA for assessing the impacts and role of the research is closely related with mode 2, and the AKIS concept. In effect, the impact pathway model intends to represent not only the inputs, outputs, outcomes and impacts but also the way in which they interact with feedback loops, set out schematically in Figure 2.

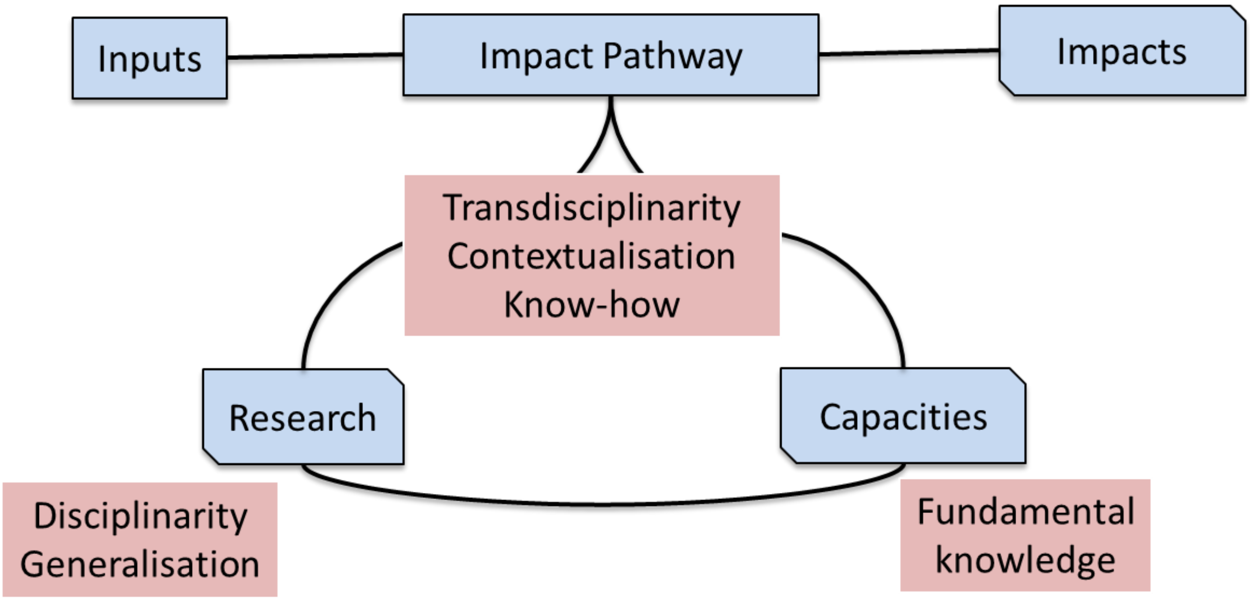

Figure 2: Impact pathway interaction

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[5] An Agricultural Knowledge and Innovation System can be defined as "a set of agricultural organisations and/or persons, and the links and interactions between them, engaged in the generation, transformation, transmission, storage, retrieval, integration, diffusion and utilisation of knowledge and information, with the purpose of working synergistically to support decision making, problem solving and innovation in agriculture." (Röling and Engel, 1990).

The role of research in agricultural innovation processes

The impact pathway is a mean of representing the change occurring between an initial state of resources (inputs) and a final set of different impacts (long-term effects, partly or wholly induced by the change) resulting from the adoption of an innovation (Probst et al., 2003; Maselli, Lys and Schmid, 2005).

Research may contribute to this change by producing specific outputs that aid innovation by actors, as well as by **supporting the building of both actors' innovation capacities** (for example by training beneficiaries in the use of new techniques) and users ability to adapt an innovation (e.g. a technology) to future and different usages. In innovation processes, new product development capacity (or new production methods, organization or marketing) and the expertise related to their utilization are crucial.

Powell and Grodal (2005) noted that networks create and reinforce such capacity by fostering innovation processes. Klerkz, Hall and Leeuwis (2009) further demonstrated the key function played by particular actors (organizations or persons operating within them) that they term 'innovation brokers'. Innovation brokers 'have a relatively impartial third-party position, and purposefully catalyse innovation through bringing together actors and facilitating their interaction'. An innovation broker expands the role of [traditional] agricultural extension from that of a one-to-one intermediary between research and farmers to that of an intermediary that creates and facilitates many-to-many relationships.

In addition to the role and importance of capacities, innovation processes require interactions between different technical, commercial and institutional spheres, as illustrated in Figure 3. When a concrete technical change emerges (such as a new product or new technique), market access is subsequently necessary to 'push' the adoption (for example, the transition to organic farming is pushed by consumer demand). At the same time, institutional acknowledgements in form of public financial support or official recognition ('official authorization') are generally indispensable to allow innovation's adoption. In the IMPRESA case studies, we have tried to consider all those aspects for assessing both the impacts and the role of research.

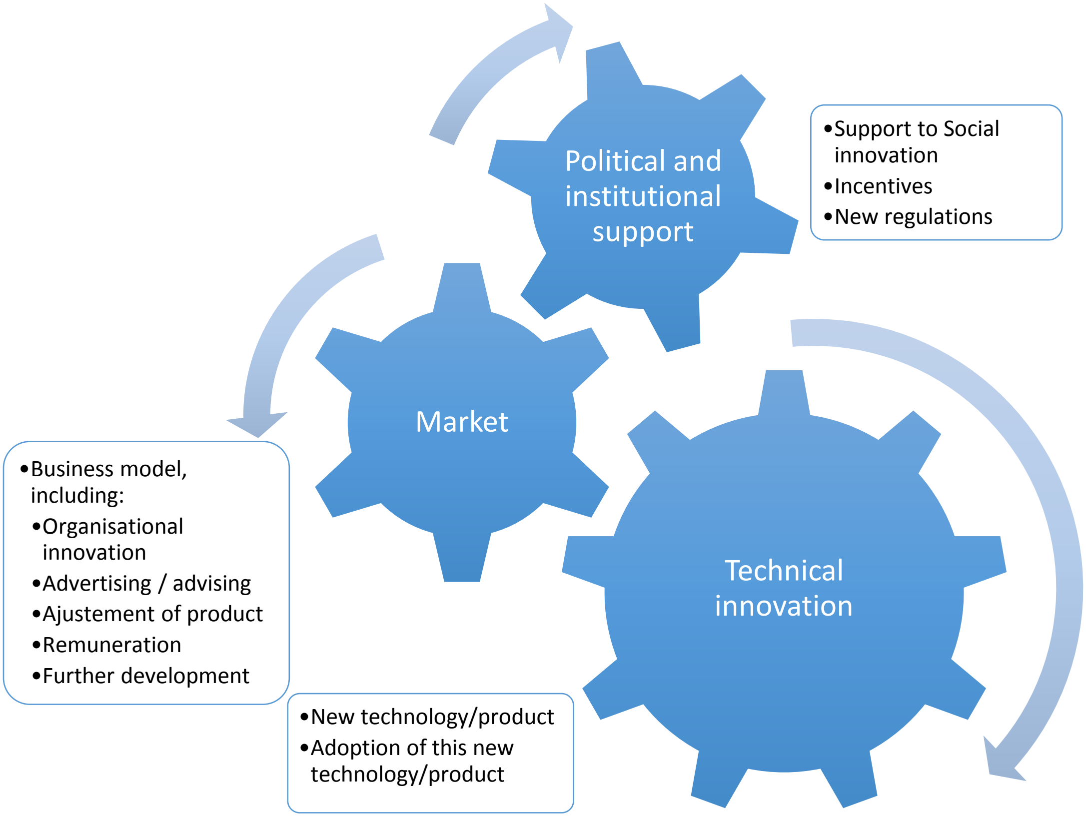

Figure 3: Innovation process interlinked with institutional, market and technical spheres

3. Methodological approach applied in the selected case studies

The general step-by-step methodology is described in the IMPRESA case study manual (Stigler, Quiédeville and Barjolle, 2014). As noted in the previous section, the methodology developed is based on Participatory Impact Pathway Analysis (PIPA) (Douthwaite et al., 2007) and complemented by some additional methods to adapt the IPA approach to the requirements of an *ex post* impact assessment (using Outcome Harvesting). It gives more importance to the role of the actor network (using either Social Network Analysis or Stakeholder Mapping) and triangulated information collected from different sources during the evaluation process (using both Process Tracing and asking questions in semi-structured interviews with actors to highlight counterfactuals).

The approach was carried out by different teams in dissimilar contexts and was designed to provide comparability and flexibility between case studies. Where appropriate and depending on the specific circumstances of each case, teams adapted these general guidelines to cope with their individual situation.

The approach consisted of seven steps, which are summarised in Figure 4 and further elaborated in detail below.

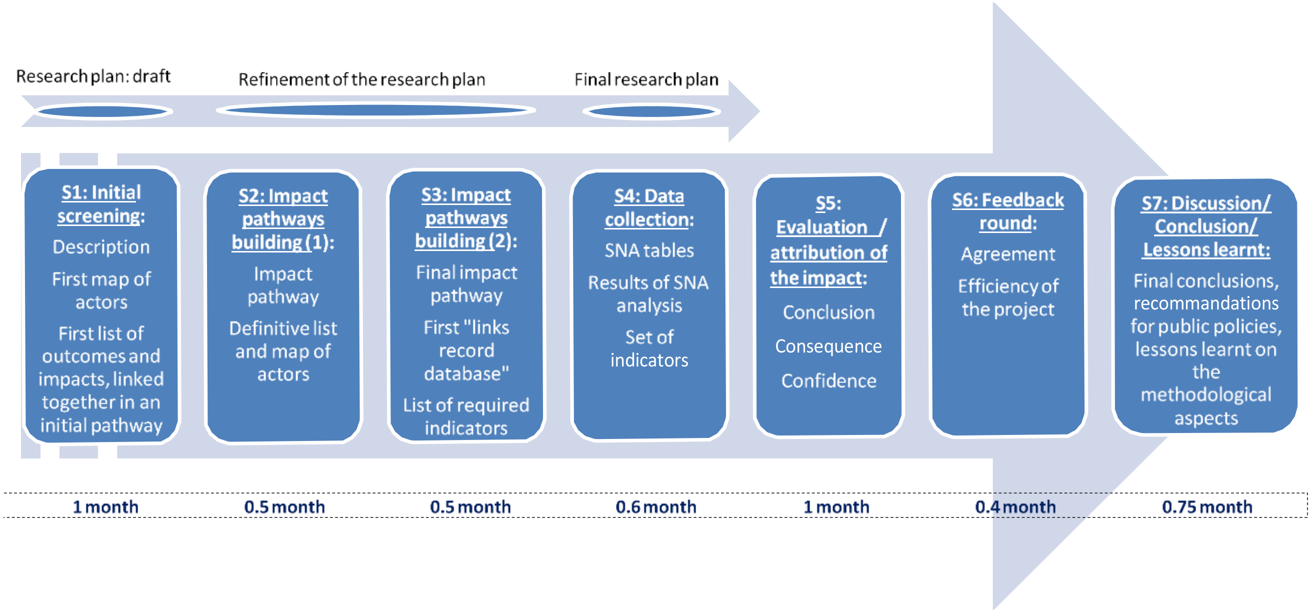

Figure 4: Steps in IMPRESA Case Study Research

S1: Initial screening of the case and actors, and impacts and research questions

In this step, the case study and its innovation narrative are described, listing the adoption phases and also drawing a first draft map of the actor network. This produces a first list of outcomes and impacts, linked in an initial pathway (the 'researcher pathway'). This step also provides the foundation for design of an initial plan of investigation that will identify the main impacts and related research questions.

S2: Stakeholder pathway building

In this step, the impact pathway is drawn from the point of view of the stakeholders. The format for achieving this was decided by individual case study teams, although two were recommended: the World Café approach and the Outcome Harvesting technique discussed in the previous section. The 'World Café' is a structured conversational process designed to facilitate open and friendly discussion. Aspects of the discussion topic were introduced into the group of stakeholders, asking for views about the research programme and innovation process. 'Outcome Harvesting' requires more structured and directed discussion in which participants were asked by the case study researchers to identify the outcomes, then to recount how such outcomes were achieved, and finally to collectively draw an impact pathway that linked together the different elements of the pathway (e.g. research activities, outputs, etc.). The step was concluded by showing the group the impact map produced by the case study team (the 'researcher pathway') so that the group could reflect on that and draw some conclusions from the similarities and differences with the ones they produced. Impacts were categorised as social (societal effects on health, education and community cohesion), environmental (emissions and usage of natural resources), and economic (local and regional impacts on overall economic and individual business growth and employment). The significance of these types of impact was subjectively assessed by the case study teams using three categories: High impact indicates a large change effect; medium impact indicates a considerable but not dominant; and low impact indicates an identifiable but not significant effect.

S3: Refinement of the pathway

The first objective of this step is to complete the stakeholders' version of the impact pathway, starting from the 'researcher pathway' and theoretical elements, particularly listing relevant links in the pathway in a database. Links indicate transmission of an effect, and in the first instance are confined to identification of the main reason for an output, outcome or impact having occurred. A further objective at this stage is to refine the research plan, recognising the impacts to be investigated and establishing the research questions.

S4: Data collection[6]

Based on the workshops which produced the stakeholder pathway, this step involves collection of data for Social Network Analysis (SNA), through in-depth interviews and assessing the extent and quality of the links through extraction of impact pathway indicators.

S5: Evaluation of the pathway

Using the Process Tracing method, theoretical explanations for each of the links are evaluated, necessary and sufficient conditions reviewed, and alternative explanations explored. Only the links considered robust enough are confirmed in the form of a final draft of the impact pathway.

[6] In some cases data collection to complete SNA was undertaken earlier, for example in the Camargue case, in the very beginning. See also Section 6.1.

S6: Feedback round

This step provides the opportunity for stakeholders to contribute to the finalisation of the impact pathway diagram and the 'links record database' by organising a further, final workshop.

S7: Conclusion

The validated impact pathway and links record database allow conclusions on the impacts to be drawn, recommendations for public policies to be made, and lessons learned on methodological aspects to be ascertained.

4. Selection and brief description of case studies

4.1 Selection of case studies

The relatively small number of six case studies, in five different countries, was chosen in order to allow detailed and in-depth comparison. These, described in detail in the next section, were selected in December 2014 and cover a wide range of agro-climatic, socio-economic and sectoral conditions.

To achieve this diversity, each investigative team produced an initial shortlist of three cases. These proposed cases were tabulated in terms of their different characteristics (agricultural sector, geographical level, type of innovation and research programme, advantages and disadvantages) for review and discussion. In addition to variation across the final set, other considerations included availability of data, the length of the innovation cycle, and the scope for collaborating with stakeholders of the case studies (at territory, regional or country level).

Although there are six IMPRESA WP3 teams, the cases were selected in only five different countries (UK, DE, IT, FR, BG); two cases were carried out in Italy, because two partners are located in Italy. We selected highly diversified cases within agricultural sectors: dairy sector in the United Kingdom, arable farming in Germany, olive farming and on-farm biogas in Italy, organic arable production in France (managed by the Swiss team), and beekeeping in Bulgaria. Furthermore, the cases studied cover different political and socio-economic conditions: Western (UK, DE), Eastern (BG) and Southern Europe (FR, IT).

4.2 Case studies overview and characterisation

The six IMPRESA case studies may be conveniently divided into two groups. The first group (summarised in Table 1) deals with production system development, whereas the second (summarised in Table 2) concerns tools and product development.

Table 1: Characterisation of three case studies dealing with production system development

PARTNERS	FiBL, Switzerland	FAO, Italy	University of Pisa, Italy
Detailed title of the case study	Transition towards organic farming in the French Camargue (territory level)	Use of integrated pest management in olive oil production in Canino (territory level)	Impact pathway of farm biogas in Tuscany (region level)
Short title used for reference	**Organic production in Camargue**	**IPM in olive production in Canino**	**On-farm biogas in Tuscany**
What is it about?	Transition towards organic farming in Camargue (rice being the main culture)	Integrated Pest Management for olive oil production.	A way to make use of biomass for renewable energy.
Relevance of the innovation / Rationale for adoption	Switching to organic in the Camargue is seen as a way to preserve the fauna and flora in the context of a very fragile area.	Reducing pesticides use for better olive oil quality and environmental protection.	Main objectives: a) reduce eutrophication of Adriatic sea through by recovering renewable energy from animal waste (manure and slurry from intensive livestock farming), and b). Direct economic support and changes in the regulatory framework boosted adoption.
Who conducted the research?	Mainly two researchers working at INRA. CIRAD and CFR were also involved when designing most of the research activities.	Public research with the Italian National Agency for New Technologies, Energy and Sustainable Development (ENEA), ERSAL and with OSCC (Oleificio Sociale - Cooperative di Canino)	The Research Centre on Animal Production (CRPA), which also benefited from research, carried out abroad (Northern Europe- mainly DE).
Adopters	Rice farmers	Olive growers (mostly farmers)	Farmers / entrepreneurs
Specific context	Fragile and wetland area Reduction of the number of authorized chemical products. Strong political support to both convert to organic farming Paddy fields allow reducing the concentration of salt in the soils and therefore makes cultivation of crop production possible.	Infestation of olive groves by olive flies Overuse of pesticides to control olive flies.	Strong financial and political support, as well as changes in the regulatory framework (external factors) provided the incentives for farmers/entrepreneurs to adopt the technology.

