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Published in:
EuroChoices

DOI:
10.1111/1746-692X.12181

Publication date:
2018

Citation for published version (APA):
Barjolle, D., Midmore, P., & Schmid, O. (2018). Tracing the Pathways from Research to Innovation: Evidence from Case Studies. *EuroChoices*, *17*(1), 11-18. https://doi.org/10.1111/1746-692X.12181

Tracing the Pathways from Research to Innovation: Evidence from Case Studies

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Summary

The complex process through which agricultural research stimulates innovation and achieves policy goals has commonly been treated as a 'black box' in the scientific literature. Statistical correlations between measured expenditure and impacts, where satisfactorily established, have mostly led to details of the research and innovation system being ignored. However, identifying and exploring causal chains of impact propagation can strengthen agricultural innovation. IMPRESA investigated impact mechanisms for research-based innovations in six case studies using a Participatory Impact Pathway Assessment approach. Several suggestions result for improving performance and public support for agricultural research. Planning for impact is needed at the design phase of research so that expected advances in technology and their consequences can be explored. At that stage and throughout the research process, soft social skills are required to promote uptake. Greater impact can be achieved through the close involvement of key public and private sector stakeholders, using stakeholder mapping as a supporting tool. There is a strong argument for the close involvement of relevant social scientists and professional facilitators from the design phase of research through to its ultimate impacts. Funding frameworks and the specification of calls for tenders would function more effectively by giving more flexibility for stakeholder engagement.

Several fundamental characteristics complicate the process of innovation within agricultural systems. Typically, there are a large number of relatively small farm businesses, dependent on primary resources of land, soil, and water. The private and public goods and services that they produce are part of more extended socio-ecological interactions, influenced by strategic and geopolitical dimensions of the food system. Moreover, agricultural research and development encompasses more than the formal institutions of research. Innovations exist in a range of modes and are influenced by multiple interactions between technological, commercial and institutional spheres (see, for example, Matt *et al*., 2017; Joly *et al*., 2016, Barret *et al*., 2016; Di Cesare and Mathe, 2017).

Farmers select, adapt and modify innovations. Occasionally, through trial and error, they are themselves responsible for important inventions. Even so, the emergence of a new product or technique often requires economic incentives to hasten adoption. A good example is the conversion from conventional to organic farming for which costs are normally higher (because of generally lower yields, greater labour requirements or specific investments, e.g., for weed control), requiring higher output prices to be economically viable. Institutional support through public regulation

(requirements for labelling and certification), and perhaps also financial backing, may be needed to encourage the adoption of this particular innovation.

Mapping research pathways

Through the IMPRESA project, we conducted a qualitative exploration of the way in which innovations come about, examining case studies of individual research and innovation cycles. Opening the process to scrutiny involved the development of a causal narrative, linking research to impacts. Sandwiched between these two ends of the innovation cycle are outputs (including traditional and modern extension communication tools, such as papers, flyers, events with stakeholders and videos) and outcomes (the short- to medium-term effects affecting the direct beneficiaries of research projects). Impacts themselves can be unintentional, as well as those anticipated in research proposals, and both negative and positive.

We were sceptical of the 'logical framework' (or log-frame) approach, which applies a unidirectional and sequential view of innovation through 'top-down' processes, i.e. from researchers to farmers. Moreover, this approach attributes all observed impacts to science and extension interventions, and neglects alternative or additional causal factors in the impact pathway. Whilst the log-frame remains in widespread use as a monitoring and evaluation tool, it is at odds with more recent evaluation approaches that understand innovation as resulting from complex interactions and learning processes, which can also involve feedback loops and shortcuts (Magro and Wilson, 2013).

The conceptual framework adopted in the IMPRESA case studies is based on a Participatory Impact Pathway Analysis (PIPA). Originally, the PIPA approach was conceived as an *ex-ante* evaluation method, to be conducted prior to implementation of research programmes and projects (Alvarez *et al*., 2010). In that form, it used a theory of change (Connell and Kubisch, 1998) to summarise how the intended innovation pathway would occur. We adapted the framework to an *ex-post* configuration because our aim was to evaluate the impacts of research at some distance in time after it had been completed.

To meet the requirements of *ex-post* evaluation, the basic framework of PIPA was complemented by additional elements. These included the use of Outcome Harvesting to identify and analyse evidence of causal mechanisms at various nodes on impact pathways. The role of the actor network was also explored, using either Stakeholder Mapping or Social Network Analysis as tools. Validation of impacts came from comparison of the information collected during the evaluation process with various other sources (triangulation), including Process Tracing. Confirmation bias is an acknowledged problem in case study analysis, since investigators can give more weight to evidence that confirms their prior opinion or belief concerning the phenomenon investigated. For example, a presupposition that researchers are poorly linked to the final beneficiaries of their work might orient evidence gathering to sources that confirm such beliefs, and neglect those that do not. To avoid this, semi-structured interviews were undertaken with actors to test the validity of explanations (technically, an active search for disconfirming evidence was undertaken). For an explanation of key terms used in impact evaluation, see Box 1.

