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Financial Impedance Matching Method for Enhancing University-Firm Technology Transfer

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Abstract

Universities and R&D institutions undertake projects to create technological solutions, and at the same time, they teach, produce new knowledge, and learn. Since most universities in the developing world lack industrial production capacities, the technology they create is considered pre-competitive. However, a major goal of technological development is to create products and make them available in the market to different economic sectors in order to help people to solve problems and improve their quality of life. Due to its limitations to accomplish this goal, the university needs to transfer its propriety technology to industrial or entrepreneurial partners. Nevertheless, the definition of technology transfer agreement terms represents a complex communication problem, particularly the appraisal of the value of the technology made by both counterparts. This is partly because current technology valuation methods often disregard the *point of view* of both counterparts, even though the university's interests are completely different from the firm's interests. This paper proposes a technology valuation method using an analogy taken from physical systems, the method of impedance matching in electrical circuits, which intends to engage both parties in a common project with a common aim. The proposed method is tested using a technology transfer contract signed between the Applied Sciences and Technology Institute (UNAM) and a producer of biomedical prostheses.

Keywords: Technology Valuation, Technology Transfer, Impedance Matching

1. Introduction

In this paper, we discuss the importance of enabling adequate communications between universities and firms as a requirement to transfer precompetitive technology developed at universities to the productive sector. The hypothesis is that if both parts, the university and the firm, act as a project team and are sufficiently committed to the technology transfer process, they will both work hard in the development of industrial R&D and the engineering of new products to launch into the market. Therefore, research, development, and innovation (R&D+I) are conducted by a project team in the pursuit of technological innovations that can impact society in many ways by helping to solve some of its problems and fostering economy. Beyond the relation of counterparts stated in technology transfer contracts, the university and the firm must act as *partners*: they must both ensure that the other party receives a fair profit and benefits for their participation in the project. However, it is necessary that the technological product carries economic value. (Cooper, 1985; cited by Boer, 1999, pp.169). Therefore, the university-firm team needs to remain effective and competitive through changing market circumstances (Griffin 1997, cited by Kumar and Phrommathed, 2005).

R&D+I requires significant investment of time, money, and qualified and talented human resources on both sides; thus, we propose that R&D+I must be developed in an environment of trust so that both parties are fully committed to accomplishing the innovation goal, and that the innovation processes faces difficult challenges when it is time for the parts to initiate intense negotiations to reach a technology transfer agreement. The method proposed in the present study uses costs development information from the stages performed by the university, as well as from those performed by the firm: R&D scaling, engineering, and new product and market development.

The idea is to contrast costs against expected revenues for an agreed number of years using a predetermined sales function to compare the contribution of each part and then simulate the process modifying some parameters affecting the stages of promotion and sales. These parameters can be used to determine the return of investment on the basis of product sales and the dynamic parameters of the sales functions used, such as the slopes of straight lines, curves, and exponential functions. Having this information on the table, the parts can negotiate their benefits and make them coincide with their respective financial contributions, adjusting things such as the payment of royalties to the university and the expected profit for each part, among others.

Electrical engineers use impedance matching in a similar way to obtain the maximum energy transfer; technology managers and analysts can use finance matching to determine the actual value of the technology by clearly defining the terms of the technology transfer contract, such as royalties, payments, and so forth, to increase the trust between the R&D+I project team members.

2. Framework of Reference

2.1 What Is Impedance Matching?

Physical systems work as a result of energy flows. Forces acting in mechanical systems are responsible for the displacement of mechanical bodies, providing them with velocity and acceleration. Normally, mechanical parts are connected to other mechanical parts, and together, they produce a certain movement that translates into work needed by human beings. Other physical systems are static, even if they have interconnected elements. For example, in electrical systems, energy is transmitted as current circulating through resistors, capacitors, or inductors. The purpose of an electrical system can be to energize the street lights on a road or to supply the power required to start a motor, depending on the scale and range of the application. In this context, impedance is the opposition that the system presents to the circulation of electrical current.

Instrumentation systems provide many other interesting examples. For example, Figure 1 shows the simple arrangement used in analytical equipment used in the laboratory or in analog industrial instrumentation panels to measure the hydrogen potential (pH) of chemical solutions.

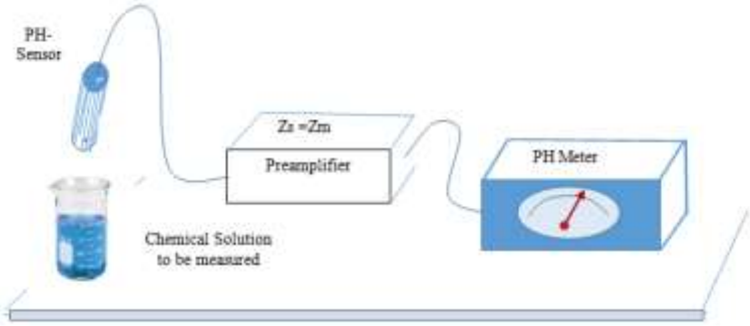

Figure 1. Experimental set-up to measure pH

The pH sensor is usually made of a type of glass having a special composition capable of producing a microvoltage, whose value depends on the acidity or alkalinity of the solution being measured. The universal pH scale ranges from 0 to 14. A solution at pH 7, which represents a neutral pH (neither acid nor alkaline), is normally used to zero the instruments.

A central concept in the present paper is that, for instance, the pH meter would fail to return a measurement if we were to connect the pH sensor directly to the pH meter. The reason is that the impedances of the Sensor (Zs) and the measuring indicator (Zm) are completely different. The impedance of the pH meter is so high that it will never detect the microvoltage produced by the sensor. For that reason, a preamplifier is used to adjust the signal and match both impedances (Zs = Zm). The preamplifier is the physical device required to achieve optimal energetic flow and transference, fundamental elements for the performance of instrumentation systems.

