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"The hardest task" – Peer review and the evaluation of technological activities

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Abstract

Technology development and innovation are fundamentally different from scientific research. However, in many circumstances, they are evaluated jointly and by the same processes. In these cases, peer review - the most usual procedure for evaluating research - is also applied to the evaluation of technological products and innovation activities. This can lead to unfair results and end up discouraging the participation of researchers in these processes. This paper analyzes the evaluation processes in Uruguay's National System of Researchers. In this system, all members' activities, both scientific and technological, are evaluated by peer committees. Based on documentary analysis and semi-structured interviews, the difficulties faced by evaluators in assessing technology products are explored. The article highlights the persistence of a linear conception of the link between science and technology and describes the obstacles to assimilate the particularities of technological activities. Refereed publications are presented as the only uncontested product. Other types of output are reviewed with suspicion. This study emphasizes the need for specific mechanisms to evaluate technological production within academic careers.

Keywords: Research evaluation; Technological outputs; Peer review; National System of Researchers; Latin America; Uruguay

Introduction

Peer review has a central place in the evaluation of researchers. It is present, among others, in funding applications, academic publications, and applications for promotion and tenure (Langfeldt and Kyvik, 2011). The precise mechanisms through which peers issue opinions have different characteristics according to the context, but they share the idea that scientific peers are the best qualified to intervene in the matter under consideration. However, there are situations within science systems in which this methodology is not the most appropriate, and yet it may still be employed.

In contrast to the evaluation of scientific outputs, the assessment of technological activities and products is a field in which there is much less consensus on methodologies. In the context of some systems, the procedures for evaluating science and technology are not adequately differentiated and traditional peer review is employed in both cases. This paper examines the effects of evaluating technological practices with a methodology originally designed to assess science. It also describes the challenges faced by evaluators in these situations, and the strategies they have found to resolve the emerging tensions.

The case selected for this analysis falls within the framework of a national researcher classification system (Vasen et al. 2021a). These systems employ peer review to assign a rank to researchers based on their previous track record. Applicants can report both scientific and technological productions, as well as other activities related to R&D. In Latin America, membership in these systems has become a sign of prestige and recognition and plays a very important role in building an academic reputation. Therefore, the signals provided in these contexts are central in the formation of career expectations for researchers (Bianco, Gras and Sutz, 2016; D'Onofrio 2020).

In addition, incentives shaping the path of researchers should be analyzed in conjunction with the characteristics of the science and technology systems within which they work (Laudel 2017). The justification for public investment in science and technology has increasingly emphasized the significance of the social and economic impact of knowledge. Nevertheless, mechanisms used to evaluate scientists do not always automatically align with this trend. Assessment systems based on peer-review continue to give preference to the opinions originated within the scientific community, appealing to the notions of “quality”, “excellence” or “academic impact” (Vessuri et al. 2013; Invernizzi and Davyt 2019)[1]. In this regard, using inappropriate methods to evaluate scientific careers may impinge on the ability of STI policies to achieve their objectives.

In peer review evaluators usually hold a prior understanding of the notions of quality and impact, yet that familiarity mostly pertains to epistemic aspects and not so much to the social and economic impacts of research. This is reinforced by the rising standardization in the measurement of the quality of scientific work (Bornmann 2013), as opposed to a lack of a consensus on how to measure its contribution to technological and social progress. Hence, even when the public policy discourse recognizes the weight

[1] This problem goes beyond the Latin American region. In the United States and Canada, tenure and promotion committees in universities do not place much value on the public impact of research (Schimanski and Alperin 2018; Alperin et al. 2019).

of those contributions, in practice, assessment criteria may fail to be consistent with these priorities (Vasen 2018).

The present research took the assessment of agricultural researchers from the Uruguayan National System of Researchers (SNI, by its Spanish acronym) as a case study. SNI is a national researcher classification system and shares many characteristics with other systems in Mexico, Brazil, Panama, and Paraguay (Vasen et al., 2021a). The focus was placed on the agricultural sciences as this is an area in which these issues have been particularly visible. Agriculture and livestock farming are the main sectors of the Uruguayan economy and all the knowledge generated in this area has a strategic value. On the other hand, in this branch of the SNI, the classical academic culture of the university meets the applied vision of the researchers from the mission-oriented institutes.

The following section presents the most relevant research on peer review and alternative methodologies used for the evaluation of technological activities, and highlights aspects specific to the agricultural sciences. Subsequently, the characteristics of the Uruguayan scientific and technological sector and the National System of Researchers are introduced. After describing the methodological strategy, the findings derived from the analysis of documents and interviews with evaluators and key informants are presented and discussed.

Review

Institutional frameworks and research evaluation procedures play a central role in fostering a science system's capacity to generate social impact. Whitley (2003) argues that science-based innovations are facilitated by systems in which there is a high level of competition between researchers for reputations, as well as a pluralistic environment that encourages intellectual risk-taking. Moreover, a strong organizational segmentation of goals and careers is associated with less pluralism and diversity and discourages cross-fertilization between different fields and approaches.

