Academic, Commercialization and Societal Effects of Joint Research

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Abstract

This work investigates the effects that a specific science industry collaboration scheme, joint research, generates in three areas: the production of academic activities, scientific knowledge commercialization, and society at large. This is an in-depth work on joint research in a developing country that covers three different types of effects. The work highlights the specific industrial contributions that make it possible for such effects to be verified, with special attention to societal effects, an aspect rarely present in the literature. Based on some dimensions that recent literature has identified and where more empirical evidence is needed, a multiple case study has been carried out through the selection of three public-private collaborations in the Argentine biopharmaceutical sector responding to joint research characteristics.

Among the main findings, the identification of the different ways in which a relationship with industry allows science: to intensify its publication activity, by having more resources and identifying new thematic niches to publish; to improve teaching, using co-generated knowledge and shared equipment; to expand its research agenda both toward applied topics and toward more basic ones. Likewise, relationship with industry allows knowledge generation that, in addition to being central in the creation of start-ups and patents, also contributes to perform new services of a commercial nature. Finally, joint research generates effects that benefit society in general, through cheaper domestic diagnostics or therapeutic solutions improving public health.

Keywords: science; industry; knowledge; joint research; biopharmaceutical

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Introduction

Science and industry are considered two different worlds governed by different approaches and strategies (Bruneel et al., 2010). Collaboration between science and industry can be carried out through multiple modalities and some of them, such as joint research, contract research, and consulting, are characterized by their strongly relational imprint, as they are based on frequent personal interactions and generations of mutual trust between the parties (Perkmann, Walsh, 2009; Milesi et al., 2017; D'Este et al., 2019). The recent literature has found that the effects of such collaboration are verified mainly in three areas: academic activities such as research and teaching; the commercialization of the knowledge generated in the academic sector; and society at large (Perkmann et al., 2021). Existing literature has tried to identify correlations between collaboration with industry and scientific publications, teaching activity, and the expansion of research into more applied areas. An attempt has also been made to verify whether linking with industry favors the creation of start-ups and intellectual property rights. However, the area, which transcends the parties and refers to possible economic and social effects for the rest of society, constitutes a little addressed aspect. Most of the existing studies are quantitative in nature and allow for finding positive correlations between science industry collaboration and several of these dimensions.I In some cases, however, the evidence is contradictory, and in others there is still little of it. On the other hand, these studies do not capture relevant qualitative aspects, for example, what are the elements provided by industry that contribute to generating effects and how does the public sector translate what it absorbs from the relationship into effects of different kinds? It was also observed that most of these studies address the problem in the context of developed countries, with few studies providing a view from developing ones.

The objective of this work is to delve into different types of effects generated by science-industry cooperation. To this end, a multiple case study is carried out in a developing country, Argentina, and in a particular sector, biopharmaceutical, which due to its characteristics allows the economic and social effects to be observed in more detail. Within science industry cooperation, a specific scheme is considered, joint research, where industry participates actively and bidirectional flows of knowledge and learning opportunities are more widespread than in other schemes.

Conceptual Framework

The evolutionary and neo-Schumpeterian approaches have contributed to the affirmation of an interactive vision of the innovation process, where the latter is conceived of as a phenomenon that, far from occurring exclusively within the firm, has a markedly systemic nature (Nelson, 1993; Lundvall, 1997; Freeman, 2004). In this way, growing interest in innovation has gone hand in hand with a growing interest in collaboration between industry and the academic and scientific-technological sector given the positive role such cooperation can play in the production system (Meyer-Krahmer, Schmoch, 1998; Lee, 2000; Schartinger et al., 2002). Science-industry cooperation can take many forms and takes place through multiple channels (Meyer-Krahmer, Schmoch, 1998; Lee, 2000; Schartinger et al., 2002; D'Este, Patel, 2007). Various works (Perkmann, Walsh, 2009; Arza, Carattoli, 2017; Milesi et al., 2017; D'Este et al., 2019) indicate that some forms of cooperation are based on frequent personal relationships, the exchange of tacit knowledge and the creation of trust. In joint research, for example, both science and industry play an active role in terms of R&D and knowledge flows between the parties assume a two-way dynamic, which generates greater opportunities for interactive learning. This work focuses on the effects, which can occur in three main areas: academic activities, commercialization of knowledge generated by the public sphere, and society in general (Perkmann et al., 2021).