A second example is an audio circuit. Figure 2 shows the connection of an audio signal source, a conventional microphone, to an audio console. Usually, such a device has a stage of electronic filters intended to modulate and tune the audio signal coming from the microphone. The signal is immediately fed into an audio amplifier to boost it to the required level. Finally, the audio output through an impedance coupler that provides different impedance options to match different speakers.

Thus, impedance is here represented by resistance, an element or device that opposes the passage of the energetic signal of the audio waves. It is extremely important that the impedances of the console and the speakers be equal to achieve optimal audio performance; otherwise, the performance of the speakers will be deficient, and the quality of the sound poor.

Circuits at the audio console provide the different impedance outputs; the user can connect an 8-ohm output to an 8-ohm speaker, a 16-ohm output to a 16-ohm speaker, or even select a special 100-ohm output to connect an earphone.

Examples abound. Sometimes a car will not start when the key is turned. The starting mechanism is not working, and there is only a ‘click’ each time an attempt is made to start the vehicle. This click sound is the starter relay closing. But energy is not flowing to the starting mechanism—no sound is coming from it. The battery might be low because the charging system is malfunctioning or simply because one of the battery’s cells has degraded and needs to be replaced. Depending on the specific failure, it could be a good idea to supply current from another car's battery.

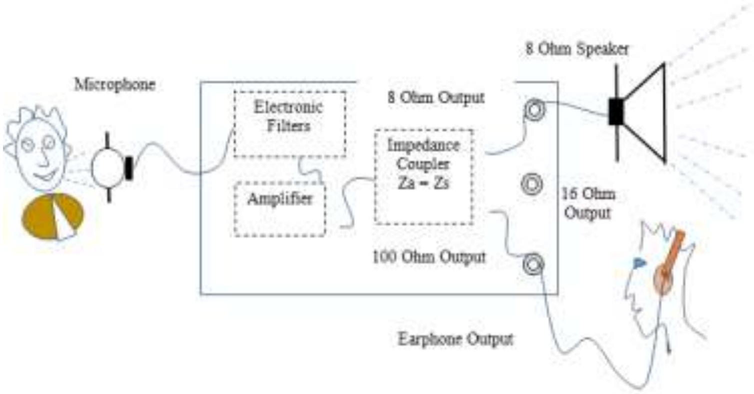

Figure 2. Audio processing impedance coupling for optimal performance

The reader might have tried to charge the battery of a large car using the battery of a small car. The result is usually that the engine never starts because the current capacity of the small car battery is unable to supply the energy required to charge the large car’s battery. Furthermore, if small gage cables are used, it might not be possible to power even a similar sized battery. This is because the current capacity of the cables is insufficient, so their impedance is more significant.

Digital systems present communication problems. For example, when trying to copy information from a USB 3.0 flash memory to a device having a USB 2.0 port, as shown in Figure 3. Most likely, in a common digital data communication system such as the one in Figure 3, copying a file from the flash memory to the device will take a long time. Depending on the file size, the copying process could take more than half an hour, making the process boring and tedious, and the completion of important work could be delayed. Conversely, when using a USB 3.0 flash memory to copy a file to a device having a USB 3.0 port, it only takes a few seconds.

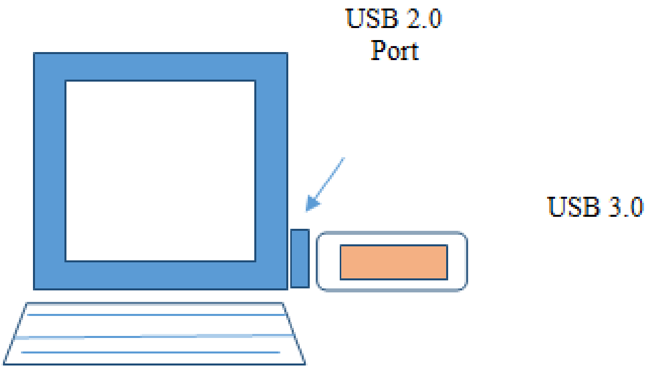

Figure 3. Difficulties of digital data communications using different speed rate specifications

In conclusion, when energy, information, or data are transferred in physical systems, adequate communication channels must be used at the interfaces so that they match the impedances to achieve the best performance. When impedance matching is achieved, energy transmission is optimal.

2.2 University-Firm R&D+I Projects

In the early 1990s, Roy Rothwell (1992) pointed out that not only technology was changing rapidly, but also the process by which technology is commercialized: the innovation process. Rothwell (1992, p. 236) proposed five generations of innovation process models: (a) first generation, 'technology push innovation model' (1950s — mid-1960s); (b) second generation, 'need-pull innovation model' (mid 1960s — early- 1970s); (c) third generation, 'coupling innovation model' (early 1970s — Mid-1980s), (e) fourth generation, 'integrated innovation model' (early 1980s—early 1990s); (f) fifth generation, 'systems integration and networking innovation model'. Two years later, Rothwell (1994) presented a detailed description of the elements of the fifth generation (5G) innovation model. Far more than just concurrent engineering, developments towards the 5G innovation process stressed the ability to control product development speed as an important core competency for the innovator organization, together with the use of computers and the internet for networking.

By the end of the 20th century, Boer (1999), was very clear in that the linkage between scientific discovery and the delivery of practical results—technology—is vital for the well-being of individuals and nations. During the first decades of the 21st century, innovation has been regarded as the successful exploitation of new ideas by organizations of any size that adopt and transform the ideas into profitable products, processes, and services (Damanpour, 1992; Johannessen et al., 2001). Vega-Jurado et al. (2009), stated that innovation strategies required the involved organizations to possess the capacity to absorb new knowledge (Cohen and Levinthal, 1990).