Box 1: Glossary of methods and concepts used in analysis of impact pathways

Stakeholder mapping	The process of identifying and assessing stakeholders in a process by determining their impact and influence within it. This is normally conducted to manage communication and reporting.
Social Network Analysis	A mathematical tool for investigating social structures. It uses graphical representations of social networks and analyses the strength of relationships based on the numbers and distribution of connections between nodes.
Process Tracing	A framework for analysis of causal mechanisms determining the influence of different pathways on outcomes and impacts, and identifying different causal paths leading to a similar outcome in different cases.
Innovation broker	Individuals whose highly developed understanding and perception provides a bridge (often customised) between knowledge producers and those who could benefit from the innovations enabled by that knowledge.
Scaling up	Spreading, diffusing, disseminating, and adoption of an innovation.
Scaling out	Replication through impacting greater numbers of individuals or businesses.

In practice, investigation of each case study was guided by a manual, developed by the IMPRESA team, to make cross-case comparison easier. This prescribed seven phases of activity, during which responsibility for developing the narrative switched between case analysts and stakeholders.

- The first phase involved an initial screening to ensure that each case could be analysed. This involved gathering written evidence, clarifying original research proposal questions and predicted impacts, and gaining the confidence and trust of everyone who had played a role in the innovation process.
- The second phase consisted of workshops in which stakeholders identified and mapped the pathways, from initial research activity to identifiable impacts. In all cases, most impacts accrued a considerable time after the research had been completed (e.g. between 5-10 years and, in a few cases, considerably longer). Enabling and hindering factors affecting the process were also noted at this stage.
- The third phase (refinement and consolidation of the pathways by the case analysts) included the creation of a database on links between actors and institutions and the selection of indicators required to validate the pathways.
- In the fourth phase, indicator data were collected in conjunction with either a social network analysis or a stakeholder mapping process.
- In the fifth phase, the impact pathway was assessed and evaluated to ensure correct and valid attribution of impacts.
- In the sixth phase, stakeholders were invited to another workshop to provide feedback on the analysis and to finalise the conclusions.
- The final phase drew out lessons and recommendations.

The original case study manual developed in IMPRESA provided an effective menu of options to conduct impact evaluations. However, experience gained in applying the process indicated the need for greater flexibility to manage the wide diversity of potential cases. Furthermore, sufficient key elements and data need to be investigated to construct a comprehensive tracing of processes and to

allow for counterfactual analysis. Conducting an *ex-post* PIPA is costly and time-consuming, and is therefore unsuitable as a routine approach to the evaluation of research impact. An early lesson learned was that the most important initial step for any case study investigation is assessment of the availability of required information. Because of the length of the innovation cycle, senior researchers may have retired or, in our experience, may have simply forgotten how and when critical decisions were taken. Hence it can be difficult to track down project or programme documentation from many years or even decades in the past.

An overview of the six selected case studies[1]

The six case studies provided insights on enabling and hindering factors which were linked with the respective social, economic and institutional contexts. We also observed the role of knowledge sharing and capacity building in the brokerage and scaling up of innovation. We deliberately chose a small number of case studies, six in five different countries, to allow detailed and in-depth comparison. The cases themselves were also diverse, with three focusing on system development and the others on the development of products and tools. The contrasting range helped to reveal how the phenomenon of impact propagation varied across the distinct contexts in which it occurred.

The cases comprised:

- organic rice production in the Camargue in France
- two cases in Italy, one dealing with Integrated Pest Management (IPM) in olive farming and the other with on-farm biogas
- a dairy cow fertility index to address diminishing lifetime profitability in the United Kingdom
- an optical crop sensor for arable farming in Germany
- a Varroa (parasitic mite) control product for beekeeping, developed in Bulgaria.

In all cases, there was evidence that impacts anticipated in the original research proposals were at least partially realised. The level of impact was considered both at farm and territorial levels; they are summarised in Table 1. However, significant unanticipated direct impacts occurred in several case studies, due to market changes or changes in various policies, including agricultural and energy subsidies. The case studies also revealed several unexpected indirect impacts, many of which were either negative or ambiguous (such as the black-market resale of subsidised Varroa control products, and the intensification of dairy systems in the UK case). Most cases contained at least elements of scaling up. Typically, this was linked to knowledge sharing between research and practice; capacity building among farmers and their advisory services; policy awareness-raising; setting up of lobbying and marketing organisations; changes in the regulatory framework; and adaptation of new products and technologies for more convenient application.