Within academic activities, research and teaching stand out. Regarding research, there is a consensus regarding the positive effect of cooperation with industry on publications produced by the scientific sector (Hottenrott, Lawson, 2017; Banal-Estañol et al., 2015; Bikard et al., 2019; Garcia et al., 2020). There is some evidence that cooperation with industry can guide public researchers toward more applied areas of research (Van Looy et al., 2006). However, it is necessary to verify whether this is associated with a reduction or an expansion of the public research agenda and, eventually, if there may be an effect in the opposite direction, that is, toward more exploratory and basic research (Perkmann et al., 2021; Verre et al., 2021).

Regarding teaching, the evidence is contradictory since, on the one hand, there is a negative effect of cooperation (in the form of consulting and in the engineering sector) on the quality of teaching (Bianchini et al., 2016), on the other hand, positive effects exist in different disciplines in terms of an improvement in the presentation of teaching material. In this case, it is necessary to delve into which elements of the relationship with industry can help enrich teaching (Hughes et al., 2016; Verre et al., 2021).

Another area where science-industry cooperation generates effects is commercialization. This field is usually approached by literature mainly from two perspectives: the generation of intellectual property rights and the creation of academic start-ups. In the first case, there are quantitative studies (Beaudry, Kananian, 2013; Libaers, 2017) that find a positive correlation between collaboration with industry and the generation of patents in the academic sector. It is worth considering whether this indicator is the most appropriate in developing countries, where there may be other effects of a commercial nature, for example the realization of new services, which emerge from the link with industry and

are highly relevant for the academic sector. Regarding entrepreneurship, there is a positive relationship between having collaborated with industry and the predisposition to create a company (Fritsch, Krabel, 2012), while the probability of founding a company declines if the researcher is a scientific advisor at a firm (Ding, Choi, 2011). In the case of long-term alliances between public institutions and firms, it is appropriate to consider which elements are absorbed and then used in the creation of a start-up and how this challenges (or not) the previous relationship with firms.

Finally, the effects on society in general are a less studied topic (Perkmann et al., 2021). From a perspective focused on the public sector, Iorio et al. (2017) consider the social motivations that underlie the decision to cooperate, while Hughes and Kitson (2012) address the socially oriented channels of universities to cooperate with external organizations. Further, Ankrah and Al-Tabbaa (2015) identify effects deriving from science-industry collaboration that transcend the parties in the economic and social field. This third type of effect needs more qualitative empirical evidence to identify, on the one hand, which elements compose it and, on the other, what the link is with science-industry cooperation.

Most of the cited works refer to North America and Europe and there are not many studies on other contexts, for example, Latin America (Arza, Carattoli, 2017; Milesi et al., 2017; Garcia et al., 2020; Verre et al., 2021). This work, then, aims to analyze the effects in the three aforementioned areas of a specific collaboration scheme as joint research through a case study within the Argentine biopharmaceutical sector. Due to its relational characteristics, joint research allows for gathering evidence that is relevant, both in terms of the chosen context and the dimensions previously indicated as vacancy areas.

Methodology

The empirical object of this work is constituted by knowledge flows between firms and public R&D institutions, within joint research collaboration. To carry out the study, the Argentine biopharmaceutical sector was chosen, its characteristics make it suitable to observe the empirical object, being intensive in science and science-industry cooperation and being focused on human health, which allows for a better observation of social and economic . Within the sector, collaborations were identified in which both parties have high R&D capabilities and are involved in long-term, highly complex and uncertain projects, which makes the presence of relevant knowledge flows between the parties, such as the generation of multiple effects in different areas, more likely. Three cases were then chosen, which coincide with those public-private collaborations involving the largest firms and some of the most prestigious institutions at a national level in that scientific-technological area. The three selected cases are presented below, with their main members and the projects they cover (Table 1).