At least during the second half of the 20th century, the source of innovation for organizations was solely its internal R&D activity; therefore, interaction with external actors was limited. Chang et al. (2002) presented a partnership program for public-private development of early-stage technological development. Today, public and private organizations have looked beyond their organizational boundaries and engaged in interorganizational collaboration to share knowledge and develop innovations. This is known as open innovation (Chesbrough et al., 2006; Lichtenthaler, 2011). The creation of strategic alliances has been a widespread practice among firms during the first two decades of the 21st century, resulting in a proliferation of collaborative activity. In this regard, open innovation is probably the sixth-generation innovation model; it can be defined as collaboration between autonomous organizations based on lasting agreements and mutually harmonizing elements of joint work using computer networks. A wide range of collaborative partnerships has arisen under this model. (Kaats and Opheij, 2014)

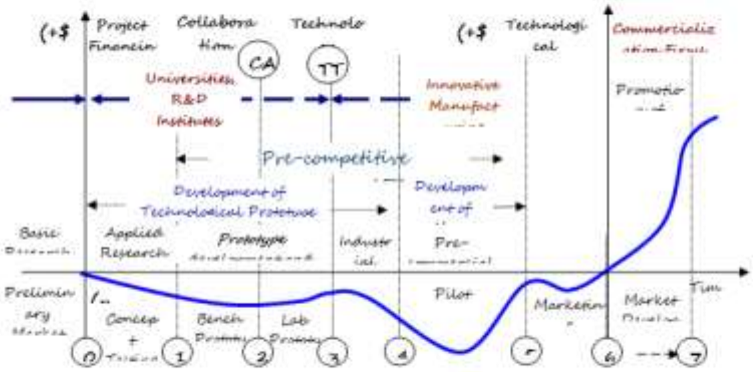

Figure 4. Innovation project precompetitive technology (PT) lifecycle (Adapted from Vega and Saniger, 2010)

In this context, the purpose of R&D+I projects is the creation and exploitation of new knowledge, an especially challenging endeavor for firms in developing countries, which need external sources of knowledge to increase their innovative capacities.

For small and medium enterprises (SMEs) in developing countries, access to increased capacities to develop new products or processes is available via collaboration with universities or public R&D centers or institutes to develop innovation projects. Hence the importance of the knowledge produced by universities for industrial innovation (Maietta, 2015; Scandura, 2016); their in-house work, core competencies, and acquisition of external knowledge from collaborative R&D+I projects become part of a complementary strategy (Vega-Jurado, Op. Cit, pp.75).

This complementarity can be observed in the different stages of the university-firm R&D+I collaborative project shown in Figure 4. The process is extraordinarily complex and requires a significant investment of time, money, and the contributions of multidisciplinary and sometimes trans-disciplinary working teams. Noticeably, the central point of the R&D+I project is the Technology Transfer Contract, and its core is the *Technology Valuation* (Razgaitis, 2009). We will now present an overview of the development process of the R&D+ I project.

The vertical axis plots the monetary investment that will be required throughout the process.

At a certain moment, the firm's officials and university academics establish connections and meet to establish project development specifications. At least the first three stages are performed by the university; these can be completed using the university's own financing or, in some cases, the firm and the university sign a collaboration agreement concerning these stages and the firm finances part of their development. Typically, when the university creates the laboratory prototype and registers the intellectual property, the knowledge must be delivered to the firm as described in the technology transfer agreement. Once the firm has obtained the knowledge to develop the technology product, in-house R&D is conducted to scale the technology to industrial grade, which once validated, gives way to the new product development project. Finally, an often-expensive marketing plan is developed and put in place to launch the new product. Sales begin when the product is in the market, and expectedly, the firm will make a profit from its market share during the product's life cycle. At this time, the firm must pay royalties to the university as agreed in the technology transfer contract. This overview represents an ideal scenario, but very *frequently, the technology transfer contract* ***cannot be signed*** *because the parties disagree on the terms*, and the R&D+I project is never developed. The next section will develop on this issue.

2.3 The Concept of Financial Impedance

As previously stated, the relationship between the firm and the university officials can start at any point during the R&D phases. In the beginning, it is an exploratory relationship in which the company shows a certain interest in the technology being developed at the university. Thus, the firm and the university decide to sign a technology transfer agreement concerning the laboratory prototype of the technology. In a somewhat mysterious way, each of the parties changes their focus to their own interests, the sense of *project team* is diluted, and the communication between the parties fades away, probably due to the expectations of both parties in regard to the financial outcomes of the project. University analysts appraise the technology and intend to see a full return of their technology development expenses under the belief that the market will accept the product immediately and that sales will follow once the product is launched. The technology will certainly be highly valuated if there are patents or other intellectual property certificates to protect it.

On the other hand, company officials might consider that the development of the new product will require important investments in materials, equipment or machinery, and additional human resources, as well as a number of adverse sceneries such as initially low sales (which could improve over the time), the technology life cycle, government permits, regulations, or quality control issues, among others. In sum, instead of focusing on shared benefits, the parties focus only on their own gain, probably because the economic contributions (investments) are unbalanced. Consequently, the parties take a selfish stance instead of acting as a team with the common purpose of developing the project, and our proposed *financial impedance* develops into the system, making communication between the parties difficult and often preventing the execution of the project. Boer, (op cit., p. V) describes the situation as follows: *"the transformation of science into technology is mediated by business forces and brings together two sets of people whose outlooks, specialized knowledge and professional languages are very different and often out of touch with each other."*

How can this problem be overcome? The purpose of the present paper is to present a financial impedance matching methodology for technology valuation based on an analogy with electrical impedance matching. This methodology intends to improve communication and understanding between the parties when negotiations are geared toward the agreement on the technology transfer terms, increasing the feasibility of a successful project. Finance matching takes place when the parties working together are granted value for the technology, and they both agree on such arrangement by signing the technology transfer agreement and carrying on with the project.

2.3.1 Technology Valuation

The determination of the price of technology, or valuation, is probably the most important input in the technology transfer process. Uncertainty is one of the key challenges when appraising technology (Hunt, 2007). Reducing this uncertainty using an adequate valuation method can be enough for having a valid estimation of the value of the technology during the negotiation process (Douglas, 2014).

There is no unique, universally valid method for the evaluation of technological assets, there are multiple aspects to consider, such as research and development costs, expected profits, the product's market value, and the prevailing standard in the industry, among many others.

