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ARTICLE

A Novel Method for Assessing the Impacts of Innovation and Technology Transfer: A Case Study of Brazilian Manufacturers in the Electric Energy Sector

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ABSTRACT

This study aims to identify and evaluate the impacts and the results of the innovation and technology transfer process (ITT) in Brazilian manufacturers in the electric energy sector. For this purpose, first, the actions to assess ITT were described, in sequence, the factors involved in it were identified and the critical points were diagnosed. From the previous factors properly determined, then a quantitative research methodology for assessing ITT impacts, which uses data from a questionnaire with specialists of Brazilian industries involved in the projects, was applied. Afterward, a sequence of T-tests is carried out to validate the hypotheses established, by using the survey's results. The results indicated that the Brazilian industries have not a model to assess the projects and their respective impacts caused by it, and then the proposed methodology can overcome this gap and it can be used effectively in a practical manner.

KEYWORDS

Innovation and Technology Transfer, Impacts of Innovation, Nationalization, Assessment Factors, Electric Energy Sector

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1. INTRODUCTION

The technological advance of the industries in their research and development centers has been a highlight for sustainable economic growth around the world. Due to a large number of technologies in the creation and innovative products, multinational companies must develop processes for transferring science, new products, knowledge, new processes, and technology in search of the nationalization of innovation and gain in the increase of competitiveness. Therefore, Innovation and Technology Transfer (ITT) in developing industries evolve into a powerful instrument for companies or countries to obtain the technologies they need for their growth. (Braga et al., 2009).

The ITT, especially for developing countries, has a high rate of unsuccessful deployment due to many aspects. In its deployment process in such countries, a failure sometimes is tragic, as the financial resources of these places are very scarce, and the deficiency of technological location prevents basic needs. Furthermore, the failures constantly create the idea of an inevitable finding that nothing in the destination location works. One of the main reasons for ITT failures is the lack of assessment of technology needs and their impacts on many aspects of society. (Hübler & Finus, 2013).

When deciding to transfer from a developed country to a developing one, the companies should consider much more than just the costs and benefits that come with buying and receiving the product/technology. In addition to the "difficult" technological features related to the project itself, many factors must be considered, including the environment in which the technology is intended to function, equipment handling skills, technology spare parts, maintenance expertise, organization, management, and procedures. The introduction and transfer of technical knowledge, used in the development of new products or processes, between organizations may be incorporated into production equipment or manufactured goods. (Rood, 2018)

Taking into account this scenery, ITT has emerged as a recent and relevant research topic among business, industry, non-governmental business, government, and, of course, the academic community. (Boddewyn, 2016). The development, trade, and application of these new technologies in developing countries bring new ways of exploiting technological assets resulting in increased profitability and multidimensional global growth due to the exploitation of assets.

ITT has been recognized as a useful approach for gaining a competitive advantage over other organizations in their supply chains. In Brazil, a developing country, the Law of Innovation (Law 10,973/2004) came to encourage and facilitate the innovation process in which different interaction strategies are used to stimulate the production, market, and institutional arrangements using technological solutions through technology transfer contracts (Cirani, 2016). The ITT is used as a tool in an attempt by two organizations to pursue a common goal, resulting in the satisfaction of the parties involved.

Despite the benefits of ITT, some authors believe that the principal obstacle of this process is the lack of physical, human, and socio-economic infrastructure, which cannot guarantee the sustainable use of the process by industries. (Giuliani & Macchi, 2014). However, other authors state that in this competitive and constantly evolving market, the transfer is an effective part of companies' technological and corporate strategies.

The ITT effectively occurs through the sharing of innovation. The process usually starts and is developed either in a government agency and/or in a private organization. In negotiations between private organizations, it must be taken into account whether these are from industrialized or developing countries for decision-making (Fernandes & Machado, 2019) . Furthermore,

the process is based on the development of technology where the technological paradigms are modified by the innovation of processes, products, or technological diffusion.

The representation and development of responsibilities are divided between supply-side and demand-side institutions. These institutions seek new "consumers" for the technology they have developed. Besides, the technological demand institutions operate in firms with technological needs and seek to bring the appropriate technology to them. However, the literature does not specifically mention the lack of information infrastructure, and they hardly report the need for specialized information services or information professionals to increase and facilitate the flow of scientific and technological knowledge between the research and economic sectors.

