Scientific Production and Intellectual Property: Analysis of the Correlations between Evaluation and Valuation of Patents in the Transfer of Technologies in Public Research Institutions

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Abstract

In Brazil, Public Research Institutions (PRI) are agents that promote innovation and technological production. The role of these institutions in social and regional development is to provide scientific and technological production and make it available for productive arrangements. This study aims to relate the evaluation and valuation of patents with the processes of Technology Transfer in Public Research Institutions in Brazil. To justify the execution of the study, it is observed that it is necessary to improve the use of technologies created in PRI so that society can take advantage of the advances promoted in scientific research, and so that the distance between industry and academia is minimized. We researched 30 Public Research Institutions, in five variables collected on the platform of INPI (National Institute of Industrial Property), ESPACENET (European Patent Office) and BDTD (Brazilian Digital Library of Theses and Dissertations). In possession of the data, the Shapiro-Wilk test and the Spearman correlation coefficient were used used to analyze them. The R software was used to apply the statistical methods. For data discussion, the reports of FORMICT (Information Form on Intellectual Property Policy of Scientific and Technological Institutions) were analyzed to guide the arguments. The data did not show normality and have moderate and strong correlations, the significance of the correlations is strong or very strong. It is believed that the patent evaluation and valuation processes have space for improvement and thus can enhance the Transfer of Technologies of PRI.

Keywords: Patents; Technology Transfer; Patent Evaluation; Patent Valuation; Public Research Institutions;

1. Introduction

In Brazil, Public Research Institutions (PRI) are agents that promote innovation and technological production. The role of these institutions in social and regional development is to provide scientific and technological production and make it available for productive arrangements, in a feedback process involving government, companies and Public Research Institutions (SEGATTO-MENDES; SBRAGIA, 2002). In this line, it is observed that the process of partnerships is essential to raise funds for technological development and to finance investments in new scientific research. The connections between PRI and companies are under discussion and under development in Brazil, so it is necessary to raise awareness of this importance for local and regional development (MÜLLER; STRAUHS, 2019).

The Technology Transfer process (TT) is a growing topic in the academic environment. As argued, the partnerships between Public Research Institutions and companies are important and are effective based on Technology Transfer contracts. TT is defined by Lima (2004) as the way to acquire and use technologies generated by third parties. In the literature there are obstacles in the TT process in Brazil, in which discussions about profit and knowledge are placed on the agenda (CONDE, 2003; ANDREASSI, 2006).

Among the PRI, the participation of universities in innovation processes and Technology Transfer stands out. Universities have the role of encouraging the creation process, emphasizing that the Technology Transfer processes promote the social reach of what is developed in the research environments (UNGUREANU; POP; UNGUREANU, 2016). It is noteworthy that with TT inventors can obtain gains from the commercial exploitation of technologies, in addition to benefiting the ecosystem to which it is inserted (SOARES, 2018). However, it is observed that as PRI produce patents, strategies are needed for them to profit.

This study aims to relate the evaluation and valuation of patents with the processes of technology transfer in Public Research Institutions in Brazil. To justify the execution of the study, it is observed that it is necessary to improve the analyse of technologies created in PRI so that society can take advantage of the advances promoted in scientific research, and so that the distance between industry and academia is minimized.

The aim is to suggest improvements the processes for evaluating and valuing patents to increase the effectiveness of technology transfers. The discussion covered in this article is based on the rate of use of technologies in commercial terms and on scientific production on intellectual property, patents, patent evaluation and patent valuation, with observation of the technology transfer phenomenon. According to Prado (2018), there is a structural process to obtain TT results (Figure 1).

Figure 1. Summary Technology Transfer Management Model
Source: Adapted from PRADO (2018)

2. Theoretical foundation

In 2020, according to data from the Ministry of Education, Brazil has more than 661 Federal Institutes of Education, Science and Technology, and about 69 Federal Public Universities. These institutions are a sample of the research and development potential that the country has, considering the existence of other Public Research Institutions. This potential should be monitored and evaluated, in this reasoning, the Information Form on the Intellectual Property Policy of Scientific and Technological Institutions (FORMICT) has the purpose of presenting numbers that guide and record these actions. FORMICT, linked to the Ministry of Science and Technology of Brazil, provides the numbers of Technology Transfers carried out by the PRI that participated in the research, and in 2018 it reached an amount of R $ 1,054,747,338.11 in TT.

To put it in context, INOVA-UNICAMP, the Center for Technological Innovation at the University of Campinas (UNICAMP), presents in data collected in May 2020, that with 131 current licensing contracts, the Institution raised R $ 1,607,722.00 in terms of financial gains. INOVA-UNICAMP, through its website, reports the number of 815 daughter companies, 31,343 jobs generated in the daughter companies and revenues of more than R $ 7.9 billion in these companies.