In this multiple case study, the main unit of analysis is the perspective of researchers belonging to public R&D institutions who collaborated with firms. However, to ensure the reliability of the collected information, two other perspectives are considered, first, the vision of firms' R&D personnel that interacted directly with public researchers and, second, the people belonging to the public institution's hierarchy that provide a comprehensive view of the projects and relationship with industry. The intention to use three such perspectives is not to make a comparison between them, but to complement and contextualize the information collected in the main unit of analysis. Likewise, the main objective is not to compare the three cases among them, but on the contrary to combine them, to provide the greatest possible empirical evidence regarding the effects resulting from the specific scheme of joint research. Regarding data collection, 34 in-depth interviews were carried out. A documentary analysis was also carried out on some secondary sources that were accessed (project forms, technical reports, and other documentary material provided by firms and public institutions).

The Three Selected Cases

In all three cases, science-industry cooperation assumes some common characteristics that correspond to the scheme of joint research. The parties are in a complementary relationship, that is, industry participation is an essential condition to generate knowledge, since capacities are needed that the public party lacks. The projects are long-term and highly uncertain, and this complementarity translates into constant interactions between the parties, who share partial results and discuss them collectively, generating feedback, all within the framework of strong interpersonal trust. This context induces bidirectional flows of knowledge between the parties and is a very different form of collaboration with respect to the transfer vision, in which an active party (public) generates and transfers knowledge to the passive one (private). Beyond the existence of peculiarities in each case, this common denominator is a rare way cooperating in a country like Argentina, where the transfer vision prevails. Even in the biopharmaceutical sector, where cooperation assumes complex and interactive characteristics, not all relationships go in the direction of joint research (partly because not all firms have sufficient R&D capabilities to generate feedback for the public partner). The three cases are analyzed below, specifying the characteristics of the actors, the relationship's historical trajectory, the projects covered, and the object of the collaboration.

Case 1. Joint Research between the LOM-UNQ and the Insud Group

The first case covers a broad set of actors. This consortium has been forming and expanding over more than 20 years and is made up, on the one hand, by the Insud Group, one of the main Argentine pharmaceutical groups that controls several firms; on the other, a series of public actors, among which the Molecular and Translational Oncology Center (LOM-UNQ) stands out as a central partner of the Insud Group, in addition to some hospitals, such as Garrahan (the most relevant pediatric hospital in Latin America). Within this collaboration two large macro-projects can be identified: immunotherapy and desmopressin. The immunotherapy project stems from Insud's relationship with Cuban biotechnological centers and covers several products: Racotumomab (a monoclonal antibody used in lung cancer), two glycoproteins with antitumor action (N-glycolyl GM3/VSSP, for breast cancer and N-acetyl GM3/VSSP, for cancer and HIV), and two biosimilar monoclonal antibodies such as Rituximab (used in non-Hodkin's lymphoma, chronic lymphatic leukemia and rheumatoid arthritis) and Bevacizumab (colon cancer). The other macro-project has to do with Desmopressin, a synthetic organic peptide used for antimetastatic functions (to prevent the spread of cancer cells after surgery), which also has a protective effect by promoting coagulation. The immunotherapy project was launched between 1994 and 1996, from the collaboration established between Insud and two Cuban biotechnology centers. The LOM-UNQ was initially incorporated into the project through preclinical services, tests on laboratory animals in cancer models, but over time it became increasingly involved in the development and clinical phases of each product, interacting closely both with hospitals and Insud's firms. While Racotumomab has been on the market since 2013, the other products are in different stages of development. The Desmopressin project presents the opposite route, it was developed entirely within the LOM-UNQ and, later, the entry of Insud allowed for carrying out co-development in two fields, veterinary and human. Currently, the product for veterinary use is on the market, while clinical trials for its use in humans are nearing completion.

