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Identification and Analysis of Technology and Knowledge Transfer Experiences for the Agro-Food Sector in Mexico

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Abstract: The purpose of this article is to contribute to the understanding of the effects generated by the technology and knowledge transfer processes in the agro-food sector, within the context of Mexico, a developing country where the economic sector is one of the most lagging in terms of technological development. To achieve this objective, academic-industry relations, key elements, results, and benefits will be examined in 87 identified cases. The analysis begins by describing the context of agriculture and the food industry in Mexico. Then, 14 cases are presented. Results show that companies implement new processes and methods or launch new products to the market, but also implement a new culture of innovation, by establishing laboratories and undertaking research areas of the firm, creating R&D programs which formalize and continue with the academy-industry alliances. The elements that were not found with the expected frequency, according to international scientific publications, was the participation of an available intellectual property.

Keywords: technology transfer; knowledge transfer; agro-food; university–industry collaborations; experiences analysis

1. Introduction

Mexican agriculture has been, since the 1940s, a sector divided between traditional agriculture, generally farmer agriculture with high levels of poverty, and business agriculture (of the farmer type, as in the United States), with high levels of innovation, productivity and competitiveness.

The farmer sector produces mainly for self-consumption and local markets, while the more technician commercial agriculture focuses mainly on international markets or large national markets. Nevertheless, the agriculture sector has played a relevant role in the growth of the developing countries [1].

According to INEGI [2] data, almost a third of Mexico's territory (29.4%) is destined for agricultural activities. There are almost 80 million acres, of which 79% are dedicated to temporary agriculture (which depends on natural rainfall cycles), and the rest, 21%, have irrigation systems.

Agricultural productivity is strongly influenced by farm size. There are around 4 million agricultural farms in the country. Of them, according to the aforementioned survey, roughly, the small ones (up to 24.7 acres) are 56%; the medium ones (more than 24.7 acres and up to 50) are 30%, and the big ones (more than 123.5 acres) are 14%. The little ones contribute to 42% of the production; the medium, 31%, and the great, 27% [2].

Despite the fact that agriculture's share of GDP is only 2.4% [3], poverty in the traditional sector is so widespread that half of the almost 60 million poor people are in rural areas, where only 23% of the Mexican population live. Of the rural poor, 17% are in extreme poverty, against 4% of the urban poor [4,5]. One of the main causes of this situation is that the income of traditional farms is strongly influenced by seasonality. As agriculture is an essential activity, almost half of the days of the year, the farmers are inactive, following the rhythms of the natural agricultural cycle [6].

What is concluded from the above data is the need for public policies that promote the development of the most backward rural areas, through investments in infrastructure, credits for the modernization of production, curbing the atomization of agricultural land, both technological transformation, as of processes and commercialization, that is, innovation as defined by the Oslo Handbook [7].

In this sense, the need to promote technology transfer between sectors acquires great relevance. This is a process in which research institutes (such as the regional centers of the National Institute of Agricultural Research, INIA, the National Institute of Agricultural and Livestock Research, INIFAP, the Maize and Wheat Research Center, CIMYT) and the country's higher education institutions (such as the University of Chapingo, the Escobar Brothers University of Ciudad Juarez, Chihuahua and the Autonomous University Antonio Narro, from Coahuila) have played, and can play, a great role, in spite of the differences in terms of the administration and management of information between academic institutions and firms [8,9].

Despite the advances in investment, Mexico has not had great performance in scientific research and innovation and is still far from being considered one of the main producing countries of science and technology. However, despite this, a part of technological development and innovation is the result of the generation of knowledge of academic institutions. There is a wide variety of mechanisms for the exchange of knowledge, tacit and explicit, between universities and industry. These exchanges occur through student mobility, staff exchange, informal information exchanges, collaborative R&D and contractual projects, conferences, consulting activities, joint ventures, scientific publications and patents [10–13]. Part of this academic productivity can be measured using a bibliometric analysis that uses international index databases as a source of information.

However, measuring the production of knowledge is far from reflecting the impact that this research has on technological development and on innovations developed or adopted by regional, national and international companies. The relationship between knowledge generation and technological development is not easy to measure since there are no sources of information or indicators that clearly reflect technological development. There are sources of information, such as databases of industrial protection, but they are insufficient, because none of them measure how many of the inventions become innovations that generate social and economic welfare.

Technology-driven economic growth directly or indirectly benefits industry, regional and national budgets [14]. The generation of knowledge and technological development, as a crucial vector of economic development, are closely linked to academic institutions (higher education institutions and research centers). So much so, that the innovation ecosystems of the regions underpin the research and development carried out by higher education institutions (HEIs) and research centers (RCs).