The approach of the TT process depends on the assessment and valuation of technologies, in short, the combination of these forms of analysis of intangible assets are ways to overcome bureaucratic barriers. In this sense, Abreu Júnior (2019) proposes a model for the Technological Innovation Centers (NIT) to expand TT. The author mentions the creation of support foundations with its own legal nature, non-profit to facilitate bureaucratic procedures. Livesey (2014), in a survey with 33 NIT (Technological Innovation Centers), reports that TT is not commonly used in universities as a strategy for harnessing technological potential, and that funding is not adequate for the development of projects.

The use of indicators in TT is beneficial for monitoring results and promoting improvements. It is observed that simple and complex indicators can promote a better understanding of the production and use of technologies (CHAPPLE et al., 2005; VINIG, LIPS, 2015; BUENO, TORKOMIAN, 2018; MARQUES, 2018). The monitoring of these indicators can indicate the generation of value in scientific production, attributing gains to society. The indicators show positive and negative factors in the development and maintenance of technologies. In this sense, it is highlighted that the search for indicators for the evaluation of patents and technology transfers can contribute to the understanding of the successes and mistakes made in scientific and technological development.

In terms of patent evaluation, it is highlighted that the models, in a more general view, can be divided into three categories: models of accounting assets; models with cash flow discount techniques and market-related valuation models (MARTINEZ, 1999; FAMÁ, 2003). There are several models of technology assessment that relate to different purposes of assessments, that is, the models depend on which types of technologies will be applied.

As an example of models found in scientific publications, we have the model proposed in the article “Forecasting of emerging therapeutic monoclonal antibodies patents based on a decision model”, the study reports on the creation of a score to classify patents for therapeutic monoclonal antibodies that have potential in biotechnology, with the aid of hierarchical analysis (PEREIRA, CG et al, 2019).

That said, it is observed that the negotiation of technologies depends on a facilitating ecosystem and it is up to the owner of these patents to carry out evaluative and valuative studies. The purpose of these potentiality studies is to amplify the obtaining of revenue, or even to avoid losses in the exploration (FREITAS, 2019). In this sense, evaluation of a technology can establish indicators of research potentiality.

In terms of patent valuation, it is observed that it must be preceded by evaluative aspects (SANTOS; SANTIAGO, 2008a). The valuation seeks adequate values so that the technologies give the expected return, analyzing it in terms of commercialization and investment risk (SANTOS; SANTIAGO, 2008b). Hagelin (2002) highlights factors of approach to the valuation of a patent, they are: 1) Assess the existence of a market for technology; 2) Analyze similar transactions in the market; 3) Analyze prices of similar technologies; 4) Has independence between the assignor and the assignee. In addition, the technology assessment and valuation processes promote the potentialization of patents, in addition to solidifying the negotiation arguments.

3. Methodology

Documentary research was used in open access databases with a quantitative approach. Public Research Institutions (PRI) were analyzed in the following categories: 1 - Number of publications of Theses and Dissertations; 2 - Number of Theses and Dissertations dealing with Intellectual Property or Patents; 3 - No. of Theses and Dissertations with Approach to Patent Evaluation or Valuation; 4 - Number of patents deposited; 5 - Number of Technology Transfers made. Each item received a nickname for identification as a variable (Table 1). The sample was selected using the annual report of the National Institute of Intellectual Property - INPI, selecting PRI with a significant number of patent registrations.

Table 1. Identification of the study variables

QUESTION	VARIABLE
1 - Number of publications of Theses and Dissertations	QTD
2 - Number of Theses and Dissertations dealing with Intellectual Property or Patents	QPIPAT
3 – Number. of Theses and Dissertations with Approach to Patent Evaluation or Valuation	QAVAVAL
4 – Number. of patents filed	QPAT
5 – Number of Technology Transfers made	QTTPAR

Source: Elaborated by the authors (2020)

Thirty (30) Public Research Institutions (PRI) were selected, as shown in Table 2. In the sample criteria, we sought PRI from different regions of Brazil that were among the 30 PRI that most deposited in the years 2016, 2017 and 2018 and that had more than 1000 publications of Theses and Dissertations. The Brazilian Digital Library of Theses and Dissertations - BDTD was used to collect the number of publications of Theses and Dissertations, since it has 118 institutions registered in its database, with approximately 639,025

thousand documents. PRI that did not have data registered, sought the data in the institution's repository. Filters were applied to select the data of interest, selecting the total numbers of each PRI, and later, applying the following filters with Boolean logic: 1- (All fields: Intellectual Property OR Patent *); 2- (All fields: (valuation OR evaluation) AND patent *).

