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Contaduría y Administración
Accounting & Management

Contaduría y Administración 64 (1) Especial Innovación, 2019, 1-17

Technology valuation at universities: Difficulties and proposals

Dificultades de la valoración de tecnologías en el ámbito universitario

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Received November 29, 2017; accepted September 27, 2018
Available online November 30, 2018

Abstract

The valuation of technology is an important part of the technology transfer process. It allows the definition of a price, the determination of a form of payment and the design of the best terms for the technology transfer to interested companies. The most common methods for technology valuation (cost, market and income) are used in companies as well as in universities and research centers. Its application faces different situations and problems, depending on who applies them and where. Despite the abundant literature on the subject, few empirical studies have been published on the difficulties that hinder the valuation of technologies in universities. The objective of this work is to identify the main difficulties faced by technology managers when they value technologies developed in universities, in order to understand the problem and offer proposals for improvement. Our research suggests that in the process of valuation of this type of technologies it is common to find difficulties that can be grouped into four factors: a) Lack of information, b) Little knowledge about valuation methods, c) Level of technology development, and d) Business practice of technology acquisition.

JEL code: D45, L24, O30, O32
Keywords: Technology valuation; difficulties; technology transfer; valuation of technology.

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La revisión por pares es responsabilidad de la Universidad Nacional Autónoma de México.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

Resumen

La valoración de tecnología forma parte importante del proceso de transferencia de tecnología. Permite la definición de un precio, facilita la determinación de una forma de cobro, así como el diseño de los términos de transferencia más adecuados a ofrecer a potenciales interesados. Los métodos más comunes para valorar tecnologías (*de costos*, *de mercado* y *de ingresos)* se utilizan tanto en empresas como en universidades y centros de investigación. Su aplicación se enfrenta a situaciones y problemáticas distintas, según sea quién los aplique y en dónde. A pesar de la abundante literatura sobre la materia, pocos estudios empíricos se han publicado sobre las dificultades que obstaculizan la valoración de tecnologías en las universidades. El objetivo de este trabajo es identificar las principales dificultades que enfrentan los gestores de tecnología cuando valoran tecnologías desarrolladas en universidades, con el fin de comprender la problemática y ofrecer propuestas de mejora. Nuestra investigación sugiere que en el proceso de valoración de este tipo de tecnologías es común encontrar dificultades que pueden ser agrupadas en cuatro factores: a) Falta de información, b) Escaso conocimiento de métodos de valoración, c) Nivel de desarrollo de la tecnología, y d) Práctica empresarial de adquisición de tecnología.

Código JEL: D45, L24, O30, O32.
Palabras clave: Valoración de tecnología; dificultades; transferencia de tecnología.

Introduction

It is necessary to carry out a calculation of the value of technology as part of the transfer process in order to have an idea of how much it is worth. This is useful information to be able to offer it in appropriate terms to potential buyers or licensees. This value depends on the nature of the technology, its degree of development, the strength of its intellectual protection, its potential to generate competitive advantages, the characteristics of the market, the degree of involvement of its developers, the capacity for commercialization or entrepreneurship, among other aspects. In addition, it varies in time and according to the circumstances that arise. As Boer (1999, p. 75) points out, technology has no intrinsic value and can only be valued in the context of a specific business situation.

In the Latin American university environment this problem is present, and it is further complicated by the fact that the vast majority of universities do not have among their functions the trade of technologies and other intellectual assets and, therefore, do not have specialized personnel dedicated to it. Nevertheless, there are a good number of them in the region that have Technology Transfer Offices (TTOs) or specialists who have been concerned not only with intellectually protecting their technological developments but also with seeking a way out to the market, so that they are used or exploited commercially. These offices and specialists use technology valuation tools, with greater or lesser success, but little has been published on how they do it and what difficulties they face in carrying out their work (Solleiro and Ritter, 2014; Chais *et al*., 2017). Knowledge of this problem can then be useful to these technology managers and provide them with examples or empirical references to optimize their valuation practices. With that in mind, this article seeks to answer the question: what difficulties do technology managers face in their valuation of technology processes or practices? For this purpose, the available information has been used in the archives of eight cases of technologies valued in a Mexican public university, which were studied with the purpose of identifying this problem,

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

proposing some alternative solutions, as well as presenting proposals for further research (Yin, 1994; Hernández *et al*., 2006).

