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Monitoring and Evaluation of Public Agricultural Research Organization: Impact oriented monitoring approach

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Abstract:

This study uses impact oriented monitoring (IOM) methodology recently proposed by Guinea et al. (2015) to identify and assess the socio-economic impact of public research organizations through case studies. IOM techniques overcome the most relevant limitations associated to mainstream research impact assessment (RIA). The IOM approach has been extended to a consideration of the multidimensional impact produced by the agricultural research and development. In contrast to previous studies, multi-criteria decision techniques based on ELECTRE III method are applied to derive global picture of impact. The methodology is expected to provide the Institute of Agro-food Research and Technology (IRTA) with useful information on how the research projects in the area of agro-food sector are generating impacts. Such analysis would support monitoring the impacts of agricultural research and assist in better targeting adequate research policy planning and project management strategies. The relevance of using new RIA approach can be evidenced by its applicability to other case studies and also its potential to be implemented in other agricultural research institutions in different countries. The use of refined methods has thus important implications.

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Keywords: Monitoring and evaluation; Public agricultural research; Societal impact; Impact identification and assessment, EL

1. Introduction

Growing social and political concerns for the effectiveness of public agricultural research make it necessary to develop robust measures that enable to evaluate the ability of research to deliver socio-economic impacts. Given the relevance of the RIA, agricultural policymakers place increasing emphasis on implementing monitoring and evaluation (M&E) tools in order to assess the societal impact of agricultural research activities. Since the 1950s, the analyses on the economic returns to research investment have gained special relevance (Griliches, 1958). Since then, RIA has received renewed attention in light of providing public research organizations (PROs) with reliable information on how the research projects are producing impacts. Different methodologies, ranging from descriptive qualitative analyses to highly sophisticated econometric techniques, have served this purpose.

During the last few years, the scientific community has produced several research studies that attempt to evaluate the socio-economic impacts of the PROs such as: Assessments of the impacts of the Advanced Technology Programme (ATP) (Ruegg and Feller, 2003), Public Value Mapping (Bozeman, 2003), the Payback Framework (Buxton and Hanney, 1996), the Social Impact Assessment Method (SIAMPI) (Spaapen and Van Drooge, 2011) and more recently the Socio-Economic Analysis of the Impacts of Public Agricultural Research (ASIRPA) (Joly *et al.*, 2015). Furthermore, PROs providing agricultural research and extension services are more and more involved in contributing to this field of interest. PROs include the Consultative Group for International Agricultural Research (CGIAR) (Walker et al. 2008), the Brazilian corporation of agricultural research (Avila *et al.*, 2015), the Commonwealth Scientific and Industrial Research Organization for Australian research (ACIL Tasman Pty Ltd, 2010) and the French National Agricultural Research Institute (Joly *et al.*, 2015).

In this context, the IRTA, representing the leading system of public agricultural research activity in Catalonia (Spain), seeks to design and implement RIA measures to monitor and evaluate the impact of research projects that are funded in the area of agro-food innovations. The IRTA, over 30 years, has made a significant contribution to agricultural research in Catalonia as well as to strengthen the research capacity with other worldwide partnerships. The main goal of the IRTA is to become the strategic ally of the agro-food sector, to conduct original research on agriculture and to be the locomotive of innovation and technology transfer for this field. Thus, it plays a significant role to enhance the system of agricultural technology in Catalonia. IRTA has continuously invest on technologies that assist agricultural development and knowledge sharing specifically in crop systems and soil management, dairy, wheat and barley breeding, fertilization and plant protection, animal nutrition, and integrated pest management for fruits and vegetables.

Consistent with previous studies, the economic analysis showed that the IRTA investment on agricultural research and development (R&D) is profitable for society through improving productivity performance of agriculture sector in Catalonia with an annual rate of return varies from 15% to 28% depending on different lag structure and real interest rate (Guesmi and Gil, 2017). However, there is a strong need to know the societal impact of R&D that goes beyond the conventional determination of internal rates of returns and scientific impact. Thus, to achieve this objective this paper proposes a methodological framework inspired by IOM and ASIRPA theories based on standardized case studies. The application focuses on case studies from four representative research areas.

The rest of the paper is organized as follows. In the next section, a literature review and the contribution of this work to previous literature is presented. Then, we describe the methodology used in our empirical analysis. The fourth section presents the empirical implementation. We finish the paper with concluding remarks.