The technology valuation process can be applied to the interchange of technological knowledge assets among private firms through negotiation. Chiesa & Gilardoni (2015) point out that, in recent years, companies have often been faced with decisions concerning not only the acquisition of external technology but also the opportunity to sell or to cooperate with other firms. However, existing technology valuation methods have certain drawbacks and limitations (Park and Park, 2002).

Vega and Saniger (2010) have stated that, almost always, people who perform technology valuations have trouble identifying the best approach to valuing intangibles, but they can draw on the most common approaches available in the current technology valuation literature: (a) monetary value models, classified into three basic approaches, namely the cost approach, the market approach, and the income approach; (b) intangible assets valuation, (c) risk-based approach; (d) real options valuation; (e) contingency valuation models, and (f) pragmatic models.

3. The Financial Impedance Matching Methodology

The financial impedance matching methodology (FIMM) can be used as a valuation strategy for technology in connection with the transfer of such technology. It is based on costs development and expected income. Figure 4 shows the different cost and income areas of the model. In the first place, university scientists and developers present the costs of the precompetitive technology prototype developed during applied research (stage 1) and technology development (stages 2 and 3). In the next step, the firm presents the estimated costs of industrial R&D (scaling costs) during stage 4, new product development costs during stage 5, and market development costs during stage 6. Once the costs-related stages have been completed and the technological product has been launched, the parties can expect an income. The following section describes the basic premises of the methodology.

3.1 Basic Premises of FIMM

a. Based on our experience, the average R&D+I project needs five to ten years for the research and development stages. The commercialization stage comes next. Exceptionally, some projects can launch technology product into the market in one or two years, including the research and development stages; of course, their aim could be the development of low-profile technology, for example, software for specific, non-complex applications.

b. Projects spanning more than ten years are most likely focused on disruptive technology applications. In these cases, stakeholders pursue them having in mind that the technology product will solve a socially important problem or will generate enormous sales, producing extraordinary profits. This type of projects cannot be handled with the financial impedance matching methodology presented here.

c. In our consideration, projects with lifespans of one or two years are not authentic innovation projects, but probably technological services projects, or projects concerning a low-technology product that does not require large investments to achieve the production and market launch stages. In these cases, the value of the technology likely ranges between 5 and 10% of net sales in royalties.

d. A successful, financially feasible R&D+I project, should achieve a return on investment in no longer than five years. If the project requires more than five years, the probability of achieving investment returns decreases dramatically because of the technology life cycle and the natural presence of market competitors. The expectation is that the product will remain in the market for fifteen or twenty years, sometimes protected by the original patent or a patent family, producing profits for the firm and welfare for the population.

e. Frequently, the university takes more than five years to complete technology product development; however, the costs used in financial matching impedance calculations need to be from the last five years, because the firm is not supposed to finance the whole project, even previously incurred costs, if it is to maintain profitability. Sometimes, the firm and the university establish a long-term R&D grant agreement. In such a case, the technology transfer terms would certainly be defined in a contract.

f. If the time required by the firm for industrial scaling and new product development is less than five years, the economic feasibility of the project increases, if further, the investments are made to scale the product, prepare it for the market, and launch it are low, the expected profitability of the project becomes proportionally higher. In these cases, the royalties for the university must be between 10% and 15% of the sales profit.

g. When a university develops an unprecedented disruptive invention, for instance, a new drug molecule against cancer, a new material with extraordinary properties or innumerable applications, a new chemical process that reduces production costs by half, among many other examples, the impedance matching valuation procedure is inoperable. In these cases, technology transfer negotiations are almost always directed to one payment purchase-sale of the technology, using as reference the benchmark of similar technology purchase-sale operations around the globe.

3.2 Application Example of FIMM

To explain the FIMM methodology, we will use basic example data and perform simulations introducing variations to the main financial variables. Let us begin by assuming the economic investments made for the R&D+I project shown in Figure 5.

During the two-year R&D stage, the university invested $50,000.00 USD in applied science research, as well as $70,000.00 USD during the three-year technology development stage. In addition, the university invested $5,000 USD to obtain a patent in Mexico. Therefore, the total investment of the university was $125,000.00 USD; the totality of this investment was, of course, financed with resources from the government subsidy to public universities. At this point, the laboratory prototype *is transferred* to the firm. In the third stage, the firm will require two years for preindustrial escalation and an investment of $50,000.00 USD, plus two more years to create the industrial product prototype during the new product development stage, which will require a $130,000.00 USD investment for a processes pilot plant.

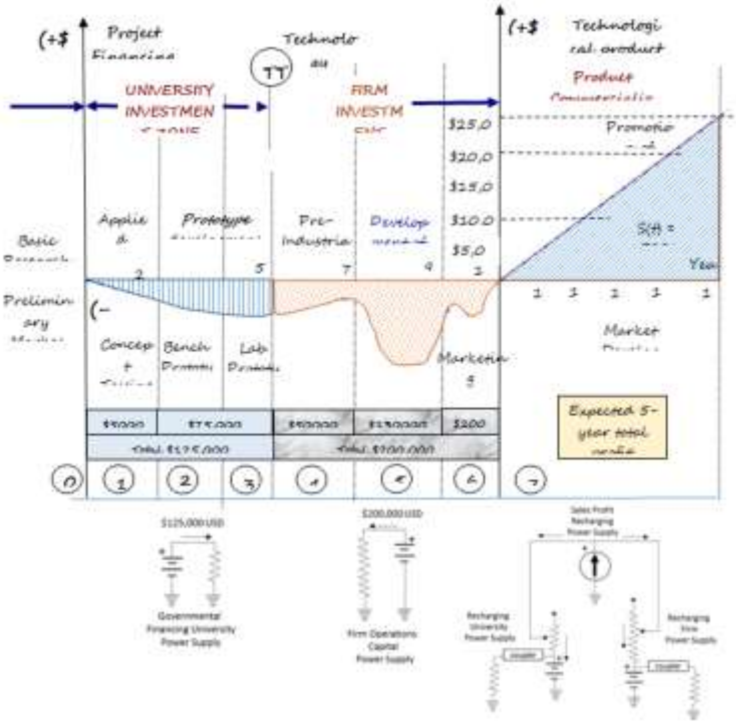

Figure 5. Sample R&D+I project conditions used to present the financial impedance matching methodology

Finally, the entrepreneur will require one year for developing the marketing strategy and the new product market launch at an investment of $20,000.00 USD. In total, the firm invested $200,000 USD. The different amounts of money invested by each party are a function of the time, human resources, equipment, or infrastructure required by the project.