Table 1: The main types and level of impact in each case at the farm and territorial levels

Case	Farm level impacts	Territorial level impacts
Organic rice production in Camargue (FR)	• increase in incomes from crop production (high) • reduction in use of pesticides (high) • reduction in use of nitrogen (moderate)	• reduction in use of pesticides (moderate) • increase in organic rice area (low)
IPM in olive production in Canino (IT)	• reduction in use of pesticides (high) • increase in incomes (high)	• improved organisational capacities (high)
On-farm biogas in Tuscany (IT)	• income diversification (high) • improved soil quality (low)	• maintenance of rural viability, i.e. farms, labour, areas (moderate) • reduced agri-food waste (moderate)
Dairy cow fertility index (UK)	• reduced calving interval (high) • improved animal health and welfare (high)	• proof of concept (high) • increase dairy system intensity (moderate) • decreased macroeconomic cost of infertility (moderate) • reduced GHG emissions (low)
Optical crop sensor in arable production (DE)	• calibration of nitrogen use to actual needs (high) • higher net income of users (moderate)	• reduction of inputs in the ecosystem (moderate) • creation of jobs (moderate)
Varroa control product in beekeeping (BG)	• reduction in use of pesticides (high) • lower bee mortality resulting in higher income (high)	• increasing conversion to organic beekeeping (low)

Assessment of the impact pathways for the six case studies showed that researchers had contributed to innovation in various ways. In some, support was provided for development of innovation capacity as part of the research process. Examples included the training of beneficiaries in the use of new techniques and promotion of adaptation of the technology to other uses.

Elements identified by stakeholders when mapping impact pathways included financial and human resources, farming techniques and products and also the interplay between individual actors (including researchers) and institutional actors. These elements, recognisable as major components of agricultural innovation systems, influenced the structure and characteristics of the impact pathway in different ways in the contextual environment of each case study. Diffusion and adoption of innovations depended on several factors, including their technical aspects, market opportunities, and institutional changes and supports. Nevertheless, in all case studies, the role of the initial research in the innovation process arose from 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, and most important, information flows between technical, commercial and institutional spheres that stimulated research activities.

Advisory or extension services normally play a significant role in building productive relationships between agricultural science and the farming community. In the six cases, however, they were found

to be of varying effectiveness, and in two cases, due to conservatism and antipathy, were even obstructive (see below). The comparative analysis between cases highlighted the importance of 'innovation brokers'. These innovation brokers, often a small number of profession - ally and socially motivated people, generally shared a common value framework. For example, in the United Kingdom case involving the dairy cow fertility index, the public service ethos left over from the former state milk marketing institutions exerted a noticeable influence over innovation adoption. However, conversely, companies marketing semen to farmers were certainly exposed to moral hazard, since genetics favouring improved cow fertility conflicted with their private economic interest in sales growth. This provides a plausible hypothesis to explain their observed behaviour, although no interviewees directly referred to the problem in this manner.

In all but one of the case studies, the initial research was made possible through substantial public funding, channelled through universities and public research institutions. The role of the private sector was also significant, although it contributed funding at later stages when potential profitability for both companies and farmers became clear. Between the initial research activity and the commercialisation phase, there was a gap in funding. Easier access to targeted, follow-up public (or private-public) funding opportunities, for example through Structural or Cohesion funding, would have sped up the incidence of impacts and the further development of innovations.

Enabling and hindering factors in institutional and policy frameworks

In each case studied, clear social, economic and environmental benefits ensued from the use of public funding. Yet there were obstacles at various points along the process which diminished their potential or delayed their realisation. A major contribution to the analysis of impact transmission comes from understanding these contextual factors, between those that discourage technology adoption, and others that enhance it. These factors related to human and social capital, relationships between actors, resource and economic prospects, institutional and policy frameworks, and the advisory and extension services.

In the research and development phase, uptake of new products and technologies was hindered by a lack of public funds (particularly the Varroa control product), absence of problem awareness (dairy cow fertility index) and the general conservatism of the farming community. In the adoption and diffusion phases, engagement with innovation was delayed by poor economic performance (biogas), high investment costs or unaffordable product prices (optical crop sensor and Varroa control product), or absence of support and even hindrance from the public advisory system (organic rice production Camargue and optical crop sensor). Specific economic factors (e.g. market demand, price of the product, registration taxes) often assumed a prominent role in the impact pathway maps. However, the effectiveness of key individuals involved in the innovation process was strongly linked to achieving impacts. These key individuals fostered trustful collaboration through networks and promoted development of beneficiaries' skills, and played an important catalytic role in producing impacts from research.