Traditional research evaluation systems face difficulties in addressing applied research and technological development. Peer review was originally designed for the context of academic science (Hackett 1990; Lamont 2009), and its extension to other types of activities is neither natural nor necessarily adequate. Other methodologies have been favored to analyze the impact of technological development. Although *ex ante* peer review has been used in some cases, such as the NSF Broader Impacts Criterion (Holbrook 2005), or the inclusion of impact statements in funding applications (Ma et al. 2020), most methodologies for evaluating technological outputs involve non-academic actors and are carried out *ex post*.

In this vein, proposals such as the Payback Framework differentiate outputs from outcomes and impacts (Donovan and Hanney 2011), while others focus on productive interactions (Spaapen and Van Drooge 2011). Additionally, approaches based on impact narratives have been developed and implemented, for example, in the UK Research Excellence Framework (Derrick 2018; Hellström and Hellström 2017). Some approaches have also sought to go beyond economic models and focus on the capacity of science policy to contribute to public values (Bozeman and Sarewitz 2011).

Specifically, in the case of agricultural sciences, participatory assessment methods such as ASIRPA (Joly et al. 2015) or ImpreSS (Temple et al. 2018) have been significant. The co-innovation framework stands out as a more holistic framework for the development of innovation that includes all stakeholders in the early stages (Percy et al. 2019; Turner et al. 2016). In conceptual terms, these methodologies are in line with the notion of responsible innovation (Macnaghten 2016; Von Schomberg and Hankins 2019).

Despite the existence of alternative developments, peer review continues to play a central role in the lives of researchers. In Latin America, national researcher classification systems are very influential and rely almost exclusively on peer review. In such systems, peers review the career of applicants, and must evaluate both their scientific and technological outputs. In recent years, there has been extensive research on peer review and the challenges posed by the growing influence of research metrics. Even if metrics replace peer evaluations only in very few cases, their consideration by evaluation committees is becoming ineluctable. Indicators often also contain disciplinary, linguistic, and geographical biases and do not take into account that limitations inherent to information sources may lead to substantial distortions (Archambault et al., 2016; Cañibano et al. 2018; Vasen and Lujano, 2017). Bibliometricians are often cautious and have warned that the goal should not be replacing peer evaluations with indicators but rather conducting more informed peer evaluations (Hicks et al. 2015; Sugimoto and Larivière 2017). Even in a context of increasing standardization, studies such as Reynert (2020) emphasize the differences among disciplinary cultures and the prevalence of more traditional criteria.

There is still limited understanding of how peer reviewers approach the evaluation of applied science and technology. The challenges peers encounter in analyzing scientific publications are very different from those that arise in the review of technological developments. The usual tools are not necessarily helpful there. The value of scientific publications for those applicants who focus on applied research and technology is a controversial issue. The relationship between academic outputs and their social and economic impact has been the object of numerous analyses (Abramo et al 2012; Bozeman et al. 2012; Lin and Bozeman 2006; Yegros-Yegros et al 2016). In that sense, there appears not to exist necessarily a conflict between academic output and collaboration with the industry. Tensions seem to be stronger at the individual than at the organizational level, and it may be possible to create “ambidextrous” researchers or groups (Ambos et al. 2008).

Finally, there is a growing concern about the negative consequences of current research assessment practices in Latin America. The inclusion of standardized mechanisms and their impact on research on topics of local interest has been among the issues most frequently discussed (Bianco et. al 2016; Kreimer 2019; Neff 2018). A consolidated regional circuit of open access science publications plays a key role in this landscape, especially in the social sciences and humanities (Babini 2020; Babini and Machin-Mastromatteo 2015; Packer 2020). Publishing within the regional circuit is valued in most national evaluations (Alperin & Rozemblum 2017; Beigel 2014; Beigel 2017; Vasen and Lujano, 2017). Regarding the evaluation of technological and "atypical" outputs, a study of assessment practices in the Mexican *SNI* shows that traditional academic publications are still the most valued outputs in evaluation systems and that knowledge transfer is not straightforwardly considered (Vasen, 2018). In addition, institutions in Argentina have implemented mechanisms to encourage more applied professional paths, albeit without achieving the expected results (Naidorf et al. 2019; Naidorf et al. 2020).

This paper presents the views of the Uruguayan peer reviewers on the evaluation of technological outputs and their stance on the link between scientific publication and technological production. Do they believe that ambidexterity is possible or desirable? How do they define the required criteria for technological production? What signals are they sending to the academic community with their feedbacks? Can they overcome the organizational and contextual limitations of a traditional peer review setting?

Background

Science and innovation in Uruguay

Science systems in Latin America have comparatively low levels of investment in R&D when correlated to GDPs. Brazil is the only country in the region surpassing a 1% investment. Out of all R&D expenditure, the fraction coming from the private sector is small in relative terms. According to data from 2019, companies in the region only execute 30.7% of R&D activities on average, while the public sector, universities and private non profit organizations execute the other 69.3%. For comparison, the percentages of execution among the private sector in more developed countries are higher: in the United States, the sector executes 72.58% of activities, and in Spain, it executes 56.1% of those activities (RICYT 2021). Productive sectors have few high complexity industries and do not require extensive scientific knowledge to develop their businesses. This has led to science systems that are more academically oriented and less technologically or innovation oriented (Arocena and Sutz 2010).