The manufacturing field has documentation, software, and codified knowledge as the central elements for transferring, making it a largely neglected and unexplored area in technological transfer studies. Thereby, needs assessment, to evaluate the real needs of technology users, should be the first step in the ITT process. The requirements must be identified and the performance of the characteristics mapped. Focusing primarily on ITT, between economies and within developing countries, they focus on the company level and encompass the wide range of technologies that support community and regional, national, and international development policies.

A key element for the ITT project has successful is related to the identification, characterization, and assessment of five main factors and their impacts involved in ITT within the industry, which includes the economic, social, cultural, technological, and environmental aspects.

Thus, in this article the research question is as follows: *Do the Brazilian companies apply a methodology to evaluate ITT projects impacts regarding the five factors implicated in them?*

To respond to the research question, first, an investigation about the factors established is conducted. Specifically, the aim is to investigate whether Brazilian manufacturers are analyzing and assessing such aspects before transferring innovation and technology to be commercialized. The methodology proposed is based on three pillars: 1) a method for collecting information, 2) a survey conducted in multinational Brazilian companies and 2) a statistical model for result analysis.

2. ITT AND ASSESSMENT INDICATORS

Innovation is an essential element for both the survival and competitiveness of business organizations. Innovation usually refers to a tool used by entrepreneurs in exploiting opportunities for many types of business operations, whereby entrepreneurs consciously make smart choices about the ideas, or sources of innovation, which can deliver desired outputs (Lopes, 2018).

The innovation success can be measured utilizing a company's process, product, marketing, and managerial innovation. However, the study scope definition is focused only on the impacts of products and process innovation in those five main indicators previously established.

The form of ITT impact depends on the degree of influence and the environment. By definition, innovation inherently has a certain degree of direct impact, which is always related to the proposed function of the basic technology. The true impact of innovative technology is perceived and assessed through the capabilities it improves and by using adequate indicators. (Guan, 2006). Therefore, the five indicators (economic, social, cultural, technological, and environmental aspects) adopted for assessment and measuring ITT projects, the respective hypotheses formulated are introduced in this section, as well as the proposed research model.

2.1. Innovation and Technology Transfer

ITT is not defined just like the transference of knowledge from one nation to another. It is a transfer method of any set of scientific progress from one company to another focused on expanding the innovation potential (Audretsch et al., 2014). However, technology transfer is not simply a movement or transfer innovation, it is a dynamic, complex, and multidisciplinary method whose success owes to circumstances coming from sources.

ITT also is recognized as a field where a succession of activities that require a multidimensional strategy and interaction tools between two or more companies during a piece of knowledge or technical generating a method to create a new process or product (Gervais et al., 2015).

ITT has contributed to the appearance of many definitions and concepts (Rodrigues Fernandes, 2019). However, the conception of transfer technology includes using, mobilization, employment, exchange, development, and management related to service, technology, product, and knowledge.

Definitively, the ITT processes are constantly reshaping in a continuous transition with four actors, enabling interfaces involving: industry-industry, industry-university, government-government, and university-government. Nevertheless, the relationship between industries plays a key role in ITT around the world.

Taking into account the ITT models, many of them have been developed over the years to help the companies to decide on the best model to plan and deploy ITT projects effectively. The models are classified as qualitative and quantitative models.

Qualitative models refer to those methods whose main goal is to delineate the activities involving in ITT management and the elicitation of elements and concerns that impact the success and effectiveness of ITT (Iyer & Banerjee, 2018), and (Khabiri et al., 2012). While the quantitative models, instead, aim at quantifying the meaningful parameters in the ITT process, such as the quantitative model based on the concept of a Potential Technology Distance (PTD) parameter between a transferor and transferee was proposed in (Sharif & Haq, 1980). However, a review of the extant literature indicates that the assessment of ITT projects' impacts in developing countries has been much discussed but little understood, especially in terms of quantitative analysis of indicators, such as proposed in this research.

2.2. Economic Impacts

As Schumpeter's view on Innovation and Entrepreneurship, the economy of each country can be positively impacted by innovation in many manners locally, regionally, nationally and/or globally. Most accurately, the economic effect is seen through the addition of new markets that sometimes is generated by radically disruptive technology, by an enlargement of the efficiency in many processes, or by the incremental changes in manufacturing.

Innovation is the main source of economic growth, job creation, and competitiveness in today's global economy, as reported by the former US president Barack Obama. There is no doubt that world-class companies generate more than profits. They are constantly innovating and can promote economic growth, employment, and significantly improve people's quality of life (Hall & Rosenberg, 2010). Sustained economic growth promotes long-term stable growth of per capita income, and innovation is especially important for people who form the basis of the economic pyramid.