Table 2: Characterisation of three case studies dealing with tool or product development

PARTNERS	Aberystwyth University, UK	IfLS, Germany	Sofia University, Bulgaria
Detailed theme	Developing an index for the daughter fertility of dairy bull semen (country level)	Optical crop sensor for precision agriculture (country level)	Disease control in beekeeping: the story of Ecostop plates© (country level)
Short title	**Dairy cow fertility index**	**Optical crop sensor**	**Varroa control product**
What is it about?	An index for bull semen that indicates its performance for the fertility of its daughters	A crop sensor for precision on-the-go nitrogen application (later growth regulator, fungicide)	A natural and efficient medicine against the most common bee disease
Relevance of the innovation / Rationale for adoption	Address the problem of the falling fertility of dairy cows (recent global tendency, various causes and remedies)	Reducing the use of inputs to the actual need of plants based on measuring their chlorophyll content and thus avoiding over-fertilization.	Huge environmental problem significantly acknowledged in Europe: increasing mortality in bees.
Who conducted the research?	Public/private research Government funding - requiring matched industry contributions. (pre-competitive fund) Academics	Public research (university institute) developing a precision crop sensor for nitrogen application. Private companies in the further development from prototype to market-ready product, constant further improvement and adaptation of the innovation for other uses.	A small but competent duo of researchers, who founded a private small company.
Adopters	Breeding companies, and Farmers	Arable crop farmers (big farms, > 250ha, mainly cereals)	Beekeepers
Specific context	Livestock fertility is affected by short-term management, but also influenced by genetics, which takes much longer to remedy. The breeding focus had been on daughter milk production, which was in some cases at the expense of daughter fertility.	Need of farmers to produce efficiently (low input, high output) in order to ensure competiveness, and high requirements on quality and traceability of products as well as environmental impacts of agricultural production (over-fertilization, nitrogen leakage).	Post-communism: no trust in public institutions and weak/ absent availability of public funding for research in R&D ('old institutions' not very flexible – not oriented to the most relevant current research needs)

5. Highlights from the impact pathway stories

The way in which sources of innovation are translated into impact is not a linear process. We have focused on Impact Pathway Analysis (IPA) in each case, rather than the more conventional logical framework or 'log-frame', to take into account the more detailed and complex causal chain that takes into account intermediate outcomes, external causes and complex interactions, as suggested by Douthwaite et al. (2003) and Springer-Heinze et al. (2003).

The decision to adopt this general approach was appropriate considering the diverse narratives of the research programmes and innovations in each case study. It was observed that various phases, moving between activities, outputs, outcomes, and impacts, were not always linear, but they overlapped with feedback loops in some cases.

In order to disentangle the impact generation systems in their various contexts, this comparative analysis of different impact pathways is in itself linear, in terms of time-sequence. This follows the approach used in the reports of each individual case study to analyse the role played by the research in the successive phases of the innovation processes. However, in addition to the variety of interactions taking place among stakeholders in different phases of the innovations, we elucidate what the interrelations between these different phases were, and how the research either facilitated or hindered these relationships.

This chapter starts by an overview of the impacts and role of research in each case. It then presents the various types of research pathways, before going on to describe the enabling and disabling factors or barriers. Finally, we characterize the different types of innovation present in the cases, based on how the research and other factors had influences on the impact pathways, but also in relation to the way the innovations were diffused.

5.1 Impacts and role of research in the case studies

In the context of programme evaluation impacts are broadly described as encompassing the entirety of effects of a particular intervention. We have chosen to use the rather narrow approach of the OECD (2015), which defines it as 'positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended'. To begin this overview, impacts themselves are identified in each case study. It then describes the way the research was initiated in each case. The final result is an account of the different steps occurring between the initiation of the research and the achievement of impacts.

A) Overview of the impacts of the research

The research evaluated in the case studies was generally oriented towards improving the economic performance of farming, or towards solving environmental issues related to farming practices, or, in the case of the UK, ensuring the survival of the industry. Objectives outlined in the research proposals related to expected outputs and outcomes, but there was minimal if any information on expected impacts. Nevertheless, in most cases expected impacts can be derived from these objectives as plausible consequences. Research focused on improving production efficiency in three cases: in the German case, the optical crop sensor aimed to optimise nitrogen input use and reduce nitrate leaching; in the UK case, the dairy cow fertility index supported breeding decisions to contribute to decreased infertility; and in the Bulgarian cases the Varroa control product to reduce varroatosis in beekeeping. Expected or assumed impacts related to improved farm profitability in the German case, and to increased animal health for the Bulgarian and UK cases.

Research in the three other cases (the two Italian cases and the case in France) aimed at developing new production or by-product processes to address environmental problems. Research focused on fostering or adopting new techniques at regional level in three cases: in the Camargue case in France, a package of research solutions aimed to increase organic production in a fragile and threatened environment; in the Canino case in Italy, the aim was to reduce the quantities of pesticides used in olive farming; and also in Italy, on-farm biogas production in Tuscany addressed animal waste treatment problems. Based on the outcomes anticipated by the research, we can deduce the expected impacts that illustrate the positive environmental (and economic) benefits of the production or by-production systems adopted.

Impacts observed in the case studies have been categorised in three ways: by the aspects influenced, using the three traditional environmental, economic and social dimensions of sustainability (Dumanski et al., 1998); whether impacts were expected, or unanticipated; the degree to which they had positive or negative effects; and by the level of significance of the observed change at the territorial level (high, medium, low).

In the case studies, research objectives and related expected impacts were mostly attained, although with significance that was different to that anticipated. Tables 3 and 4 below provide an overview of positive impacts that were identified, verified and quantified at the respective levels considered. The level of significance of change at the territory level is indicated in brackets ranging from high to low. Positive environmental and economic impacts were identified in all cases. At least two case studies also showed positive social impacts, i.e. the Bulgarian beekeeping and Italian olive production IPM cases indicated increased organisational capacities. Economic impacts, such as increased incomes or income diversification, had highest significance of change at the territory level. Nevertheless, this could be a consequence of the fact that economic impacts can be measured and quantified more easily than environmental and social impacts, and generally receive more attention in studies.

Additionally, some significant positive but unexpected impacts, with low to moderate significance of change, have been observed:

- Increasing conversion to organic beekeeping (Varroa control product in beekeeping) (low);
- Maintenance of rural viability (on-farm biogas in Tuscany) (low to moderate);
- Stimulation of a common learning process of users and non-users (Optical crop sensor) (impact level unknown).

All negative impacts identified in the six case studies were unexpected, because the research programmes did not consider those possible impacts for various reasons (lack of awareness, funding reasons). Two types of unexpected impacts, direct and indirect, were identified.

Table 3: Main types and levels of impacts observed in the case studies dealing with production system development

Case study	Impact level	Impacts (level of significance of change at the territory level in brackets)	Range of the levels of change
Organic production in Camargue (FR)	*Farm level*[7]	Increase in incomes on crop production (high) Decrease in the use of pesticides (high) Decrease in the use of nitrogen (moderate)	Increase in net margins per hectare about 111% when converting to organic farming (fully or partially) 51% from 2000 to 2014 (concerning the Treatment Frequency Index) 24% from 2000 to 2014
	Territory level	Rise of organic rice surface (low) Reduction of the use of pesticides (moderate)	1400 ha in 2014 compared to 1000 ha in 2008 and 200 ha in 1981 (some data missing) 8.5% from 2000 to 2014
IPM in olive production in Canino (IT)	*Farm level*	Decrease in the use of pesticides (high) Increase in incomes (high)	Only 32% reduction from 1981/1982 to 1985/1986; before IPM introduction ca. 7kg/ha, after adoption 1 kg/ha (active ingredients) Better price on national and international markets due to the high olive oil quality through better production; price of olives paid to farmers increased as well
	Territory level	Improved organizational capacities (high)	Strengthened position of the cooperative, value of membership and authority to monitor members 'cultivation practices and certify their products, eventually leading to collective milling, branding & marketing of their olive oil. OSCC cooperative assumed new roles of advisory service provider, monitoring, quality assurance and certification (with OSCC brand).
On-farm biogas in Tuscany (IT)	*Farm level*	Income diversification (high) Improved soil quality (low)	n.a. n.a.
	Territory level	Maintenance of rural viability (farms, labour, area) (moderate) Less agri-food waste (moderate)	increase in hired labour, decrease in household labour n.a.

n.a. = not available

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[7] organic and partially-organic farmers

Table 4: Main types and levels of impacts observed in the case studies dealing with tool or product development

Case study	Impact level	Impacts (level of significance of change at the territory level in brackets)	Range of the levels of change
Dairy cow fertility index (UK)	*Farm level*	Reduced calving interval (high) Improved animal health and welfare (high)	Stabilisation of the national herd calving interval (CI) in 2002 and 2003, and a steady decrease after 2005; steady decline from 429 days in 2010 to 418 in 2015 n.a.
	Territory level	Increase the intensity of dairy system (moderate) Reduced GHG (low) Decreased macroeconomic cost of infertility Proof of concept (high)	n.a. Reduction in emissions intensity per cow and per kg milk solids (modelled) Cost of subfertility to the UK dairy industry is £350m per annum. The value of improvements arising from the project since implementation in 2002 is conservatively estimated to be £16.25m (Defra, 2006)
Optical crop sensor (DE)	*Farm level*	Adaptation of nitrogen to actual needs (high) Higher net income of applicants (moderate)	e.g. nitrogen reduction for winter wheat between 2 to 18% Reduced input use, better threshing performance, better quality and increased yields.
	Territory level	Reduction of inputs in the ecosystem (moderate) Creation of jobs (moderate)	Reduced input use (N and growth regulators) Estimated around 50 jobs
Varroa control product in beekeeping (BG)	*Farm level*	Reduction of pesticide used (high) Lowered bee mortality resulting in higher income (high)	The combination of natural substances produces very good results compared to other medicines, providing high therapeutic activity against varroatosis up to 94% for 45 days[8]
	Territory level	Increasing conversion to organic beekeepers (low)	

n.a. = not available

[8] Due to the rather complex nature of the anti-Varroa treatment in combination with other traditional and mechanic methods it is not possible to attribute decrease of the bee mortality exclusively to the use of Ecostop.

Unexpected direct impacts

The Italian case dealing with on-farm biogas in Tuscany experienced conflicts of moderate significance between producers and citizens about odour. However, in most cases, the extent of the negative impacts was either unknown or could not be assessed. In the Bulgarian case, an illegal black market emerged in reselling the subsidised product (under study). In the Camargue, the total area under rice decreased on at least some farms that converted to organic production, as a consequence of the crop rotation required by the system.

Unexpected indirect impacts

The case studies also revealed a number of unexpected indirect impacts, some being either somewhat negative or otherwise ambiguous. The company studied in the Bulgarian case lost sales, and therefore profitability, because of the black market mentioned above. The dairy cow fertility index assessed in the UK case study contributed to intensification of milk production, and while that had potential positive effects on farm profitability there were also negative ecological and partly social impacts that were not anticipated. Other unexpected and negative social impacts were mainly observed in a shift in power relations concentrating greater influence in private companies, in the case of the optical crop sensor in Germany. Also, in the UK, there is particular concern over potential for private companies to exert increased control as a result of their collection of and access to a wide range of farm business performance information (so-called 'big data'). However, within the scope of the IMPRESA project, it was not possible to assess the degree of the effect of this increased control of companies.

B) From initiation of the research to achieved impacts: an overview

General aspects

In half of the cases, scientists from public research institutions played a major role in initiating the research (DE, FR, UK). In two other cases, the research was initiated by government agencies (IT1, IT2) and, in the other case, the original initiative came from scientists in private companies (BG). Private companies came into the research at different stages; some at the outset, identifying issues at the beginning of the research programme. In addition, in two cases the involvement happened later, either once the research was under way or in the diffusion phase.[9]

Research approaches also differed between the six cases. For instance, two, the N-sensor in Germany and organic rice production in Camargue, included formal on-farm field trials. Participatory training sessions involving researchers and farmers were also held in the Camargue case.

[9] See the Impact Pathway diagrams of each case study in the annex for more detail.

Case by case in detail

FR: transition to organic farming in the Camargue

Although quite applied in its objectives, research in this case appears to have been mostly scientist-driven. The initiating actors were public agricultural research bodies, in particular INRA. Farmers did not play a major role in initiation or design of the research programme, since their relationships with INRA were relatively weak and generally informal. In particular, because of this informality there was no detailed information exchange on management of organic production systems in Camargue. While the research produced some outputs, they led to outcomes and impacts with quite moderate effects.

IT: IPM in olive production in Canino

Government agency initiated the research. Based on applied initial research, it focused on understanding prevailing pest problems and development of a model to predict insect population and to establish thresholds for treatment. The project consisted of a single integrated action that combined research and advisory services to assist olive growers and the cooperative to adopt IPM. The role of research was fundamental in linking the network of actors and ensuring leadership and accountability of the project.

IT: on-farm biogas in Tuscany

In Tuscany, the pilot project was led by a well-established research institution (CRPA) based in another region of Italy (i.e. Emilia Romagna) as main research objective was to reduce environmental pressure in livestock farms. The innovativeness and research quality associated with the pilot project under study allowed knowledge to circulate within the scientific community, but was unable to stimulate technology diffusion throughout Italy as a whole, since there was a lack both of institutional support and of coordination among the upstream and downstream chain of stakeholders. Agronomic research carried out outside Italy widened the range of suitable substrates and raised the methane yield of anaerobic digestion, thus helping the establishment of efficient and successful firms producing both digestion pools and anaerobic bacteria. Those firms become leaders of biogas plants' market, overshadowing the role played by research institutions (notably CRPA), which, however, still provide advisory services. The research helped target the improvement of existing biogas technology to meet the needs of Italian farmers.

UK: dairy cow Fertility Index

The research was government- and science-driven, as a response to the increasing problem of dairy cow infertility (the infertility itself already highlighted by research). The Fertility Index research funding ensured the participation of partners that were essential to the project: through their participation and provision of data, the milk recording companies and breeding companies enabled the use of on-farm records to reveal the fertility results of individual bulls for the first time. When the project uncovered the poor daughter fertility from some of the top-selling bulls, the breeding companies, having access to the results, were able to remove them from the market; hence, farmers were unconscious early adopters of the outputs of the project. After the Fertility Index was finally published, it was incorporated into the industry-breeding standard, which was then used by breeding companies in their catalogues, enabling farmers to make conscious buying decisions on the daughter fertility of bull semen.

DE: optical crop sensor

The initial research that led to the development of optical crop sensor was solely science-driven, undertaken within a Collaborative Research Centre funded by the German Research Foundation (DFG). Subsequent research and development, however, were taken over by a private company. The initial research was crucial for the achievement of impacts since it led to production of the prototype, and developed the knowledge required by the key researcher who subsequently developed the sensor in the setting of a private company. Continuous adaptation and enhancement of N-sensor functions and algorithms, combined with marketing and advisory activities, have contributed to growing demand for the sensor. Interactions with farmers who provided feedback on the technology as well as contributing ideas for other uses have been particularly relevant in this second stage of research and development.

BG: Varroa control product

The development of the Varroa control product in beekeeping in Bulgaria arose from broad on-going research of a private company rather than being the result of a single research project. The research activities included efforts to develop new products, to improve existing ones, and various associated activities such as improvement of equipment, certification of good pharmaceutical practice, and quality control. The two leading scientists, also the co-founders of the private company, used their existing scientific network from previous university research to identify and frame the resistance issues in Varroa control. These private sector scientists, along with a small number of highly engaged beekeepers, conducted the clinical trials of the product. Other private companies contributed to impact during the development phases of the product. Although connections with the scientific community contributed an effect on the development of the product itself, the involvement in the beekeeping communities was crucial in the gradual formation and establishment of a broad, robust network for popularizing the product among beekeepers.