Agricultural technology is a sector of crucial importance for the region's exports (Thomas and Gianella 2009). Public agricultural research institutes have historically played a central role in adapting new technologies to local soil and climatic conditions and favoring their adoption by producers (Arboleya and Restaino, 2004). In recent years, agricultural research institutes have also started to adopt technology transfer, intellectual property, and innovation management systems (Bin et al, 2013). On the other hand, regarding scientific development, these institutes are still struggling to catch up with the growing importance of biotechnology and molecular biology in agricultural sciences (FONTAGRO, 2017).

The science and technology system in Uruguay is one of the most consolidated of its kind in the region. Research activities are spearheaded by the *Universidad de la República* (*UdelaR*), the most prominent higher education institution in the country founded in 1894 and carrying out activities in all fields of knowledge. The university landscape is also made up of a recently founded public university of technology and 5 private universities. Other renowned research institutions include the Clemente Estable Biological Research Institute (*IIBCE*), founded in 1927, and the Pasteur Institute of Montevideo (*IPMON*), founded in 2004. Finally, the National Institute for Agricultural Research (INIA) is of special interest for agricultural research. INIA is a mission-oriented research institution, with a history strong link with the needs of local agricultural producers. In contrast, the Faculties of Agronomy and Veterinary Science at UDELAR are more academically oriented.

At the institutional level, the most prominent measure taken in the last few decades was the creation, in 2006, of the National Agency for Research and Innovation (*ANII*), a government agency fully dedicated to science, technology, and innovation. Among its responsibilities, it is charged with supporting academic science, technological development, and innovation.

The design of a coordinated national STI policy strategy has not yet been fully accomplished. In 2005, an Inter-Ministerial Committee for Innovation was created. Up until 2010, it held a key role, losing prominence later. Additionally, there is a consulting National Council on Science and Technology (*CONICYT*) and, up until 2020, the country had a National Science and Technology Secretariat with a limited scope of impact over the stakeholders of the system. The government that took office in March 2020 has initiated a review of the institutional structures for science and technology. Four studies are underway and in December 2021 a workshop was organized to systematize lessons learned from the 2010 national STI plan. The topics covered included: 1) survey and evaluation of regulations for the development of science policies and activities, technology and innovation; 2) characterization of actors and their capacities in the R&D system; 3) evaluation of the resources and instruments for promoting science, technology and innovation; 4) operation and articulation of the science, technology and innovation system, and 5) general principles for a new institutional design. A series of stakeholder discussions will be held throughout 2022, and the government is expected to come up with a proposal at the end of this process.

Uruguay’s National System of Researchers

This paper specifically focuses on the assessment conducted within Uruguay's National System of Researchers (*SNI*). The *SNI* was established by legislation in 2007 to strengthen and consolidate the scientific community, periodically assess and categorize researchers, and establish an incentive system for the creation of knowledge in all disciplines (*ANII* 2018).

SNI belongs to a family of national researchers' classification systems (NRCS) that has expanded across Latin America and Spain since the 1970s (Vasen et al 2021a). In addition to the Uruguayan SNI, other examples of NRCS include the Mexican SNI, the Brazilian productivity scholarships, and the Spanish *sexenios* (Neff, 2018; Sarthou, 2016; Sandoval-Romero and Larivière, 2020). These systems have sought to provide financial and symbolic support for researchers in countries where universities have a strong professional orientation and tend to place a high teaching load on faculty. Through these systems, professors at universities or research institutes, obtain recognition for submitting their research activities for evaluation to a peer review system organized at the national level. If successful, they are awarded a rank and, in most cases, also a monthly financial incentive. These systems have been effective in increasing traditional scientific publications, but there are doubts about their ability to also promote activities with greater social impact (Sanz-Menéndez, 1995). They may even be counterproductive, insofar as they reward classical academic careers (Vasen, 2018).

Since 2008, every November in Uruguay there is a call for researchers to apply for admission in the system, renew their category, or be considered for a promotion. All information must be uploaded to *CVUy*, a standardized curricular platform. Results are generally available in May of the following year. There are no quotas, all researchers who pass their evaluations are granted a category within the system and are eligible to receive a financial incentive. Researchers can be awarded the “initiation” category (3 years, renewable for only one additional 3-year term), Level I (3 years, with consecutive renewals for 3 years), Level II or Level III (3 years, with consecutive renewals for 4 years). The most outstanding Level III researchers can be selected as emeritus researchers, a lifetime position. There is also a category of “associate researcher” for Uruguayans living abroad.

The financial incentive is paid directly to the researchers’ bank account without intervention from his university or research institution[2]. As of 2021, initiation researchers receive monthly 182 USD, Level I 243 USD, Level II 304 USD, and Level III 365 USD. In the early years of the system, the incentive represented an attractive extra income. However, over the years, the values did not increase significantly, and nowadays the symbolic value of membership in the system is much more important than the economic dimension. As of today, the incentive represents an additional monthly payment approximately equivalent to 10% of the net salary.

The system operates within the scope of the ANII and it is led by an Honorary Commission (*CH*) in charge of all governance and of making strategic decisions. The *CH* is made up of 5 members, out of which one is appointed by *UdelaR*, two by *CONICYT,*

[2] Only researchers living in Uruguay and holding a position in a university or research institute are eligible to receive the financial incentive.

and two by the board of directors of the *ANII*. The agency provides administrative and financial support, but the system is governed by the research community.