2. Literature review

Within the RIA literature, studies are mainly based on conceptual, quantitative and qualitative techniques depending on the impact areas considered and the assessment level of research (e.g., programme, organization, project, technology, or other). While the conceptual analyses embrace the development of frameworks or concepts for measuring impacts of agricultural research, qualitative and quantitative methods allow using nominal or ordinal data through interviews and questionnaires and generating numeric measurement in a standardized way, respectively (Weißhuhn et al., 2017)). The authors reported that there is a tendency of preferring quantitative methods for economic impacts, and qualitative methods for social impacts.

A first group of studies has been interested in econometric methods to determine the rate of return to research spending (Alston *et al.*, 2011) in order to justify the investment effort (Bozeman and Melkers, 1993; Georghiou and Roessner, 2000; Salter and Martin, 2001; Ruegg and Feller, 2003; Donovan and Hanney, 2011). A second group has focused on determining indicators for 'productive interactions' between different stakeholders involved in the impact-generating mechanisms (Spaapen and Van Drooge, 2011). Another type of analyses tried to map the 'public values' of research programmes using case study approach (Bozeman, 2003), Bozeman and Sarewitz, 2011).

First attempts to assess the impact of research on society used the Payback Framework, which has been applied to the outcomes of health research structures (Buxton and Hanney, 1996; Hanney *et al.*, 2004; Donovan and Hanney, 2011). This approach relies on a logic model of the research processes, various types of research paybacks and expected impacts. The 'payback' or benefits from research originally encompass five domains namely, knowledge production, research targeting and capacity building, informing policy and product development, health and health sector benefits and broader economic benefits (Guinea *et al.*, 2015). The categories of impacts and the way that underpin this method make this framework to be more suitable to the health sector, however, it can be adapted to other research areas (Joly *et al.*, 2015). This constitutes the main limitation of this approach.

Apart from Payback, several studies have proposed other empirical approaches, models, and frameworks to examine the impact of research activity. (Bozeman, 2003) and (Bozeman and Sarewitz, 2011) developed the Public Value Mapping (PVM) approach taking into account the public good characteristic of science. The authors' proposal permits assessing the public values of research including environmental quality and sustainability, healthcare, and provision of basic needs. The method recognizes that the different dimensions of impacts are conditional upon the objective of a given research level. Nonetheless, the aggregation of these dimensions is still difficult and providing generic metric represent the main drawback of the PVM techniques.

The CGIAR has conducted several RIA studies. The original conceptualization of the "impact pathway" due to this group" (Douthwaite *et al.*, 2003; Walker *et al.*, 2008). The method designs the different phases of impact generation, the actors involved, the flow of resources, and the progressive transformation of knowledge in outcomes and impacts (Matt *et al.*, 2017). However, the problem of impact attribution is still unsolved (Kuby, 1999; Douthwaite *et al.*, 2003). In this context, the SIAMPI approach draws upon the concept of 'productive interactions' between researchers and stakeholders involved in generating societal impacts and society (Spaapen and Van Drooge, 2011). This method permits to identify the contributions of each actor to achieve societal impact.

Although these innovative RIA frameworks attempted to develop sound and robust tools on impact-generating mechanisms, they do not provide sufficient information regarding the type and amplitude of the impact. While the RIA literature has heavily debated on the proper specifications to assess the outcomes of research, less attention has been paid to deal with the broader impact of R&D investment and to provide clear measurement for each of the main dimensions of impact, or the resources for producing it (Gaunand *et al.*, 2015). As discussed by Bornmann (2013), the main challenge of RIA analyses is to implement 'an accepted framework with adequate data sets, criteria, and methods for the evaluation of societal impact. The abovementioned drawbacks have been widely discussed in the RIA literature and recent methodological improvements have been proposed.

The ASIRPA methodology, proposed recently by INRA researchers, overcomes the most relevant limitations associated to mainstream RIA models. This framework allows accounting for and measuring the broader impact of scientific activities (environment, public policy, social, health, culture) without foregoing the advantages of the aforementioned applications. The ASIRPA methodology mainly relies on standardized case studies, combining qualitative and quantitative techniques, across different INRA research departments. Furthermore, the advantage of this approach is that it considers the contribution of networks of actors to the innovation process as well as enables the scaling-up results from individual case studies to a global picture of impact (Joly *et al.*, 2015). Three main standardized tools underpin the ASIRPA theory namely, the impact pathway, the chronology and the vector of impact.