The valuation of the technology can be carried out using different methods. What is sought with them is to have an idea of the value of the technology and from this to define a potential price of the same, often in the form of royalties to be charged. In other words, "technology valuation provides a set of techniques and tools that assist technology sellers and buyers in preparing a business case for a particular technology and to agree on a future value and hence a potential price" (Probert *et al*., 2011).

Different methods are used to value technology based on different approaches, each of them with strengths and weaknesses but which offer the opportunity to compare results from different perspectives, providing more coherence that gives certitude to the exercise (Razgaitis, 2002, p. 48). Thus, Sullivan (2001, pp. 264-265) states that the value of intellectual assets is quantified in monetary terms through the use of three classical methods: The *market method*, which uses the market price agreed between buyer and seller as the best monetary measure of their utility; The *income method*, used when a market price is not available, and that is based on calculating the cost of future benefit flows by subtracting them from the present value[1]; and The *cost method*, which calculates the costs necessary to duplicate or reproduce an intangible good.

Based on these three classical methods or approaches, also called *accepted* (Smith and Parr, 2005, p. 148), *traditional* (Yan et al., 2010, p. 1932), or *basic* methods (Murphy *et al*., 2012, pp.), others have been proposed for specific purposes that are variants or derivations of these three. Sullivan (2001, pp. 266-267) describes, for example, in addition to the three already mentioned, the following: Technological factor, prepared by Dow Chemical for internal valuation; Expected value adjusted for probability, which allows risk elements to be quantified; Risk/obstacles index, which quantifies risk mathematically; Profit from sale, which calculates royalties based on net sales; Sullivan method, based on the knowledge of the company; Make an offer, when no market information is available; and The 25% rule, which provides an admitted value, even if it is not precise.

Razgaitis (2002, p. 38) reports four methods for the valuation of technology, in addition to those of cost, of market (that are denominated Industrial Standards, where the key is finding a benchmark), and of income (Discounted cash flow): 1) *Rating/Ranking*, 2) *Rule of thumb* (25% rule and other variants), 3) *Advanced methods*, such as the de Monte Carlo simulation and Real Options, and 4) *Auctions*.

Other methods have been reported in the literature, such as those that Wang and Edmondson (2014, p. 1141) present groups under the three basic technology valuation approaches: Under the cost approach: *Reproduction Cost Method* and *Replacement Cost Method*; under the market approach: *Direct Market Value Method* and *Analogy Method*; under the income approach: *Direct Cash-Flow Method*, *Relief from Royalty Method, Multi-Period Excess Earnings Method and Incremental Cash-Flow Method*.

An alternative factorial method has been used in the Mexican university environment for some years, although in a restricted way (Roa *et al*., 1989). The following six adjustment factors are used to calculate a royalty rate to be charged for a developing technology: technological intensity, international competitiveness, degree of development, associated commercial advantages, degree of exclusivity, and degree of integration of the technological package.

[1] These methods are also referred to as discounted cash flow. They use discount or interest rates for analysis and decision making between investment alternatives. The reference is taken as the value of money in a determined period of time brought to the current moment (WIPO, 2012).

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

These factors adjust a royalty rate obtained from market information (average royalty rate of similar transactions), which is averaged with the estimated profitability of the project (IRR) adjusted, in turn, by the real interest of the market.

It must be noted that, according to some authors, the maturity of the technology and the business determines the valuation of technology method to be used. Thus, Khoury *et al*. (2001, pp. 79-80) suggest that the less mature both of them are (technology and business) it is best to use a cost method; if a vision and a business plan are available, then it is best to use the income method; and if the business and the technology are mature, then the market methods seem to be the most indicated.