In recent years, academia-industry collaborations (A–I) have generated substantial international interest as a source of knowledge production and new technological advances, fostering the economic and innovative competitiveness of the regions [15,16]. One of the main motivations for the increase in public policies to promote A-I links in the Latin American region is the potential benefit in technological and innovation capacities in the private sector [17]. Academic institutions become a stakeholder that aims to maximize the benefits of technology transfer and the burdens on budget constraints [14].

Although there are many success stories of companies that make links with academic institutions throughout the world, in Mexico, the culture of academia-industry linkage is still scarce. According to an interview with the current head of the National Council for Science and Technology, Carmen Álvarez-Buylla, in Mexico, there is a lack of culture of connection with the industry, as well as the protection, exploitation, transfer and use of knowledge. There is even little culture to take

advantage of what we generate for ourselves [18]. In Mexico, there are support programs that promote academia-industry linkage, as a mechanism to encourage the creation of innovations. However, tools are needed to evaluate the effectiveness of a link between the industry sector and the education sector. In addition, the open innovation nature of the agro-food sector [14] makes technology transfer processes more complex, since there are less absorption capacities in companies of this economic activity compared to those of other technologically more advanced sectors, due to their nature.

The objectives of this research include, on the one hand, the identification and analysis of experiences of various institutions of higher education (HEIs) and research centers (RCs) that have culminated the implementation of knowledge and technologies generated by them within the agro-food sector in Mexico. On the other hand, we have the objective of identifying different types of elements involved in the processes of technology and knowledge transfer (TKT), as well as the benefits and results that have generated those involved. In particular, we need to know if the communication and information technology is used, and if there is the creation, storage and exchange of knowledge [19].

The methodology consisted of searching in the Scopus and Web of Science databases. Nevertheless, on these websites, we did not find relevant or useful documents. We also searched on official websites of organizations and institutions working on TKT, in which 87 cases corresponding to the agro-food sector in Mexico were identified.

This document contains, in the second section, the theoretical review on technology and knowledge transfer processes in the context of national innovation systems. In the third section, the qualitative and quantitative methodology that was used to carry out the study is described. Section four presents the results of the research regarding the experiences in TKT analyzed in the agro-food sector in Mexico. Finally, the conclusions are presented in the final section.

2. Materials and Methods

2.1. The Transfer of Technology within the Framework of National Innovation Systems

Scientific research and development (R&D), and innovation projects, play a key role in the technological and socio-economic development of countries. As pointed out recently by the OECD [7], the ability of a nation to generate and benefit from an innovation policy depends primarily on planning and pursuing a quite complex system, commonly referred to as the triple helix model (THM). This is an innovation system based on a direct relationship between three main actors: higher education institutions (HEIs) and public research institutes, government and business sector, as depicted in Figure 1. Since its emergence, the THM had been the basis of several theoretical and empirical studies to understand and assess the dynamic phenomenon of multiple reciprocal academia–industry–government relations, responsible for the creation of knowledge, technology transfer and knowledge capitalization.

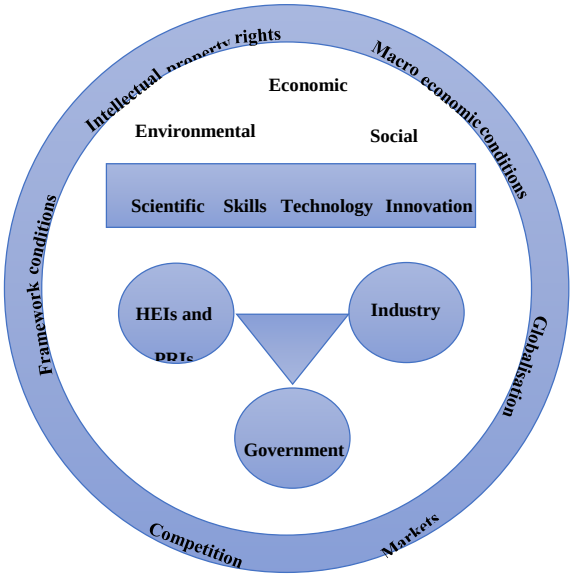

Figure 1. Illustration of the main actors and constituents in an innovation system. Source: adapted from OCDE, 2014.

The triple helix model considers the university academy as a primary participant in any typical innovation system [20]. The THM assumes that academy bodies, the government and the private and industrial sectors may play a significant role in the establishment of innovation policies, with strong economic growth and social transformation effects. However, the implementation of the THM requires dramatic HEIs transformation, from just being a teaching institution to becoming a teaching and research institution, along with novel legislative and specific bylaws to regulate the relationship of university, industry, or private sector and government.