Case 2. Joint Research between the LCC-UNL and the Amega Biotech Group

In this second case, unlike the previous one, there are only two cooperating actors: Amega Biotech Group and the UNL. Amega Group includes three companies and one of them, Zelltek, was founded as an incubated start up within the UNL. The LCC-UNL stands out as the main knowledge generation actor upon which Amega relies and also shares the same physical space as Zelltek within the UNL. The cooperation between Zelltek and the LCC-UNL covered countless projects over more than 20 years, among which the development of erythropoietin (EPO), which motivated the emergence of the incubated firm, stands out. Within this consortium, two specific projects are considered, which coincide with the development of two highly complex proteins: Etanercept (for the treatment of rheumatoid arthritis, childhood rheumatoid arthritis and psoriatic arthritis) and truncated coagulation Factor VIII (an essential element in the blood coagulation process and used to reverse hemophilia A). Within the same physical space, there is coexistence between LCC-UNL researchers and the firm's R&D personnel in such a way that in the daily dynamics of the laboratory, lines between what is private and what is public, between academic and business, are blurred. On the one hand, this coexistence means that public researchers located there are familiar with the problems that other R&D groups, without links to industry, perceive as distant or completely foreign. On the other hand, this aspect allows the firm to take advantage of the continuous flow of human resources and knowledge existing in the laboratory. This peculiarity has enhanced R&D collaboration opportunities, which is reflected in the richness of the co-development agenda between parties,

Table 1. **The Selected Cases**

Case	Firms	Public partners	Projects
1	Insud Group	Laboratorio de Oncología Molecular de la Universidad Nacional de Quilmes (LOM-UNQ) and other institutions	- Desmopressin: for veterinary and human use - Immunotherapy: monoclonal antibodies and other products
2	Amega Biotech Group	Laboratorio de Cultivos Celulares de la Universidad Nacional del Litoral (LCC-UNL)	-Recombinant proteins: Etanercept and Factor VIII
3	BioSidus	Instituto de Biotecnología y Medicina Experimental (IByME), Instituto de Virología del Instituto Nacional de Tecnología Agropecuaria (IV-INTA)	-Transgenic animals: human growth hormone, insulin, etanercept and VHH nano-antibodies

Source: authors.

within which the two aforementioned proteins stand out. Currently, the development of these products has already concluded and the Group is undertaking the necessary clinical trials for their regulatory approval.

Case 3. Joint Research between IByME, IV-INTA, and Biosidus

The third case involves the company Biosidus and two public institutions, the Biology and Experimental Medicine Institute (IByME) and National Institute of Agricultural Technology (INTA). The collaboration between Biosidus and the IByME has a history of 20 years and is at the base of the generation and consolidation of the platform for transgenic animals, surely one of the greatest achievements of Biosidus, while firm's collaboration with the IV-INTA began later, having started in 2010. Both collaborations have the use of a transgenic animal platform in common, which is employed to generate a series of products to be used in human health, such as human growth hormone, insulin, etanercept, and VHH nanoantibodies. Biosidus was pioneer in Latin America in the development of a transgenic animal platform, which consists of using cows as production systems, inserting the gene that produces a protein or molecule of interest into an animal (that is, genetically modifying the animal) to then obtain that protein or molecule in its milk. From the beginning, the IByME has collaborated with Biosidus in the development of this platform, being the main external source of knowledge of the firm in transgenesis and cloning. The Physiology of the Mammary Gland Laboratory assumed a key role from 2003 in producing most of this project's knowledge and providing the firm with critical human resources. The IByME has accompanied Biosidus in the development of a technological platform and has collaborated on each of the proteins the firm decided to produce, for example, human growth hormone (for the treatment of delayed growth in children and Turner syndrome), insulin (to treat diabetes and hyperglycaemia), and etanercept (for rheumatoid arthritis). The objective of the collaboration with IV-INTA is to use this platform to produce another molecule, the VHH nanoantibody, which is a monoclonal antibody derived from camelids that neutralize the Rotavirus infection, the main agent that causes diarrhea in children worldwide. Until now, the production of all molecules has been achieved in transgenic cows, with different levels of productivity, however, the transgenic cow platform faces critical uncertainties from a regulatory point of view and there are still no products on the market.