As a development of the sample cost scenario, and in order to simulate the process, let us suppose that after studying the features of the new product and the behavior of the market, university technology transfer executives and entrepreneurs both *agree* in that product sales will present simple growth for a five-year period, averaging $5000.00 USD in sales profits per year, i.e., product sales will behave according to the function $S(t) = 5000t$, in USD. In this first scenario, total profits will be $75,000 USD after five years of commercialization. (Note 1)

In the basic example, total university investment during the first three stages is $ 125,000.00 USD, the firm invests $200,000.00 USD during stages 4, 5, and 6, and expected sales for the first five years of commercialization are $ 75,000.00 USD.

The lower part of Figure 5 shows the total investment obtained from an analog governmental university financing "power supply" of $125,000.00 USD. The firm's operations capital power supply is $200,000 USD. In the lower right section, an analog current source that recharges the voltage of both parties' power supplies; in other words, the money invested returns and will generate profits hereafter.

4. Simulation

Table 1 shows that the firm invests $75,000.00 USD more than the university. As can be observed in the financial impedance matching section, on the right, if the firm is granted 80% of the sales profits obtained during years 11 to 15 and the university is granted 20% of such profits, the firm will not see a return of investment after 5 years of commercialization: its excess investment is $15,000 USD, and the university will be granted $15,000 USD in royalties. It does not seem to be a good business for anyone.

Table 1. Sample base conditions

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$125,000				
Firm	5-10	$200,000				
Firm's Difference		$75,000				
	11		$5,000	$4,000	$71,000	$1,000.0
	12		$10,000	$8,000	$63,000	$2,000.0
	13		$15,000	$12,000	$51,000	$3,000.0
	14		$20,000	$16,000	$35,000	$4,000.0
	15		$25,000	$20,000	$15,000	$5,000.0
Total Profit			$75,000	$60,000		$15,000.0
University Down Payment						$0.0
Total university earnings				**No Financial Impedance Matching**		$15,000.0

Example 2 introduces small variations to example 1. Table 2 shows a scenario in which the firm reduces costs associated with the production line and invests $175,000.00 USD ($25,000.00 USD less than in example 1). In this scenario, the difference between the firm's investment and its partner's is $50,000.00 USD.

Table 2. Sensibility to firm investment

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$125,000				
Firm	5-10	**$175,000**				
Firm's Difference		$50,000				
	11		$5,000	$4,000	$46,000	$1,000.0
	12		$10,000	$8,000	$38,000	$2,000.0
	13		$15,000	$12,000	$26,000	$3,000.0
	14		$20,000	$16,000	$10,000	$4,000.0
	15		$25,000	$20,000	-$10,000	$5,000.0
Total Profit			$75,000	$60,000		$15,000.0
University Down Payment						$0.0
Total university earnings				**Weak Financial Impedance Matching**		$15,000.0

Expected sales profit is again $75,000.00 USD. The financial impedance matching section on the right shows that the firm makes profits during years 4 and 5 of commercialization for $10,000.00 USD; the university is not entitled to a down payment and its royalties are only $15,000.00 USD after commercialization for five years. The financial situation is quite balanced for both parts, but these conditions make the project an effort-intensive endeavor that will yield only limited results.

The example in Table 3 highlights the sensibility of the R&D+I project to an increase in sales. We will now examine the scenario when sales increase slightly, and the expected sales profit is $115,000 USD instead of $75,000 USD.

The university invests $125,000.00 USD, and the firm invests $200,000 USD. As can be appreciated in the financial impedance matching section, the university is not granted a down payment. Therefore, the firm invests $75,000 USD more than the university.

In this case, the entrepreneur sees ROI by the fourth commercialization year and makes profits for $17,000 by the fifth commercialization year. The university obtains total royalties for $23,000. The result is very similar to the result of example 2;

Nevertheless, although the arrangement is more beneficial to the university, it might not be attractive to the firm. One more time, the example shows that the process is sensitive to sales performance and to differences in investment between the firm and the university.

Nevertheless, although the arrangement is more beneficial to the university, it might not be attractive to the firm. One more time, the example shows that the process is sensitive to sales performance and to differences in investment between the firm and the university.

Table 3. Example 3: A modest increase in sales

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$125,000				
Firm	5-10	$200,000				
Firm's Difference		$75,000				
	11		$10,000	$8,000	$67,000	$2,000.0
	12		$15,000	$12,000	$55,000	$3,000.0
	13		$20,000	$16,000	$39,000	$4,000.0
	14		$30,000	$24,000	$15,000	$6,000.0
	15		$40,000	$32,000	-$17,000	$8,000.0
Total Profit			**$115,000**	$92,000		$23,000.0
University Down Payment						$0.0
Total university earnings					**Weak Financial Impedance Matching**	$23,000.0

Table 4 presents a simulation in which the expected sales profit increases two-fold with respect to the base example ($150,000 USD).

Table 4. Example 4: A two-fold increase in sales

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$125,000				
Firm	5-10	$200,000				
Firm's Difference		$75,000				
	11		$10,000	$8,000	$67,000	$2,000.0
	12		$20,000	$16,000	$51,000	$4,000.0
	13		$30,000	$24,000	$27,000	$6,000.0
	14		$40,000	$32,000	-$5,000	$8,000.0
	15		$50,000	$40,000	-$45,000	$10,000.0
Total Profit			**$150,000**	$120,000		$30,000.0
University Down Payment						$0.0
Total university earnings					**Financial Impedance matching**	$30,000.0

In this case, the firm sees ROI by year 13, and it profits an additional $45,000 in year 14 and $5,000 USD in year 15. The university is granted $30,000. Business conditions are improving, but there is still room for improvement.