As pointed out by Etzkowitz [21], the transformation of academic institutions from teaching to research-teaching distinctiveness started in the late 19th century with the founding of the Massachusetts Institute of Technology (MIT) in 1862, and Stanford University in 1891.

The academic activities, based on highly qualified research groups, were involved in producing innovative knowledge. It was this capability of producing new knowledge that gave these universities the power to create new technologies and successfully transfer them to already existing industries (MIT case), or to create new industries (Stanford case), with a significant impact on the regional economic development. The transformation phenomenon experienced by HEIs is part of an academic evolution process towards a new development phase, described as the entrepreneurial university institution, resulting in a coherent teaching, research, and economic expansion enterprise.

The entrepreneurial university allows one to generate regional economic growth and plays a primary, rather than a secondary, social role in the transition from an industrial-based society to a knowledge-based society [21].

Currently, the academy is expected to contribute mostly to the development of technological and social innovation, by transferring research results to the market. However, the academic institutions do not have, as a mission or as a substantive function, the commercialization of their research products. Then, it is necessary to transfer the knowledge and technologies generated to the business sector, whose nature is implicitly intended to profit, and through that, contribute to increase economic income and generate new jobs, among others collateral social benefits.

Knowledge transfer between academia and industry is considered an important driver of innovation and economic growth, as it eases the commercialization of new scientific knowledge within firms. Academic engagement, after all, aims to develop novel knowledge that benefits the academic and industrial partner.

For the purposes of this investigation, TKT is both the technology movement and the know-how flow between partners (individuals, entities and companies), with the objective of improving at least one knowledge and ability of the partners, as well as strengthening the competitive position of each of the associates [22]. Regardless of the environment, the objective of any knowledge transfer project is to successfully transfer the source knowledge to a recipient.

The link between the academy and the productive sector is not something new, but it is necessary [23]. The academy-industry collaborations have aroused great interest as a source of knowledge production and new technological advances, fostering the economic and innovative competitiveness of the regions [15,16]. This has brought with it a substantial increase in research on this type of collaborations, which is a complex and multifaceted research field [24].

It is important to understand the mechanisms that encourage and hinder academy-industry collaborations; the differences that may exist in different regions and countries, as well as the results and benefits that are generated with this type of relationships, so as to allow the actors involved to undertake collaborations. It is also necessary to generate appropriate arguments for responsible for creating public policies that foster academia-industry linkage.

Policy makers have identified the key role of technology and knowledge transfer (TKT)—and academic entrepreneurship in particular—for the promotion and improvement of innovation capacity, as well as the economic growth of a national innovation system [25,26]. Therefore, it is politically expected that the academy will contribute with new impulses for the development of technological and social innovation, by transferring research to other stakeholders in the innovation system. For example, TKT, in the form of academic spin-offs, allows academics to extend their economic and social impact beyond the research system [27]. Consequently, TKT and the commercialization of science have become essential for academic institutions in recent years, and are increasingly valued by government, public policies and financing schemes [28–31].

2.2. Technology and Knowledge Transfer in Open Innovation

Open innovation has been defined as "the use of intentional inputs and outputs of knowledge to accelerate internal innovation and expand markets for external use of innovation, respectively" [32]. Open innovation is now more focused on using external sources of innovation, such as clients, rivals, and universities [33]. In this process, the knowledge transfer, contributions such as time, work and other resources obtained through inter-organizational collaboration play an important role for innovation. On one hand, collaboration could be perceived as knowledge that flows through the organization limits; on the other hand, different ways to organize open innovation practices could bring companies closer to each other in terms of possible partnerships in new initiatives [34].

2.3. Food Industry in Mexico

This sector in Mexico has a value chain made up of 152 economic branches, with a total of 791,346 people employed. Leading companies participate in the processed food sector, the vast majority from the United States. In 2012, there were, in Mexico, 156,815 firms in the food industry sector, located mainly in the state of Mexico, Puebla, Oaxaca, Federal District and Veracruz. The sector represents more than 23% of the GDP of the manufacturing industry, and more than 3.69% of the national GDP. Given that scenario, Mexico is the second largest supplier of processed foods to the United States; the Mexican food industry is the third largest producer of processed foods in America (behind the United States and Brazil), and there is a large number of people working in this industry [35].

For the 2012–2020 period, the production of the industry in Mexico grew up at an annual average rate (AAGR) of 7.6%. The products with highest added value are the activities of malt processing, processing of agricultural products (other than corn and wheat), and in the production of edible vegetable oils and fats, as well as industrial baking, the preparation of concentrates, powders, syrups and flavor essences for beverages and the elaboration of dairy derivatives and ferments.