Joint Research Effects in The Cases

Academic Activities

In relation to the publications, in Case 1 it is observed that the practices developed during the interactions between industry and hospitals is an important source of time savings, since it allows for a more accurate choice of both the preclinical models to be used, such as the specific subgroup of the pathology toward which to direct the study, for example, where patients have fewer therapeutic alternatives. This is important for LOM-UNQ researchers, who try to publish in journals with a preclinical and clinical perspective, where reviewers are very familiar with what happens in the preclinical phase or in new drugs development. Likewise, LOM-UNQ researchers highlight that some publications arise as a result of research questions that originate in industry during the collaboration. Garrahan Hospital researchers underline how collaboration with industry and the LOM-UNQ has allowed them to publish articles on retinoblastoma and Racotumomab in the journal of the International Society of Pediatric Oncology and in an English ophthalmology journal, both with high-impact factors. In Case 2, LCC-UNL researchers highlight that research activity in their discipline is very expensive and collaboration with industry helps to improve the opportunities for publishing since, by having public facilities in terms of access to supplies, equipment, and financial resources provided by the firm, this translates into greater speed in obtaining results and publishing them. Finally, in Case 3 collaboration with industry determined a leap in quality in publication activity, for example, several IByME publications could be carried out thanks to the infrastructure and capabilities that Biosidus provided for carrying out innumerable experiments with transgenic animals. More recently, IV-INTA highlights the publication of two articles in high-impact journals (PlosOne and Plos Pathogen).

About the direction of research, in the studied cases it emerges that the link with industry exposes the public actors to problems that, otherwise, would not be under consideration. In both Cases 1 and 2, joint research has allowed the public sector to multiply existing research lines and enrich the research agenda. This is due, firstly, to the public sector's greater economic resources (as a result of collaboration with industry) to finance and support new lines of research, which in several cases are not firm linked. Secondly, the public sector is introduced to unfamiliar, new topics as a result of the broadening of horizons through interactions with industry by addressing applied problems closer to the productive phase. Third, some issues are not of direct interest to the firm but may be in the future, and the public's decision to address them, in addition to intellectual curiosity, is further stimulated by the presence of a potential adopter with which there is already a lasting and trusting relationship. The public sector's research agenda, then, is not reduced but rather broadened and diversified. Furthermore, it can also be extended in the direction of basic science. For example, in Case 1, LOM-UNQ researchers point out that from the initial collaboration with Insud in immunotherapy, a new line of research was started in which new antigens linked to Racotumomab were identified and characterized, which it represents feedback from applied research to basic research that was determined

by the interaction with industry. On the other hand, in Case 2, the LCC-UNL, as a result of the collaboration with industry, has over time moved from an initial very applied and production-oriented activity toward an expansion of its basic research, for example, on issues such as vaccines and stem cells (unrelated to the firm) or on a frontier issues that few research groups in the world address, such as immunogenicity. The LCC-UNL linked up with the University of Rhode Island, where advanced research is being carried out on the subject of immunogenicity with transgenic animals, and sent some of its researchers to the US to receive training in these techniques. The LCC-UNL autonomously decided to address this new topic, not only due to its being a possible interesting new line of research, but because it predicted that Argentine health authorities would eventually require this type of control for medicines' approval, which may be of interest to Zelltek. The existence of such an intense and long-standing collaboration with industry has been a stimulus for public researchers to broaden their agenda toward a more exploratory area and Zelltek has already requested permission from the LCC-UNL for Factor VIII and Etanercept, two central products of the joint research agenda.