Table 2. Public Research Institutions selected for the study

PUBLIC RESEARCH INSTITUTIONS	**BRAZILIAN REGION**	**AMOUNT**
Universidade Federal de Goiás	Midwest	3 (10%)
Universidade de Brasília	Midwest	
Universidade Federal de Mato Grosso	Midwest	
Universidade Federal da Bahia	Northeast	10 (33,3%)
Universidade Federal de Pernambuco	Northeast	
Universidade Federal do Piauí	Northeast	
Universidade Federal de Sergipe	Northeast	
Universidade Federal do Rio Grande do Norte	Northeast	
Universidade Federal da Paraíba	Northeast	
Universidade Estadual do Ceará	Northeast	
Universidade Federal Rural De Pernambuco	Northeast	
Universidade Federal de Campina Grande	Northeast	
Universidade Federal do Maranhão	Northeast	
Universidade Federal do Pará	North	3 (10%)
Universidade Federal do Tocantins	North	
Universidade Federal do Amazonas	North	
Universidade Estadual de Campinas	Southeast	8 (26,7%)
Universidade de São Paulo	Southeast	
Universidade Federal de Minas Gerais	Southeast	
Universidade Estadual Paulista	Southeast	
Universidade Federal de Alfenas	Southeast	
Universidade Federal de Juiz de Fora	Southeast	
Universidade Federal de Ouro Preto	Southeast	
Universidade do Estado do Rio de Janeiro	Southeast	
Universidade Federal de Santa Catarina	South	6 (20%)
Universidade Federal do Rio Grande do Sul	South	
Universidade Federal de São Carlos	South	
Fundação Oswaldo Cruz	South	
Universidade Federal de Viçosa	South	
Universidade Tecnológica Federal do Paraná	South	
TOTAL		**30 (100%)**

Source: Elaborated by the authors (2020)

To obtain the number of PRI patents, the INPI database was used. In terms of TT, the data made available by the Innovation Centers of each PRI was observed, however, when the information was of restricted knowledge, the INPI bases were used to search for Technology Transfer (TT) and the databases from ESPACENET (European Patent Office) to investigate PRI partnerships with companies. Thus, the number of TT considered in the first order was informed by the Innovation Centers, and in second order, the patents developed in association with companies. The data found at the INPI in the TT databases were disregarded because they did not present values close to those reported by the Innovation Centers.

With the data in hand, the Shapiro-Wilk normality test was performed to observe the sample's distribution characteristics. Shapiro and Wilk (1965) originally tests the normality of samples smaller than 50. The test is defined by:

$$W = \frac{(\sum_{i=1}^{n} a_i x_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Royston (1995) provided a study using the AS R94 algorithm for the test to be applied to samples with $3 \leqslant n \leqslant 5000$. The calculation of the p-value depends on the sample size (Shapiro & Francia, 1972). R software was used for statistical calculations. The tested hypotheses were: H0 = Normal Distribution and H1 = Other Distribution are adopted.

Spearman's correlation coefficient was used to understand the possible relationships between the 5 variables studied. Spearman's correlation coefficient measures the relationships between variables with a trend scale ranging from -1 to +1. A positive relationship shows that the data increases or decreases together, and a negative relationship, that the data progresses in opposite directions (ROQUE, 2003).

Siegel (1975) reports that Spearman's correlation coefficient is a non-parametric measure defined by:

$$r_s = 1 - \frac{6\sum_{i-1}^{n} d_i^2}{n(n^2-1)}$$

In Spearman's correlation coefficient, for samples with observations greater than 10, significance can be estimated with the p-value (SIEGEL, 1975). To describe the degree of correlation between the variables, the scale described in FOWLER; COHEN and JARVIS (2013) was used, according table 3.

Table 3. Spearman's correlation coefficient values

Value of coeficiente (positive or negative)	**Meaning**
0.00 to 0.19	very weak correlation
0.20 to 0.39	weak correlation
0.40 to 0.69	moderate correlation
0.70 to 0.89	strong correlation
0.90 to 1.00	very strong correlation

Source: FOWLER; COHEN and JARVIS (2013)

In Spearman's correlation test, H0 = No significant correlation is assumed and H1 = There is correlation. The p-value is used to estimate the probability of this correlation being random, as shown in table 4, the p-value to estimate significance in rejecting H0, that is, the more the p-value is close to 0, the more significant

it is the correlation.