5.2 Types of research pathways leading to impacts

A) Innovation phases, critical points and scaling up

Innovation phases

The introduction to this chapter suggests that impact pathway narratives tend to be structured chronologically. In all six cases, the IMPRESA research teams identified research and diffusion, which includes adoption (sometimes also described as the implementation) phases. The UK case involved some unconscious adoption during the basic research phase, as breeding companies removed those bulls with poor daughter fertility performance from the market. In some cases, a phase in which the marketable product was developed (R&D) can be described. In this section, we endeavour to show how, from an innovation theory perspective, activities, outputs and outcomes play a role in the different phases of diffusion in the case studies. While we use the classical distinction of the three phases of innovation (research, development of a marketable product/ process and diffusion including adoption) we recognise that the innovation system approach involves a succession of processes and interactions between actors which helps to provide a more precise explanation of how the results of science relate to observed impacts.

Table 5 provides an overview of the timing of these phases in the six case studies, while identifying specific related events and (where possible) the rate of adoption from phase to phase. Note that the date of initiation of research analysed in the cases ranges from 1979 (IPM in olive production in Canino) to the year 2000 (dairy cow fertility index). Additionally, in five of the cases it took six or seven years from initiation of the research to the start of the diffusion activities; however, in the IPM in olive production in Canino case, the period between was only four years. Thus, diffusion phases in the case studies lasted from few years in the case of IPM in olive production in Canino (IT) up to around three decades from the market entry of the innovation in the case of on-farm biogas in Tuscany (IT).

The activities in the diffusion phases varied considerably, and, in most cases, it is not easy to define a clear boundary between them. It should also be noted that the pre-research phase played an important role: it encompassed the identification of issues/research questions, the building of networks and trust among different actors, or events that led to the initiation of research, such as agenda setting at a political level.

Table 5: Phases in the analysed case studies in IMRESA project

Phase	Organic production in Camargue (FR)	IPM in olive production in Canino (IT)	On-farm biogas in Tuscany (IT)	Dairy cow fertility index (UK)	Optical crop sensor (DE)	Varroa control product in beekeeping (BG)
Research	2000-2006	1979-1981	1980-1986	2000-2006	1994-1996	1999-2001
Development of a marketable product/ process		1981-1983	1990s and early 2000s	2005-2007	1996-1999; 2006: ALS[10] launch 2008: growth regulators	2000-2006
Diffusion and adoption	2006-2007 (OPRESA table[11])	1983-1985/86	Late 2000s	(2002) 2005 until now	1999 until now	2007 until now
Specific events	2003: rice value chain established; 2010, 2011 adaptation research	1998: PDO[12] registration	2009: feed-in tariff scheme, following EU Renewable Energy Directive	2002 some bulls removed from market. FI launched 2005. 2006: FI incorporated into £PLI[13]; 2007: indices for UK imports published FI weighting increased in £PLI		
Indicators of adoption levels	(1980: 200 ha) 2008: 1000 ha 2014: 1400 ha	1982/83: 59 farmers 1985/86: 904 farmers (98% of all members)	2008: 3 plants 2014: 29 plants	2010: widespread use by breeding companies	2015: 700 farmers est. 700,000 ha in DE	23 – 25% adopters in 2014 in BG

Critical points

Critical points are defined as the impact pathway links that would not have been activated without the research. That is, they mark aspects or events deriving from the research and without which there would have been either no progression, or significantly less progression, along the impact pathway. In each of the six case studies, we identified a number of frequently occurring critical points. The identification of problems relating to farm profitability or to environmental impacts of agriculture, subsequently addressed in the research, were crucial in the cases of organic production in Camargue, the dairy cow Fertility Index, the optical crop sensor and in

[10] Active Light Source.
[11] One of the research/extension projects analysed in the case study.
[12] Protected Designation of Origin.
[13] Profitable Lifetime Index.

Varroa control. Another important critical point was the establishment of networks (or reconfiguration of existing networks) connecting different types of actors (researchers, extension workers, companies or farmers' organisations). This latter critical point was observed in the setting up of the research group in the UK, in the increasing influence of INRA and CIRAD over organic production in Camargue, and in Bulgaria through the integration of the research team into the veterinarian scientific and the beekeeping communities. On-farm trials were identified as a critical point in both the Camargue organic production case, and the Bulgarian case of the Varroa control product. In the two cases where product innovation was developed and marketed by private companies (optical crop sensor in Germany and Varroa control product in beekeeping in Bulgaria), the development of a promising prototype was a critical point for diffusion. In the UK, the production of the Fertility Index was an essential step that enabled information produced by the research to be utilised. Alignment of policies, relevant financial support instruments and the occurrence of commodity price fluctuations provided the critical point in enabling extensive installation of on-farm biogas production in Tuscany.

Scaling up

Scaling up is defined as the institutional expansion from adopters and their organizations to policy makers, funding institutions, and other stakeholders, and is in turn the foundation for the scaling-out (or wider diffusion) process (Douthwaite et al. 2003) and essential for building a more enabling environment for innovation to be adopted. Most case studies contain at least elements of this scaling-up phenomenon. Typically, the scaling up was linked to capacity building and to the research done, in raising awareness, to the setting up of lobbying and marketing organizations, to changes in the regulatory framework and to developing convenient uses of the new product/technology. Examples of this are:

- Creation of value chain in the case of organic production in Camargue;
- Registration of Canino olive oil as a PDO in the Italian IPM case;
- Three major changes in the Italian biogas case study:
    i. availability of advisory services;
    ii. feed-in tariffs for renewable energy generated from biomass;
    iii. creation of the Italian Biogas Consortium, a representative body of biogas producers;
- In the UK dairy cow Fertility Index case, involvement of the MDC, inclusion of the FI (and its subsequent increased weighting) in the £PLI, and the decision of the MDC to establish an extension function;
- The registration as Veterinary Medicinal Product and subsidised provision of the Ecostop product by the National Beekeeping Programme in the Bulgarian case.

B) Types of activities, outputs and outcomes

Following this overview of the chronological progression of six cases that describe changes from phase to phase, the focus turns to analysis of complexity of the pathway. The degree of this complexity depends on the number of elements (activities, outputs, outcomes, impacts, external factors) included in the pathway, as well the linkages between them. The number of elements is determined by the framing of the case study, in terms of the research itself and the territorial demarcation. Furthermore, the specification of the elements varies, from highly detailed elements (such as 'research reveals 1% per year decline in calving interval') to very general categories (knowledge of farmers' problems and constraints). The categories discussed below provide an overview of these elements identified as activities, outputs and outcomes from the participatory process used to analyse research impact.

Types of activities:

Activities are defined as actions taken or work performed by researchers and other actors involved, through which inputs such as funds, technical assistance and other types of resources are mobilized to produce specific outputs. The research activities identified across the case studies exhibit a multitude of elements, which can be regarded as relevant for identifying impact pathways. They comprise R&D-related, capacity-related and market-related activities.

R&D-related activities:

- Problem identification (in on-farm biogas, dairy cow Fertility Index, Varroa control product).
- Application for funding for research (successful in the case of dairy cow Fertility Index and unsuccessful in the case of Varroa control product).
- Implementation of research (all cases).
- End-product development (dairy cow Fertility Index, Varroa control product, on-farm biogas).

Capacity-related activities:

- Networking between actors/stakeholders (on-farm biogas in, Varroa control product).
- Dissemination actions (publications, extension, advice) (all cases except Varroa control product).

Market-related activities:

- Product registration, securing intellectual property rights (optical crop sensor and Varroa control product).
- Marketing activities by producing companies (optical crop sensor, Varroa control product).
- Financial support (Varroa control product) or fixed price paid to farmers (on-farm biogas) giving market advantages.

- Institutionalising roles, setting up organisations (on-farm biogas, dairy cow Fertility Index).

These elements provide a reasonably comprehensive overview of activities constituting an innovation diffusion process, although surprisingly, the impact pathways do not include activities and outputs that include the physical production of the (embodied elements) of the innovation. In addition, while not all types of activities are mentioned in all cases, this does not imply that they did not take place, but rather that they seem not to have had any influence on achievement of the impacts identified.

Types of outputs:

Outputs are defined here as products, capital goods and services resulting from an activity, and may also include changes resulting from the activities that are relevant to the achievement of outcomes. Following Earl and Carden (2002), and Byrne and Ragin (2009), they should be directly achievable and observable. In the case studies, outputs observed were mostly described as tools and events for creating and sharing knowledge, as well as new products. Examples from the case studies are summarised below.

- Increased knowledge and capacity building in the form of typologies, problem identification, accruing at the level of researchers, organisations and also among farmers (organic production in Camargue, IPM in olive production, dairy cow Fertility Index, Varroa control product);
- Publications such as PhD theses, leaflets and reports (organic production in Camargue, IPM in olive production, dairy cow Fertility Index, optical crop sensor, on-farm biogas);
- Description of approaches for the use of knowledge and products (organic production in Camargue, IPM in olive production in Canino);
- Dissemination events such as lectures and workshops (organic production in Camargue, IPM in olive production in Canino, on-farm biogas in Tuscany, Varroa control product, optical crop sensor); laboratory establishment (IPM in olive production in Canino);
- Publication of in outreach journals (on-farm biogas in Italy) ;
- New products: Prototypes (optical crop sensor, Varroa control product), products (including tools, models, indices) (IPM in olive production in Canino, dairy cow Fertility Index, Varroa control product, optical crop sensor), adapted designs of plants (on-farm biogas in Tuscany);
- Official recognition (incorporation of Fertility Index into the Profitable Lifetime Index £PLI, and subsequent higher weighting in £PLI).

Types of outcomes:

An outcome is defined here as the achieved short-term and medium-term effects of the outputs of an intervention. According to Earl and Carden (2002), an outcome implies changes in the behaviour, relationships, activities and/or actions of a boundary partner[14] which can be logically linked to a programme (or project, or activity). This aspect covers the largest number of elements in the case studies and relates both to primary and secondary outcomes at beneficiary (producer) level, as well as to outcomes at a higher, institutional level.

The adoption of the innovation is the central element in outcomes at beneficiary level in all case studies. However, note that the UK dairy cow Fertility Index case differs from other cases, in that the adoption with the greatest impact occurred at supplier rather than producer level. In addition, while almost all cases indicated additional adoption, or scaling-out, beyond the territorial boundary set by the studies, this was not investigated in detail. Accordingly, within case study regions, the following outcomes from adoption, at the level of beneficiaries, were observed.

- Changing resource use (optical crop sensor);
- Changing performance and yields (dairy cow Fertility Index, optical crop sensor);
- Increased costs (optical crop sensor);
- Increased generation of data and its management (optical crop sensor);
- Reduction of externalities (on-farm biogas, Varroa control product).

The following outcomes from adoption at a higher level were observed.

(1) Changes in relations between actors, organisational structures, adjustment of markets, and opinions:

- Changing relationships, power relations and influence between actors and stakeholders (organic production in Camargue);
- Increased organisational capacities (IPM in olive production in Canino);
- Essential advisory services (optical crop sensor);
- Engagement of UK Milk Development Council in information dissemination (dairy cow Fertility Index);
- Proof of concept and development of further breeding indices in United Kingdom (dairy cow Fertility Index).

[14] Boundary partners are "individuals, groups, or organizations with whom the programme interacts directly and with whom the programme can anticipate some opportunities for influence" (Earl et al., 2001, p. 9).

(2) Market adjustments:

- Establishment of supply chains (organic production in Camargue);
- New target group (organic beekeepers Varroa control product);
- Increased attractiveness or demand for the innovation (optical crop sensor, Varroa control product);
- Development of competing innovations (optical crop sensor).

A number of elements have been important in all pathways. These include, firstly, multiplier elements, which contain several strong forward linkages; secondly, reflective elements, which have linkages in both directions reinforcing their effects; and thirdly, dead-end elements (at the level of outputs and outcomes) which do not contain any forward linkages (these final elements can, however, be important in understanding boundaries and barriers in the impact pathway. Table 6 provides an overview of the specific elements for each of the cases studied.

Table 6: Impact Pathway characteristics compared

	Organic production in Camargue (FR)	IPM in olive production in Canino (IT)	On-farm biogas in Tuscany (IT)	Dairy cow fertility index (UK)	Optical crop sensor (DE)	Varroa control product in beekeeping (BG)
Level of complexity	Complex, detailed	Linear, detailed	linear	Linear at onset, complex further on	Complex, detailed	Complex, detailed
Multiplier element	CEBIOCA project Activity 2 : experimentation; Output 3: ORPESA leaflets; Output 4: knowledge about weeds; Outcome 8: adoption of organic production	Outcome 3: OSCC strengthened organisational capacity; Outcome 4 adoption of IPM	Activity 5 knowledge brokerage; Outcome 5 scaling up in Italy and adoption in Tuscany	Activity 3 Project LK0639 initiated; Output 3 Fertility Index Published Activity 4 MDC promotes FI	Output 3 market entry; Output 5 site specific fertilizing	Activity 6: additional laboratory trials / improvement; Output 5 Ecostop product
Reflective elements	Outcome 8 adoption of organic production mode – Outcome 9 institutionalisation of the supply chain	Output 2 entomology laboratory – Output 3 model developed for site specific forecast for pest control; Outcome 1 pest' management strategies developed – Outcome 2 decision support system developed	Activity 4 international collaboration – Outcome 1 Knowledge exchange over time	Activity 5 Indexing International bulls	Outcome 14 demand growth – Outcome 16: other competing sensors are developed	
Dead-end elements		Output 5 Reports/ publications/ seminars; Outcome 5 Scaling up of Canino model		Outcome 4: reduction in speed of increase of calving intervals	Outcome 13 Data management	Outcome 9 Diffusion to EU and non-EU countries

5.3 Enabling and disabling factors

This section highlights the factors identified as enabling progression from initial inputs towards the assessed impacts, and also those that can be seen as barriers. Activities, outputs and outcomes directly linked to research, or influenced by it, have mostly been considered in the previous section. Factors analysed in this section are not always directly linked to research, but can be associated with the capacities of the actors (other than researchers) who contribute to the creation of innovations. These factors can be internal, because they may influence the strength of linkage between two elements or to their quality and intensity. Others are external factors, not linked to the research intervention, and can include changes in the political framework conditions, such as CAP payments, or energy policy, or pressure on actors such as a change of state of a natural resource, or a new market opportunity or constraint.

Common enabling factors, in several cases, were:

- the existence of trust between actors;
- good communication between stakeholders at various levels;
- the prospect of profitability; and
- the institutional and policy framework, with its ensuing funding.

The profitability factor, in particular, can have a mixed dimension, in the sense that profit for one actor may lead to loss of profit for another. Overall, the cases show that the interplay and dependencies between these human, social, institutional and economic factors to a large extent determine research impact.

The following sections explain the effects of these factors in the context of human and social capital; relations between actors, resources and economic prospects; and institutions and policy frameworks.

Human and social capital, relation between actors

Enabling factors

Human and social capital aspects have been identified as very important factors that influence impact pathways (in particular in the dairy cow Fertility Index and the Varroa control product).

Trust between different actors is seen as an important prerequisite for achieving impacts in all cases. The Varroa control product case explains how trust was essential for the initiation of research in the particular post-socialist context:

> *'Most of the relations among actors are informal and personal, but not institutional. In other words, the network is driven by professional qualities and social ties the actors have developed over time with the core scientific team. This specificity is typical for the post-socialist context, where the trust in and the importance of the public institutions is very low in relation to the trust in private and informal relationships'* (Slavova et al. 2016)

Regional variations of trust by farmers in commercial sales representatives were observed in the UK dairy cow Fertility Index case; such variation can be explained by the availability or otherwise of government support for agricultural extension in some regions, making it possible to cross-check information. Where information could not be verified, farmers of necessity had to trust commercial representatives.

Human capital (embodied in the education and training of farmers) has been reported as an important prerequisite for adoption. Especially for the adoption of optical crop sensor, a high level of technical expertise is required. In the dairy cow Fertility Index case, from anecdotal evidence it seems that college-educated grandsons (where enthusiastic lecturers promoted the Fertility Index as a tool for improved performance) were more influential on the grandfathers' semen purchasing choices than were their fathers. The survey among beekeepers conducted in the case of Varroa control (BG case) showed that 68.3% of respondents are university graduates. Sharing information among a few people, and a mixed network (scientists and professionals) is a key success factor. '*To create hierarchical and close network was a strategy to preserve the know-how and control over the flow of the information'* (Slavova et al. 2016).