Regarding teaching, science-industry collaboration can strengthen it in three different directions. First, co-generated knowledge in joint research flows through researchers and teachers to the students.[1] Secondly, the public sector can use firms' equipment to carry out the practical and laboratory part of teaching, facilitating and enriching the teaching task. This is particularly visible in Case 2, where students use the equipment installed at the LCC-UNL, more than half of which belongs to Zelltek. The possibility of using firm's equipment allows students to have a deeper understanding of R&D activities, allowing them to see and use equipment that is not readily available in the academic field. It also serves as a means of obtaining data for students who are writing their thesis. Finally, researchers use the experience of joint research itself in teaching, for example, in subjects such as formulation and project management, and as a paradigmatic model of scientific-technological management to convey the difficulties and potential of such collaborations and foster a culture of commitment to the application of knowledge (Cases 1 and 3).

Commercialization

Within the LOM-UNQ (Case 1) some researchers created their own enterprise, which is focused on Functional Foods and the Nutraceutical approach. It is about vitamin-mineral formula development including functional extracts, basically from vegetables, characterized and enriched with functional principles. Although they are not pharmaceutical products, they follow some development stages similar to drug formulas. Researchers acknowledge such developments derive from applying critical knowledge gained through collaboration with industry over the course of 15 years. On the other hand, Case 2 is even more interesting because originally a start-up arose, which was later bought by the Amega Group. Then intense and growing joint research activity was established between the LCC-UNL and Zelltek, with a multiplication of lines of research. From this alliance an incubated firm was created, Empretech, dedicated to veterinary vaccine production. The firm is oriented toward animal health, but it benefits from knowledge acquired by the LCC-UNL throughout these years of close collaboration with Zelltek. Researchers point out that veterinary medicine is currently getting closer to pharmaceuticals in work methodology and many aspects and criteria. With the knowledge jointly developed by Amega and the LCC-UNL, new discoveries may be used and incorporated by this new firm. Likewise, in 2020 another firm was created, Biosynaptica, which although it is in the pharmaceutical field, does not compete with Amega's interests and is nourished by the knowledge generated by researchers in collaboration with industry. In addition to entrepreneurship, commercialization effects are also manifested in two other aspects: the creation of new intellectual property and the generation of new services. In all three cases there is evidence of the creation of new intellectual property as a result of collaboration with industry. In the Desmopressin project (Case 1) there was a previous LOM-UNQ patent that was later licensed to the Insud Group and later more patents were generated on a panel of derivatized peptide products and a new family of Rac compounds, which are jointly owned with industry. In the Immunotherapy project, on the contrary, there were already patents held by industry prior to collaboration, which has maintained control of intellectual property in this area. In Case 2, although collaboration with industry is mainly focused on biosimilar products, where patents are an obstacle, LCC-UNL has generated several patents directly related to the Amega Group, for example on vero cells, which can be used for human vaccines and, more recently, a molecule for therapeutic use in neurodegenerative diseases obtained by genetic modification of EPO. In Case 3, Biosidus and the IByME have a long history of jointly generating patents related to the transgenic animal platform and, with respect to IV-INTA, in 2018 the transgenic bovine platform producing VHH was jointly patented. In all cases, the creation of new patents is strongly related to collaboration with industry, although its commercial exploitation is still far away for many of them. However, joint research also generates effects in other commercial aspects, which can be very relevant for the public sector. In Case 1, within the Immunotherapy project, LOM-

[1] In Case 1 this occurs particularly in postgraduate courses, while in Case 2, in addition to it, for example in the Doctorate in Biological Sciences, developed knowledge is also used in undergraduate courses, such as Cell Cultures, Molecular Biology for cell culture in animal cells and Downstream Processing, within the degrees in Biotechnology and Biochemistry..