Problematic of technology valuation

Three basic variables participate in the valuation of technology, according to what was indicated by Murphy *et al*. (2012, p. 8): 1) Information inputs (measurement of complex and confusing reality), 2) Valuation methodology that translates those inputs into a value outcome, and 3) Interpretation of the resulting value outcome. However, it is very common that not all the information required (particularly market and financial information) is available or that it is not of high quality, that is, that it is not complete and accurate (Murphy, 2012, p. 68), that the methods cannot be applied due to lack of information or scarce practice in the use of valuation tools, or that the interpretation of the data obtained leads to a good result in negotiations with possible licensees since the essence of this latter is uncertainty. In addition, it has been identified that the literature on the subject focuses predominantly on the explanation of the methods, merits, and implications of specific tools, with little available research that considers a contextual and process perspective (Dissel *et al*., 2008, p. 2074).

This is part of the problem that a Technology Transfer Office (TTO)—or more specifically, a technology manager—faces in a valuation of technology process. Other contextual factors such as maturity level of the technology, the degree of uncertainty that surrounds the particular valuation question, or the identity of individuals wishing to establish this value also play a role (Dissel *et al*., 2008, p. 2073). Another aspect to consider that complicates the technology valuation process is the fact that it "belongs to an integrated valuation domain in which various sciences such as economics, business/administration, and engineering are required in addition to market information based on understanding of the technology. Therefore, it is difficult to conduct a systematic and completely objective evaluation" (Hong, 2010, p. 121). Therefore, "the TTO personnel need to have the knowledge of technology valuation method, understand the valuated technologies, and master the industrial developments and market trends" (Wang, 2016, p. 1324).

The valuation of technology is further complicated if there are no specialized personnel to carry out technological and competitive surveillance that facilitates the obtaining of technical, market, economic, and regulatory information, as well as the identification of possible licensees for the technology. The lack of all the necessary information makes it difficult to make a comprehensive evaluation of the technology (Lynn, 1989)[2] and its respective valuation,

[2] In cases where a technology evaluation is not carried out, there is a risk of not having quality information available for a full valuation and of limiting the use of quantitative valuation methods, as the evaluation provides an opportunity for in-depth analysis of the technology and its commercial potential. Thus, for example, Lynn (1989) includes in their evaluation method a series of technology, financial, legal, engineering and production, marketing and market characterization factors; in addition to eight factors that he considers critical for an integral evaluation of the technology: need, sales´ functional feasibility, profitability, competition, product differentiation, production feasibility and market

particularly if it is sought to use quantitative methods that require information on income, production and distribution costs, business profitability rates, royalty rates in the market, among other issues specific to revenue-based methods. As Wang (2016, p. 1321) points out: "The mathematical operation using an equation to calculate value is not difficult; the most complicated point is the information of profit amount, income form, and risk factor for the income approach."

The nature and maturity of the technology are also determinant in the use of some specific method of valuation of technologies that arise from the academic field. Wang (2016, p. 1323) found that it is still difficult to implement the income approach, because the technologies developed by universities – Taiwanese in this case-, are mostly embryonic technologies, and their future development is considerably uncertain. He also identified that it is difficult to find transaction prices that serve as a reference for valuing this type of technologies, so it is not easy to use a market approach (Wang, 2016, p. 1324). This difficulty was also reported by Vega-González *et al*. (2010, p. 538). Another factor identified by Wang (2016, p. 1326) that affects universities in the implementation of their valuation methods are government regulations, as some of them may limit the use of some method and the price of the technology in question. Some of these difficulties have also been pointed out by the Russell Group, which brings together several British universities, when it reports that: "The valuation of intellectual property assets can be extremely challenging due to market uncertainty related to early-stage university technologies, including timescales to market, investment needs, and avenues to achieving commercially viable outcomes (House of Commons, 2017, p. 25).

However, despite the abundance of literature on valuation methods, our study indicates that there is little empirical evidence on the difficulties faced by managers in the valuation of technologies from the university environment[3], which hinders their learning and prevents them from having references to similar problems that could be used for their benefit or to develop best practices[4]. Hence the importance of their study. Thus, the objective of this work is to identify the main factors that hinder the valuation of technologies developed in universities, in order to better understand their problems and to offer proposals for improving the process itself.