Three different committees are involved in the assessment of applications (see figure 1). First, the Technical Advisory Commissions (*CTA*) carry out a detailed assessment of the applicants and recommend a decision for each application. Currently, there are eight *CTAs*, each made up of 5 members (all of them Level II or Level III SNI members), representing the different fields of knowledge: Exact Sciences, Natural Sciences, Medical and Health Sciences, Agricultural Sciences, Engineering and Technology, Social Sciences I, Social Sciences II and Humanities.

After review by the CTAs, applications are reassessed by a multidisciplinary selection committee (CS), made up of at least one representative from each field of knowledge. Most often, *CS* members have previously been members of the *CTA* of their discipline. The *CS* is responsible for reviewing the recommendations of the *CTAs* and balancing the requirements between disciplines. *CS* may endorse the decisions of the *CTAs* or propose a different category for the applicant.

Lastly, cases are reviewed by the Honorary Commission, which settles cases in which there are conflicting positions between the *CTA* and the Selection Committee. There is also an *ad hoc* reviewing commission that hears the appeals to decisions raised by applicants.

In 2021, 1855 researchers had been assigned categories in the system (see table 1), out of which 245 (13.2%) belonged to the field of agricultural sciences. The area is the 3rd largest in the system, after natural sciences (629, 33.9%) and social sciences (376, 20.3%). On the other hand, the distribution of the institutional affiliation of the members is very uneven. UDELAR concentrates 74.6% of all SNI members. INIA accounts for 4.3% of the total categorized members, which represents about 31.0% of members in agricultural sciences (see table 2). The importance of INIA is far from marginal. It is the institution with the second largest number of researchers after UDELAR in the entire system, closely followed by IIBCE. However, while the institutional culture of IIBCE and UDELAR are similar, INIA is a mission-oriented research institution, and the clash between institutional cultures has been a source of friction in the early stages of the system.

	Initiation	**Level I**	**Level II**	**Level III**	**Total**
Agricultural sciences	109	95	31	10	245
Health sciences	94	101	30	12	237
Exact and natural sciences	157	312	122	38	629
Social sciences	149	168	48	11	376
Humanities	54	88	25	11	178
Engineering and technology	61	80	40	9	190
Total	**624**	**844**	**296**	**91**	**1855**

Note: emeritus and associate members are excluded.

Table 1. SNI members by category and field (2021). Source: ANII.

Institution	Total
UDELAR - Universidad de la República	140
INIA - Instituto Nacional de Investigación Agropecuaria	76
IIBCE - Instituto Clemente Estable	9
Other	12
No data	8
Total	**245**

Table 2. Affiliation of SNI members in agricultural science. Source: ANII.

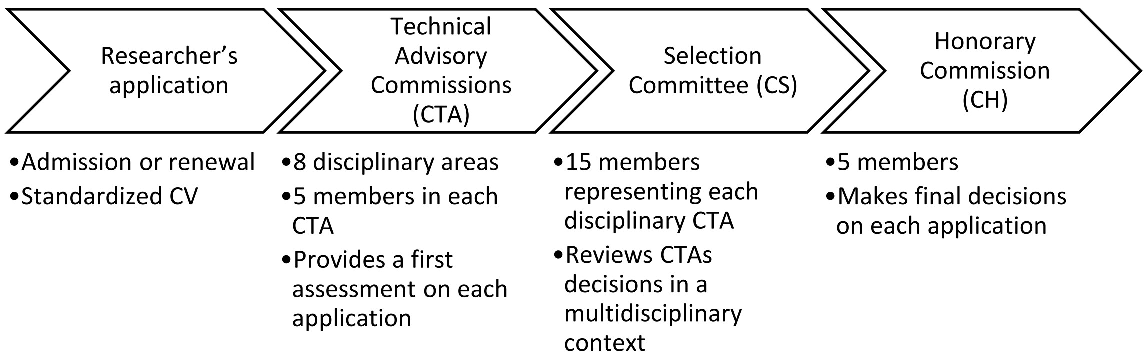

Figure 1. SNI categorization process workflow. Source: Prepared by the authors.

Materials and Methods

This paper is part of a growing corpus of qualitative work on the evaluation of science (Bruun-Jensen 2011; Kaltenbrunner and De Rijcke 2016; Lamont 2009; Rushforth and De Rijcke 2015; Samuel and Derrick, 2015).

The goal of the project (funded by INIA) was to analyze the evaluation that Uruguayan researchers in the field of agricultural sciences undergo. A specific component of the project addressed evaluation practices within SNI, which holds a key role in the structuring of the production of scientific knowledge in the country. The research is based on official documents and 22 semi-structured interviews conducted in Uruguay between July and November 2019.

Documents were collected, including regulations on the operation of the *SNI*, assessment criteria guidelines, and other internal documents provided by evaluators during interviews. In addition, a total of 22 interviews was conducted, 13 of which corresponded to evaluators from the agricultural sciences who had participated in *CTA, CS,* and *CH* commissions in the last 5 years. The other 9 interviews focused on contextualizing the evaluation work and were conducted with authorities from universities and the public research system, as well as with other key informants. The interviews lasted between 45 and 80 minutes and were recorded and transcribed for detailed analysis.