UNQ collaborated with Insud to develop two sophisticated analytical techniques to evaluate Rituximab. All the knowledge received from the Insud Group has allowed LOM-UNQ to currently have a platform for the evaluation of preclinical efficacy of any type of biosimilar substance. In Case 2, the firm's know how was essential to developing quality control techniques necessary for the evaluation of products. When Zelltek was absorbed by Amega, all these techniques remained as an inheritance in the LCC-UNL, which today provides quality control services for approximately twelve pharmaceutical firms, both national and foreign. In Case 3, IByME researchers applied part of the knowledge developed together with Biosidus in the provision of services within the framework of another collaboration, with a startup created by a public university.

Socioeconomic Effects

Science-industry collaboration also generates effects on society at large. The public sector's commitment to the application of knowledge and to reaching out to society translates into patients whose quality of life improves thanks to the drugs developed. In Case 1, LOM-UNQ researchers emphasize that society begins to benefit from cancer drugs' effects already during clinical trials, because they offer an alternative treatment before the product is approved. In addition, once the product is approved, to the extent its beneficial effects are demonstrated for subsequent pathologies, the impact on society grows. In Case 2, LCC-UNL researchers emphasize that joint research allowed for the development of two biosimilars that, once approved, could reach Argentine patients at a significantly lower cost compared to the original products, which are currently imported. This doubly favors the Argentine health system, on the one hand, due to lower costs, for example, on the Argentine market there is currently no original EPO, since it costs 10 times more than the local biosimilar version; on the other, import substitution represents a saving of foreign exchange needed to acquire them, an important point for a country with chronic problems of foreign exchange availability. To this must be added the advantage of being able to gradually strengthen an industrial sector, in this case biopharmaceuticals, which, being intensive in knowledge, is essential for the country's development. In Case 2 another consequence was also observed deriving from the Amega Group and LCC-UNL collaboration. These two entities agreed with the Pharmaceutical Industrial Laboratory (LIF), the public drug production firm of Santa Fe Province, so that the latter can manufacture some of the drugs produced by Zelltek, used to treat diseases such as cancer, multiple sclerosis, HIV, and chronic kidney failure. The agreement implies that LIF can manufacture and sell these medicines at cost price since both Amega and the UNL waive corresponding royalties, generating a price drop and a positive impact on provincial health spending. On the other hand, the objective of reaching society can be achieved through other ways, for example, regardless of concrete results from collaboration projects, there are possibilities for lateral applications of knowledge that are exploited above all by the public sector, as is the case of diagnostic kits developed for Garrahan Hospital and Malbrán Institute. In Case 1, when the immunotherapy project was started, the idea of developing a quantitative PCR-based tumor diagnosis kit arose. However, the kit was not feasible from a practical point of view and it was decided to transfer its know-how to Hospital Garrahan. This hospital currently has a molecular diagnosis service for residual pediatric cancer cells, especially retinoblastoma and neuroblastoma, which it offers to the community. The knowledge underlying this development was jointly generated by LOM-UNQ and Insud. In Case 3, IV-INTA underlined that VHH not only serves to create a therapeutic product protecting against a certain pathogen but also to diagnose the presence of that pathogen. As a result of what the IV-INTA was developing together with industry, the Malbrán Institute (the national reference institution for the prevention, control, and research of all pathologies, including neonatal diarrhea), asked the IV-INTA to develop an Elisa kit for Rotavirus. In this way, IV-INTA researchers obtained the kit prototype in five months and Malbrán Institute no longer has to import it. Based on this, the Malbrán Institute orders diagnostic kits for other pathologies such as human influenza and another public institution, the Leloir Institute, asked that IV-INTA develop kits for breast and colon cancer. The social impact, in these lateral applications of knowledge, is verified through import substitution and national health system diagnostic capacity improvement.

The summary of joint research effects on academic activities, commercialization, and society is described in Table 2.

Conclusions

This work has analyzed the effects that joint research generates in different areas. For this, a case study has been carried out in the Argentine biopharmaceutical sector through the selection of three science-industry collaborations where both firms and public institutions are active in knowledge generation and maintain long-term links in the framework of highly uncertain projects. The analysis of the cases has allowed for gathering empirical evidence that allows one to deepen different dimensions that make up the effects.