Our research identified nine difficulties that technology managers encounter when valuing university-sourced technologies (also called technological developments). These can be grouped into four factors: a) Lack of quality information—that is complete, accurate, and timely—on commercial aspects, production and marketing costs, royalties charged on similar technologies, as well as on the direction of the project; b) Lack of valuation skills by the managers in charge; c) Maturity of the technology, since the lower the degree of development, the less information and the greater the uncertainty there is (which determines the method to be used); and d) Form of business operation, since companies in certain sectors do not like to invest in R&D or comply with environmental regulations or, which was common to find in the

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penetration. A good part of this information is also required to carry out an adequate valuation of the technology. For their part, Van Norman and Eisenkot (2017, 198) point out that the decision on whether an invention has "sufficient" potential commercial value varies from university to university and depends on many factors, among which: 1) The income to be obtained from royalties for the license, 2) Whether a commercial entity is already interested in the discovery and is capable of developing it, 3) How broad or enforceable the resulting patent is likely to be, and whether copyright is a more suitable protection tool.

[3] Bortolussi e*t al*. (2013, p. 7) have found that "there is still little information in the state of the art regarding which method is most commonly used by businesses and universities."

[4] A similar problem has been reported about the learning that technology transfer managers have in TTOs. The understanding of how they learn and share knowledge is limited. There are no studies systematically investigating how the practices of university TTOs are developed and refined over time (Weckowska, 2015, p. 63).

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

cases studied, are not interested in the technologies developed because they are outside their areas of interest for partnering.

In addition to this chapter, the article includes a description of the methodology used, which incorporates a description of the cases studied and the reasons why they were selected; it continues with a section on analysis and discussion of the results and at the end presents conclusions and suggestions for future work.

Methodology

Activities carried out

In order to carry out this work, we focus on the analysis of project files, emphasizing the problem of the valuation of technologies developed in a university environment with the intention of obtaining information to determine the most appropriate price and form of payment to potential licensees of the same, without forgetting that the results generated in technology valuation studies are often highly subjective, uncertain, and complex. This favors the use of an inductive rather than deductive approach (Dissel *et al*., 2008, p. 2076), the conclusions of which are not necessarily generalizable.

The literature published on the subject was reviewed in order to find similar experiences useful to characterize the problem of valuation in the context of the transfer of technology developed in universities. In addition, information was obtained on the technologies and their evaluation from direct observations, interviews with the developers of the technologies, the review of the files of the eight cases studied, and various publicly available documentation (articles, reports, interviews, and websites).

Selected technologies

In order to carry out this work, the valuation activities of eight different technologies, applicable in different industrial sectors or sub-sectors, were analyzed. These were developed by researchers from a Mexican public university and valued between 2011 and 2016 by a group of technology managers, using four valuation methods (Table 1): One based on market information, another on the use of adjustment factors applied to a royalty calculation algorithm (Roa, 1989), and two more based on the income method—the 25% rule and a discounted cash flow method.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

Table 1
Assessed technologies and methods used

No.	Level of development	Application sector or subsector	Used valuation method
A	Pilot plant	Food industry	Market method
B	Clinical Stage 3	Chemical industry (pharmaceutical)	Royalty adjustment factors 25% rule Discounted cash flow
C	Pilot plant	Textile manufacturing, paper industry, chemical industry	Market method Royalty Adjustment Factors Discounted cash flow
D	Prototype	Manufacture of measuring equipment, electronic components and accessories	Market method
E	Functional	Beverage and tobacco industry	Royalty adjustment factors 25% rule Discounted cash flow
F	Prototype	Construction	Royalty adjustment factors 25% rule Discounted cash flow
G	Pre-clinical stage 2	Chemical industry (pharmaceutical)	Royalty adjustment factors Discounted cash flow
H	Pre-industrial	Waste management	Market method Royalty adjustment factors Discounted cash flow

Source: own elaboration.

The results obtained from the valuation of the technologies were validated, at different times, with the respective researchers who developed them and in six of the cases they were used to generate terms of reference for technology transfer, or patent license, which were discussed with possible licensees, reaching transfer agreements with two of them.