Table 5 presents a scenario in which the firm lowers its new product development costs, investing a total of $175,000. In this case, the firm invests $50,000 USD more than the university, in addition to a $10.000 USD down payment.

Table 5. Lower investment, down payment

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$125,000				
Firm	5-10	$175,000				
Firm's Difference		**$50,000**				
University Down Payment		**$10,000**				
New Firm Investment Dif		$60,000				
	11		$10,000	$8,000	$52,000	$2,000.0
	12		$20,000	$16,000	$36,000	$4,000.0
	13		$30,000	$24,000	$12,000	$6,000.0
	14		$40,000	$32,000	-$20,000	$8,000.0
	15		$50,000	$40,000	-$60,000	$10,000.0
Total Profit			$150,000	$120,000		$30,000.0
University Down Payment						**$10,000.0**
Total university earnings				**Financial Impedance matching**		$40,000.0

Considering an expected sales profit of $150,000 and the same amount in royalties, the firm will see ROI by the year 13 and profit $80,000 during years 14 and 15, while the university will make a $40,000 profit. This result is much better for both parts.

Table 6. Scenario is optimal for the firm

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 90% of Profit	Firm Investment Return	Royalties 10% of Profit
University	1-5	$100,000				
Firm	5-10	$125,000				
Firm's Difference		$25,000				
University Down Payment		$10,000				
New Firm Investment Dif		$35,000				
	11		$10,000	$9,000	$26,000	$1,000.0
	12		$20,000	$18,000	$8,000	$2,000.0
	13		$30,000	$27,000	-$19,000	$3,000.0
	14		$40,000	$36,000	-$55,000	$4,000.0
	15		$50,000	$45,000	-$100,000	$5,000.0
Total Profit			$150,000	$135,000		$15,000.0
University Down Payment						$10,000.0
Total university earnings				**Strong Financial Impedance Matching (good for the firm)**		$25,000.0

Example 6 presents the ideal case on the firm's side: the firm sees ROI by year 12, and its profits are $174,000 USD for years 13, 14, and 15. It should be highlighted that the university's benefits are limited to a 10% profit in the form of royalties and a $10,000 down payment. This result requires *both parties* to make special efforts to lower investment costs associated with the development of the technology product and an expected $150,000 USD profit.

Example 7 presents a scenario in which both the university and the firm lower their investment costs, and a $10,000 USD down payment is made in favor of the University; the firm invests $35,000 USD more than the university, and the expected sales profits are $150,000, plus 20% university royalties; the firm sees ROI by the year 12, and its profits are $143,000 USD for years 13, 14 and 15, while the university profits $40,000 USD for the whole project, $10,000 of which becomes available when the contract is signed. This is the ideal scenario for both parties, where financial impedance matching is finally achieved.

Table 7. Both parties lower their investment costs and down payment, high sales expectations

R&D+I Project Data						University
	R&D Project Years	USD Investment	Expected Sales Profit	Firm 80% of Profit	Firm Investment Return	Royalties 20% of Profit
University	1-5	$100,000				
Firm	5-10	$125,000				
Firm's Difference		**$25,000**				
University Down Payment		$10,000				
New Firm Investment Dif		$35,000				
	11		$10,000	$8,000	$27,000	$2,000.0
	12		$20,000	$16,000	$11,000	$4,000.0
	13		$30,000	$24,000	-$13,000	$6,000.0
	14		$40,000	$32,000	-$45,000	$8,000.0
	15		$50,000	$40,000	-$85,000	$10,000.0
Total Profit			$150,000	$120,000		$30,000.0
University Down Payment						$10,000.0
Total university earnings				**Ideal Financial Impedance Matching (good for both parties)**		$40,000.0

5. Results

Table 8 summarizes the different technology valuations used in the simulations described in tables 1 to 7, as well as other project performance indicators.

These data show that the initial approach to the project is inoperable: neither of the parties obtains acceptable results. Similarly, when the firm decreases its investment costs or a 35% improvement in sales profits is expected, the firm sees a return on its excess investment by the fourth year in addition to marginal gains. The fourth example shows that the simulation is sensitive to the expected sales profit because, when this figure is doubled, the firm receives a return on its investment by the third year, which naturally improves its profits.

The fifth example uses both conditions, i.e., it simulates workable actions by the firm to lower its investment costs as well as high sales profits expectations. *These special conditions result in a state of financial impedance matching for both parties* because the firm obtains ROI by the third year and profits $80,000 USD for the next two years, while the university's earnings are a $10,000 USD down payment and 20% of profits as royalties.

Interestingly, examples 6 and 7 are very positive on the firm's side, but they impose an extremely difficult and improbable condition that consists in lowering the firm's investment costs to one-third of the figure in the base scenario ($25,000 USD instead of $75,000 USD). This scenario includes high sales expectations. In this case, the University is given a $10,000 USD down payment and somewhere between 10 and 20% of sales profits as royalties.

If, due to technical reasons or other externalities, the firm is unable to reduce its investment costs, and its excess investment is still $75,000, the outcome is similar to examples 3 or 4, depending on the expected sales profits, in which the value of the university's technology is 20% of sales profits or 5% of total sales.

Table 8. Summary of project performance indicators and university technology valuation

Example	Firm's investment difference	Expected sales profits	Time to achieve ROI after commercialization	Firm's profits	**University Technology valuation**
1	$75,000	$75,000	No investment return after five years	No earnings	No down payment and 20% of profits as royalties
2	$50,000	$75,000	4 years	$10,000	No down payment and 20% of profits as royalties
3	$75,000	$115,000	4 years	$17,000	No down payment and 20% of profits as royalties
4	$75,000	$150,000	3 years	$50,000	No down payment and 20% of profits as royalties
5	$50,000	$150,000	3 years	$80,000	$10,000 USD down payment and 20% of profits as royalties
6	$25,000	$150,000	2 years	$174,000	$10,000 USD down payment and 10% of profits as royalties
7	$25,000	$150,000	2 years	$143,000	$10,000 USD down payment and 20% of profits as royalties

Finally, in an R&D+I project scenario where the R&D investment by the university is higher than the investment made by the firm to commercialize the product, the firm will see ROI soon, profits will be obtained since the first or second operation years, and total profits will be high. In such cases, the university must be granted a substantial down payment and/or attractive royalties.