Globally, in 2012, the sector generated a production of 4657 billion dollars, China being the main producer worldwide. At the national level, the production in 2012 in this sector was of 124,924 million dollars, highlighting the State of Mexico, followed by Jalisco and the Federal District. The consumption was slightly higher than production, which represents a mirror trend.

Despite the important role it plays in the national economy, the sector is classified by the OECD as the low intensity of technology. Nevertheless, it is in this production process that more innovations have been done. The expenditure on scientific research and experimental development (GIDE) in this Mexican sector is the second most important in the manufacturing industry in 2011, with 5.1%.

According to the sectorial analysis of the food industry in Mexico, carried out in the CONACYT State and Regional Innovation Agendas project, the challenges for the sector consist of the following: developing innovative ecological products; packaging and preservation of products (food quality and safety, and sustainable and renewable materials), and research on the relationship between human physiology and food and beverages (increase knowledge about satiety to decrease caloric intake and control weight, and the impact and assimilation of nutrients in the human body).

The above challenges allow the industry to adjust to the growing market trend of changing diets and times available to prepare fast and practical meals. This trend requires innovations to be able to offer changes in the composition of diets and foods that have a great impact on health and well-being, specifications for labeling according to regulations, quality labels, functional and low-calorie foods, prepared meals, or easy to prepare with a limited amount of ingredients and advertising according to regulations.

The standards of quality, safety, and nutritional content, required in the food market, imply that the agriculture and food industry should adapt to new technologies in production and marketing. The objective is to meet the standards of presentation, color and size of products, institutional packaging, and the supply of consumer ready products.

According to The Mexico-United States Foundation for Science [36], the low productivity of agricultural activities in Mexico is explained by the low incorporation of technology and the lack of innovation. These precedents will lead to an increase in the percentage of spending on research and technological development in the sector, according to OECD recommendations. It will seek to establish a new public policy for agricultural innovation and strengthen the institutional framework for research, technology transfer, and agricultural innovation.

The food industry supply chain begins with the processing of agricultural products. Thus, raw materials are transformed into processed foods, as they pass through physical and chemical procedures, increasing its shelf life. From a process perspective, the value chain is made up of eight stages: ingredients and agro-inputs, processing, product, packaging, storage, channel, distribution-logistics and consumer [36]. The main opportunities for collaboration in technology transfer are identified in the processing, product and packaging links, since the sector lags behind in incorporating added value in its offer.

Methodology

The first idea was a statistical analysis of data with systematized information on TKT, based on the identification of scientific articles in Scopus and Web of Science databases, but it was scrapped because we did not find papers related with the Mexican agro-food sector. Then, we decided to carry out a mostly qualitative approach study based on searching documented cases on official websites.

This study used a mixed research methodology. In a first phase, a qualitative approach was used, and in the second, a quantitative one. The qualitative methodology consisted of the analysis of cases of technology and knowledge transfer, using data reduction, through the search, and the identification and selection of documents that were reviewed for filtering based on three established criteria. Later, the contents were reviewed for the extraction of the most relevant data, that would allow one to generate a concentration table of the information corresponding to the different cases analyzed. On this table, different elements are described: title of the document (report, news, article, etc.) from which the

information was obtained, the source of the publication (news agency, government agency, entity, etc.), a brief description of the case and/or the transfer mechanism, the higher education institutions (HEI) or research centers (RCs) involved in the case, as well as the results, benefits and important elements to carry out the transfer.

From that summary, in the second phase, a quantitative analysis was made, by counting frequencies that allowed grouping different types of elements and results/benefits, which allowed for a basic descriptive statistic.

(a) First phase

Systematic searches were conducted, during the month of January 2019, in journals indexed in the Scopus database, to identify scientific articles which document cases of technology transfer and knowledge at the international level. The criteria established to select the cases to be analyzed were the following:

1. Specifically describe the case between two or more organizations that did a TKT.
2. To be a case from Mexico.
3. Belong to the agro-food sector.

The query or search words used were "knowledge, technology, transfer case", obtaining a total of 2617 documents, of which the majority were rejected, because they presented international cases or addressed the TKT issue at a theoretical level, without describing a particular case. Then, only 27 were about the TKT in Mexico. Subsequently, 19 documents were discarded, because they did not fill the criteria of documenting one or more cases of TKT in Mexico. Of the remaining 8 documents, no case responded to the criteria of belonging to the agro-food sector in Mexico.