Brief description of the technologies valued

Technology A

During the nixtamalization process, the husk is separated from the corn grain to transform it into a dough with which tortillas are made and a residual mixture is produced called *nejayote*, a by-product that is currently thrown into urban drains causing pollution problems due to the high amount of organic matter it contains. The technology developed can be adapted economically and simply to the current process of nixtamalization resulting in a *nejayote* that meets the standards for the discharge of wastewater, in addition to increasing the performance of the product and reducing the consumption of water needed for the entire process.

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Technology B

As a result of research, it was discovered that Dapsone has a therapeutic effect in different diseases or degenerative neurological affectations. For example, it is used to treat strokes, epilepsy, spinal cord injuries, head injuries and brain hemorrhage. A soluble pharmaceutical form of Dapsone (Dapsol®) was developed that facilitates its application to the patient (with injections), even if the patient is unconscious, and allows a faster absorption of the drug by the patient.

Technology C

This biotechnology transforms crustacean waste into chitin and chitosan. It is a biopolymer extraction process, in humid base, by means of fermentation, in which microorganisms and enzymes that fulfill the function of purifying the chitin of proteins and minerals are used. Unlike the process commonly used in the chemical industry to obtain these biopolymers, in which high value by-products such as protein, astaxanthin, and calcium are destroyed by the use of corrosive substances such as sodium hydroxide and hydrochloric acid, this process is not corrosive and makes it possible to take advantage of these by-products.

Technology D

This technology consists of a calibration system of cochlear implants (CI), which are hearing prostheses inserted into the skull that produce electrical stimulation of the auditory nerve and are used by children and adults who, due to a sensorineural hearing loss, have partial or total hearing difficulty. The devices that compose it allow, through a non-invasive measurement, the adjustment of the electric current levels of the intracochlear IC electrode array, corresponding to the thresholds of auditory perception and maximum comfort also called stimulation parameters.

Technology E

A device used to measure the flow and percentage concentration of carbon dioxide and oxygen in gaseous streams from biological processes. The results obtained can be used as indirect measures of the growth and physiological activity of microorganisms in these processes. The device allows real-time monitoring, facilitates data capture and analysis, as well as decision making during the execution of biological processes, providing information to modify operating conditions and achieve a regulated growth of microorganisms. Unlike the equipment used today, it does not require sampling of the culture and, therefore, avoids the risk of contaminating it.

Technology F

Manufacturing process of bars for parking lots and devices to delimit exclusive lanes of fast transit bus systems and cycle paths. The products are manufactured from plastic waste such as polyethylene, high density polyethylene, thermoplastics, among other rigid and semi-rigid plastics. Due to their special shape, which includes semi-elliptical ends, the road delimiters produced reduce the damage caused by the impact of tyres and cause the vehicle to return to its lane in the event of the invasion of confined lane or delimited area.

Technology G

This technology consists of semiconductor polymer implants capable of inducing the reconnection between the affected cells of a fractured spinal cord, also favoring its neuroprotection. It was developed based on copolymers, as well as polymers of an aromatic and heterocyclic organic chemical compound added with a solid halogen micromineral, which are synthesized by plasma. Semiconductor polymer implants are well tolerated and integrated into the spinal cord injury, and offer an alternative for the recovery of individuals with paraplegia or tetraplegia caused by a spinal cord injury.

Technology H

System for the treatment of wastewater from homes and commercial and service establishments, and even industrial wastewater, whose effluents have a high content of fats and oils, organic compounds and metal ions, suspended solids, including particles emulsified by the presence of detergents. The system uses a mixture of a biopolymer with different salts to carry out the coagulation and flocculation of the contaminating agents.

Selection of the valued technologies

In order to define the technologies to be studied, the following elements were taken into consideration: a) All the cases have been analyzed using known valuation methods: five of them were valued using three methods, one used two and in two other cases only the market method was used (Table 1); b) Given that the intention was to analyze the problems of valuation of technology, cases of different technologies were chosen according to their nature and application in various sectors, in order to have a broad spectrum (Table 1); c) It was considered important to have first-hand information on the cases to be valued, so the continuous interaction with researchers and the existence of historical archives was decisive for their choice; d) All the projects selected have been carried out in different academic departments of the same University; e) One more reason that determined the selection of the eight cases was that the results of the valuation studies, carried out between 2011 and 2016, were available, the objective of which was to determine the most adequate royalty rates to be charged in the event of their transfer.