Table 4. Significance values for correlation probability

P-value	**P-value %**	**Evidence for rejecting H_0**
> 0.1	>10%	Very weak
0.1 - 0.05	10%-5%	Weak
0.05 - 0.01	5%-1%	Strong
< 0.01	<1%	Very strong

Source: FOWLER; COHEN and JARVIS (2013)

To discuss the results found, the FORMICT reports (Intellectual Property Policy of Scientific, Technological and Innovation Institutions in Brazil) for the years 2016, 2017 and 2018 were analyzed. The report presents the consolidated data provided by the Scientific, Technological and of Innovation (ICT) to the Ministry of Science, Technology, Innovations and Communications (MCTIC) on the Intellectual Property Policy of institutions in Brazil. It focused on data from Public Research Institutions. Figure 2 presents a summary of the methodology.

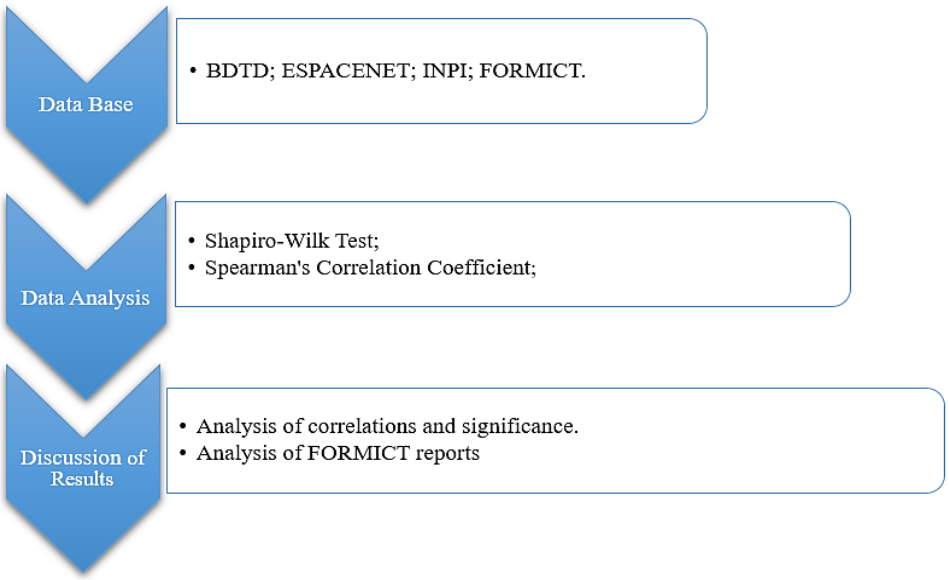

Figure 2. Summary of methodological steps
Source: Elaborated by the authors (2020)

4. Results and Analysis

The data, in a brief descriptive analysis, reflect the economic, social and geographical differences in Brazil. Some institutions have numbers of publications of theses and dissertations far above the average, while others have numbers up to 80 times lower. The number of patents and technology transfer follow visible variations. Table 5 describes the data statistically.

Table 5. Descriptive data analysis

	Mean	**SD**	**Median**	**Min**	**Max**
QTD	15198.37	18863.7	7299.0	1046	88662
QPIPAT	53.87	56.5	33.5	1	265
QAVAVAL	7.45	8.8	5.0	0	40
QPAT	323.5	354.6	228.0	14	1403
QTTPAR	23.57	45.48	6.5	0	197

Source: Elaborated by the authors (2020)

To test the compliance of the data in a normal distribution, the Shapiro-Wilk test was applied in software R. Figure 3 shows the scatter plots around the mean and the p-value of the Shapiro-Wilk test. $\alpha = 0.05$ was adopted to establish statistical significance for normal distribution. As shown in Figure 3, the p-value is less than the value of α, rejecting H0 and assuming that the data do not have a normal distribution for all variables. It should be noted that the Outliers were included because they are important for the study.