So-called soft factors, such as establishment and development of professional networks, sharing non-pecuniary values and organisational aspects play a very important role in facilitating the pathway to impact in all six cases. The studies suggest that they are of equivalent importance to the hard factors of scientific experimentation, measurement, analysis and modelling, and should be taken into account in funding allocations. Capacity building may be supported by establishing new, dedicated actors in such networks, such as a new cooperative (or similar association) with the specific function and purpose of enhancing impact. Although initially regarded as newcomers with specific disadvantages that can entail, if taken seriously by long-established research institutions they can renew and improve the links among the stakeholders (these issues will be further developed in Chapter 8).

Ownership of an innovation is central for ensuring long-term continuation of the adoption process. In the agricultural sector, promotion of on-farm research and farmer-to-farmer exchanges can perform that important function. In many cases, direct participation of farmers in experimenting with the new techniques boosts adoption. This was the case in Canino and in Camargue, when the innovation involved a mix of new farming practices. However, it is essential that farmers participating in the experiments are carefully selected, as they have a more important role than merely providing an experiment site. In the Bulgarian case, they were described as opinion leaders; in the UK case, as trusted commercial farmers recognised in the wider agricultural community as early adopters. From this discussion it can be concluded that individual characteristics (capacity, commitment, passion), combined with strategic networking between different types of actors, can strongly enhance agricultural research impact.

Disabling factors and barriers

Human capital was most often the starting point of innovation. In the six cases investigated, the innovation process mostly started at very small scale, with one or at most only a few people actually committed and active. Such minor cases deserve more attention from leading agricultural research institutions, since they are not always considered as interesting enough to devote sufficient attention and support. This was prominent in the case of organic farming in Camargue, where the interest of a single researcher impelled a cascade of research projects, although the lead rice research institution in the region ignored the topic in its activities. The same phenomenon occurred in the case in Bulgaria, where researchers felt they had to quit the public research institutions in order to be able to pursue the innovation process. German and UK cases also confirm that successful innovations are most often initiated and developed by a very small number of people (between one and three) in a less formal context.

Another major hindering factor identified in several cases was risk aversion. While this can be a strategy for increasing resilience in uncertain or difficult conditions, there were links to the social context of the particular case. While conservatism displayed many variations in its expression, the most frequent factor was the reluctance of the farmers to adopt new farming techniques. For example, conversion to organic farming in Camargue was inhibited because the advisory services did not support its uptake, and only after the entrance of a new research organization were the most innovative farmers enrolled and a snowball effect developed. A further social barrier, linked to conservatism, was found in Camargue where the lack of peer-to-peer effect between farmers hindered the progression of organic farming practices, and can be attributed to a closed mind-set in the region. Conservatism of a different kind was observed in the dairy cow Fertility Index case, where the breeding industry, veterinarians and farming sector itself failed to recognize the importance of the genetic aspect of the fertility problem.

In other cases, social barriers appear to be linked to conflicts of interests with central actors in the existing network who can be resistant to certain changes that diminish their influence, their power, or their economic ascendency (such as in the Fertility Index in the UK, or the transition to organic farming in Camargue).

Resources and economic prospects

Enabling factors

Developing specific market linkages may support the innovation process. Consumers were observed to be drivers of market change in the case of organic rice in Camargue. In the UK case, involvement of the supply chain (semen sales companies) in the research partnership meant that the product catalogue could rapidly reflect the results of the research (semen from poorly performing bulls was withdrawn from sale) without financial disadvantage or adverse publicity. Logistic issues may present substantial barriers to innovation; solutions observed included restructuring an organisation to undertake marketing activities, and establishment of a new cooperative organisation.

Disabling factors and barriers

In almost all cases, change was very slow where end-users did not recognise direct benefits in the short term. Enrolling farmers can be a huge challenge and can take several years. High initial costs in relation to benefits constitute a major barrier to adoption. Adaptation to new circumstance, such as health or environmental concerns, appears very slow when economic incentives are small or too long term (such as for the Fertility Index in UK). In response to this barrier, lobbying by influential organisations can change legislation or argue for a direct public financial support. This was the case for on-farm biogas, but is also observed more generally, for example in provision of conversion incentives for organic farming.

Prices for inputs can be both a barrier or enabling factor, e.g. increasing input prices for nitrogen served as incentive for the adoption of the (potentially input-saving) optical crop sensor also in Western Germany, which showed more cautious adoption rates earlier on as compared to Eastern Germany.

Another barrier in innovation diffusion and hence impact was divergent interests between large and small private companies during the research and development phase of the optical crop sensor. The smaller, and more flexible, marketing and advisory company involved with farmers was keen to improve or extend functionality of the sensor; the larger company responsible for its technical development was less ambitious and therefore responded much more slowly in appropriate product adaptation.

Institutional and policy frameworks

Institutional and policy frameworks have played important roles as both enabling but also as hindering factors. They were particularly important for research funding, product registration and marketing innovations to promote their diffusion.

Enabling factors

Formal support and research funding

Research funding as part of the policy framework has been an enabling factor at different points in pathways. The UK Ministry of Agriculture, Fisheries and Food (MAFF)[15] co-funded the initial research in the dairy cow Fertility Index case once it had become clear that there were no economic drivers to solve the infertility problem in dairy cows, despite its long term negative impact on economic performance. The German case on optical crop sensor shows that even a relatively small budget for initial basic research (as part of a Collaborative Research Centre funded by the German Research Foundation, DFG) can be a strong enabling factor to support development of the product. The backing provided by the institutional framework in the research phase had a moderate influence in the case in France (organic production in Camargue), and was decisive factor in the on-farm biogas case due to its heavy reliance on public financial support. Public subsidies received by beekeepers from the National Beekeeping Programme in Bulgaria to combat the Varroa mite aided diffusion of the Varroa control product.

The formal PDO (Protected Designation of Origin) recognition in 1996 of Canino Olive Oil, which required IPM in the specification of the production process, contributed at a later stage to enhanced appreciation of its quality and resulted in attractive market opportunities and greater competitiveness in national and European markets.

[15] Following reorganisation of government departments in June 2001, the functions of MAFF were absorbed into the new Department for Environment, Food and Rural Affairs, or Defra.

Disabling factors and barriers

The Bulgarian case demonstrates how difficulties in accessing funding for research can hamper the impact pathway.

> *'The two inventors of the product (the core team) made repeated attempts to apply under different programs in order to receive public funding. These attempts put the development of the product at risk, because of the requested bribes (in order the project to be supported) and because of the high prices for consultation in the preparation of projects. In addition, applying for public funding appeared to be time and human resources consuming. As a result these barriers were overcome through private funding'* (Slavova et al. 2016).

Corresponding to enabling factors of personal commitment noted above in the discussion of human and social capital, the inadequate contributions of official partners involved in the initial phase of organic production in Camargue constituted a barrier for successful diffusion. Similarly, in the UK case of the dairy cow fertility index, '*considerable reluctance by the breeding companies to engage with the project due to understandable nervousness about potential findings*' had an obstructing effect (Fowler and Midmore, 2016). However, this latter problem was overcome by existing positive relationships between researchers and one of the private sector companies involved, which was sufficient to induce the less unenthusiastic, competing companies to participate.

Registration of innovations as patents or trademarks has been an enabling factor in some cases. However, regulatory bodies may also hinder diffusion, as observed in the Bulgarian case. Official recognition of the Varroa control product in beekeeping as a veterinary medicinal product (VMP), an important prerequisite for the diffusion of the innovation, was a lengthy and costly process.

Advisory services

The role of the advisory services has attracted particular interest in these case studies, as they are often key intermediaries in the diffusion of innovation, or at least are seen as such from a classical innovation theory point of view. They can contribute important human and social capital to the process, although their role, structure and mandate vary according to the policy and governance framework in the different regions. Consequently, the roles undertaken by the advisory services, both public and private, differed between the six case studies. The IPM in olive production in Canino is the only case where the advisory services were included in the research and development activities. Elsewhere, other actors either implemented extension activities, or changed roles to become advisory service providers to aid diffusion of the innovation. The participatory nature of the research work in organic production in Camargue required advisory activity. However, in this case, lack of strategic support for conversion to organic farming practices from the Centre Français du Riz, the official public advisory body for the crop was a limiting factor in adoption, and emphasised as an obstacle by farmers.

In the German case on the optical crop sensor, private technical advisory services are sold as part of an attractive innovation 'package' for farmers. However, experience varies between regions. Thus, for example, in one region public advisory services were involved in testing studies on the optical crop sensor, which produced negative or at best ambiguous results and consequently were not promoting the technology. In other regions with positive results, public advisors actively promoted the N-sensor. Consequently, adoption rates vary among regions, even those with similar farming structures.

In the UK, existing advisory services were not active in promotion of the dairy cow fertility index. This was probably because the credibility of the commercial advisory services requires demonstrable short-term improvements because of advice given; therefore, long-term improvements, such as any impact of genetic changes, tend not to be promoted.

5.4 Characterisation of research-based innovations

This section illustrates the diversity of the six research-driven innovation case studies, and aims to improve of understanding how these differences might influence both the pathways and also the impacts achieved. It starts with a brief description of the novelty exhibited in each of the case study, and characterises the innovations using different typologies.

In line with the widely used OECD typology of agricultural innovation (OECD, 2013) all innovations observed in the case studies are process-innovations, which occurred at beneficiary (farmer or beekeeper) level.[16] This is very common in agriculture, as at the farm level, many innovations relate to production techniques, for example the adoption of improved seeds, irrigation systems, and waste management technologies.[17] Table 7 provides characteristics of each of the innovations analysed in the six case studies.

[16] The UK dairy cow fertility index case is an exception, as it is a process and product (or tool) innovation, at the level of breeding companies, rather than at the farmer level; however, indirectly, farmers are also beneficiaries.

[17] What is considered here and in the agricultural sector related literature as "process innovations" for farmers would be considered as "product innovation" for downstream industries. (OECD, 2013, p.12).

Table 7: Characteristics of innovation in the six case studies

	Organic production in Camargue (FR)	IPM in olive production in Canino (IT)	On-farm biogas in Tuscany (IT)	Dairy cow fertility index (UK)	Optical crop sensor (DE)	Varroa control product in beekeeping (BG)
Type of innovation at farm level	Process	Process	Process	Product/tool and process	Product (company level) and process (farm level)	Product (company level) and process (farm level)
Radical – incremental	Radical	Rather radical	Radical	Radical	Incremental	Rather radical
Embodiment of knowledge	Disembodied	Disembodied	Complex	Embodied	Embodied	Embodied
Adoption costs	Medium to high	Medium	High	None	High	Low
Period of commitment	Long-term (conversion to organic)	Long-term (as cooperative member compulsory)	Long-term	Long term (to achieve impact)	Long-term (due to investment costs)	Short-term (flexible, yearly changes possible)
Level of diffusion[18]	Early adopters	Late adopters	Early adopters	2 phases: unconscious early, and Late majority	Early majority	Early adopters

Most of the impact pathways indicate that the farmers adapt a set of production practices to their particular local context and even to their particular individual situation (see the summary provided in Box 1). The three product innovations (optical crop sensor, Varroa control product in beekeeping, dairy cow Fertility Index) are embodied innovations (see Table 7). In these cases, private companies had a major role in the research and development phase.

When identifying the phases at which public institutions and private companies participate, their respective levels of involvement depend on:

- The payback period: private companies invest in projects by direct funding or by providing tools if there is short term direct benefit for them.
- Ownership of distribution rights of the innovation: private companies are involved when they own the distribution rights.

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[18] Rogers (1962) distinguishes between innovators, early adopters, early majority, late majority, and laggards.

The UK case is an exception as private companies played a central role by providing data and funds. They had been reluctant participants initially, although they were instrumental in adopting results very early. Because they had access to the research results on bulls whose daughters' fertility was poor, they were able to unobtrusively withdraw their semen from the market, in effect making farmers unconscious early adopters.

Box 1: Summary of the six cases with a focus on innovation type

The research in the case study in France on organic production in Camargue led to a set of innovative techniques considered collectively as process innovation: development of crop rotation systems; mechanical false-seed bed techniques; late seeding and flooding paddy fields; increased crop seeding rate. In addition, it prompted development of an organic value chain for rice, which can be considered an additional organisational innovation.

The IPM case study in olive production in Canino developed a standardized model for monitoring infection of pests, based on enhanced understanding of insect pest dynamics in the region. As a process innovation, it modified the olive production process. Within the context of Canino, the innovation is considered to have reached maturity, as almost all cooperative members have adopted the specific integrated pest management procedures.

The Italian case of on-farm biogas in Tuscany is more complex, as it comprises different technical (process) innovations developed at different times. The pilot project involved plant installation and monitoring, as well as the developed data acquisition hardware and software for calculating the energy balance, measuring liquid and gas flow rates, CHP thermal and electric efficiency, the released volumes of biogas and other gases.

The dairy cow Fertility Index developed in the UK case study is a tool supporting selective breeding and is, as such, considered a process innovation at the level of breeding companies. The innovative aspect of this index is the use of farm milk recording data matched with genetic information on breeding stock to produce an Index providing information on predicted daughter fertility of bulls.

The Yara N-Sensor is a German product innovation developed at the level of upstream industry. It uses analytical technology in a novel way to gauge localised crop nitrogen content and translate this into site-specific fertiliser and growth regulator applications. However, full use of the sensor requires its combination with modern agrochemical application equipment that can process the site-specific applications immediately and adjust fertilizer application levels for the particular location.

Ecostop is the second upstream industry product innovation studied. It was developed as a Varroa control product for beekeeping by a private company in Bulgaria. The innovation combines a developed medicinal product to fight Varroatosis in bees on natural basis with a carrier plate that controls evaporation of the medicinal substance. The product is patented and registered as a VMP.

Innovations also differ in the way they convey knowledge. Knowledge can be embodied in machinery or equipment, and also in human capital through hiring of employees who possess new knowledge, or using contract research and consulting services. Disembodied technology or knowledge includes know-how, patents, licences, trademarks and software. These types of intellectual property have a specific cost structure in which development and other expenditure is front-loaded; because disembodied technologies are generally replicable at much lower cost, private research and development effort is protected from free-riding through time-limited monopoly of its use. In the theory of transfer of knowledge, the distinction between these two types is particularly relevant when transfer has a spatial dimension (for example, from one country to another), because transmission of disembodied knowledge or technology can be achieved at much lower costs than in embodied technology.

The costs of adoption of a particular innovation can be an important factor influencing decisions of farmers. These vary greatly in the six cases: in the UK dairy cow Fertility Index case, there are no costs as the nature of the innovation led to the initial unconscious adoption by farmers. At the other extreme, the cost of investing in an optical crop sensor includes up to €40,000 for the equipment as well as ongoing service costs. The costs of converting to organic production vary considerably but can be estimated as medium to high, and incorporate capacity building and learning costs, physical investments and also reduced revenue within the conversion period from lowered yields that are not compensated by premium output prices. Adoption of the Ecostop Varroa control product in beekeeping can be achieved at modest cost; for most beekeepers the annual charge is reimbursed up to 80% by subsidies received from the National Beekeeping Programme; even for those not eligible for reimbursement, the price of the product is moderate to relatively low.

The adoption costs described above also influence commitment. In all cases except for the Varroa control product in beekeeping, the commitment to the innovation is long term. However, even in the case of Varroa control, a yearly change of product is possible and also desired to counteract development of resistance in the Varroa mite. Longer term commitment is necessarily required of dairy farmers in using the Fertility Index to improve their herd fertility. They need to use the Fertility Index to support their selection of appropriate sires year after year to have long-term impact on their herd fertility.

6. Experience of and learning from the PIPA application

As noted in Chapter 3, *ex post* validation of the Participatory Impact Pathway Assessment (PIPA) presented a challenge, which has not been previously encountered. In addition, certain additions and enhancements were required, including Outcome Harvesting and counterfactual questioning. The common case study manual to guide procedures to study widely differing innovations in diverse contexts provided a menu of options for the teams that used it, and it will be clear from preceding chapters that these opportunities have been extensively utilised. In this Chapter, the broader understanding gained from this experience is discussed, along with a brief description of the modifications, which have been made to the updated case study manual.

6.1 Using the case study stepwise procedure

The seven sequential steps envisaged in the manual provide the framework for this section, and issues and problems arising from each are discussed in turn. An overall evaluation from the experience is then provided to provide a conclusion and a link to the description of the revised manual.

The **first step** involved an initial screening of each case study, to acquire documentary materials, to contact and interview key actors, and to develop a preliminary impact pathway map as the basis for subsequent steps. There were considerable difficulties in identifying and accessing the original proposals and interim reports of the research projects chosen for case-study analysis, compounded with greater length of time that had elapsed since projects concluded. Where commercial sensitivities existed in research either partly or fully conducted by private companies, these difficulties were compounded. Contacting key actors also presented difficulties in coordinating their busy schedules with time-consuming semi-structured interviews, and it was also difficult to convince them of the interest and the value of the case study for their professional work. Different approaches were deployed to overcome this latter problem, such as use of telephone and small group interviews. Drawing the preliminary pathways proved challenging as well, particularly in representing feedback loops and in distinguishing, at this stage, between outputs and outcomes.