Analysis and discussion of the results

Valuation as part of the transfer process

The eight cases studied make up a sample of technologies generated in a public university, with a degree of development at pilot plant level or similar (Table 1), on which technology management activities have been carried out with the ultimate purpose of bringing them to the market via transfer or licensing to a company interested in their use or exploitation.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

Table 2 shows the activities carried out at various times by technology managers with the support of research professors. These activities, which can also be seen as stages of a technology transfer process, are: industrial protection, integration of the technology package, preparation of market and financial studies, technology evaluation, valuation of technology, promotion with national and international companies, identification of potential licensees, negotiation with interested companies, and signing of technology transfer and patent licensing contracts. As can be seen, the valuation is only one of the stages that make up this process.

It can also be observed that both the knowledge of the market and the economic impact of the technology are necessary to be able to carry out the valuation of the technology, facilitating the use of methods based on income, the 25% rule, or the method of adjustment factors. Among other issues, knowledge of the market and marketing channels of products manufactured with technologies similar to the one being valued allows possible licensees of the technology to be identified.

On the other hand, the lack of an integrated technological package demerits the value of the technology because it implies that it will require more development work and, therefore, more investment. It should be remembered that the technological package is integrated as the R&D project progresses, in which logs are generated, obtaining test results, documents, plans, manuals, biological material or artifacts, as well as various types of intellectual assets. Thus, if the degree of development of the technology is incipient or embryonic, its technological package will have little content and its value will diminish, in addition to the fact that information (technical, economic, market) will be needed to carry out its evaluation, as Wang points out (2016, p. 1323).

It is noteworthy that in most cases there has been no prior evaluation of the technology, as can be seen in Table 2, which has undoubtedly prevented technology managers from having a broader perspective on it, on the business, and its regulatory, commercial, and financial context. It is likely that the lack of evaluation will not lead to the development of more effective technology commercialization strategies and it will be difficult to decide which is the b*est value conversion mechanism*[5] to bring them to the market.

[5] Sullivan (2001, p. 55) proposes six value conversion mechanisms: direct sale, external licensing, joint venture, strategic partnership, integration (creation of a new business), and donation.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

Table 2.
Activities done for the transfer of technology

Activity Technology	Industrial Protection	Technological package integration	Market research	Financial study	Technology evaluation	Technology Valuation	Promotion with companies	Identification of Licensees	Negotiation	**Contract signing**
A	Patent	Complete	Done	Done	No	Done	At a national level	Yes	Concluded	Yes
B	Patents	Partial	Done	Done	No	Done	At a national level	Yes	No	No
C	Patent	Complete	Done	Done	No	Done	At a national level	Yes	Ongoing	No
D	Patents	Partial	Done	Done	Done by a third party	Done	At an international level	Yes	No	No
E	Patent	Complete	Done	Done	Done	Done	At a national level	Yes	Concluded	Yes
F	Unit model	Partial	Done	Done	No	Done	At a national level	Ongoing	No	No
G	Patent	Partial	Done	Done	No	Done	At a national and international level	Yes	Ongoing	No
H	Patent	Partial	Done	Done	No	Done	At a national level	Yes	No	No

Source: own elaboration.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

Valuation difficulties

The revised literature emphasizes the primacy of cost, market, and revenue methods for the valuation of technologies and patents, as well as their strengths and weaknesses (Razgaitis, 2002; Smith and Parr, 2005; Murphy *et al*., 2012; Cárdenas *et al*., 2016). The latter two approaches were used in the case studies (Table 1). The managers who carried out the valuation made the decision at the time to not use the cost method, since in none of the cases was information available on the costs incurred during the formulation and execution of the R&D projects that generated the valued technological developments.

Table 3 presents an overview of the problems of valuation of technology in the investigated projects. The case studies were carried out in order to identify the main difficulties encountered in the valuation of these technologies originating in the university environment.