Two different question guides were employed, one for evaluators and the other for contextualization interviews. The evaluators' guide had 8 questions that covered the organization of the evaluation work, the main discussions held within commissions, the particularities of agricultural research as compared to other fields of knowledge, and the difficulties in assessing technological outputs and knowledge transfer activities. In the case of interviews with key informants, the guides focused on the role of the *SNI* within the national context, the vision of the interviewee on the kind of assessment conducted by the *SNI,* and the means available to evaluators for the analysis of technological outputs and outreach activities. In this second group of interviews, conversations were less structured, and given the heterogeneous nature of the group, were steered based on the profile of the interviewee. For instance, in the case of an international consultant who had collaborated in the design of the *SNI*, specific questions were raised on the design of the evaluation system and, in the case of a high ranking university official, questions were posed regarding the tensions between assessments conducted by the university and the one conducted by the *SNI*. Both documents and interviews were coded using a quantitative data analysis software package, based on a list of subjects drafted by induction. Finally, a thematic analysis of the content was conducted.

The evaluation of technological outputs: criteria and procedures

Current *SNI* regulations indicate that the activity of researchers shall be assessed based on (i) the originality of their work -confirmed by peer review, patents, or other methods-, (ii) their contribution to the development of lines of research and (iii) to solving societal problems in Uruguay, and on national and international leadership (*SNI*, 2014, article 9). In a similar vein, the official document outlining the assessment criteria is focused on traditional scholarly work (*SNI* 2020)[3]. Scientific publications, postgraduate education, and institutional development in science and technology are particularly valued. Special

[3] Unlike the usual practice in other research assessment systems, SNI has only one set of criteria applicable to all disciplines.

emphasis is placed on originality. The significance of research contributing to the solution of national problems is addressed in highly general terms. Technological outputs are scarcely mentioned and there are no specific details on the assessment of technological development and innovation. Patents are only used as a means of verifying the originality of the technological work conducted, but not as the preferred output of the research process.

The challenges posed by the assessment of technology led the System's authorities to create a specialized Commission to deal with the issue in 2010. It was called Specialized Advisory Commission (*CAE*) and operated for just one year. Its goal was to analyze the cases of applicants that presented "rare" or "atypical" outputs that required a holistic and multidisciplinary perspective. The commission heard but 9 cases, most in the agricultural sciences and related to researchers affiliated with INIA. When concluding their work in 2011, its members drafted a note addressed to the Honorary Commission indicating that the criteria they used to validate the output were: the production of original knowledge and the existence of a research process connected to the technological output. To evaluate such attributes, the members looked for peer-reviewed publications and funded projects connected to the processes being assessed. In their opinion, such aspects were sufficient to indicate that the established assessment criteria were being met. Given its lack of detail, the description of technological outputs and processes provided by candidates in *CVUy* could not be considered. The recommendation made to "atypical" applicants by the commission was for them to validate their work through peer reviewed publications.

The experience within the *CAE* revealed the challenges existing for the evaluation of technological profiles within *SNI*. This was not repeated, and since then the evaluation of technology-oriented applicants is carried out along with the rest of the applications within the framework of the disciplinary organized CTAs.

The next two sections focus on the difficulties faced by evaluators in the case of technological products and the "solution" they find for controversial cases. Finally, the problem is discussed in a broader context.

The view of evaluators

During the interviews conducted for this research in 2019, evaluators recognized technological outputs as one of the most difficult aspects to deal with in their work within the *SNI* commissions. They report having faced four major issues: (a) unclear scope of the concept of "technological output", (b) challenging verification of originality, (c) unfeasible assessment of social impact, and (d) limited availability of information.

(a) *Scope.* The first difficulty lies in defining what may be understood as a technological output. To illustrate this, evaluators always compare the outputs of technological work with those of scientific work. In the technological field, there is less consensus on how to ascertain the value of the outputs, as there is in science.

> When we considered technological outputs, the possibilities before us were so broad… Because you read “bibliographic outputs”, and that means journals, books, book chapters, etcetera. When you read the [*CVUy* section on] technical outputs, you find technological outputs, but also reports and white papers; this is much broader. (Interview 21, *CH* member)

> When considering the technical outputs outlined in the regulation, it was always difficult to define what a technological output is and how to assess it. That was hard from the beginning. (Interview 17, *CH* member)

These quotes illustrate how evaluating technology is a task that evaluators find problematic and are not familiar with. The lack of standardization causes them disorientation and discomfort. How they will move forward on the problem, as will be seen, involves making the strictly technological elements disappear. This enables them to employ the usual methodologies for the evaluation of scientific work.

(b) *Originality.* Evaluators are particularly interested in validating the originality of the technological products under review. They seek to verify that those outputs are, indeed, innovations at a global level, and not mere local adaptations of technologies developed abroad. As the quotations below show, the evaluators understand that the objective of the SNI is the creation of original knowledge. The adaptation of a pre-existing technology to the local context (a common situation in the agricultural field) is not considered to fall within this objective.