6. Technology Valuation

As can be seen in Tables 5 and 7, the technology valuation for the best financial impedance matching simulations is $40,000 USD; this figure considers one $10,000 down payment plus

20% in royalties over the first five commercialization years, equivalent to $30,000 USD. The total amount can be stated as the price of the technology in the terms of the technology transfer contract, which makes additional negotiations unnecessary since the responsible company officials participate in the execution of the FIMM.

If the firm asks for a *one payment technology sell*, we suggest adding at least $30,000 USD for the commercialization profits of years 15 to 20. This amount assumes that product sales will follow the same trend as they did during the first five commercialization years.

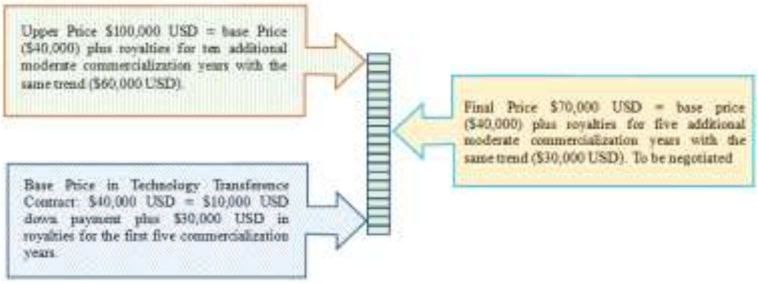

Figure 6. Final technology valuation using the financial impedance matching method (FIMM)

The technology might still survive in the market for some time before its life cycle ends. In such a case, this period can be used for further negotiations. Figure 6 shows the result of this FIMM exercise of technology valuation.

7. Methodology Validation

The FIMM presented in the present paper was applied to the valuation of technology associated with the project described in this section (see Vega-González and Vega-Salinas, 2018).

Technology Transferor: Center for Applied Sciences and Technological Development (CCADET), National Autonomous University of Mexico (UNAM).

Technology Recipient: Name omitted due to confidentiality reasons (private company in the biomedical supplies field, located in Jalisco, México).

Project description: In 2014, medical staff from the maxillofacial department at the Mexican General Hospital (HGM) presented a problem to CCADET´s Technology Research and Development Unit (UIDT): they needed to produce polymethyl methacrylate (PMMA) implants using molds in the hospital. Academic coordinators of the National Laboratory of Additive and Digital Manufacturing (MADiT) established collaboration with HGM doctors, and a solution to manufacture the implants using digital technologies emerged by the end of 2014. The project protocol required testing the molds manufactured with the new technology in hospital patients. Protocol testing was approved by the medical committee, and by the end of 2015, the legal representative of the counterpart firm expressed the interest in obtaining a license to use the manufacturing technology. With the authorization of HGM's research area, the firm and UNAM signed a technology transfer licensing agreement in February 2017.

Intellectual property: UNAM obtained an authorship rights certificate in 2015 for the technical report "Optimization of the manufacturing process for facial-skull implants"; in addition, the UNAM R&D team put together the information elements to produce a special Industrial Secret document to protect the high-quality implant manufacturing process.

Characteristics of the Technology: the technology to manufacture skull-facial implants was developed by MADIT (Institute for Applied Sciences and Technology, ICAT) in collaboration with the maxillofacial surgery medical team from the HGM, where ICAT operates the UIDT.

MADIT promotes research and development in the field of additive manufacturing (design, materials, properties, and processes, among other aspects), 3D scanning, and nondestructive testing for applications in different fields of science. The project intended to use this new technology to replace the old mold manufacturing process used to produce facial skull prosthesis. Before the new technology, PMMA prostheses were elaborated using traditional methods; surgeons had to wait from 15 to 20 days to use the prostheses because the entirely manual process took that long. The surgeon's technical team would make a model of the implant using soft clay and gently adjust it. Then, they elaborated the male or female mold in PMMA and cured it. Regrettably, these implants sometimes required adjustment during the surgery, which made the process longer and more traumatic for the patient. On the other hand, implants produced using additive manufacturing and computerized techniques take only three to four days to be elaborated and tested for use in surgery. No implant rejections have been reported since 2015; the prostheses fit perfectly on patients' skulls.

Technology Transfer Project Milestones: (a) first skull prostheses are used in surgery in late 2013, (b) intellectual property copyrights and trademark are obtained in 2015, and industrial secret protection is obtained in 2017; (c) a five-year Technology Transfer and Licensing Agreement is signed between UNAM and the firm in 2017.

Impacts: the technology recipient firm conducted a market profile study in which an average of 15 to 20 patients per month requiring some type of implant surgery was detected only in the HGM; considering the regional hospitals in Mexico City and other major Mexican cities, the demand is expected to be 150 implants per month, or nearly 1800 implants per year. UNAM reserved its right to moderate the final public price of the implants to make them affordable to the average patient. In addition, a clause in the technology transfer agreement establishes the donation of two implants per year to low-income patients evaluated by social work staff.

FIMM Technology Valuation Results: Contract parts work on the investments and sales expected to define a technology value of $5,000 USD down payment and royalties for 3.5% of net sales (about 15% of the expected profit). At an average price of $750.00 USD per implant, expected sales are $1,250,000.00 USD per year, with expected royalties of roughly $40,000 USD per year. Concerning the social impact of these PMMA digital implants, expectations are that the devices will have been implanted in 1000 patients by 2020.

Disclaimer: during 2017, the firm built a prostheses manufacturing plant, investing more than $150,000 USD in the facilities, plant equipment, and salaries of the specialized personnel required to run the factory. Regrettably, by the time that this paper was drafted, the company had not been able to launch the product due to the long time required to obtain health risk clearance from the Mexican Federal Health Minister.