Joint research positively affects the quantity and quality of scientific publications, through material resources and new questions coming from industry and through the dialogue between preclinical and clinical actors that it promotes. The public research agenda is expanding, not only due to the greater availability of resources, but also due to the presence of a private partner as a stimulus for approaching new research topics. These

Table 2. **Joint Research Effects on Academic Activities, Commercialization and Society**

Types of Effects	Evidence of the cases in the different dimensions
	Academic activities
Publications	- Increased productivity motivated by new questions that originated at the firm - Increased impact index due to the better ability to choose preclinical models and pathological niches (thanks to the dialogue between preclinical and clinical actors promoted by industry) - Greater speed in obtaining results and publishing them thanks to firm's resources
Research direction	- Multiplication of research lines thanks to resources derived from collaboration with industry - New applied research topics that are or could be of interest to the industry - New research topics that are more exploratory and basic due to intellectual curiosity and due to the greater resources derived from collaboration with industry and the encouragement of having an adopter with whom there is a long-term alliance
Teaching	- Transmission of scientific-technological content developed together with industry to undergraduate and postgraduate students - Use of firm's equipment for practical teaching activities - Use of joint research experience as a management model, to encourage commitment to the application of knowledge
	Commercialization
Start ups	Creation of firms by researchers thanks to the knowledge absorbed during joint research, but in commercial areas not competing with the private partner
Patents and new services	- Creation of new intellectual property related to the collaboration with industry as well as licenses - Reuse of knowledge absorbed from industry (analytical control techniques) in services for other firms and institutions, with increased resources for research
	Society in general
Healthcare effects	- Medicines curing patients, from the clinical phase until market introduction, when regulatory authorities may extend their use to further indications - Cheaper medicines and lower expenses for the health system and patients (the articulation with public medicine production deepens price drops)
Imports substitution	Foreign exchange savings and strengthening of a local high-tech industry
Lateral applications of knowledge	Knowledge generated in treatment products is used for other developments contributing to a diagnostic capacity increase of different pathologies

Source: authors.

new topics belong both to the applied area, where industry has greater knowledge, and to more basic and exploratory lines. Joint research may be helpful as well for teaching, through the transmission to students of both co-generated scientific-technological knowledge and the associated experience itself as a management model and through the use of a firm's equipment in the practical part of teaching.

This type of collaboration also has a positive effect on the commercialization of academic knowledge. In the cases, public participation not only generates patents linked to its work agenda with industry, but these actors also absorb industrial knowledge to generate new services that, in turn, increase resource availability for new research lines. On the other hand, researchers find an incentive to create startups, exploiting knowledge acquired during interactions with industry and focusing on sectors and products not competing with a partner's business.

Regarding the effects for society in general, the cases make it possible to identify some dimensions: an improvement in quality of life and public health through innovative medicines; lower public and private spending on health for lower-cost medicines; greater foreign exchange savings due to import substitution; strengthening of a knowledge-intensive local industrial sector; and lateral applications of collaboration-generated knowledge to respond to other health and social needs.

A limitation of this work is that it analyzes a single sector and similar dynamics take place in other high-tech sectors. The selected cases are exceptional in the Argentine context, which allows for seeing only indirectly the (cultural, business, and technological) obstacles preventing the generation of virtuous effects in the three considered areas. As a future agenda, it is necessary to consider other associative schemes, such as contract research and consulting, to analyze how the dimensions considered here behave. Particular attention deserves to be paid to the analysis of industry feedback's impact on public R&D in terms of learning and research direction. Relating to public policy recommendations, it would be desirable to encourage associative and sectoral financing instruments that encourage joint research and deliberately promote the achievement of effects in the three mentioned areas, so that these are not merely emerging from virtuous cases or depend exclusively on the commitment and will of certain actors. In this sense, the socioeconomic sphere is the most sensitive since it transcends the collaborating partners.

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