> It is extremely hard for us; it is hard when a researcher presents a technological output (...) The *SNI* is interested in rewarding the creation of original knowledge; hence, the issue lies in discerning which products involve the creation of original knowledge and which don’t. Because when working on classical research, on research, one already has sufficient structured ways to report findings, like papers, for example. When moving to technological progress, we face the issue of identifying wherein lies originality... (Interview 16, *CTA* member).

During the interviews evaluators often mention that they can rely on the peer review mechanisms of scientific journals to validate the originality of scientific work. However, validating originality in technological outputs is a much more complex task, for no “shortcuts” can be used as it happens with papers. It is a task that they must undertake themselves.

Although patents may be accepted as proof of originality, they are aware that not everything is patentable and that patenting rates in Uruguay are very low. What is more, in process or organizational technologies a consensus has yet to be achieved as to how to conduct a just evaluation.

In the case of cultivars[4], for instance, the National Seeds Institute (*INASE*) does not have procedures in place for the registration of all species. So, a rice cultivar could unfairly be considered more valuable than a yam or eucalyptus cultivar simply because one may be registered before *INASE* and the others may not. As a result, albeit evaluators may ultimately accept registrations as validating instances, they tend not to trust them.

The search for originality is translated then into an analysis of the scientific knowledge involved in the development of the technological output. Evaluators look for papers that can confirm that the technology is based on original scientific research carried out by the applicants themselves. In the end, the system's culture makes it so that technological originality is understood as derived from scientific originality. This view expresses an extremely linear conception of technological development and innovation. In it, original scientific research must first be carried out and published, and only then technological development can be undertaken.

(c) *Social impact*. A third controversial issue relates to the social and economic impact of the technologies under review. Official evaluation criteria require only a verification of the originality and the scientific basis of the technology under review. However, evaluators are inclined to go one step further and consider adoption and impact. Is adoption by producers a required condition for the technology to be considered positively in the evaluation process? Does the magnitude of its economic impact need to be taken into account? Evaluators cannot reach a unanimous consensus on that front.

> I can develop 50 varieties, none of which are used in the real world. So, I carried out technical work, yet it had no impact on production. I can patent those varieties, but I can be patenting something no one consumes... (Interview 26, *CTA* member).

> It is difficult to assess contributions when varieties are developed, but not really used. And sometimes they are not used because they are no better than what we already have... So, it is difficult to establish parameters: they are built when cases are discussed. (Interview 28, *CTA* member)

As noted in the first quote, probably a patent or variety registration would be enough as a measure of originality. Yet such registrations would not suffice if the assessment criteria included the extent they have been adopted by producers or on their value in the face of existing varieties. Technological products are not only required to be original and based on original scientific knowledge, but they must also be adopted by users and generate positive social and economic impacts. This perspective places additional demands on researchers, since the processes by which technology has a social impact are complex and, in many respects, beyond their control.

[4] Plant varieties are regsitered in accordance with UPOV conventions. See Sanderson (2019) for a detailed account.

(d) *Data available to evaluators*. Applicants must upload their production in the *CVUy*, a standardized curricular system developed by the *ANII*. Technological outputs may only include a 500-word description, and attaching supporting documents is no easy feat (a document should be uploaded in a cloud, such as Dropbox or Google Drive, with a link to this included in the output description).

On the other hand, as noted in the following quotation, a lack of standardization in the information submitted complicates the evaluation.

> For many technologies, researchers submit reports or present their outputs, somehow accounting for their research with multiple documents that are far more valuable as means to discuss the use of such technology with those who adopt it than as documents that allow for assessing whether the technology considered has been validated or has had an impact, or how much original research lies behind that technology or if it is an adaptation of technology already existing within our system. In that sense, this is the hardest task we face. (Interview 22, *CS* member)

Hence, evaluations conducted by peers in many cases require additional information unavailable in the official application. Evaluators sometimes consult with colleagues they consider experts in the field. In the Uruguayan case, this is made easier by the reduced size of the scientific community, particularly in the agricultural field. Evaluators often know someone more familiar with the specific development to enquire over more details. This is done informally and is not officially recorded in the proceedings.

Evaluating technology through scientific publication: a linear solution to hard cases

The most challenging discussions regarding the evaluation of technological production revolve around the profile of certain applicants. These are professionals who have a great deal of technological expertise but are not used to publishing scientific papers. Their profile is more applied, and it is more common for them to be affiliated to INIA than to a university. When reviewing applications that present technological productions but few or no scientific papers, evaluators find themselves in a difficult position. The following quotes show the doubts they have about technologies that are presented without documentation of the scientific research behind them.

> Discussions have centered around whether a technological development involves or not original knowledge production. If it does: why does this not merit a scientific publication? (...) I strongly believe that a good technical output cannot be achieved without a strong scientific basis (Interview 24, *CTA* member).

> There were cases of people that had technological outputs and demanded to have them considered in the *SNI* evaluation. If the contributions were original: why were no attempts made to produce publications describing that finding and development? If it was possible to produce publications for that kind of development, but they were not produced: why was that? (Interview 25, *CTA* member)

An argument could be made that technological advances are not necessarily published in scientific journals, as they may be subject to confidentiality or may not be of interest to the disciplinary communities. Despite this, most evaluators consider evaluating technological outputs *through* scientific publication as a viable option. They claim that in the process of producing truly original technological innovations, publishable results are always generated.