Another innovative evaluation methodology has been proposed by Guinea *et al.* (2015) based on the IOM approach. This recent RIA framework try to provide a straightforward and clear method to gather, organize, and discriminate between data on project results and impacts. The approach inspired by the payback model consists of two well differentiated components namely, the theoretical framework component and the impact monitoring system. While the former is designed to identify and classify inputs, activities, outputs, and impacts generated by research according to time or categories, the latter deals with the data collection and the assessment tool through the results framework, the coordinators' survey, and the end users' opinion. The advantage of this methodology is that it can be implemented during and after the project life to examine immediate and short-term impacts, as well as some evidence of future long-term impacts.

This article contributes to the RIA literature both from a methodological and empirical point of view. To our best knowledge, this work is the first study that apply IOM approach to the agricultural research area. Second, we extend IOM and ASIRPA methodologies by using ELECTRE techniques to derive reliable typological analysis of impacts. Finally, the present work is of great importance to support decision and policy making in agricultural research.

3. Methodological framework

As proposed in the literature above, many efforts and initiatives have been made to develop consistent RIA tools in order to achieve a better understanding of societal impact generation and help science policy-makers in 'making choices among competing paths to desired social outcomes' (Bozeman and Sarewitz, 2011). Our specification follows the path blazed by Joly *et al.* (2015) and (Guinea *et al.*, 2015). However, we modify the IOM approach to accommodate the diversity of the impact dimensions inspired by the ASIRPA methodology. We also slightly modify the typological analysis used by both approaches to accommodate more the heterogeneity of scales within the agricultural sector.

Ranking and classifying impacts is a complicated task because there is typically more than one dimension for measuring the impact of each project and more than one decision maker. ELECTRE method is an alternative technique well suited to deal with multiple criteria problem. It encompasses several interesting advantages. Dealing with either qualitative or quantitative nature of criteria presents an important feature of this approach. Furthermore, using a normalization technique makes this method suited to accommodate heterogeneity of scales. There is a wide agreement on the relevance of RIA analyses in terms of accountability and M&E performance of the PRO and learning purposes. By measuring global impact, we can assess which research project can generate high impacts including economic, environmental, social, political and health level. Hence, it is useful to better understand in which types impact is mostly achieved and if certain categories of projects achieve more impacts than others, and also to identify projects that could be recognized as success stories (Guinea *et al.*, 2015). It is a key tool for learning purposes and management of impact within a PRO.

The ELECTRE III method is suited to deal with multidimensional aspect of agricultural R&D impacts. Based on this approach, we seek to assess the relative performance of different research projects to achieve societal impact. The original conceptualization of outranking is due to Roy (1968). The EECTRE III technique relies on fuzzy binary outranking relations through three steps. The first one consists of constructing the performance matrix and defining the multi actors' preferences. Then, the second step permits to build a partial outranking. Finally, the last stage allows deriving final alternatives ranking.

Consider a multi-attribute decision making problem with j criteria and n alternatives. Let C_1, …, C_j and A_1,…,A_n denote a coherent family of criteria and the set of alternatives, respectively. A standard feature of this methodology is the decision matrix which presents the starting point for most outranking methods and defines the alternatives' performance to be evaluated with respect to determined criteria (Pena *et al.*, 2007). The decision-makers preference requires definition of the following parameters: indifference q_j, preference p_j, and veto v_j thresholds as well as criteria weight w_j. Based on the indifference and preference thresholds, this technique is adequate to take into account the imperfect knowledge of data and uncertainty with regard to the definition of criteria (Figueira *et al.*, 2010).

ELECTRE III is innovative in that it introduces the notion of pseudo-criteria. The latter is assumed to be a function gj associated with two threshold functions, $q_j(\cdot)$ and $p_j(\cdot)$. Let $g_j(a)$ and $g_j(b)$ represent individual partial preference function of the alternative **a** and **b** with regard to the criterion j, respectively. Depending on these parameters we can determine the preference relation between alternatives for a particular criterion leading to four cases Roy (2013). Equivalent preferences (I) are obtained if the difference between alternatives' assessment $g_j(a)$ and $g_j(b)$ is so small (lower than q_j) and the decision maker cannot distinguish between variants: (a I b) $\Leftrightarrow g_j(a)-g_j(b)\leq q_j(g_j(a)$.