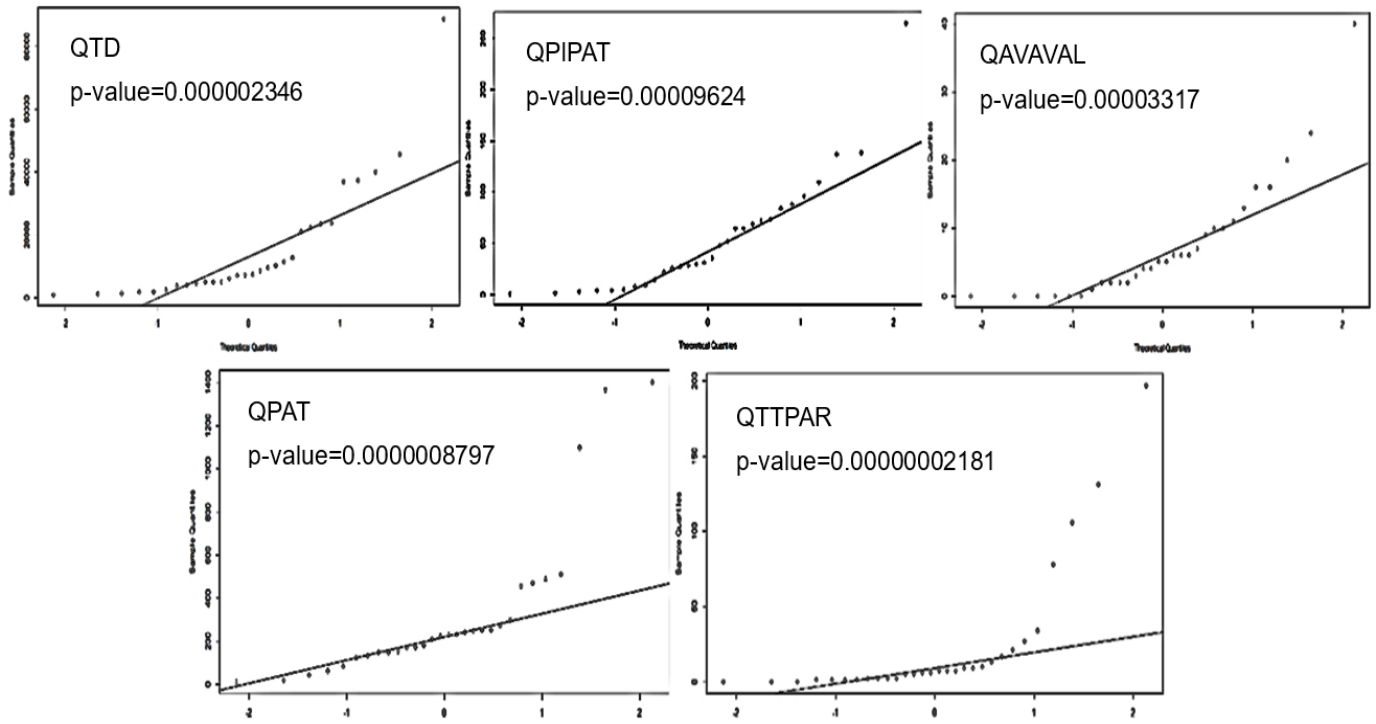

Figure 3. Graphs of the Shapiro-Wilk test and p-value of the variables

Source: Elaborated by the authors with survey data (2020)

With the convention of a different distribution than normal, Spearman's correlation coefficient was chosen to analyze the relationships between variables. With the application of the method, a graphical correlation matrix was generated to illustrate the results obtained (Figure 4). The figure shows the variables studied and the coefficient values that can range from -1 to +1. The greater the relationship between the variables, more the number tend to blue. And the more it tends to the negative value of the correlation (-1), the more the color approaches red. The white color means neutrality (0).

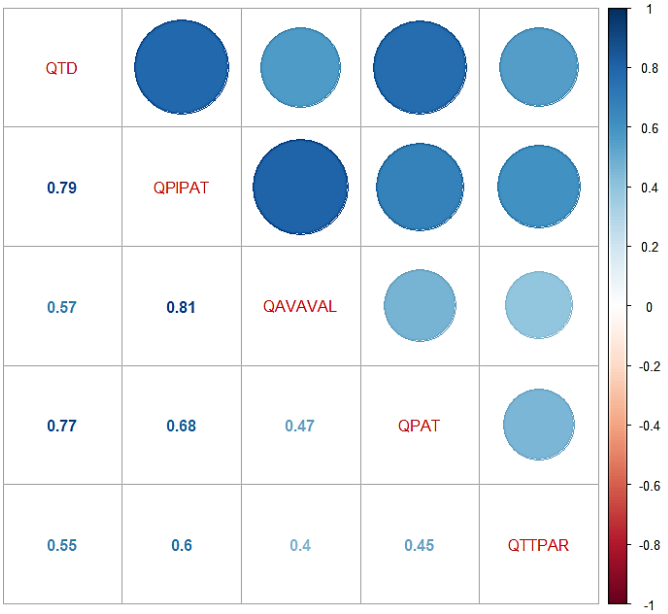

Figure 4. Correlation matrix of the studied variables
Source: Elaborated by the authors with survey data (2020)

The correlation coefficients found are moderate to strong. Strong correlation results are presented between the variables QTD - QPIPAT, QTD - QPAT and QPIPAT - QAVAVAL. In other words, the more scientific knowledge is produced, the more it is necessary to know about Intellectual Property, and the more it is necessary to protect in the form of a patent. It is noted, in a strong relationship, that the more you study about Intellectual Property and patents, the more it is necessary to study how to evaluate and value these technologies.