Furthermore, they believe that it is not the case that scientific journals are unwilling to publish contributions that are applied or have a local rather than a global impact.

> I work, for example, on cattle management, and whatever is discovered is then published, right? And sometimes it is published along with rather practical, specific recommendations. So, sometimes I think that this argument is used to avoid the hassle of publishing, of undergoing the classical peer-review. (Interview 16, *CTA* member)

Evaluators consider that the absence of publications in these applications cannot be attributed to a lack of interest on the part of the journals. In this perspective, journal peer review would guarantee the reliability of the technological proposal. Failure to submit the results for publication generates distrust about the soundness of the work carried out.

> We should check that the technological output is backed, to some extent, by a verifiable scientific or academic output. How can you trust crop handling methodologies, for instance, if they have not been peer-reviewed and assessed? What is the quality of that technological output? (Interview 15, *CTA* member)

Evaluators tend to believe that these applicants have failed in their ability to create adequate scholarly products and that they use the argument concerning the difficulty of publishing on local and applied topics as a "shield" against legitimate criticism of their work.

In summary, *SNI* evaluators consider that the methods available within the system to assess technological work are not sufficient to verify whether these outputs are original and based on high-quality scientific research. As a result, they argue that the best way to assess them is to do so indirectly, through scientific publications. One might wonder, then, if what evaluators propose is in fact an assessment of technological outputs. By demanding technological developments have attributes often associated with scientific practice (originality, connection to funded research projects), what is ultimately being done is a substitution of the assessment of technological outputs for an assessment of applied or strategic research.

Discussion

Peer review was developed in the context of academic science and has become the gold standard in that setting. However, this methodology is not necessarily the most appropriate when seeking to evaluate non-standard practices within scientific careers. This research presented some of the challenges that arise when peer committees are employed to review the careers of researchers engaged in technological development and innovation. In the following, five main points are discussed, namely the lack of clarity in criteria, the inadequacy of evaluation systems, the prevailing mindset that governs the processes, the characteristics of the agricultural sciences, and the political-organizational aspects of science systems.

First, the traditional evaluation criteria for science cannot be straightforwardly transposed to the evaluation of technology. In science, evaluators consider the originality requirement to be met when a paper has been accepted for publication in a peer-reviewed journal. Academic impact is generally understood in terms of citations, although more recently alternative metrics have also gained traction. However, in the case of technological products, these criteria are neither applicable nor necessarily adequate. There is no simple way to ensure the originality of a technological product, especially in (geographical, institutional, or disciplinary) contexts where patents are not common, and no other reliable registers exist. On the other hand, analyzing the impact of technological products cannot neglect social and economic aspects, and there is little consensus on how much is reasonable to demand of researchers in this respect.

Secondly, the evaluation of these professional profiles calls into question the competence of peer reviewers. The procedure assumes that peers have the necessary knowledge to carry out an adequate evaluation of this type of product, and thus correctly assess the trajectory of the researchers who have developed them. Yet, in practice, this is not so simple. Evaluators, as has been shown, state that this is "the hardest task" they face. To assess these cases more adequately, they resort to solutions outside the regulations, for example through informal telephone consultations with experts. In this way, they strive to accomplish a task for which they are not always qualified, and which takes place in an institutional context that is hardly suitable for it.

These structural limitations of the evaluation processes are not exclusive to the Uruguayan system but can be found in the context of many of the researcher classification systems in the region. These systems have emerged to foster academic research and were not designed to address the specific challenges linked to technology and innovation. Both the criteria documents and the structure of the evaluation mechanisms associated with them have only very recently begun to introduce amendments for assessing careers oriented to technology and innovation.

In Brazil, the CNPq productivity grants have now incorporated a dedicated track for "technological development and innovative extension", with different criteria and a separated pool of evaluators from the traditional research grant program. The Mexican SNI created a cross-cutting commission that assists the disciplinary commissions in the evaluation of technological products. In Spain, a differentiated system of *sexenios* has recently been created for those who wish to be credited for technological activities. In Argentina, researchers who declare that they belong to a Technological and Social Development Project (PDTS) are eligible for a differentiated evaluation that focuses on the fulfillment of the project's objectives and not on the publications made during the period under review. As for SNI in Uruguay, a special commission to deal with these cases was created in 2010, but its recommendations ended up reinforcing the classic academic criteria. Beyond the SNI, INIA in Uruguay has promoted a process of evaluation and certification of technological products involving potential users through a multidimensional perspective, which could eventually be integrated into the evaluation of the SNI (Echeverría, 2001; Vasen et al., 2021b).

Third, a certain "linear mindset" permeates the evaluators' outlook on technological development. They believe that scientific publications are required for a positive evaluation within the system. Researchers who only submit technological developments are viewed with suspicion. This requirement is not applied symmetrically, since basic researchers who only submit publications are not required to be involved in technological activities. Ambos's (2008) idea of ambidexterity may be borrowed to think about this asymmetry in demands. Research-focused one-handedness is not a problem, since members with publications in high impact journals can advance seamlessly within the system, without being required to contribute anything related to applied knowledge, technology, or innovation. On the other hand, technology-focused one-handedness is not acceptable. Those with a heavy focus on technology and innovation are faced with an adverse scenario. The SNI tolerates ambidexterity when researchers have a strong track record in research but does not encourage it. As a result, the system consolidates the view of technological production as a subsidiary or derivative of science and not as an autonomous and heterogeneous practice.