(b) Second phase

An exhaustive websites review was carried out, during the months of February to October 2019. That revision was made on web sites of higher education institutions, research centers and official entities which participate in such processes, such as the National Council of Science and Technology (CONACYT), the Ministry of Economy, and the Advisory Forum of Sciences and Technology, among others [37–45]. This review was intended to search for news or reports on documented cases of TKT made in Mexico. Thus, 209 documents were identified, of which a depuration was made following the three established criteria, to identify the cases oriented to the agro-food sector and analyze them in detail. A total of 190 cases of TKT were detected, of which 103 were discarded because they were not records for the agro-food sector, leaving 87 cases left to analyze.

3. Results

Experiences in Technology and Knowledge Transfer in the Agro-Food in Mexico

A total of 87 cases of technology and knowledge transfer for the agro-food sector in Mexico were analyzed. The analysis performed about 14 different cases, summarized in Tables 1 and 2, and contains information associated with different elements that were presented in the documented TKT cases, such as the knowledge or technology transferred, a brief description of the main characteristics of the case, and the transfer mechanism used, document title, source, benefits and results obtained.

Table 1 presents a sample of technology transfer cases that were supported with financial resources by the CONACYT innovation stimulus program, whose main objective was to promote technological development and innovation through academy-industry links. In this type of project, it is observed that the transfer of technology is mainly oriented to the development of new products, or to the addition of value in existing products, as well as to the design of new production lines or the improvement of existing production processes.

Regarding the development or improvement of products, the tendency was observed to use plants and their fruits as raw materials to create food products or supplements, with approaches oriented to

the organic, functional, sustainable, and the reduction of health risks, and the creation of by-products derived from waste (shells, bones, seeds, skin, etc.) Regarding processes, the main trend is to improve the productivity, efficiency, and profitability of production, as well as to extend the shelf life of products. There are few projects that address the issues of safety and packaging.

Table 2 presents a sample of cases that were promoted by the Science Advisory Council. In these types of projects, it is not observed that the cases present any trend or pattern regarding the type of technological transfer carried out. The cases are very different between them, such as the development of a by-product, generation of a food supplement for animals, creation of insecticide biological for agricultural pests, a bio-preparation usable for the soil, among others.

What stands out in most cases are the testimonies of the businessmen who point out that, thanks to the financial support of the government and the link with the academic sector, they were able to achieve a reduction in time in the execution of the project, while they appreciated to the technological capacities that the institutions have, since in Mexico, the culture of academy-industry linking is emergent.

Table 1. Cases of technological transfer in Mexico. Projects supported by Innovation Incentives Program (IIP).

Projects	Results	Linkage
Super food of dairy origin	Feregrino Brothers developed techniques for the extraction of nutrients, proteins and minerals from milk and their presentation in edible bars (milk in bars).	CIAD Campus Hermosillo
Machinery for the sugar industry	Tecnomec Agrícola developed a mechanized system of sugarcane post-harvest optimized and economically sustainable.	Polytechnic University of Aguascalientes (PUA), Technological University of Aguascalientes (TUA) and Panamerican University.
Beta-glucan for the food industry	Nutriproteomics developed a product using betaglucans (a fiber with nutritional value that allows the stimulation of the immune system).	Technological Institute of Colima (ITC) and the Center for Innovation and Agrofood Development of Michoacán (CIDAM)
New technical processes for ice cream making	Helados Milky Mich developed a strategy to contribute to the reduction of health risks caused by the consumption of sugars.	Autonomous University of the State of Hidalgo (UAEH)
Supplement Development food based on amaranth	Project of Amaranth Company build a semi-automated machine prototype to manufacture different amaranth products with nutritional quality	Department of Engineering-Universidad Anáhuac de Oaxaca (UAO) and the Technological University of the Central Valleys of Oaxaca (TUCVO)
Improve the quality of fruit and vegetables in postharvest	Esteripharma produced a system which optimizes the avoidance of wasting fruit and vegetable products in the post-harvest. The technological process validates and refines the germicidal effect of the super oxidation solution (SES) on fruits	National Polytechnic Institute (IPN)
A timely screening test for avian influenza	The UNIMA Company developed an on-site screening test, simple to apply by the same farmer and with immediate results, and development of three new tests for as many animal diseases, which are based on the method and technology	CICESE and ITESM Guadalajara.

Table 1. *Cont.*

Projects	Results	Linkage
Processed bean development fortified	Agroindustrias San Blas developed a production line at experimental pilot plant level of bean puree ready for consumption fortified with DHA (docosahexaenoic acid), intended for food suppliers	Tepic Technological Institute (ITT) and the Autonomous University of Nayarit (UAN)
A new way to take advantage of the coconut	Several producers in the Southeast Mexico use a product developed from coconut grease for baking and water for drink.	Ibero-American University in Puebla (UIP) and the Polytechnic University of Pachuca (UPP).
Pigment Processingnatural resistant todegradation for use in food products	ALTECSA Company processes technologies for obtaining and stabilizing water-soluble and fat-soluble natural pigments, to provide greater resistance to degradation by the action of sunrays, temperature changes, and pH variations.	Center for Research in Applied Biotechnology (CIBA) of the IPN and Ministry of Economy.