Weak preferences (Q) corresponds to the existence of an observable difference between $g_i(a)$ and $g_i(b)$ is observable (between q and p), however the decision maker hesitates to validate strict preference in favor of the two alternatives: (a Q b) $\Leftrightarrow q_j(g_j(a) < g_j(a)-g_j(b)\leq p_j(g_j(a)$.

Important difference between $g_j(a)$ and $g_j(b)$ (higher than p_j) leads to strict preferences (P) and alternative **a** is strictly preferred to **b:** (a P b) $\Leftrightarrow$ pj(gj(a) < gj(a)-gj(b).
The last one (R) considers that **a** and **b** are incomparable if the difference between $g_j(a)$ and $g_j(b)$ is so high (higher than v_j). This introduces a new preference relation that accounts for situation in which the decision maker cannot compare between alternatives representing a further original characteristic of the model (Buchanan et al., 1999; Figueira et al., 2005; Solecka, 2014): Non (a S b) $\Leftrightarrow p_j(g_j(a) \leq g_j(a)-g_j(b)$

The second stage of the analysis consists of building the outranking relation between alternatives. Concordance $C_j(a,b)$ and discordance $D_j(a,b)$ indices are used for this purpose. While the former ensures that **a** is at least as good as **b** considering all criteria, the latter assesses the strength of the evidence against this assertion. These indices take values between zero and one and can be specified as:

$$C(a,b) = \frac{\sum_{j=1}^{n} w_j \cdot cj(a,b)}{\sum_{j=1}^{m} w_j} \tag{1}$$

And

$$C_j(a,b) = \begin{cases} 0 \ if \ \mathrm{p_j} \leq g_j(b)\text{-}g_j(a) \\ 0 < C_j(a,b) < 1 \ if \ \mathrm{q_j} < g_j(b)\text{-}g_j(a) < \mathrm{p_j} \\ 1 \ if \ \mathrm{g_j}(b) - g_j(a) \leq q_\mathrm{j} \end{cases}$$

(2)

$$D_j(a,b) = \begin{cases} 1 \ if \ \mathrm{v_j} \leq g_j(b)\text{-}g_j(a) \\ 0 < D_j(a,b) < 1 \ if \ \mathrm{p_j} < g_j(b)\text{-}g_j(a) \leq v_\mathrm{j} \\ 0 \ if \ \mathrm{g_j}(b) - g_j(a) \leq p_\mathrm{j} \end{cases}$$

Where W_i represents the jth criterion index and $c_j(a,b)$ is its corresponding concordance index. The partial concordance index can be defined based on the following conditions:

- The index equal to one if $g_i(a)$ is better than $g_i(b)$ and lower than the indifference threshold q_i involving that **a** is at least as good as **b**,
- The index takes the value of zero if $g_i(a)$ is worse than $g_i(b)$ by at least preference threshold p_i and we cannot accept the hypothesis that **a** is at least as good as **b**,
- The index takes value between one and zero if $g_i(a)$ is worse than $g_i(b)$ but limited between q and p, there is neither a total concordance nor discordance that **a** is at least good as **b**.

On the other hand, the discordance principle looks to see whether there is no criterion for which **a** is worse than **b**.

- if $g_i(a)$ is worse than gi(b) by at least veto threshold v_i, then g_i is in discordance with respect to the hypothesis that **a** is at least as good as **b** and $D_i(a,b)=1$,
- if $g_i(a)$ is better than $g_i(b)$ and lower than the preference threshold p_i indicating the absence of discordance $D_i(a,b)=0$,
- if $g_i(a)$ is worse than $g_i(b)$ but bounded between p_i and v_i involving a partial discordance which takes the value between zero and one.