Data on the research output of the SNI members show the effects of this culture. Whereas scientific outputs significantly increased between 2009 and 2017, technical outputs decreased in all areas of knowledge, particularly in agricultural sciences, where the annual average output per researcher decreased from 0.83 to 0.12 (see table 3). Some researchers with a more applied profile may have left the system as they realized all the existing difficulties for evaluating their work. Those who remained may have adapted to the new standards. Although they may continue producing the same technological outputs, they have learned that these productions are not valued by the system and stopped reporting them. While it is difficult to establish how much of this can be attributed to changes in the activities performed and how much to underreporting, one thing is clear: the system has given strong signals that it is the classical academic products that are important. Researchers may therefore legitimately wonder why they should waste time conducting or reporting these activities.

	Agricultural sciences	Medicine and Health	Natural and Exact Sciences	Social Sciences	Humanities	Engineering & Technology	Total
	Papers in Scopus-Indexed Journals						
2009	0.98	1.66	1.42	0.15	0.09	0.61	0.99
2017	1.44	1.59	1.46	0.45	0.19	1.29	1.12
Variation	47%	-4%	3%	200%	111%	111%	13%
	Technical/technological output						
2009	0.83	0.2	0.28	0.68	0.56	0.86	0.49
2017	0.12	0.05	0.15	0.2	0.14	0.28	0.16
Variation	-86%	-75%	-46%	-71%	-75%	-67%	-67%

Table 3. Annual average productivity of *SNI* members. Source: ANII (2018).

Fourth, there are some aspects specific to the agricultural sciences that are worth reflecting on. On the one hand, in recent decades, research agendas connected with genetics and molecular biology have gained prominence, turning agricultural sciences more directly related to basic science. On the other hand, tension persists between the vision of research expressed by university scientists and that represented by the staff of a public research institute such as INIA. While the former is much closer to academic science, the latter is presented as mission-oriented and aims to have a more direct and immediate impact on the productivity of the national agricultural sector. In this context, it is not surprising that the most conflicting cases of SNI researchers presented in the previous section correspond to "old school" INIA researchers, i.e., those with a less science-based technological production and a more direct link with agricultural producers. On the other hand, the SNI evaluators are mostly from the "new school" and have a more academic orientation.

Lastly, Whitley's (2003) discussion of the organizational aspects of science systems that promote or hinder the generation of innovations provides a broader context. In this sense, the SNI can be said to promote a model of competitive hierarchies. Its focus on peer evaluation and the high delegation of evaluation tasks to peers gives greater space to reputational competition. On the other hand, the strong prestige component associated with SNI membership works by restricting pluralism and flexibility in the careers. Even those who do not have a classical profile are attracted by the prestige of belonging to the system. This can have harmful consequences for the effectiveness of STI policies that promote the social and economic impact of knowledge. Without other spaces of symbolic recognition for those dedicated to technology and innovation, membership in the SNI becomes the main aspirational model. This undermines the efforts made by STI policies to give greater importance to the commercialization and application of knowledge over academic research.

Conclusions

The evaluation of academic outputs is substantially different from that of technological developments. The latter requires a multidimensional approach and the participation of non-academic stakeholders, which can hardly be achieved through traditional peer review. The case analyzed here illustrates the consequences of implementing inappropriate methodologies. Criteria are not specific enough, peers are not always trained to carry out such evaluations, institutional mechanisms are inadequate, and the underlying conceptual assumptions of reviewers are not in line with these activities. The results of this study support the idea that adaptations must be made to the classical peer review system in order to adequately evaluate technological production. Peers can continue to play a central role, but it is imperative that the evaluation system recognizes the specificity of this task.

In Latin America, private investment in R&D is low and the vast majority of these activities take place in universities or public research institutes. In this context, national researcher classification systems based on peer review are the most prestigious instance and, based on a linear conception, they end up inducing researchers to a more classical academic model. In this way, researcher classification systems exert a strong symbolic influence on the system as a whole. This is reinforced by the lack of a counterweight that could balance expectations. A dynamic private sector that demands knowledge and offers professional and economic opportunities for innovation could fulfill this role.

Looking at the big picture, tensions emerge between the more comprehensive national STI policies, oriented towards economic and social development, and researcher classification systems, oriented by a more classical or linear academic model. Evaluation processes may be improved to better address the particularities of technological production. Examples of this include cross-cutting commissions, as implemented in Mexico, separate calls for applications, as in Brazil, or certifications with the participation of potential users, as developed by INIA in Uruguay. These measures, however, do not address the structural problems. Without a national innovation system that fosters greater pluralism and intellectual flexibility, atypical or eclectic careers, such as those of technologists or innovators, will not be appropriately recognized. The existence of a heterogeneous set of producers, funders, and demanders of knowledge is a prerequisite for operational improvements to remain more than bureaucratic curiosities and have actual effects.

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