Source: own elaboration with data from Innovation Incentives Program (IIP). CONACYT 2019.

Table 2. Cases of technological transfer in Mexico. Projects supported by Sciences Advisory Council.

Projects	Results	Linkage
Production of plants of new cocoa varieties in Tabasco	Producers from Tabasco plant; a new variety of cocoa which results are higher productivity, disease tolerance and better organoleptic properties, and establishment of a bio factory for the propagation of selected cocoa genotypes.	INIFAP-CONACYT
Designing aloe product that copes with abiotic stress damage in crops	Mezfer developed a liquid concentrate of organic aloe, ideal for the recovery of crops subjected to situations of abiotic stress, high or low temperatures, drought, hail or contamination with chemical products.	CINVESTAV Irapuato.
Technological development for poultry farms	Permanare et Renovare Salutis developed a product named Modulín Avis, a food supplement for chickens which improve the immune response of farm birds and protect them against bacterial, viral, and parasitic infections such as salmonellosis, influenza, coccidiosis, among others.	Faculty of Pharmacy of the Autonomous University of the State of Morelos (UAEM).
Production of electricity from residues of meat industry.	ROMASE proposed an investigation to solve the polluting behavior of animal waste, such as viscera, hooves, fur, excrement, and blood for the purpose of treating the waste of the meat industry and mitigate climate change. The result was a kind of bio digester that degrades wastes quickly, transforms them into biogas, electrical energy, and compost.	Popular university of State of Puebla (UPAEP)

Source: own elaboration with data from National Institute for Forestry, Agriculture and Livestock Research (INIFAP, 2019) (official site), and Sciences Advisory Council (2019).

With the research methodology used, it was difficult to identify scientific publications on cases of TKT for the agro-food sector from the searches carried out in the Scopus database, so it is observed that the scientific publication on cases of TKT for the agro-food sector in Mexico, that is, the publication of these cases, has not yet formally worked, but rather, in the form of reports or news published by government agencies or academic institutions. Despite this, the results of our study find some similarities with studies carried out in other countries, such as the benefits that are generated for

companies by having access to expert knowledge, and the use of highly specialized infrastructure and equipment.

4. Discussion

4.1. Resultados y Beneficios de la Transferencia de Tecnología

In the qualitative analysis, it is observed that the State plays an important role as a promoter of the academia-industry linkages, through the granting of financial support for the execution of research, technological development and innovation projects, which represents a valuable mechanism for the transfer to the productive sector of the results of the applied research projects of the universities. In addition, it seems that the HEIs, RCs and the business sector prefer to collaborate through projects, where the formal rules that generate trust between the parties and allow a win-win relationship are present.

According to different approaches that consider the TKT to be successful, we find that in Mexico there are experiences of different levels. There are cases at the most basic level where success is defined as the number of knowledge transfers that take place over a certain period [46]. We identified such cases because there is a critical mass of them, despite the little documentation and dissemination that the issue still has in Mexico.

Regarding the approach based on the project management literature [47], there are successful transfers that have managed to be on time, be within the planned budget and produce a satisfied recipient [48]. Some of those cases indicate that, even, it was possible to reduce the normal execution time that the project would have had without the linkage, or without the economic support of the state.

Regarding the degree of knowledge that is recreated in the recipient, there are successful exchanges of knowledge in which companies dominate and put into practice product designs, manufacturing processes and organizational designs that are new to them [49]. Knowledge transfer is seen as a dynamic learning process where organizations continually interact with customers and suppliers to innovate or imitate creatively [50]. In other words, they manage to recreate the knowledge package of the source in the recipient (the results and benefits identified in the study indicate new products launched to the market, new processes launched, etc.)

Regarding institutional theory [51], which defines success as the degree to which a recipient obtains ownership, commitment and satisfaction with the transferred knowledge (knowledge internalization), several cases were also observed, in which companies not only implement new processes and methods or launch new products to the market, but also implement a new culture of innovation by generating laboratories and research areas of the company, creating R&D programs, which formalize, and continue with, the academy-industry alliances.

On the other hand, on the 87 cases analyzed, a basic descriptive statistic was carried out: frequencies related to important elements of cases qualified as TKT, as well as the benefits and results obtained in each case. The information is summarized in Tables 3 and 4, respectively.