The results show moderate correlations for most variables. The moderate correlations are: QTD - QAVAVAL, QTD - QTTPAR, QPIPAT - QPAT, QPIPAT - QTTPAR, QAVAVAL - QPAT, QAVAVAL - QTTPAR and QPAT - QTTPAR. It is noted that with the increase in scientific production, moderately, there is an increase in the work on the evaluation and valuation of patents, and an increase in the amount of Technology Transfer (TT). In continuity, when analyzing the scientific production related to Intellectual Property and patents, the number of patents and TT is moderately increased.

The results referring to scientific production on the evaluation and valuation of patents show that the greater the production, the greater the quantity of patents and Technology Transfer, in a moderate way. Finally, the number of patents moderately influences TT. Table 6 summarizes the degrees of correlation.

Table 6. Degrees of correlation between variables

Correlation	Meaning
QTD - QPIPAT; QTD - QPAT; QPIPAT - QAVAVAL.	STRONG CORRELATION
QTD - QAVAVAL; QTD - QTTPAR; QPIPAT - QPAT; QPIPAT - QTTPAR; QAVAVAL - QPAT; QAVAVAL - QTTPAR; QPAT - QTTPAR.	MODERATE CORRELATION

Source: Elaborated by the authors (2020)

The results regarding the significance of the correlations were classified as strong and very strong, therefore, the correlations found by means of Spearman's correlation coefficient have statistical significance and can be considered relevant for the study. Figure 5 presents the histograms of the variables, the bivariate dispersion graphs, the correlation coefficient and the indicators of significance (p-value).

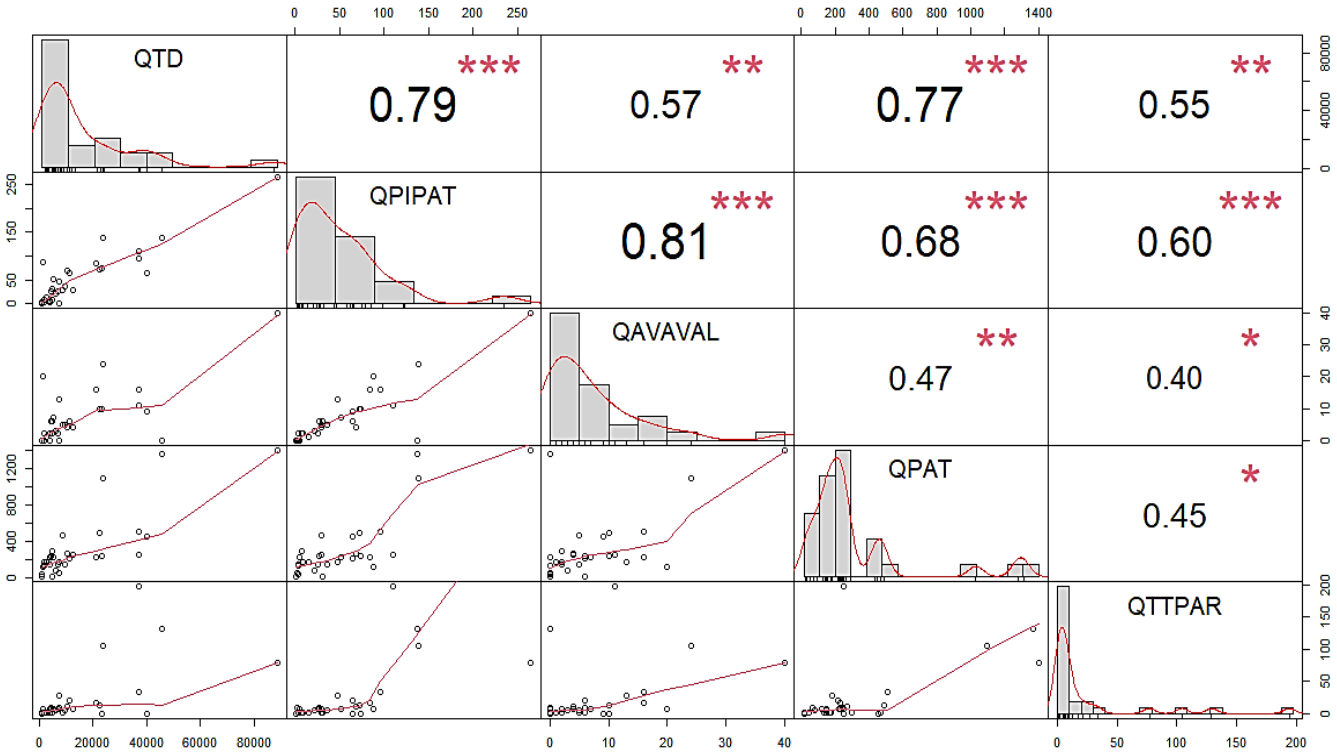

Figure 5. Histograms, bivariate dispersion, Spearman correlation coefficient and significance of the correlation