8. Conclusion

In developing countries, university and company officials focus on their own interests when engaging in technology transfer negotiations. Protecting our organization's business might seem a natural course of action, but it should not affect the common pursuit of a successful technology transfer process. The present article has proposed a different approach—it involves a different mindset in which both parties, the university and the firm, act as a team whose goal is to launch a new technological product into the market to fulfill one or many social needs.

On this basis, the financial impedance matching method presented in the article seeks to engage parties in a common project with a common goal. The methodology is based on an analogy with physical systems, in particular, with the concept of impedance matching used in electrical circuits to optimize energy transfer. The method was employed to simulate the performance of financing in an R&D+I project under different scenarios where project conditions varied. Both parties, the firm and the university, act as the players in the simulation, and they are fully aware of the changes proposed to determine the value of the technology developed by the university.

In conclusion, we were able to use the FIMM in an R&D+I project to valuate university technology. The different results of the simulation help the parties to define the most adequate and fair technology transfer payment terms, overcoming the complex communication problem between the parts.

The most important variables affecting project performance are the excess investment exercised by the firm, expected sales and market behavior, and especially, the expected profits, the number of years to complete the project, and expected time to recover the investment. Naturally, the entrepreneur will be interested in a high return on investment; therefore, a company will tend to make important investments when significant sales are expected. To the extent that escalation and new product development costs are reduced, the financial performance of the project improves. This result is completely consistent with the two major corporate strategies leading to competitive advantage noted by Porter (1985): cost leadership and product differentiation.

The described technology valuation method allows both parties to use a simple tool where different income scenarios are considered in order to balance technology development costs and new product development investment. The result is a technology value that offers both parties a fair return, commensurate with their individual contributions. In addition, this approach to technology valuation can be adopted by universities and collaborating firms to develop mutually advantageous technology transfer contracts.

Notes

Note 1. According to Boer (Op cit, pp. 205), initial sales expectations for new products grow enormously; for that reason, the present study uses a linear function to simulate matching moderately.

References

Boer, F. P. (1999). The valuation of Technology. *Business and Financial Issues in R&D* (pp. 403). John Willey & Sons, ISBN0-471-31638-5

Chang, C. K. N., Shipp, S. S., & Wang, A. J. (2002). The Advanced Technology Program: A public-private partnership for early stage technology development. *Venture Capital, 4*(4), 363-370.

Chesbrough, H. W., Vanhaverbeke, W., & West, J. (2006). *Open innovation: Researching a new paradigm*. [e-book], Oxford: Oxford University Press.

Chiesa, V., & Gilardoni, E. (2015). The valuation of technology in buy-cooperate-sell decisions. *European Journal of Innovation Management, 8*(2), 157-181.

Cohen, W., & Levinthal, D. (1990). Absorptive Capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*, 128-152.

Damanpour, F. (1992). Organizational size and innovation. *Organizational Studies, 13*(3), 375-402.

Douglas, W. (2014). *How to measure anything: Finding the value of "intangibles" in Business*. John Wiley & Sons, Inc., Hoboken, New Jersey

Hunt, F., Thorn, V., Mitchell, R., Probert, D., & Phaal, R. (2007). Internal technology valuation: Real world issues. *PICMET Proceedings* (pp. 1736-1742). August, Portland, Oregon – USA.

Johannessen, J. A., Olsen, B., & Lumpkin, G. T. (2001). Innovation as newness: What is new, hownewand new towhom? *European Journal of Innovation Management, 4*(1), 20-31.

Kaats, E., & Opheij, W. (2014). *Creating Conditions for Promising Collaboration: Alliances, Networks, Chains, and Strategic Partnerships*. Springer Briefs in Business. ISBN 978-3-642-41443-5 (eBook).

Kumar, S., & Phrommathed, P. (2005). New Product Development. *An Empirical Study of the Effects of Innovation Strategy, Organization Learning, and Market Conditions* (p. 201). Springer. ISBN 0-387-23271-0 — ISBN 0-387-23273-7.

Lichtenthaler, U. (2011) Open innovation: Past research, current debates, and future directions. *The Academy of Management Perspectives, 25*(1), 75.

Maietta, O. W. (2015). Determinants of university–firm R&D collaboration and its impact on innovation: A perspective from a low-tech industry. *Research Policy, 44*, 1341-1359.

Park, Y., & Park, G. (2002). A new method for technology valuation in monetary value: procedure and application. *Technovation, 24*, 387-394.

Porter, M. E. (1985). *Competitive advantage: Creating & sustaining superior performance*. New York: The Free Press.

Razgaitis, R. (2009). *Valuation & Dealmaking of Technology-based intellectual property* (p.

626). Hoboken, New Jersey: Wiley. ISBN 978-0-470-19333-4.

Rothwell, R. (1992). Successful industrial innovation: Critical factors for the 1990's. *R&D Management, 22*(3), 221-239.

Rothwell, R. (1994). Towards the Fifth-generation Innovation Process. *International Marketing Review, 11*(1), 7-31. MCB University Press.

Scandura, A. (2016). University–industry collaboration and firms' R&D effort. *Research Policy, 45*, 1907-1922.

Vega-G, L. R., & Saniger, B. J. M. (2010). Valuation Methodology for Technology Developed at Academic R&D Groups. *Journal of Applied Research and Technology, 8*(1), 26-43. México. ISSN 1665-6423

Vega-González, L. R., & Vega-Salinas, R. M. (2018). Overview case analysis applied to Technology Transfer Projects (TTP): Cases of a Mexican Public University. *Journal of Technology Management and Innovation (JOTMI). Número Especial sobre Transferencia de Tecnología, 13*(3), 90-103. ISSN: 0718-2724.

Vega-Jurado, J., Gutiérrez-Gracia, A., & Fernández-de-Lucio, I. (2009). La Relación entre las Estratégias de Innovación: Coexistencia o Complementariedad. *Journal of Technology Management & Innovation, 4*(3), 74-88. ISSN: 0718-2724.

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