A transversal analysis of the eight cases studied allows us to identify difficulties that are common to most of them and others that are only specifically presented (Table 3). Among the former, the difficulty that technology managers had in six cases (A, B, C, E, F, and H) to obtain information that would allow them to identify the market and its characteristics (size, supply and demand, existing products, prices, competing companies, marketing channels, among others) stands out. The foregoing is of special notice because they are projects that have already been executed at least up to the pilot plant level and should have such information. But this has not been the case. This is a common peculiarity of R&D projects carried out in universities without the participation of a contracting company or entity, which respond to the legitimate interest, from the academic point of view, of generating new knowledge in a specific field rather than solving a specific problem or market demand. This means that managers who value technologies must first identify that market nationally and internationally. This leads to the valuations taking longer to execute, especially if the TTO does not have specialists in technological and competitive vigilance to obtain this information.

Table 3
Difficulties in carrying out the valuation of technologies for their transfer

Case	Difficulties encountered
A	Ignorance of valuation methods of the technology managers. Lack of information on the nixtamalization market and marketing channels. Lack of information on royalties and technology transfer transactions in the industry. Non-compliance with regulations by companies in the sector.
B	Poor knowledge of valuation methods by technology managers. Difficulty in understanding the technology on the part of the managers who valued it. Information obtained from the market limited only to incidences of the ailment (cerebral infarction) at a national and international level. Initial difficulty in obtaining production costs of injectable drugs.
C	Poor knowledge of valuation methods by the technology manager responsible for the project. Difficulty in understanding the technology on the part of the managers who valued it. Ignorance of the international market and its characteristics. Production at industrial levels conditioned to the supply of raw material.
D	Poor knowledge of valuation methods on the part of the project manager. Lack of specific references to royalty rates in the market: only aggregated data on the health sector were obtained. Partially integrated technology package. Disinterest in technology by international cochlear implant producers.
E	Lack of accurate information on royalties and transfer transactions in the sector. Difficulty in understanding the technology on the part of the managers who valued it. Difficulty for developers and licensees to identify the potential market. Constant additions and improvements to the technology delayed the obtaining of a final version, ready to be commercialized.
F	Lack of references to royalty rates charged for the production of similar products. Scarce information on road plans and commercial real estate developments in cities of the country to estimate the market. Information provided by inventors of development and production costs only at the laboratory level. Non-integrated technology package.
G	Development at pre-clinical level. Lack of references to royalty rates for similar technologies. Lack of information on production and marketing costs. Reluctance of contacted companies, organizations, and foundations to invest in clinical phases (risk aversion).
H	Ignorance of the market and its characteristics. Lack of accurate information on production and marketing costs. Intellectual property protection initially limited to a single area of application. Differences between researchers on design aspects (process and engineering) and the direction of the project.

Source: own elaboration.

Closely related to the above is the even greater difficulty of having reliable information on forms and costs of production and commercialization of products similar to those that could be produced with the valued technology, as well as on the prices of the offered products or services.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

To obtain this information, in some cases (B, D, E, H) managers have had to resort to contacts or specialists with experience in the industry who have supported them by providing first-hand data and information on plant arrangements, brands and models of machinery and equipment, costs of raw materials as well as of production and marketing, prices, personnel requirements, wages and salaries, same as ways of organizing and carrying out the manufacture of similar products. Where this has not been the case, they have had to seek the information with the help of researchers and sometimes other TTO collaborators.

Also related to the same type of difficulty, we find the need for information that serves as a reference on patent licensing or technology transfer agreements similar to those valued; this was the case of technologies A, D, E, F, and G. In most cases aggregate information was only found in a specialized journal (*les Nouvelles*) and in books published on the subject, for example, Parr (2007). There was a need to buy information on transactions and royalties. This information was used to identify royalty ranges and was useful for valuing A and D technologies where only the market method was used, although it was also used for valuing C and H technologies. It is also possible to mention the lack of information caused by disagreements among researchers, and between researchers and the licensee on design aspects or on the direction of the project (cases E and H); as well as the lack of communication between developers and technology managers that influenced, for example, so that in case H the initial protection of the technology was limited to only one application sector. The latter was corrected after discussions with a company that had shown interest in the technology.