The **second step** involved gathering together stakeholders in the impact pathway for workshops. Again, there were difficulties in uniting diverse groups of stakeholders in a single location, worsened considerably with increasing geographic scope of the case studies. This was resolved in some cases by incentivisation (including relevant speakers to address topics of interest for stakeholders, and supplying refreshments), holding duplicate workshops in different locations, and in one case by substituting workshops with a series of individual semi-structured interviews. Within the workshops themselves, recall problems were sometimes evident, and individual dominance, conflicts of interest and rivalries required sensitive facilitation. It was also more difficult to maintain a clear focus when the case involved a programme of research activities (as, for example, in the transition to organic farming in the Camargue case) rather than a project leading to a single identifiable innovation. Maps drawn by stakeholders were more detailed and contained additional links, compared with the initial pathways constructed by the case study research teams.

The **third step** involved refinement of the impact pathway. The additional information collected in the previous step allowed a table of links to be created, further extended and improved. It also added more links and complicated the map, and again the linear nature of the representation proved limiting. As a consequence, direct attribution of impacts became more difficult, and the different strength of linkages (weak, moderate, strong and critical) perceived by different stakeholders proved difficult to reconcile. Consequently, final refinement needed to be postponed to later stages.

The **fourth step** used Actor Mapping or SNA to identify indicators of impacts. SNA was not always appropriate, and in fact was only applied in two cases, for various reasons including the simplicity of the actor network, adequacy of alternative frameworks of analysis, unwillingness to respond to the relevant questions, or non-availability of key actors. Correspondingly, Actor Mapping was deployed in the other four cases without specific difficulties being encountered. Since indicators of impact were participant-defined, it proved difficult to elicit clear quantitative measures in most cases.

The **fifth step** provided an evaluation of the impact pathway maps. Conceptual questions arose from this exercise, particularly in relation to the nature and boundaries of research activities and to attribution of identified impacts to specific causes. However, the table of links proved to be a useful means of generating additional insights. Conversely, as a tool for linking networks with the evolution of the impact pathway, SNA proved to be of limited value.

The **sixth and seventh steps** involved obtaining feedback from the stakeholder participants on the evaluation of the impact pathways, to validate the final conclusions that were drawn. As in the second step, it was equally difficult to reassemble the stakeholders and alternative strategies for validation included telephone interviews and smaller meetings with representative stakeholders or key actors. Nevertheless, it was difficult to come to a clear consensus on the draft conclusions. The final conclusions differed little from those drawn in the previous step, and left unresolved some issues of differences of opinion expressed during the different phases of the evaluation process, of verification of conflicting information and assessment of disconfirming evidence, and finalising of the impact pathway.

The objectives for adopting a participatory approach to impact pathway assessment were two-fold: to create interaction between stakeholders to extend and refine insights on the process of impact generation; and to promote a more effective culture of impact among them. In both respects, the adoption of this novel implementation of PIPA can be considered successful, even if challenging.

While the case study manual provided flexibility in order to cope with widely differing cases, the individual teams appreciated the overall structured approach, which supported the process of evaluation. Particularly in step 2, both evaluators and participants found the workshop process stimulating and enjoyable, and ultimately the approach yielded richer and more accurate insights than would have been obtained from a more classical approach conducted by a detached expert-evaluation team.

Nevertheless, drawbacks included holding and managing workshops, difficulties in accessing relevant documentation, and ambiguities relating to outputs, outcomes and impacts. Validating impacts through use of counterfactual questions were not easy, and mapping problems included management of considerable complexity and differentiating between the different strengths of linkages and impacts themselves.

6.2 Towards an improved methodology

While the original case study manual provided a menu of options for the conduct of individual evaluations of impact, experience of its use indicates a greater need for flexibility to cope with the very wide range of cases that can occur. The IMPRESA project is developing an updated PIPA case study manual, which can be recommended for general use, based on the experience reported here. This section outlines the main avenues for improvement and indicates the outlines of the refined, more customisable approach.

The geographical scope of the impact pathway itself is an important issue. While a single workshop in step two is appropriate for a small area (such as Camargue or Tuscany), a rethink is required at national or even larger scale. This is because attribution and measurement of impacts pose different problems at larger geographic levels, diffusion arises differently and spill over is more likely.

When research is funded privately, data about adoption processes and functioning of the innovation network can be commercially sensitive and therefore unavailable. In these cases, collection of data and its interpretation has to rely more on inference-based or additional stakeholder interviews and more extensive triangulation. In this respect, an important preliminary for any case study investigation is an assessment of the availability of information, since analysis is unreliable or indeed not even possible if there are insufficient data; moreover, an important recommendation to be discussed in the final chapter of this report concerns increasing the availability of information from future research programmes.

A further avenue for improvement concerns definitions of the concepts of outcomes and impacts, which otherwise can cause substantial confusion. The proposed definition of an outcome is a (likely or achieved) short- or medium-term effect of an intervention-based innovation; it involves changes in behaviours, relationships, or actions of the stakeholders linked to the research programme or innovation under review, such as innovation adoption, job creation or development of new supply chain institutions. An impact, correspondingly, is defined as an effect produced by the intervention, positive or negative, directly or indirectly due to the research, and expected or unexpected, not covered by the definition of outcome; it can be observed in the short term although more likely to be manifest in the medium and long term.

As the previous point suggests, impacts themselves are not always easy to identify, and reliance on their elicitation from stakeholder engagement makes this even more challenging. Potential impact lists can be useful in this respect, to provide a starting point for discussion. The updated PIPA case study manual will identify a range of potential impacts, which may be useful for future research impact evaluation studies.

Finally, in assessing the role of research in assessing impacts, it is often difficult to cope with the complexity of innovation processes and the fact that many factors external to the research also contribute to impacts. Thus, in the first instance it may be preferable to use a two-stage process, firstly considering the impacts of the innovation, and secondly estimating whether and to what extent they resulted from the underlying research. With regard to later, higher order and multi-scale impacts, tools for their identification were not included the original case study manual and require further development to be included in the revised version.

Incorporating these avenues for improvement in an updated case study manual requires two major changes. Firstly, the manual will be less prescriptive in terms of the recommended approaches at each step of the process, so as well as providing a preferred method, one or more alternatives allowing case study analysts to arrive prepared for the next stage of the method are suggested. Secondly, as well as renaming some of the original seven steps of the process, two additional steps are added. The first new step, coming after step 4, involves process tracing, evaluating links in the pathway through triangulation of evidence and testing the reliability of alternative explanations. The second new step results from dividing the former step 5 into two elements. In the first part, which is concerned refinement of the comprehensive impact pathway, drawing of a simplified pathway is added. This is in order to facilitate validation and reporting, and only includes the most important links. The second part expands step 5 to consider importance of the impacts at the territorial, regional and national level.

In essence, this chapter has considered lessons arising from the case studies for methodological practice in assessing the impacts of agricultural science. While this is an important consideration, a much more substantive commentary can be articulated on the processes by which these processes occur, and the wide diversity of pathways to impact. The final chapters of this report address these issues, firstly by considering the extent to which the objectives of this part of the IMPRESA project have been achieved, and finally by addressing the recommendations for both research practice and policy that can be drawn from comparing and contrasting the underlying individual case studies.

7. Conclusions from the comparative analysis of case studies

Five objectives were set out in Chapter 1 for this work on case studies of the impact of scientific research on agriculture. Summarising, these objectives were:

1. to develop and test a mixed-method framework for assessment; from that
2. to provide an assessment which would be useful for improving the scope and focus of research policy; in particular,
3. to identify factors that support or impede effectiveness and performance in achieving desired impacts;
4. to contribute to the development of quantitative indicators of research impact; and
5. to engage, in each case, with the actors and stakeholders involved.

This chapter provides an assessment and commentary on how far these objectives have been met.

Development and testing of an *ex post* participatory impact pathway presented some problems which have been discussed throughout this report, and particularly in the previous chapter. The relatively linear structure of the analysis requires searching for a rationale of causalities that cannot fully capture the systemic nature of science-based innovation in agriculture. Narrative histories of the three main non-linear components around the pathway, innovation, research and capacity-building processes, can contribute to fuller explanation of the theory of change in each case. In addition, in implementing the approach in an extensive range of specific contexts and of research questions, case study teams responded to limitations by introducing a set of *ad hoc* enhancements that were tailored to individual circumstances. Most of these have been incorporated into an updated version of the case study manual, based on the proposals set out in Chapter 6; its improved flexibility provides scope to adapt the mix of methods and tools while still providing a framework for valid and perceptive assessment of scientific impact.

In line with the principles of case study design and analysis (as proposed for example by Yin, 2013), a limited number of widely differing cases have been selected. Rather than achieving *inductive* generalisation, from which categories and patterns might be identified, the objective has been to seek *analytic* generalisation, in which previously developed theory (the theory of change adopted classically in innovation studies) forms a template for comparison with the empirical results of the case study. The objective is to use many observations, in a limited number of cases, to test and improve theory. Rather than ignoring the contextual and incidental factors that contribute to an explanation of impact, they are taken into account to determine whether the necessity of abstracting from them in statistical generalisation is causing omitted variable bias.

In the six case studies, the diversity in activities, outputs, outcomes and impacts of agricultural scientific research is very large. Nevertheless, all provided evidence that their intended impacts were met, at least to some extent, though it should be noted that due to the studies being constructed through interplay between investigators and stakeholders, the ambition to pursue a negative case proved impossible to fulfil. Publicly funded research projects emphasised production of positive impacts, whether monetary or otherwise (such as improved compliance with regulatory frameworks) for the communities of beneficiaries.

Significant unintended direct impacts occurred in several case studies. In organic production in Camargue, significant marketing changes and withdrawal of market support policy required an upscale of the adoption. Conversely, in the case of on-farm biogas in Tuscany, adoption was increased by the introduction of more favourable policy support. The optical crop sensor case in Germany, ostensibly designed to optimise fertiliser use, had additional impact from its adaptation to reduce pesticide use, which was not expected.

The case studies also revealed a number of unexpected indirect impacts, many of which were either negative or ambiguous. An illegal black market developed in the resale of (subsidised) Varroa control products in the Bulgarian case, which decreased sales and therefore impacted on the profitability of the company. A predictable indirect impact of the N-Sensor could potentially be lower profitability of private companies experiencing reduced sales of nitrogenous fertilisers and also pesticides; however, as YARA, the initial developer, is one of the world largest fertiliser producers, enhanced application systems can be regarded as a diversification and market control strategy. The dairy cow fertility index assessed in the UK case study may have contributed to the intensification of dairy systems, with potential direct positive effects on farm profitability but a range of potentially negative indirect impacts on social and animal welfare and point pollution problems. Other unexpected and negative social impacts were also observed, mainly in shifting power relations towards private companies. Digital technology, in particular, can shift control and power towards private companies if they are able to collect and exploit the resulting 'big data'. This shift was observed in the German optical sensor case, and commented upon as a potential danger in terms of data on breeding genetics in the UK case study. This particular unintended impact is an example of extension of the frame of analysis of agricultural science impact and, although the possible consequences of this were not further explored in this study, it provides the basis for a recommendation in the following chapter.

In every case analysed, the role of research in the innovation process was embedded in a set of preceding, related, or subsequent innovations of a different nature. These included changes in governance, in market conditions, in the legal framework, and in financial support. A variety of social factors, linked to capacities of the key actors, were found to foster the innovation process. Most importantly, these included trust among actors that fostered networks and collaboration, as well as contributing to development of the skills of beneficiaries. Economic factors also often play a prominent role. An example was the role that markets played in the fostering of IPM techniques in olive oil production. This, primarily second order, effect occurred because while PDO designation was more important for consumer willingness to pay than the IPM technique, the latter's effect on enhancing the high quality of the oil obtained from good farming practices was a major influence on the acquisition of the PDO certification. Institutional support varied widely across the six cases. In four cases the research was initiated or financed through public agencies; in the Varroa control product and on-farm biogas cases the role of private companies was dominant.

In the research and development phase, factors that held back innovation development included a lack of public funds (Varroa control product); lack of awareness of a problem (dairy cow fertility index) and general conservatism of the farming community towards adopting new products/technologies. In the adoption phase (were diffusion is part), poor economic performance (biogas), high investment costs or product prices (optical crop sensor, Varroa control product), and absence of support from the public advisory system (organic production Camargue, optical crop sensor) hindered or slowed the uptake of an innovation.

In each of the case studies, the role of public advisory services was either limited or non-existent. Some involvement existed in the IPM in olive production case, and also, although to a lesser and partial extent, in the case of organic rice production in Camargue. Otherwise public extension services did not play any role, either because the innovation did not fit with their scope of activities (beekeeping product, on-farm biogas) or because the private sector dominated the innovation process (optical sensor). In the UK dairy cow fertility index case, advisory services did not promote the innovation because its impacts were long term, and commercial advisory services focus on management approaches, which, by providing short-term results, reinforce their value to the farmers.

A range of measurable indicators of research impact were identified at the conclusion of the case studies, although alongside these there were also impacts that could not be measured accurately. In addition, indicators were also very specific to each case. The intention that qualitative case study methods should contribute to development of quantitative estimation of research impact was therefore not realised, and this diversity has clear implications for evaluation practice. The multiplicity and complexity of impacts, the factors that enhanced them and the barriers that stood in their way would not have been identified in any of the innovations reviewed, had a structured case study approach not been employed to investigate them. This poses a challenge: a set of indicators sufficient to tackle the inherently multifaceted, non-linear and random processes by which research causes social, economic and environmental benefits would be large, and difficult to interpret; correspondingly, monetisation of research impacts would necessarily neglect important aspects of the mechanisms of research impacts that may adversely affect the choices that policymakers implement.

Participation of actors and other stakeholders at case study level was the final objective of the study described in this report. The *ex post* nature of the case studies made this difficult in some instances, especially where the original research took place many years previously and key actors or stakeholders had retired or had moved to different positions. The involvement in the case study work was highly valued by research actors, although it was sometimes difficult to convince other relevant stakeholders of the potential benefits of their participation, given the complexity and abstract level of the research. Finally, involvement of stakeholders was hampered by time constraints on their availability, particularly the final beneficiaries, where participatory fieldwork coincided with major labour input peaks in agriculture and beekeeping.

The need for expertise in participatory methods and facilitation skills was emphasised, as there was a need to cope with dominance of some stakeholders in discussions and to manage conflicts between participants. Given the importance placed on capacity building along the innovation process, and also the contribution that an enhanced capacity can make to the impact itself, subsequent recommendations recognise a need to incorporate relevant social scientists and professional facilitators when designing research projects.

8. Recommendations

The impact pathway approach taken in this comparative case study analysis of applied[19] agricultural research has helped to understand the role of research in achieving impacts, and has provided insights into enabling and hindering factors in the social, economic and institutional dimensions, and particularly the role of capacity building in brokering and diffusion of innovation. Agricultural innovation processes take place in a complex system, and theories of change in each case study cases explain impact pathways from scientific research in agriculture to impacts at different geographic levels from individual farms through to national (and sometimes international) scale, with involvement from local institutions to global institutional levels.

The main components of this system are natural, financial and human resources, farming techniques and the products, individual actors (including researchers) and institutions, and linkages with markets, regulations and policies. Any and all of these elements can and do influence the impact pathway. Diffusion (including adoption) of innovation depends on a number of factors including technical aspects, market opportunities, and institutional change and support. Although clear social, economic and environment benefits do result from public funding of these activities, obstacles at various points along the process can diminish or delay the full potential from being realised. While farmers (when mostly not aware of the role of research) recognise technical aspects as making the “real” change, more fundamental transformations require market incentives to push the adoption of radical changes in the mode of production. Institutional acknowledgement, including peer recognition of innovations and opinion leaders, public support, and sometimes formal legal recognition enables adoption of innovations.

This final chapter examines what is needed to enhance the impact stemming from public support for agricultural science, addressing how the main problems could be overcome from changes both to research practice and to the policy environment in which that research takes place. There are clear interactions between these two domains, in that each set of activities influences the other, and the recommendations are designed as far as possible to take these into account. However, suggestions for development are identified in two categories, those that are primarily relevant for researchers and those that could be adopted by policymakers.