In contrast to other methods, this approach is fundamentally non-compensatory since the weights assigned to criteria are "coefficients of importance" and not substitution rates (Vincke, 1992; Figueira *et al.*, 2010)) Moreover, the concordance and discordance principles support the non-compensatory character of the Electre methods. The final step in the construction of the outranking model is to derive the credibility index S(a,b) which assesses to what extent the assertion "a is at least as good as b" is valid. The degree of outranking relation is calculated based on concordance and discordance indices and expressed as:

$$S(a,b)=\begin{cases} C(a,b) \; if \;\; \forall\, j,\; D_j(a,b)\le C(a,b), \\ C(a,b) \displaystyle\prod_{j\in J:D_j(a,b)>C(a,b)} \frac{1-D_j(a,b)}{1-C_i(a,b)} \end{cases} \tag{3}$$

Where J represents a set of criteria.

The last step of this analysis focuses on deriving the final ranking relations from the credibility matrix to obtain two ascending (bottom-up) or descending (top-down) pre-orders. The alternative representing the highest index value is placed at the top of the top-down pre-order. Analogically, the bottom-up ranking is carried out in a similar way except that the set of alternatives with the smallest (rather than the largest) qualification are retained first. The intersection of the two procedures conducts to derive the final ranking. Furthermore, the latter can be illustrated graphically.

4. Empirical application

Following previous literature (Spaapen and Van Drooge, 2011; Bornmann, 2013; Joly *et al.*, 2015), the empirical application is based on only successful cases proposed by the heads of different IRTA research disciplines. IRTA's communication department has been contacted to collect data using "highlights: fact sheets" of research results during the last years. IRTA's communication department has been contacted for this purpose (Gaunand *et al.*, 2015). The innovation project/activity report that constitutes the database of our analysis include information on department, title, subject type, abstract describing the innovation, the topic, content, strengths, partners, products/output, patents, prospects or long-term impacts.

A preliminary list of potentially successful research project/activity has been elaborated during several meetings and cases are mainly organized around four scientific divisions, namely plant, animal, environmental and agro-food industries sciences. As proposed by Matt *et* al. (2017) the selection focuses on a significant research results from IRTA laboratories that generated or are likely to have an impact on society. Furthermore, we only consider cases that have academic and non-academic impacts. In addition, to address the representativeness issue of the diversity of IRTA's activities, selected cases are expected to show high impact and to be based on excellent and recent science (Research Evaluation Framework, 2011).

Besides the impact categories defined in the IOM methodology (knowledge production; research targeting and capacity building; informing policy and product development; health sector benefits and dissemination and knowledge transfer), we extend it to consider the characteristics of the agricultural sector. Like ASIRPA approach, five dimensions have been defined to measure the impact of agricultural science on the society. The quantification and qualification of impacts mainly rely on descriptors, gathered based on exhaustive literature review, through interviews with different stakeholders involved in the research activity (De Jong *et al.*, 2014). Four standardized analytical tools integrated the approach, including: 1) a project results framework; 2) a coordinators' survey; 3) an end users' survey, and 4) an assessment tool (scoring matrix). Standardized process allows to homogenize and aggregate these descriptors in order to get valid indicators, specific to each impact dimension, for all case studies (Joly *et al.*, 2015). Due to time-consuming to collect data form different stakeholders involved in the generation of impact, results will be presented at a later phase.

5. Discussion and conclusions

Monitoring and evaluation plays an important role to provide information about results and impacts in order to justify continued support from both national and international funding agencies. However, refined and robust M&E tools are needed to achieve a reliable assessment of societal impacts for project management, accountability objective and organizational learning.

The originality of our approach lies in its flexibility to combine two recent approaches namely, ASIRPA and IOM in order to provide a complete method for the assessment of the societal impact of a PRO. Furthermore, adapt the IOM approach to account for the specificities of agricultural sector and the multidimensional impact of R&D. Moreover, we also slightly modify the typological analysis used by both approaches to accommodate more the heterogeneity of scales within the agricultural research filed. ELECTRE method has been employed for this purpose. The main advantage of this technique is that deal with either qualitative or quantitative nature of criteria. By measuring global impact, we can assess which research project can generate high benefits for society.

The empirical implementation relies upon successful cases proposed by the heads of different IRTA research disciplines. We used a limited sample of research projects to validation purpose. However, it could be generalized to other cases studies and adapted for other research institutions. Due to time-consuming to collect data form different stakeholders involved in the generation of impact, results will be presented at a later phase. It is worth noting that methodological improvements are still needed within RIA analyses to optimize the data collection procedure, analysis and interpretation of results (14).

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