Source: Elaborated by the authors (2020)

*** Extremely Significant (Very Strong, p <0.001) ** Very Significant (Very Strong, 0.001 <p <0.01) * Significant (Strong, 0.01 <p <0.05)

The correlations with the publications of Theses and Dissertations are significant in the studied variables, with emphasis on the production of studies on Intellectual Property and on the production of patents. The variable Number of publications related to Intellectual Property or patents correlates with extreme significance with all the variables studied, showing that Intellectual Property can represent a link between the variables. The variable of Number of publications on patent evaluation or patent valuation is extremely significant with the production on Intellectual Property or patents, and in decreasing order of meaningfulness, with the number of theses and dissertations, the number of patents and the number of technology transfers.

Patents have an extremely significant correlation with scientific publications in the researched institutions. As patents are produced, interest, in decreasing order, in evaluation and valuation and technology transfer increases. When it comes to Technology Transfer (TT), as institutions study Intellectual Property and Patents, this variable increases, and to a lesser extent, institutions seek or perform TT, increase their studies on patent evaluation and valuation, as well how they increase their technological portfolio. Table 7 summarizes the significance of the correlations.

Table 7. Degrees of meaningfulness between variables

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Correlation	Meaningfulness
QTD - QPIPAT; QTD - QPAT; QPIPAT - QAVAVAL; QPIPAT - QPAT; QPIPAT - QTTPAR;	VERY STRONG
QTD - QAVAVAL; QTD - QTTPAR; QAVAVAL - QPAT; QAVAVAL - QTTPAR; QPAT - QTTPAR.	STRONG

Source: Elaborated by the authors (2020)

4.1 Discussion of Results

This section addresses a discussion of the results obtained. There are institutions with a high number of publications and patents, however, a low number of publications on evaluation and valuation and Technology Transfer, and some institutions have a high number of patents and, however, have a low number of theses and dissertations and Transfer of Technologies.

Due to this specific difference in each institution, it chose to analyze the normality of the data and the use of the chosen methods. Through these choices, it is possible to analyze, in general, the correlations and the possible influences between the variables and thus suggest improvements in the processes of evaluation, valuation and Technology Transfer. Although an abnormality was found in the distribution of data, significant relationships can be observed on the analyzed data. For ethical reasons, the data found is not

exposed, and as they are of great value, a new article is needed to present PRI efficiency rates instead of the data.

In order to elucidate the data and strengthen the argument of the need to evaluate and value technologies with more dense means, some data collected from the FORMICT report (Intellectual Property Policy of Scientific, Technological and Innovation Institutions in Brazil) of the years 2016 to 2018 was analysed. Table 8 presents data on the number of institutions surveyed and which of these report having TT.

Table 8. Degrees of meaningfulness between variables

Year	**Sample of RPI**	**Number of Public Institutions with TT**	**% of Institutions with TT**
2016	193	42	22%
2017	212	39	18%
2018	209	47	22%
		Average	20,7%

Source: Elaborated by the authors with FORMICT data (2020)

From the data observed in the report, there is an average of 20.7% of PRI between the years that report having performed TT processes. Taking into account that it is a sample survey and that the number of IPP in Brazil is much higher, it leads to believe that this TT process should be improved. It is observed in the data found in the research, that some institutions have greater weight in terms of efficiency in the process of using patents. An example in the data found is the case of the Federal University of Santa Catarina, which when compared to the number of patents with the amount of TT, PRI has a utilization of 78% of its technologies in the form of TT.

From a financial perspective, although the TT numbers are low, the values from these technologies are considerable. It is believed that the management models used in the technological portfolios have technologies that generate significant dividends for PRI. It is noteworthy that for a good advantage of a technology, the processes of creation, development and economic exploitation must be linked to the evaluation and valuation processes of these technologies, as exposed in the results of the correlation between the variables. With this, the PRI can generate contracts with well-founded negotiations, choosing to commercialize the technologies exclusively, without exclusivity, or other form of agreement. Figure 6 shows the evolution of gains from the exploitation of technologies by PRI.