It is also important to note that, while the European Commission’s Framework Research Programmes are an important funder of agricultural science, responsible for 10% of the spending within the European Union, the other 90% of public activity in this discipline is funded by National or Regional governments or their agencies. Consequently, in order to achieve improved agricultural science impact, these recommendations are addressed equally to the latter; and, more importantly, the scope for improvement depends mainly on the recommendations being implemented at all levels of administration across the European Research Area.

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[19] Note that conversely, in the case of basic research, curiosity-driven investigation need not always be successful and failure can also be a valuable result of the research if a hypothesis is disproved. Hence there need not be direct beneficiaries as intended in applied research and impact evaluation as outlined in this chapter is not necessarily appropriate.

In summary, the recommendations all require greater acknowledgement of the important role of 'soft' factors in promoting applied research impact, and widening the role of all stakeholders in the innovation system. It must be acknowledged that this approach constitutes a challenge to existing power relationships and existing innate conservatism associated with the dominant log-frame approach of evaluation. It also affects wider issues concerning the collaboration between public and commercial interests and the equitable sharing of benefits between them. This will not be easily or swiftly accomplished, as it requires the embedding of a universal culture of impact, a change in the mental habits of scientists, extension workers organisations and beneficiaries. The ambition is for all actors and stakeholders to recognise the importance of the frameworks in which they work, and to anticipate and address hindering factors as well as to promote the factors that facilitate impact. Maintaining these attitudes at the forefront of every stage, from initial research to dissemination and adoption, would improve and extend the social, economic and environmental benefits that flow from public funding of applied agricultural research.

8.2 Recommendations for researchers

In general terms, it is important to embed a culture of impact across the entire applied research process. Thus, these specific recommendations relate to research design and planning; to the process of research itself; to the analysis of performance to influence subsequent projects and programmes after completion; and to the overall institutional context in which research takes place. Of these, recommendations relating to the initial pre-research phase of activity are of paramount importance. This is because, if established without some participation from stakeholders other than scientists or policymakers, it is much harder to incorporate these perspectives once the research is under way, and the possibility of mis-targeting or minor relevance is much more likely to occur. Nevertheless, the other recommendations for interim review and effective impact monitoring should not be neglected; otherwise, stakeholder engagement could lapse into symbolic lip service, with minimal enhancement of impacts.

Ex ante research impact assessment

- Recommendation 1.1: Plan for impact at outset of the research design.
- Recommendation 1.2: Involve key stakeholders (including private sector) at early stage in the research.

Consideration of how beneficiaries will adopt research results to achieve impacts is often neglected in the design and initiation of research activities. Across the entire wide range of case study contexts described in this report, human and 'soft' factors were identified as major influences either enabling or disabling adoption. They would have been highlighted if the technique of *ex ante* impact pathway analysis had been applied, and this could have fostered the adoption of the research outputs. Research activities would generate outcomes that are more accurate and more long-term impacts if the researchers plan interaction with the stakeholders in advance by considering pathways to impact at the design stage. Relevant stakeholders include key potential advisors in the agricultural knowledge and innovation system, intermediaries related to new product or technologies (for example dealers) and others from policy and civil society institutions. Greater interactions among committed key partners will support the program, and facilitate achieving and disseminating the results.

This primarily requires good contextualization of the scope of the research and anticipation of all its possible uses. In itself, this exercise provides scope for increased research relevance, for example extending, in discussion with key stakeholders, the identification of factors, which could hinder adoption of the expected results.

Expected impacts using the *ex-ante* impact model may be more accurately and systematically identified and evaluated than when relying on the more traditional linear impact pathway embodied in the log-frame approach. It requires activities, outputs, outcomes, external factors, potential risks and inter-relations including feedback loops to be identified. Many guidelines and tools exist (see, for example, Springer-Heinze et al., 2003) although care and competence are required to adapt them to specific sectors, contexts and research projects.

This shift from the log-frame to an 'outputs-outcomes-impacts' oriented approach in planning research projects does requires additional competences. In particular, participatory *ex ante* exercises require social science skills at this stage and in later stages, particularly to contribute insights on the sociological and economic characteristics of beneficiaries and the broader value chain into which any impacts might be absorbed. In this and in further stages, the implications of capacity building in the innovation system and its interaction with research activities is central in enhancing the scope and scale of beneficial societal impacts. For example, stakeholder mapping and analysis is a useful tool for cataloguing the different interests and skills of potential interested actors and aligning them with the goals and objectives of the research programme (see, for example, Sutherland et al., 2011).

Maintaining impact focus within project implementation

- Recommendation 2.1: Consider impacts mid-term project reviews.
- Recommendation 2.2: Provide project resources for 'soft factors'.

Uncertainty and the unexpected are intrinsic to the research process. While it is of primary importance to involve external actors and stakeholders at the design phase, they can also play a useful role in the implementation phase by being made aware of progress and interim findings and contributing to revision of the impact model. External experts also give useful feedback in regularly assessing achievement of outputs and outcomes. When judging their own activities, researchers may be prone to confirmation bias with respect to the uptake of their results and broader impacts. External views on enabling and disabling factors of adoption may improve researchers' understanding of the context of their work and to undertake any necessary adjustments, especially where beneficiaries are not taking up the results as fast as planned.

External reviews help reveal new aspects and weaknesses and can identify new options for improving outcomes and impacts. It may be particularly useful to involve intermediary organisations, such as the Technology Centres in Germany, which have responsibility for promoting innovations and thus embody intimate knowledge of enabling and disabling factors. A formal requirement to conduct mid-term external reviews, together with resources committed for this purpose, should refine strategies based on an *ex ante* impact pathway assessment once the nature and potential impact of innovations becomes clearer. Flexibility, in particular in projects that use participatory, interactive, multi-actor approaches, can utilise an evaluation of gaps between expected and achieved to improve the efficiency of activities, outputs and outcomes, and to make any necessary revisions in terms of scope and targeted beneficiaries.

Equally, agricultural science project resources need to be dedicated to what are often described as 'soft factors'. These include trust, network, and capacity building, as well as the more traditional training, information and outreach that can promote communication between researchers and other actors and stakeholders. While most publicly funded research now requires dissemination planning to be developed alongside the main scientific effort, this recommendation seeks to widen the scope. Communications professionals can advise on improving outreach of results.

It is important, for example, that scientists of all disciplines should be trained to adapt their language and communicate more effectively with practitioners, as well as better understanding and taking into account their viewpoints and feedback. Correspondingly, it is recognised that a limited number of farmers play an influential role in opinion formation in the agricultural community as a whole. Impacts can be achieved more effectively when they are enrolled in the piloting of new products, services or techniques that engender innovation in farming practices. These farmers are often better placed to digest the volume and complexity of research project results and what is worth or not worth adopting. Nevertheless, targeted knowledge dissemination efforts are required to reach them; moreover, these can be much more efficient than traditional approaches such as presentations at fairs and shows, leaflets and webinars, since most farmers trust other farmers more than they do information that may be perceived to be associated with official institutions.

Expertise in conflict management is equally important. The case studies indicate that conflicts can arise between the researchers and groups of certain farmers and other stakeholders, and these have detrimental effects on the full achievement of impact potential. Awareness of these potential conflicts is therefore very important. Risk aversion is widely observed in the farming community, and innovations can be opposed by farmers who do not understand new methods, and by intermediaries who may have conflicts of interest, which favour old solutions. In transdisciplinary projects, some partners lose interest or participate only in order to control the outcome. Research project leaders can and should be trained to promote trust creation among partners and stakeholders, and to acquire skills in conflict resolution. Equally, clear commitments should be built into project governance, especially in for public private partnerships (PPP), including mechanisms which oblige partners to contribute to the project as promised and to respect agreements, for instance, in the sharing of data.

Finally, while participatory methods may support the identification of more and better impacts, work on the case studies themselves indicates that care is required in their judicious application. Participatory methods require skilled facilitators, and unless properly managed, they can consume excessive amounts of resources and time. Here, the stakeholder mapping and analysis mentioned earlier is useful. Stakeholder representatives should be selected with care to prevent private and individual interests from over-influencing the general interests of the group. Discussions between the stakeholders and the researchers involve many trade-offs which can best be managed by an external and neutral mediator with trained facilitators provided with appropriate expert briefing, and social science skills are needed to help interpret the data resulting from participatory methods. Perspectives and backgrounds of participants may be very different, and these particular communication skills are required to offset the sometimes wide interest gap between participants and researchers, which may hinder active and positive feedback.

Ex post impact evaluation

- Recommendation 3.1: Enrol researchers into a new 'culture of impact'.
- Recommendation 3.2: Where appropriate, conduct *ex post* Participatory Impact Pathway Assessment.

Case study investigations show that where researchers are aware of and motivated towards achieving impact, the efficiency of agricultural research in achieving impact improves. It should be helpful, therefore, to have formally identified and recorded expected outputs, outcomes, impacts and related indicators to inform a proper 'evaluation phase' once the project is completed. This should identify unexpected impacts and lessons learned, to help to improve subsequent project preparation to address remaining research gaps.

Under certain conditions, the participatory assessment approach summarised in this report may be useful for performing an *ex post* impact evaluation. However, there is a trade-off in terms of elapsed time from the end of the project. Normally projects are led by senior scientists in mid-career or later, and so, if too long a time elapses, access to key actors and project documentation may be limited, which caused problems in some of the cases analysed here. However, impacts (especially the unintended, which are usually the most important and interesting to evaluate) are observed only after widespread adoption has occurred more than five to ten years, or more, after end of the initial research phase. In fact, the innovation-adoption-impact cycle can be longer than a Principal Investigator's expected future career, and as a consequence, and for projects with significant and enduring impacts, an *ex post* PIPA would be useful as a means of consolidating the culture of impact among the research community.

Managing research calls and funding frameworks

- Recommendation 4.1: Build flexibility into calls for projects to allow for new stakeholder perspectives.
- Recommendation 4.2: Design funding frameworks to gain early involvement of the private sector.
- Recommendation 4.3: Monitor research output with data collection tools and protocols at early stage.

It is possible, as observed in the case of the transition to organic farming in Camargue, that diffusion goes beyond that which was initially expected, and projects need to be adapted to take new stakeholders, who were not considered at the beginning of the project, into account. In the Camargue case, farmers needed access to new markets for a large range of organic products in order for them to be able to adopt organic rice production techniques to improve the overall economic balance of their farming activities. To cope with these and similar eventualities, social science involvement can assist in engaging with stakeholders who bring different views and experiences. Additionally, scope for flexibility should be planned into research programmes to enable researchers to adapt to changing circumstances or feedback from stakeholders. Institutions and funders can promote thinking outside the box by assimilating flexibility in the design of project calls and by leaving room for suggestions of topics to be tackled by future programmes.

Funding tools that build in checks for the potential for private interests can enhance efficiency of research impact. These should be applied prior to design of calls for new projects. Effective engagement of private research in public funding schemes improved the efficiency of impact in three of the cases analysed in this report (Varroa control product, dairy cow fertility index, optical crop sensor) and was important in a fourth (on-farm biogas). In the UK dairy cow fertility index case, the involvement of private sector breeding companies as research partners allowed initial adoption of research results at the earliest opportunity, in only two years into the research project. However, while successful models of public-private partnerships exist in many countries there can be adverse consequences. Tensions and trade-offs between long-term public interests and the shorter term private motivation of commercial companies has been observed to lead to difficulties in the impact pathway: benefits accrued to a limited circle of private companies (in the on-farm biogas case in Tuscany, research was done in another region with a restricted group of private companies); in the dairy cow fertility index case a clear conflict of interest occurred; and in the Varroa control product case, lack of public funds for public interest innovation support delayed development and dissemination.

Each research team, to a greater or lesser extent, experienced difficulty in obtaining data about research programmes after they were completed. Funders should require, and research institutions should develop, effective information management systems, particularly for projects involving private companies. Data collection tools and protocols should be developed at early stage to monitor research outputs. Both the funders and the research institutions should ensure that documentation and its accessibility are secured for the conduct of *ex post* research evaluations, and given previous discussion, available for sufficiently long periods after research programs are completed. The funders also need to be flexible enough for subsequent revision, depending on the nature of challenges encountered regarding unintended stakeholders or impacts.

8.2 Recommendations for policy makers

Innovation theory (e.g. Saviotti, 2001) suggests that, while impacts of the research and the innovation cannot entirely be directed by policies and regulations, they play a crucial role in creating a suitably enabling environment for innovation, in contributing to capacity building and in facilitating access to funding. Recommendations to policy makers at the European and national government levels are focused on four key areas that have arisen from this comparative case study analysis.

- First, public support for agricultural research needs adequate and effective complements in the form of advisory services and the innovation support actions that they perform;
- second, governance arrangements to protect the divergence between public and private interests in jointly funded and managed agricultural science projects need to be clarified and strengthened;
- third, coordination of support between complementary policy strands, especially between research support and Rural Development Programmes, should be improved;
- and finally, open access to research data needs to be assured, not only to aid impact evaluations but also to promote the process of innovation and to make sure that public actions are fully accountable.

Strengthening agricultural innovation support

- Recommendation 5.1: Strengthen agricultural extension and advisory services as educators, knowledge hubs and innovation facilitators.
- Recommendation 5.2: Engage key actors in research and innovation and experiment with their potential roles.
- Recommendation 5.3: Coordinate and improve effectiveness of support instruments for capacity building, networking and funding of innovation brokers.

Advisory or extension services can and do play a significant role in building productive relationships between agricultural science and the farming community. However, as demonstrated by the case study investigations, they can be less than adequate or even have economic interests, which diverge from innovation adoption. While conventional innovation theory acknowledges a linear role of transmission for advisors, between innovators and adopters, the innovation system approach recognises their active role as bridging institutions (for capacity building, including knowledge sharing and information brokering, facilitation of collective processes of enrolment, awareness-raising and opinion shifting).

Conversely, actors from other parts of the agricultural innovation system can also have considerable effects in promoting impacts, and there are several examples where an individual's strength of character, in terms of commitment and passion for research as well as their knowledge and soft skills, has played a central role. Often, as the case studies demonstrate, within the innovation system, the same individuals can take on different roles at different points of the process; in the initiation phase of research, identifying problems and creating awareness, in conducting research itself, and in the innovation diffusion phase.

The comparative case study analysis reported here confirms findings of other innovation studies (e.g. Brunori et al., 2013; see also the SOLINSA project's findings[20]) highlighting the importance of innovators and the function of 'innovation brokers'. The innovations investigated often originated from a small number of professionally and socially motivated people who shared common values. Trust within this small group, particularly where diverse individuals such as farmers, researchers and private business actors are involved, was found to be a powerful enabler of innovation. Therefore, additional support to strengthen agricultural advisory services needs to be qualified by measures that support a more flexible approach to the promotion of adoption science-based innovation at farm level, in terms both of scaling-out and scaling-up.

Concrete measures that can achieve this include provision of incentives for continued professional development of advisors, making it an opportunity to use knowledge from a range of sources, including the supply chain and farmer opinion-leaders as well as researchers, to identify main gaps and issues for research at the earliest point possible in the innovation process. Continued professional development should also include development and provision of tools for networking and brokerage, targeting capable individuals in different types of organisations (within research institutions, advisory services and farmers' organizations). This would also provide a framework for interaction, to create awareness among concerned stakeholders and gain their active commitment in research and innovation diffusion; and could encourage researchers to get feedback from advisors, which informs them of practical applications and problems arising from their projects.

In different contexts, advisory services are provided by either public or private commercial organisations, or a mixture of the two. No distinction should be made regarding strengthening of either strand of service, as long as services are impartial and operate with a long-term perspective, since duration in time is essential for the development of relationships of trust with farmers, improving the chances of successful and eventually earlier adoption of more relevant innovations.

Engaging with the private sector

- Recommendation 6.1: Develop a code of practice for public-private partnerships in research and innovation systems.
- Recommendation 6.2: Identify 'honest innovation brokers' to ensure that relationships function in the public interest.

From the comparative case study analysis, the private sector has been shown to be capable of having a strongly positive influence in the efficient functioning of impact pathways, which has

[20]Available at: http://www.solinsa.org/

been reflected in many of the recommendations made so far. Coordination of the complementary skills of the private sector with public research activities can increase relevance (e.g. in improving awareness of the demand for innovations); improve their acceptability (e.g. bridging the gap to markets); and accelerate their impacts (drawing on private sector expertise to make diffusion more efficient). There are also counter-examples that demonstrate negative aspects of private-public interaction, although these stem from lack of mutual understanding and poor coordination; they could be corrected with an appropriate enabling institutional conditions.