The most important elements that stand out in the TKT processes for the cases analyzed in this investigation highlight the participation of HEIs or RCs, the participation of researchers, the need for knowledge, and the economic support of the government. On the other hand, the element that is not found as often as expected, according to international scientific publications, is the participation of available intellectual property. That is, as shown in Table 3, the intellectual property that would have been generated from these TKT processes. However, the TKT processes did not arise from a previously existing intellectual property, being a point that does not match international scientific publications.

It is necessary to highlight that the participation of students is still very low, so it would be useful to analyze this issue regarding HEIs, and what can be done about it. On the other hand, it is striking that the signing of contracts or formal linking is still very incipient, because only 11 percent of the cases had the signing of a legal document, something that is also different from what the international literature highlights.

Table 3. Important elements that appear in the TKT processes of the 87 cases analyzed.

Element	Frequency	Percentage
Need for knowledge	79	91%
Need for equipment	33	38%
Interest of creating enterprises	7	8%
Intellectual property available	2	2%
Participation of HEIs and RCs	85	98%
Participation of researchers	82	94%
Participation of students	7	8%
Signing of an agreement or binding contract	10	11%
Government support	74	85%
Private sector support	20	23%

Source. Own elaboration.

Regarding the results and benefits identified, the creation of new products, improvement in processes and methodology, as well as the development of equipment and prototypes or pilot plants, such as quality improvement and product improvements, stand out. Meanwhile, the least declared benefits are those obtained from publications. In that case, intellectual property was transferred from one organization to another by that means, which happened in 2 percent of cases (Table 4).

Table 4. Results/Benefits identified from the 87 analyzed TKT cases.

Result/Benefit	Frequency	Percentage
Enterprises creation	10	11%
Job creation	13	15%
New products development	44	51%
Intellectual property development	21	24%
Obtaining certificates	3	3%
Methodology transfer	12	14%
Intellectual property transfer	2	2%
Consulting received	6	7%
Human resources training	5	6%
Partnership agreement	8	9%
Development of equipment and prototypes or pilot plant	27	31%
Quality improvements	26	30%
Production improvements	19	22%
Process and methodology improvement	33	38%
Publications	2	2%
Acknowledgments (grants)	3	3%
Time reduction	10	11%
Costs reduction	4	5%

Source: Own elaboration.

4.2. The Relation between the Experience of Technology Transfer, and Open Innovation in the Agro-Food Sector in Mexico

Open innovation implies an environment in which information and knowledge become means of interaction between members of a business ecosystem [34]. The interactions in this medium take place through informal trust-based structures that generate contractual agreements and reduce transaction costs [52]. In that environment, valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well. This approach places external ideas and external paths to market on the same level of importance as that reserved for internal ideas and paths to market during the Closed Innovation era [53].

The agro-food sector in Mexico has technological capabilities that are lagging far behind other economic sectors. A little command of general-use technology predominates in it; it is a labor-intensive

sector with very low levels of study; there are limitations in access to public services and, its economic agents, recognize their limitations and are constantly seeking external support to complement their capacities and resources. This profile makes the agro-food sector more prone to open innovation.

In general terms, innovation has a dynamic that can be described as an inverted U. However, open innovation has an unpredictable path, it fluctuates frequently, and is very diverse, because it depends on the factors that stimulate it, the strategy of innovation adopted, the industry in question, and the time in which it can create levels of performance [54].

In the experiences of technology transfer in the agro-food sector in Mexico, it is observed that there are two key elements in the ecosystem that have facilitated open innovation [34]: (1) the orchestration of the process, where the state has the role of key player. The requirement for project financing is the maintenance of academic-business relations; (2) geographical proximity, since it has been observed that, in most of the sustained links, companies and academic institutions are located in the same state of the country.

These elements have allowed one to take advantage of open innovation, which allows free access to all, and encourages collaboration to improve the system, create new products, create or improve production processes, access new markets and improve innovation capabilities in companies [55]. This is reflected in the acquisition of complementary skills and resources produced by universities and research centers.

Open innovation has even transformed public organizations, as they have had to overcome cultural barriers, legal obstacles, and institutional dynamics [56]. However, this transformation has not been complete since; although the government in Mexico has acted as an orchestrator to motivate the academic-business ties, it sometimes generates the opposite effect, with rigorous regulations and extensive bureaucratic procedures to obtain economic benefits. Many companies feel inhibited from continuing the procedures losing the support.

To convert an industry like the agricultural sector, the existence of a business model is very important, since it is a guide to achieve market growth. However, having a sophisticated business model requires technological development [57].

In this regard, it can be said that, in the agro-food sector in Mexico, there are few experiences in which the transfer of technology and knowledge aims to improving marketing. Seen with optimism, this represents an area of opportunity, especially in the context of the fourth industrial revolution [58] and the health pandemic that afflicts the world.