Another type of challenge encountered refers to the lack of knowledge and skills to assess technologies on the part of technology managers. This evidently arose when the team began to carry out the first valuations between 2011 and 2013, particularly with cases A, B, C, and D. As time went by, the group of managers was trained, learned more valuation methods, and gained experience in the matter. Linked to the above is the observation that the training, more administrative and economic than technical, of two of the four participating managers influenced that their learning process was not given more quickly, as it was difficult for them to fully understand the nature and characteristics of the technologies to be valued, as happened with technologies B, C, D, and E.

Less frequently we find other difficulties to carry out the valuation of technologies. One of them is to have incomplete technological packages, in one case because technology G is not very mature (far from the market yet); and in two others (D and F) because the developers have not paid enough attention to this requirement, having only a part of the documentation necessary for the industrial manufacture of the technology. This affects the value of the technology in question, as it increases the investment that the licensee has to make to acquire the missing know-how and, therefore, increases the cost and risk of the project.

Finally, there are difficulties in the valuation of technologies concerning an external component. Risk aversion by companies in the application sectors is very common in countries such as Mexico. In particular, it has been difficult to obtain funding for clinical trials of G technology, despite the fact that it has been developed by a group of excellent researchers from four prestigious organizations and has very interesting market potential. It is also possible to mention the scarce attention that companies of certain sectors pay to the fulfillment of environmental norms, causing them not to be interested in optimizing their processes, which could benefit from the use of A or H technologies; or the disinterest shown by companies dedicated to the manufacture of cochlear implants by the D technology (at an international level, since there is no one to manufacture in the country), patented in several countries and successfully used in more than 200 applications with minors, because apparently the technology is not aligned with their business areas.

Conclusions

Derived from our empirical data, this article contributes to the literature a series of elements that allow better understanding the valuation process of technologies generated from R&D projects, in early stages, in public universities, identifying a set of difficulties that arise in this activity. We argue that these difficulties form a specific problem that can be solved by the actors participating in the process if they are better trained in the use of the different valuation methods (Koury, 2001; Razgaitis, 2002; Dissel *et al*., 2008; Probert *et al*., 2011), obtain the necessary information to evaluate technologies in their prototype stage, and deepen the analysis of the business dynamics and sectors of application of such technologies in such a way that they can define more successful negotiation and transfer strategies (Wang and Edmonson, 2014; Van Norman and Eisenkot, 2017). It is also recommended that technology managers know and adopt good marketing practices in public universities, nationally and internationally, as to increase the efficiency of technology transfer in them (DeVol *et al*., p. 33).

This work contributes to the theory of valuation of technology in an academic setting. In particular, it is shown that the evaluated cases support the findings partially reported in the scarce literature found on the subject and contribute by providing more precise information on the difficulties that, in practice, are presented in the valuation of this type of technologies in whose development companies have not participated (Vega-González *et al*., 2010; Wang, 2016; Chais *et al*., 2017). The cases were used to identify, above all, the difficulties experienced by technology managers who valued technological developments, which does not mean that there have not been adequately resolved situations, or that good technological management practices have not been used during the execution of the projects. However, we believe that practitioners—technology managers, entrepreneurs, consultants—will find in this work a set of factors to be addressed to improve their valuation practices in similar contexts.

Thanks to the case studies, it was possible to identify nine difficulties that hinder the valuation of technologies of university origin that must be overcome if we want to achieve better results in technology transfer, namely: lack of accurate market information, lack of knowledge of production and marketing costs, lack of reference information on royalties in the sector, lack of information on the direction of the project, lack of knowledge to valuate technologies, low level of technology development, low degree of integration of the technology package, risk aversion by companies, and technologies outside the business radar of the companies. These difficulties can be grouped, for analytical purposes, in four factors: i) Lack of information, ii) Lack of valuation skills, iii) Maturity of the technology, and iv) Form of operation of the companies.

For the rest, it is evident that, in order to deepen the understanding of these factors and their importance, more empirical work is required to be carried out in other universities to test and validate the results obtained. It may also be of interest to carry out future research on the use of other valuation methods and the difficulties faced by other types of organizations.

http://dx.doi.org/10.22201/fca.24488410e.2019.1811

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