Governance of formal Public-Private Partnerships for agricultural innovation has been addressed by national authorities (and the European Union as a whole). Moreddu (2016) has set out the main conditions that need to be fulfilled with regard to ensuring an appropriate balance of interests. These include: ensuring international competition between private enterprises for participation; facilitating SME involvement (as they often play a crucial role in innovation); and attention to intellectual property rights; high reciprocal financial leverage and long term commitment; with limited contributions from the public sector; flexibility to cope with rapidly changing technological environments; efficient organisation and management; and a commitment to extensive and thorough evaluation.

However, whilst appropriate for the foundation of contractual relationships in major research programmes, engagement with the private sector in fostering innovation and delivering extension advice to farmers extends beyond such formal settings. Interaction and cross-fertilisation between the public and private sector extends throughout the impact pathway, with possible misalignment of their respective interests and scope for opportunism on both sides. Development of a code of practice to manage public-private relationships within the agricultural innovation system should include broad principles, as a prerequisite for activities, that both assure the public welfare interest but also provide for equitable gains for private companies, and also ensure transparency to maintain trust, especially where the engagement is predominantly in the dissemination phases of the impact pathway.

The code of practice should be complemented with arrangements to appoint an 'honest broker' – case studies provide examples of innovation brokers who provide this role, perceived as independent and professional by all stakeholders and able to acting at the interface between sectors to link their interests in a way that fosters innovation. Funding for innovation should support actors that are able to play the role of innovation brokers and network facilitators, and more generally reinforce capacity building in the field of knowledge management, group facilitation and innovation brokerage.

Strengthening and coordinating research and innovation policy

- Recommendation 7.1: Integrate research and innovation support instruments.
- Recommendation 7.2: Coordinate innovation support instruments with agricultural policies.
- Recommendation 7.3: Include stakeholders in research programming and evaluation.

In most case studies, initial research was made possible through substantial public funding, channelled through universities and public research institutions.[21] Correspondingly, the private sector contributed funding at later stages, when potential profitability for both companies and farmers was realised. In the gap between the initial research and the commercialisation phase, easy access to targeted follow-up public (or private-public) funding opportunities would promote continuation and further development of innovations. Such funding should be established, developed or improved based on common rules, information sharing platforms and administrative interfaces between research funding agencies and those funding development and testing.

In our case studies, the role of regional and rural development funding in support of agricultural innovation (from the Structural Funds programmes or the precursors of the current EAFRD) has not been prominent in terms of promoting impact of research.[22] Most of the cases involved mature innovations, and current instruments may not have been available at the time they were needed. However, there is sufficient evidence elsewhere which, combined with the case study experience, suggests that these instruments could be better targeted towards agricultural innovation needs. The small size and large number of relatively isolated farming businesses need to be taken into greater account in designing, targeting and implementing relevant innovation support.

A better interface between innovation support and the agricultural policy framework should be developed at all levels (EU, national, and regional) to create an enabling environment that fosters more agricultural research-based innovation. The recently-established European Innovation Partnerships for Agriculture make a useful step in this direction, but greater efforts are required at all levels, to inform the innovators and researchers of funding opportunities, to give more credit to the role of research in innovation processes, and support capacity building, including a shift towards farmer-initiated innovation. Equally, the administrative burden should be kept minimal for all actors. A very significant challenge, identified in the case of the Varroa control product, is the urgent need to ease registration and authorisation regulations for agricultural innovations to enable upscaling to EU level at the diffusion stage of new products.

A further impediment to research impact arises from the prevalence of conventional, linear pathways in identifying research questions, which can be linked to the intensification of farming practices. Criteria for research career progression are also based largely on bibliometric measures of publication. While such systems are useful in assessing fundamental science, and evaluating research quality, in applied agricultural science the important contribution to beneficial impacts for farmers and wider society is often neglected. This can create large gaps between research outputs and their usefulness, particularly in terms of long-term social and environmental impacts.

[21] In the atypical case (the Varroa control product) access to public support for the research was difficult, and as a consequence research progress was hampered.

[22] Again, the Varroa control product provides an atypical case; in this instance EAFRD funding provided significant assistance towards its adoption.

To ensure that public research funding achieves public-interest benefits and that projects address economic, environmental and social challenges in broad perspective, stakeholders should be selectively and strategically involved in the initial design of research programs. At European Union level, this has been pioneered in the initiation of research programs in the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI), which includes two bodies that advise its governing council, a scientific advisory board and a stakeholder advisory board. Regions and member states should establish processes of research programming, implementation and evaluation where stakeholders have a strong mandate and are adding to a more balanced view of societal problems that would be addressed by research. Through that, it can be ensured that strategies and projects are relevant to solve real life issues in the agricultural sector.

Availability and access to research data

- Recommendation 8.1: Strengthen availability and open access to research data and results for assessment of impacts and general interest.

Information and data from previous research projects, which is required for the assessment of research impact, proved difficult to access in a number of cases. This was particularly so where industry actors played a central role in research and innovation. These problems of access to information and ownership of data need to be resolved, for two linked reasons: complete transparency is required to justify public expenditure on research; and the efficiency of research expenditure can be judged where outcomes and impacts are monitored to assess and illustrate its impact.

A standardised, structured framework for collecting and making available information from all stages of research implementation is required. This should start from calls and proposals, include all research data and reports to scientific publications, and extend to measures of adoption of the new products or techniques. Recognising that the context and rules under which research is conducted is highly diverse, indicators of impact may be constructed using an *ex ante* Participatory Impact Pathway Analysis, or may be tailored according to monitoring needs of specific research funds, or may be completed in an *ad-hoc* manner using indicators to fulfil specific needs of particular research institutions. Conceptually, this recommendation corresponds to the Common European Research Information Format (CERIF)[23], which is an international standard relational data model for storage and interoperability of research information. In Germany, work towards an operational system complying with the CERIF criteria has been funded by the German Federal Ministry of Food and Agriculture (Wolf et al., 2014).

Similarly, the Coherence in Information for Agricultural Research for Development (CIARD)[24] movement aims make agricultural research information and knowledge publicly accessible, and

[23] This framework is now managed by euroCRIS: http://eurocris.org/cerif/main-features-cerif
[24] See http://www.ciard.net for further information.

has made progress towards global standards on open access and data management in agricultural research. Based on this initiative, recommendations set out by the European Commission on access to and preservation of scientific information (COM (2012) 4890) are strongly supported: in particular, that “research data that result from publicly funded research become publicly accessible, usable and re-usable” and “datasets are made easily identifiable and can be linked to other datasets and publications through appropriate mechanisms, and additional information is provided to enable their proper evaluation and use” (p.6). The European Commission (the Directorates-General for Research & Innovation and for Agriculture & Rural Development) should adopt further steps to promote implementation of existing standards and initiatives. In particular, subject to compliance with privacy standards, it should make research documents, bids and reports freely accessible.

These efforts should be replicated by national, and where relevant, regional institutions in the member states, and standards should be further developed also to include indicators that allow for the assessment of (broader) impacts. In addition, private companies involved in agricultural research should declare their R&D activities (investments in research, research objectives, types of innovations) to ensure transparency in research projects that are fully or partly publicly funded.

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Appendix 1: Glossary

The IMPRESA project mainly uses the Organisation for Economic Co-operation and Development (OECD) terminology published in the 'Glossary of Key Terms in Evaluation and Results Based Management' (2002b), the 'Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development' (2015), and the 'Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data' (2005). It is indicated where terminology commonly used by the European Commission differs from the OECD.

Activities: actions taken or work performed through which inputs, such as funds, technical assistance and other types of resources are mobilized to produce specific outputs.

Actors: Individuals (or institutions) engaged in the process of research and development. Actors are also stakeholders (see below), but stakeholders are not necessarily actors. The structural patterns of relationships between actors can be investigated using Social Network Analysis.

Beneficiaries: The individuals, groups, or organizations, whether targeted or not, that benefit, directly or indirectly, from the development intervention. Related terms: reach, target group.

Counterfactual: The situation or condition, which hypothetically may prevail for individuals, organizations, or groups, were there no development intervention.

Development (as in R&D): The application of research findings or other scientific knowledge for the creation of new or significantly improved products, applications or processes.

Diffusion: The way in which innovations spread, through market or non-market channels, from their very first implementation to different consumers, countries, regions, sectors, markets and firms. Without diffusion, an innovation has no economic impact. The minimum requirement for a change in a firm's products or functions to be considered an innovation is that it is new (or significantly improved) to the firm (OECD 2016).

Impact: Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended (Development Assistance Committee, 2002).

Direct impact: those effects caused directly by our activities, at the same time, and in the same place.

Indirect impacts. Impacts on the environment, which are not a direct result of the project, often produced away from or as a result of a complex pathway. Sometimes referred to as second or third level impacts, or secondary impacts.

Cumulative impacts: Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project.

Innovation is the implementation of a new or significantly improved product (good or service) or process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations. (OECD 2016). In contrast to the OECD definition (which sees innovation as a process); the EU provides a different definition: An innovation is a new or significantly improved product (good or service) introduced to the market or the introduction within an enterprise of a new or significantly improved process. Innovations are based on the results of new technological developments, new combinations of existing technology or the use of other knowledge acquired by the enterprise.

Impact pathway: a means of representing the change occurring between an initial state of resources (the inputs) and a final set of different impacts (the long-term effects, partly or essentially induced by the change) resulting from the adoption of an innovation.

Incremental innovation: can be defined as the refinement, improvement, and exploitation of existing innovations. Incremental innovations build on and reinforce the applicability of existing knowledge, and subsequently strengthen the dominance and capabilities of incumbent firms and the dominant design. Incremental innovations are characterised by reliability, predictability, and low risk (Narayanan and Colarelli O'Connor, 2010).

Radical innovation: can be defined as innovations with features offering dramatic improvements in performance or cost, which result in transformation of existing markets or creation of new ones. They involve fundamental technological discoveries for the firm, and thus are new to the firm and/or industry, and offer substantially new benefits and higher performance to customers (Narayanan and Colarelli O'Connor, 2010).

Outcome: The likely or achieved short-term and medium-term effects of an intervention's outputs (Development Assistance Committee, 2002*).*

Outcome implies changes in the behaviour, relationships, activities and/or actions of a boundary partner that can be logically linked to a programme (Earl and Carden, 2002; Earl et al., 2001; Byrne and Ragin, 2009, p 343).

Output: the products, capital goods and services, which result from a development intervention; may also include changes resulting from th*e intervention, which are relevant to the achievement of outcomes* (Development Assistance Committee, 2002)*. Outputs are directly achievable and observable* (Earl and Carden, 2002; Byrne and Ragin, 2009).

R&D: see separate definitions for Research and Development. R&D should exclude: Education and training (but should include, if possible, research conducted by PhD students at universities or research agencies). Science and technology information services (e.g. extension or advisory services).

Technical services such as topographical mapping and geological, oceanographic, and meteorological surveying. Indirect support to R&D or activities related to the financing of R&D (but should include direct administration and clerical activities for R&D).

Research is the creative work and original investigation undertaken on a systematic basis to gain knowledge.

Stakeholder: anyone who can affect, or is affected, by a research project and its dissemination. In some definitions, stakeholders are those who have the power to impact a project in some way.

Uptake: The adopted products/processes are continuously and definitely used/employed in the firm's production system (final stage of an innovation diffusion).

Appendix 2: List of Acronyms and Abbreviations

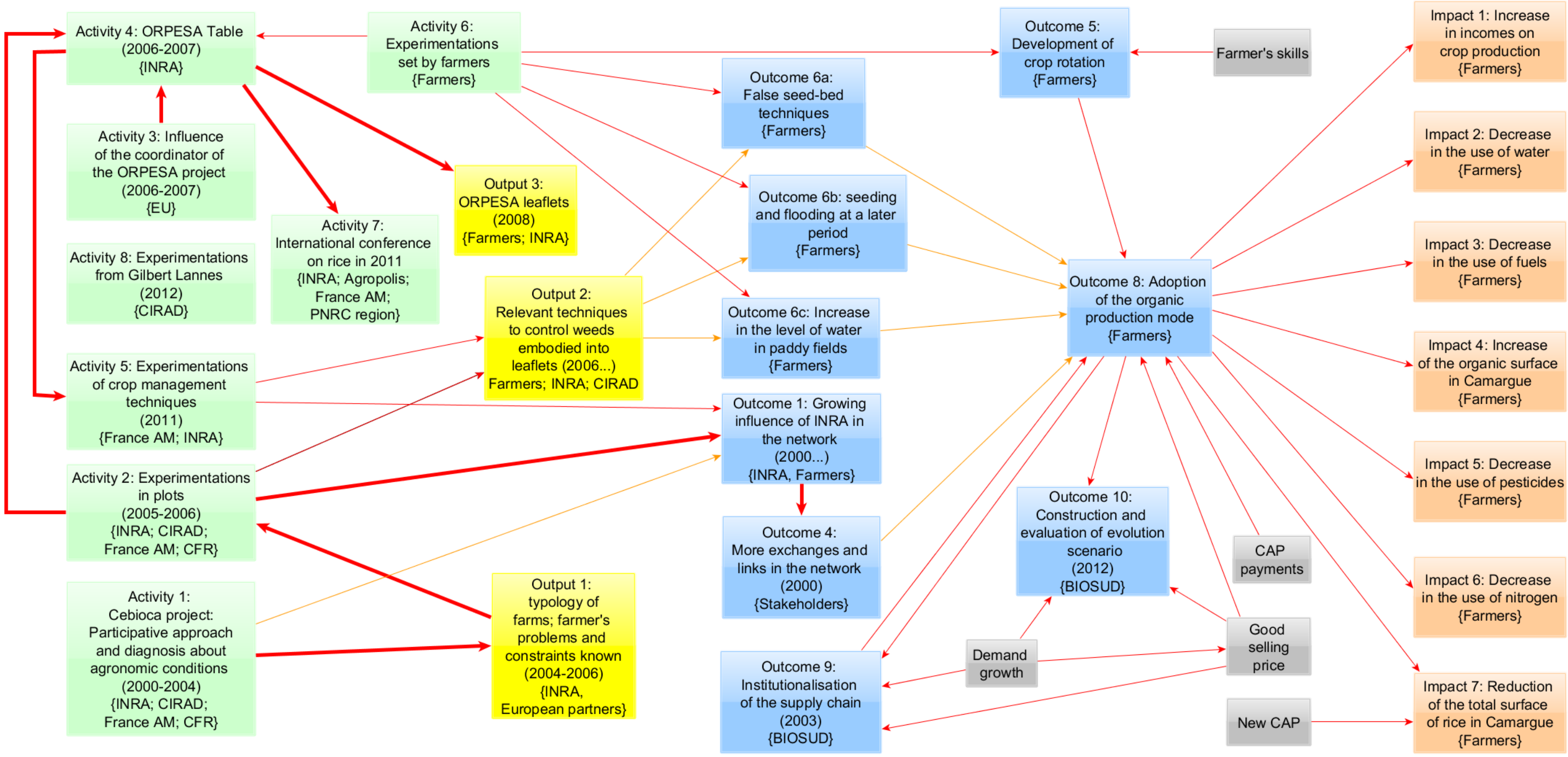
AGDR	Research and Extension Unit of the FAO
AKIS	Agricultural Knowledge and Innovation System
ALS	Active Light Source
BG	Bulgaria
CAP	Common Agricultural Policy (of the EU)
CERIF	Common European Research Information Format
CFR	Council on Foreign Relations
CH	Switzerland
CHP	Combined heat and power
CI	Calving Interval
CIARD	Coherence in Information for Agricultural Research for Development
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (French Agricultural Research Centre for International Development)
COM	European Commission
CRPA	Centro Ricerche Produzioni Animali – (Italian Research Centre on Animal Production)
DE	Germany
Defra	Department for Environment, Food and Rural Affairs (UK)
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
EAFRD	European Agricultural Fund for Rural Development
EEA	European Environment Agency
ENEA	Originally (1982) Energia Nucleare ed Energie Alternative, now (since 1991) Ente per le nuove tecnologie, l'energia e l'ambiente (Italian National agency for New Technologies, Energy and Sustainable Economic Development)
ERSAL	L'Ente Regionale per lo Sviluppo Agricolo del Lazio (Lazio Regional Agency for Agricultural Development)
EU	European Union
FACCE-JPI	Joint Programming Initiative on Agriculture, Food Security and Climate Change
FAO	Food and Agriculture organization of the United Nations