The coronavirus pandemic will bring an increase in safety and security rules, which will drive the appearance of business models that involve a creative recombination of technologies and markets [57]. Well taken advantage of, the circumstance will be key for the subsistence and expansion of companies in this sector.

The fourth industrial revolution, for its part, is producing a rapid change in the paradigm of innovation from producer to user [59,60]. This is another challenge for the agro-food sector in Mexico because, being the most backward sector, it faces a paradox: it increasingly deals with consumers hyper connected to the internet.

Based on the TKT experiences analyzed, the open innovation pattern that occurs most frequently in the agro-food sector in Mexico is of the type of incoming innovation [33], since most of the technology transfer and knowledge come from external sources. External sources are universities, research centers, and specialized institutes.

According to the testimonies of the companies' personnel, for the agro-food sector in Mexico, one of the main benefits of the open innovation scheme is access to the specialized knowledge and infrastructure available in research centers and universities. This equipment, naturally, causes a reduction in time and costs in solving problems, or in the development of their products and processes [55].

5. Conclusions, Limitations and Future Research

According to the results and benefits that could be identified from the analyzed cases, the companies of the agro-food sector declare having had results and benefits, such as the creation of new products, improvement in processes and methodology, as well as the development of equipment and prototypes or pilot plants, quality improvement and product improvements, that is, in those links of the value chain where the sector lags behind in Mexico. All this can be translated into economic and social benefits derived from TKT processes.

However, according to existing studies, in the agro-food sector in Mexico, there are still many areas of opportunity and challenges to be addressed. These areas include, among others, the adoption of new technologies in production and marketing that meet the standards of presentation, color and size of products, institutional packaging and the offer of ready-to-consumer products, which allow to meet the standards of quality, safety and nutritional content required in the market, as well as the adoption of creative business models necessary for the reorganization of production, consumption transport and delivery systems. For all this, there are various higher education institutions and research centers that have the required technological capabilities, and that hardly the majority of companies in this sector could acquire on their own in the short or medium term, so that the processes technology transfer through academic-industry linkages would be very appropriate, on the one hand, to meet the technical needs of companies and, on the other hand, for academic institutions to solve some budget deficiencies. Apparently, it can be recommended to other companies in the same sector, that they seek to carry out technology transfer activities as a possible mechanism to achieve positive impacts on their business.

It remains, as a task for the academic sector and the government sector, to do more promotion of this type of TKT activities. On the one hand, the government must continue with the initiatives to support the university-industry linkage and, on the other hand, on the side of the academy, research developments, the knowledge that is being generated and the technological capabilities existing in the different areas and research groups. Thus, the productive sector could identify those areas where they can go and make links, waiting for a TKT that can have positive impacts, which generate wealth in the company.

Social benefits can also be obtained at the regional and national levels, such as the generation of jobs, the development of new products and the training of human resources, all of which contribute to improving the economy.

From this study on the processes of TKT, it is observed that, for the agro-food sector, there are both opportunities for improvement and unexploited lines of research, consisting of the documentation and dissemination of cases of TKT that are presented in our country. This statement is because, so far, publications could only be identified on sites of RC, government dependencies, education institutions, or news agencies, but not on scientific databases. Besides, we observe a line of research opportunity applying our own survey based on the identified cases of the agro-food sector, given the limitation to find systematized information on cases in scientific databases.

For small and medium-sized Mexican companies (SMEs), it is very important to connect with the academic sector to be able to acquire technological capabilities. In this way, they can have access to high-level infrastructure and specialized knowledge that they could not otherwise aspire to, due to the level of investment that needs to be made to acquire them on their own.

For the TKT processes in the agro-food sector in Mexico, government support has been important, as well as collaborations with HEIs and RCs that contribute to the participation of expert researchers and students committed to the generation of new knowledge, which contribute their knowledge and experiences to the development of equipment and optimal infrastructure for the development of projects.

The obtaining of results on new advances in products, technologies and improvements in methodologies and quality is observed in the analysis, leading to new jobs, and the creation of new spin-offs and intellectual property registration.

In other words, TKT is an important mechanism for generating positive impacts on Mexican SMEs in the agro-food sector.

On the other hand, the results of the study contribute to identifying useful elements to be able to propose a technology and knowledge transfer model, applicable to the knowledge generated and the technology developed in the agronomy department of the University of Guanajuato, and appropriate to the needs of the productive and social sector in the context of Mexico.

Generally speaking, TKT can be a source of improvement of companies' capacities, with innovation, improvements in processes and technology, which impacts positively for the society, through the creation of new jobs and companies, as well as an additional monetary income for the HEIs and CIs that transfer their knowledge and technologies.

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