Institutional and policy frameworks, unrelated to the research intervention, also featured in all cases, either as enabling or hindering factors. They included changes in policy frameworks, such as the CAP, bioenergy subsidies, or pressure on actors, for example brought about by a change in the state of a natural resource, or a new market opportunity. In some cases, product registration and marketing played an important role in innovation diffusion. For example, patents or trademark registrations sometimes acted as an enabling factor, whereas in other cases the length of time and costs involved in regulatory processes hindered diffusion.

Perspectives for increasing the impacts of agriculture research

The cases demonstrate that a wide range of external contextual influences play a role regarding the emergence, the uptake and the scaling out of innovations, impacting a greater number of individuals, businesses or communities. These influences included public policies, institutional frameworks and governance, and markets. Even so, agricultural research and development policies are the key stimulus for leveraging the potential of new technologies. They are also highly influential in promoting awareness of the range of innovations available to enable the agricultural and food sectors to adapt to economic, social and environmental changes. These insights arose as a direct consequence of the participatory nature of the evaluation process. Beneficiaries, and other actors involved across the innovation process, assessed the extent to which research contributed to achieving the impacts envisioned at the outset of the research activity, particularly regarding their own expectations.

Our evaluations show that to increase the impacts of agricultural research, efficient use of public research funds should be assessed against overarching policy goals. Where conflicts of interest arise between European or national agricultural research policies and the needs or expectations of farmers and food enterprises, this provides a clear signal that the performance of the overall system needs to be scrutinised. Some steps to address this have already been implemented. For example, in the United Kingdom there is a commitment to regular evaluation of agricultural research policy (Defra, 2014) and, more recently, at the European level a multi-stakeholder approach is now required for certain topics in the H2020 research programme, and within the European Innovation Partnership and its Operational Groups.

Other important insights that can be drawn from the IMPRESA experience

The IMPRESA project involved detailed observation and analysis of innovation processes and how public or privately funded research contributes to impact. Focusing in depth on a small number of cases revealed the importance of the quality of research processes, especially in terms of linkages created between technical innovations and changes in governance, market and policy support.

The main recommendation emerging from this part of the IMPRESA project is that planning for impact should take place at the outset of research design, and include an assessment of the prospective use of anticipated innovations. At that stage, and also later in the research process, soft social skills are required to promote uptake. This would gain impetus by involving key stakeholders (including the private sector) at an early stage in the research, with the assistance of the stakeholder mapping tool. We recommend involvement of relevant social scientists and professional facilitators at the design phase of research projects.

Research calls and funding frameworks would work better if greater flexibility was provided for stakeholder and beneficiary engagement. As the implications of applied projects become clearer, the orientation can be adapted to improve and extend impacts. Providing scope (and incentives) for early involvement of the private sector could also be helpful, prior to the design of projects and during their formative stages. These changes could reduce tensions between different actors and facilitate the resolution of potential trade-offs between long-term public and short-term private interests. If these proposals were incorporated into *ex-ante* research impact assessment and adopted as routine practice by the research community, beneficial impacts would be enhanced, and negative effects forestalled.

While stakeholder engagement in the initial, pre-research, phase of activity is of paramount importance, it needs to be maintained across the entire innovation cycle. Suggestions for effective impact monitoring at interim review stages can help to avoid minimal, token enhancement of impacts. Previously we noted that being able to select a piece of research for impact evaluation

depends on the availability of adequate documentation. Within ongoing projects, monitoring research outputs with data collection tools and protocols should start at an early stage in the research process. This will also, contribute to a more effective information management system, required for projects at national and European levels. A requirement to develop an impact evidence portfolio within projects could, on its own, be sufficient to engender and embed a 'culture of impact' across the entire applied research process. Assessing impacts in mid-term project reviews would maintain impact focus during project implementation, and present opportunities to revise options for outcomes and impacts. As noted earlier, the application of *ex-post* impact studies with the Participatory Impact Pathway Analysis (PIPA) methodology cannot be recommended as a general evaluation approach because of the cost and time required. However, the approach could be usefully applied to a small number of selected cases to continue, and extend, knowledge of the processes of impact generation. It would also help to instigate and embed a pervasive culture for seeking impact at the institutional level.

[1]Each case study is described in an individual report, along with an overall cross-case comparative analysis, available at http://www.impresa-project.eu/reports-and-publications/reports.html#c442.

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