FI	Fertility Index (UK dairy bull index of daughter fertility)
FiBL	Forschungsinstitut für biologischen Landbau (Research Institute of Organic Agriculture in Germany, Austria and Switzerland)
FR	France
GHG	Greenhouse Gas
IMPRESA	IMPact of RESearch on EU Agriculture. Framework VII funded project, the subject of this report.
INRA	L'Institut national de la recherche agronomique (French National Institute for Agricultural Research)
IPA	Impact Pathway Analysis
IPM	Integrated Pest Management
IT	Italy
MAFF	Ministry of Agriculture Fisheries and Food (UK, superseded by Defra in 2001)
MDC	Milk Development Council (UK body funded by a levy on milk sales)
OECD	Organisation for Economic Cooperation and Development
OSCC	Oleificio Sociale Cooperativo di Canino (Italy)
PDO	Protected Designation of Origin.
PIPA	Participatory Impact Pathway Analysis
PPP	Public Private Partnerships
R&D	Research and Development
SME	Small and medium-sized enterprises
SNA	Social Network Analysis
SRA	Scientific Research on Agriculture
UK	United Kingdom
VMP	Veterinary Medicinal Product
WP3	Workpackage 3 of the Impresa project
WP4	Workpackage 4 of the Impresa project
£PLI	Profitable Lifetime Index (UK dairy index)

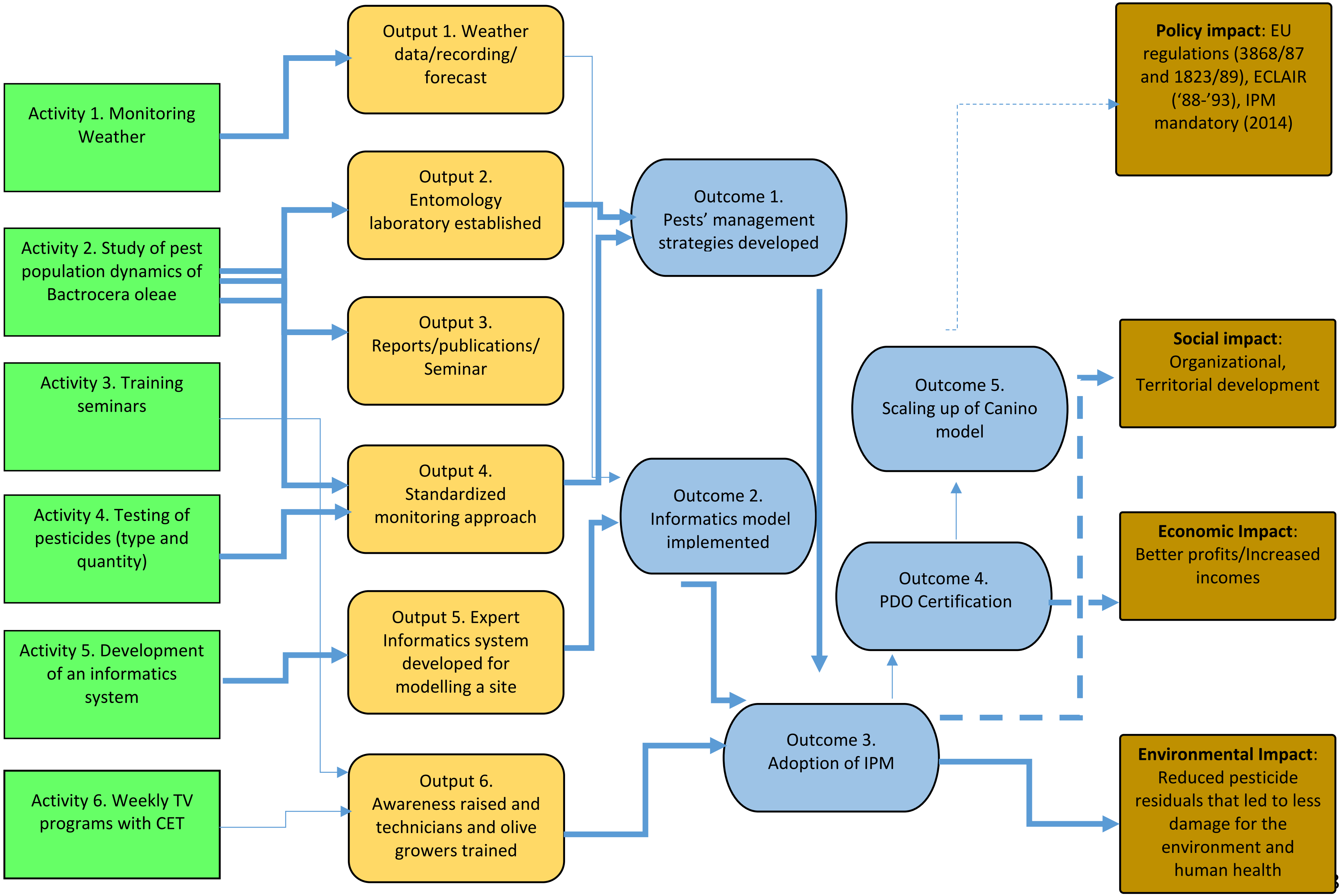
Appendix 3: Case study summaries

Each of the case studies are summarised in 4 pages briefs; we might put these in the Annex or at least the links on the Website.

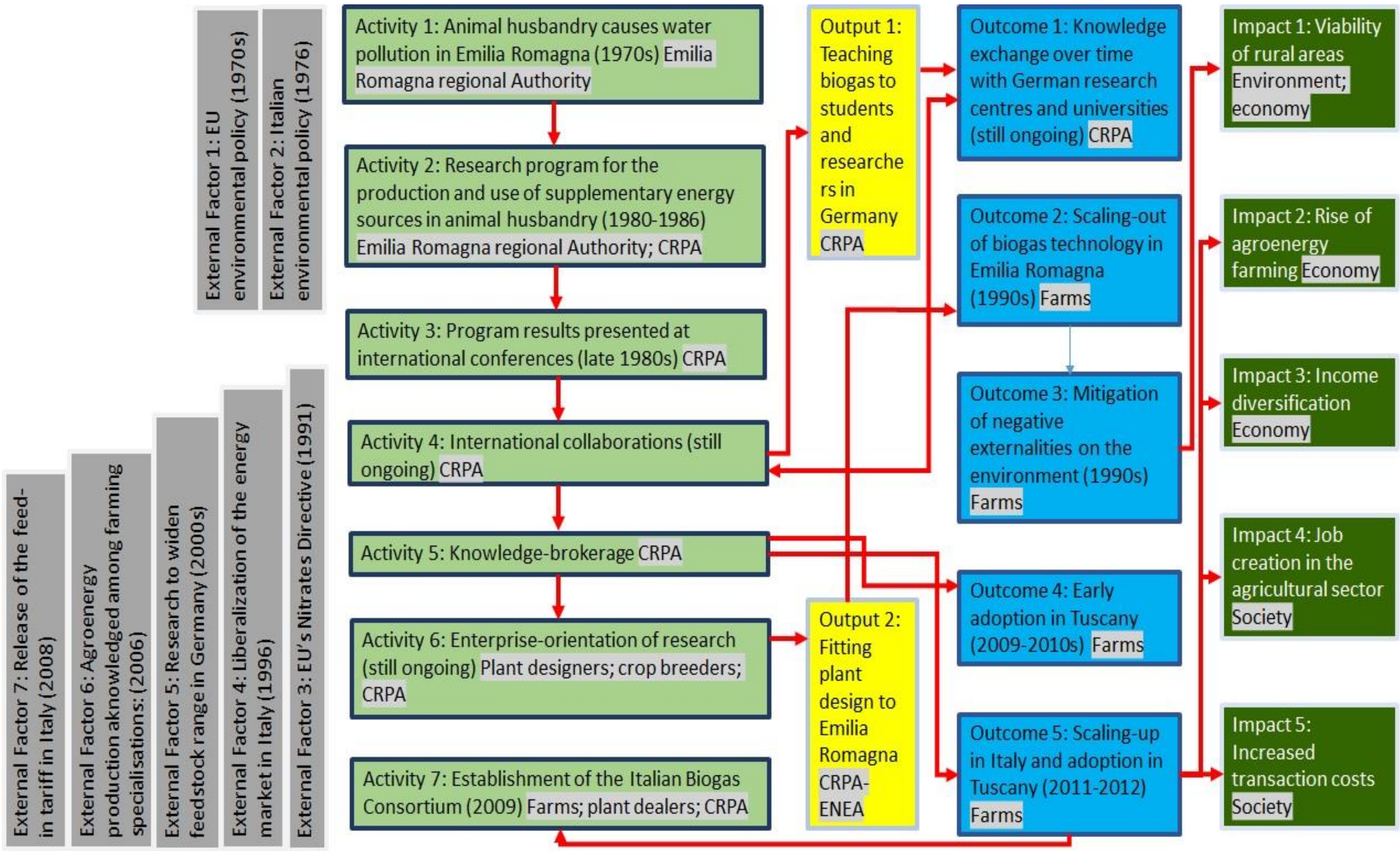
A1. Organic production in Camargue (France)



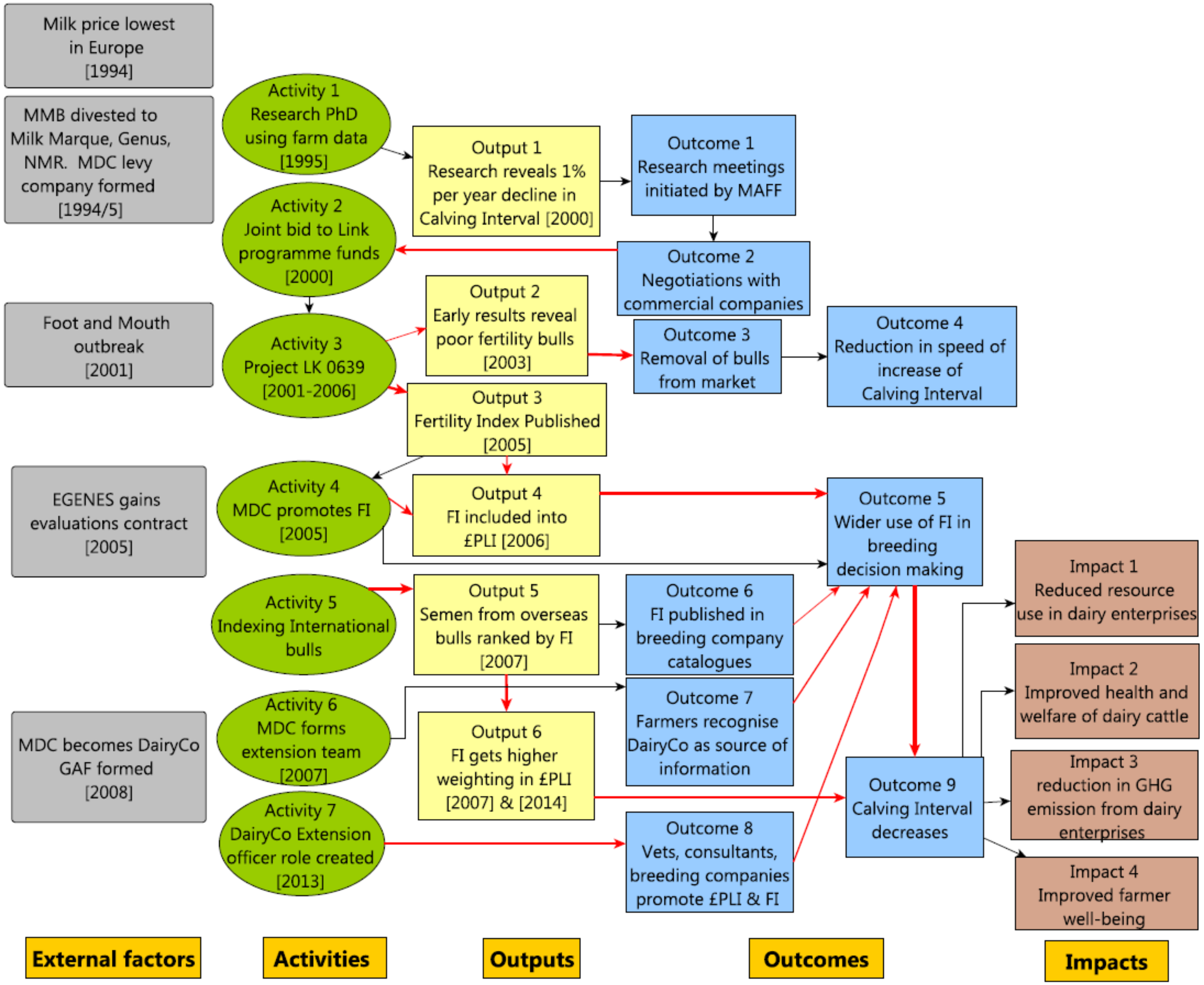
A2. IPM in olive production in Canino (Italy)



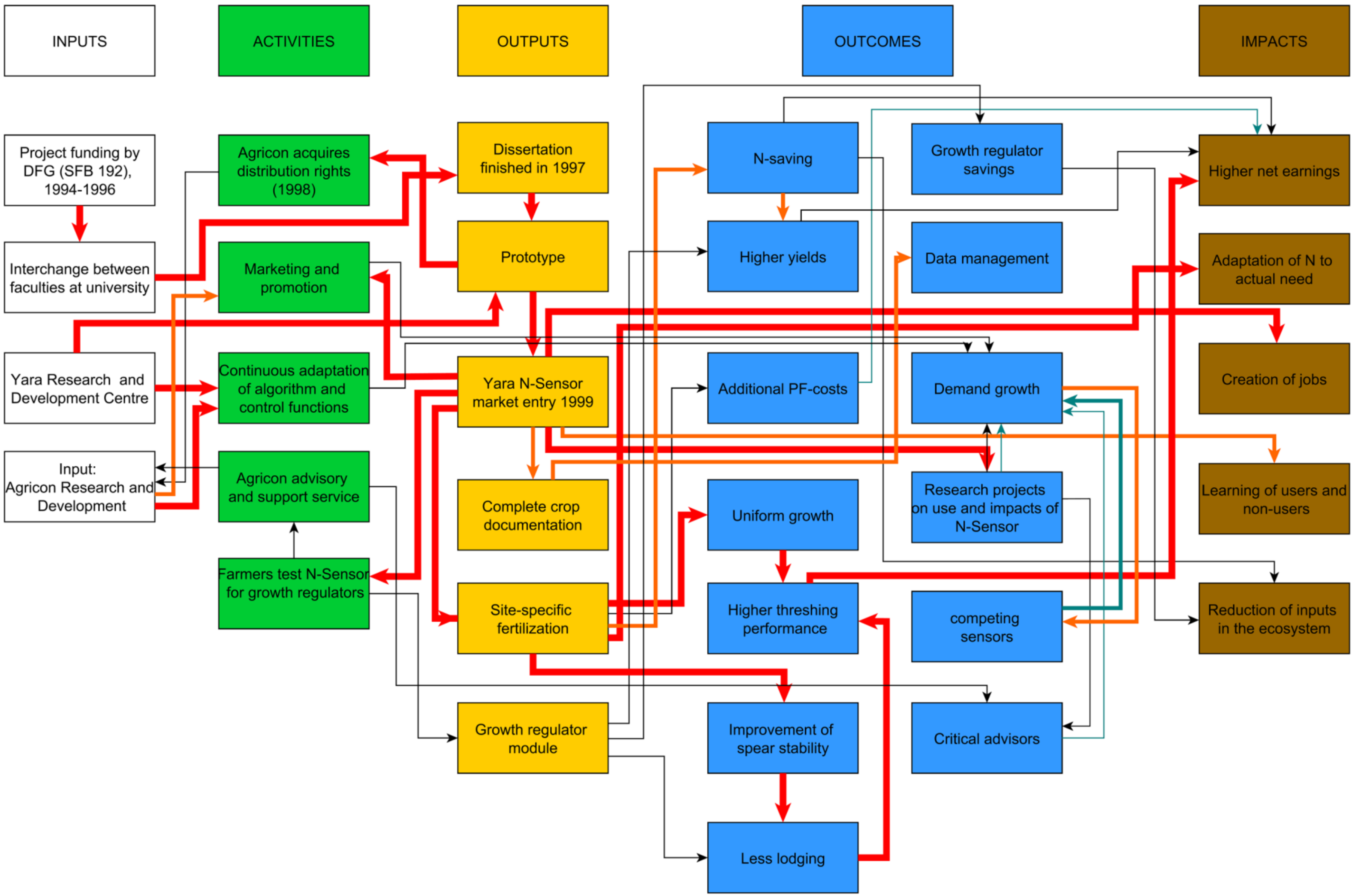
A3. On-farm biogas in Tuscany (Italy)



A4. Dairy cow fertility index (UK)



A5. Optical crop sensor (Germany)



A6. Varroa control product (Bulgaria)