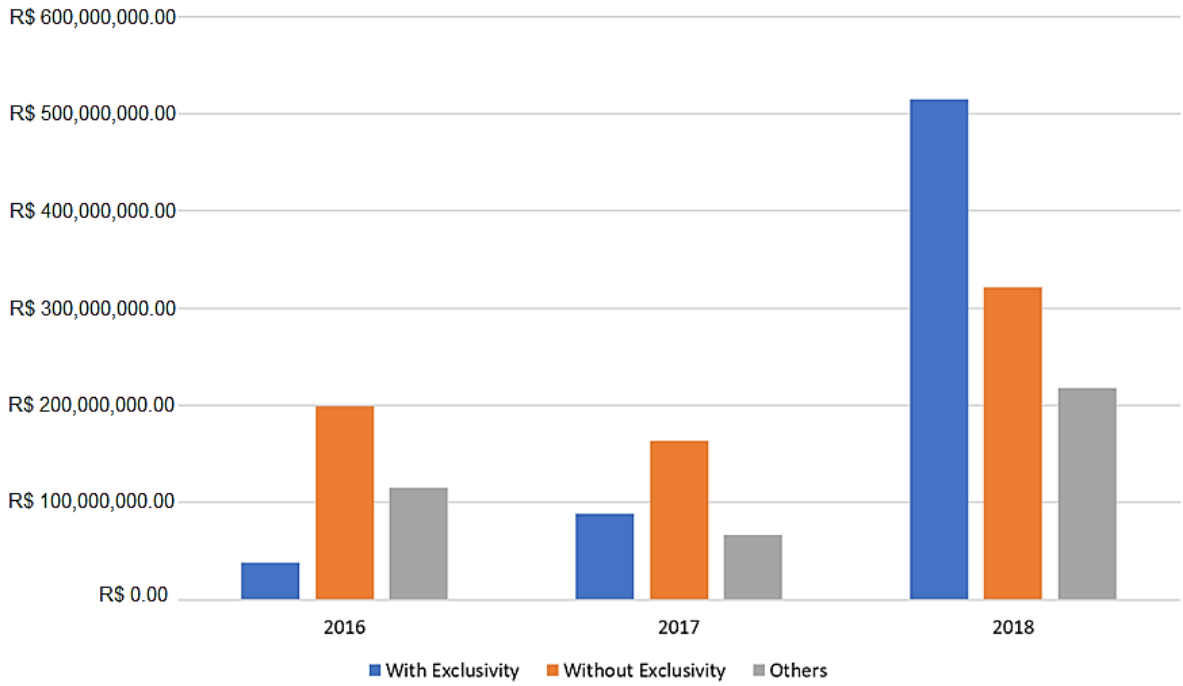

Figure 6. Evolution of gains with TT by PRI from 2016 to 2018
Source: Elaborated by the authors with FORMICT data (2020)

With the visualization of the data, between the years 2016 and 2018 there was an increase in the gains of PRI that managed to commercialize their technologies. The values reflect that with efficient processes, expressive results can be obtained. In a comparison with the data obtained with the relationships between the studied variables, it is observed that the Technology Transfer and Patent Evaluation and Valuation processes are crucial to enhance the exploitation results of the technologies, and in a greater result, achieve social arrangements such as products and services.

The correlations found in this study do not imply causality, that is, it does not mean that the variables can cause the others, or cause a Technology Transfer (TT) phenomenon. What is indicated is that, statistically, the variables have a relationship and that they must be discussed and implemented by the PRI managers so that they can evaluate the effectiveness of the actions carried out by them.

5. Final considerations

Based on the researched sample and the results obtained, it is concluded that the correlations between scientific production of theses and dissertations, production on Intellectual Property or patents, production on evaluation and valuation of patents, production of patents itself and the realization of Transfer of Technologies are moderate to strong. The significance of these correlations, as approached statistically, ranges from strong to very strong, that is, it can be concluded that there is relevance in the approach observed at work. It should be noted that productions on Intellectual Property are a key point for the creation of patents and technology transfers (TT), in which the more one understands about the process, the chances of creating partnerships that return gains are increased.

The creation of patents becomes a way to enhance the capillarity of PRI in productive arrangements,

however, it points to the processes of evaluation and valuation of patents as facilitating mechanisms for the process of transferring these technologies. It is considered that it is necessary to expand scientific production aimed at the evaluation and valuation of patents to improve the processes of creating patents with market potential, since the moderate correlations are concentrated in the relationships between these variables.

As stated in the paper, citing the case of INOVA-UNICAMP, it is observed that the gains for the University are in the millions, while the value generated by companies from technological production, are in the Billions. These values are extraordinary at the level of Brazil, however, we emphasize that with the improvement of assessment, valuation and Technology Transfer processes, these gains can be leveraged for PRI, and thus can generate the investment feedback process.

It is suggested that researchers evaluate the innovation processes of their institutions and may suggest adjustments, including the scientific knowledge already published on the subject. Observing the specificities of the institutions and their regional and economic context is also a necessity to accurately diagnose the details of PRI.

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