The correlation between innovation and economic progress is broadly investigated. However, it does not mean that people have a good understanding. Numerous researchers already mentioned that those who do not trust that innovation will harm employment opportunities have no experience to support it. Indeed, the evidence points in another direction and establishes a

positive relationship between employment and innovation (Ribeiro et al., 2019). It is competitive in many sectors, generates income, and improves lives.

Different types of innovation usually lead to different economic outcomes. Process innovation can improve the production efficiency of products and services, while product innovation can improve quality, expand product categories, and even open up new markets. They have different employment outcomes: process innovation can boost productivity and substitute labor, while product innovation has the potential to generate new jobs by establishing new customers or extending existing ones (Edquist et al., 2001).

The impact of innovation on the economy can be measured using several metrics, such as the number of exports, wages, sales, value-added per employee, and so on. Innovative firms are usually more competitive at the global level and can export more, and consequently, due to their high productivity, they pay higher salaries.

Considering the current scenery of ITT in companies and the economic impacts as aforementioned, the proposed qualitative study is based on the economic aspect of the projects, which is the key element for decision-making. Therefore, the economic dimension is the main variable, its aspects are shown in Table 2, and the other hypotheses are formulated regarding such a premise.

2.3. Social Impacts

The social growth promoted by ITT is accountable for sustainable expansion, notably in the global South. Since the 1990s, an estimated 1 billion people have avoided severe poverty, 2.1 billion people have reached greater cleanliness, and more than 2.6 billion people have access to better suitable water sources (Assembly, 2013). Over the past three decades, the global under-five mortality rate has dropped significantly from 91 per 1,000 live births to 43, as well as other social advancements are reported today.

Taking into account such advances, ITT has played a crucial role in this advancement. Innovative technologies are helping citizens and governments to interact with each other more effectively and increasing the range and efficiency of public services. As the penetration rate of telecommunications services continues to grow during the last years, many countries are now able to utilize them to expand the services offered to the population, which include medical care, financial services, among others.

ITT is one of the key factors for narrowing the gap between developing countries and industrialized countries. In addition to infrastructure, an efficient and healthy workforce, roads, and access to information and education, technology can also assist these countries to move forward (Sachs, 2015). Nowadays, traditional energy sources such as fossil fuels are dropping, and the use of renewable energy based on water, wind, or solar energy may provide an opportunity for developing countries to not copy the same path chosen by industrialized countries, but move forward with the energy sector. Therefore, ITT can exert social influence in many fields of society around the world.

Nonetheless, the need for the social impact of ITT around the world is still in great demand. Much hope has been placed on technological innovation. However, innovation in itself is not enough, thus the social impact of them is a new parameter to be considered in an ITT implementation and use of such technologies at a large scale. Social impact means a positive change for society, but the social impact of ITT remains so limited because its effects on society are neglected during the ITT concept phase.

The above considerations, together with the views of social impacts of ITT projects, it is a consensus that they have the capability to positively affect people's quality of life, which guided the authors to propose the social impact is likely to be positively correlated with innovation in the context of developing countries, as in the following hypothesis:

- **H1:** The ITT projects focused on economic results enables positive social impacts in developing countries.

2.4. Cultural Impacts

New products, processes, and innovative services are usually launched around the world every day, yet it is not uncommon for they have high rates of adoption in some countries but low rates in others. Hence, ITT can influence the cultural foundation of populations at the regional level and more broadly on society as a whole.

The phenomena of how new technologies including those created through ITT can be explained, but not only, by the theory of "diffusion innovations" (Rogers, 2003). Such a theory discusses the influence of culture on how innovation spread through human civilization. The author emphasizes that diffusion is the method of how the news and uptake innovation is transmitted through social connections and networks concerning time. The experience of this theory is distinct and multidisciplinary where four elements affect directly the rate of innovation spread itself, being they: 1) the innovation itself; 2) the communication channels; 3) time; and 4) the social system.

The main outcome is that an eventual selection of technology, process, or product by community relies on the shift in the behavioral action that must increase from the new adoption that makes distribution or spread the idea or product feasible. The selection of one of these elements previously mentioned does not occur concurrently and selected people with unique features from the social norm adopt them. Thus, to obtain the innovation appeal to a more extensive target audience, their profile requires to be comprehended beforehand. Such a procedure will ensure a more efficient promotion of the technology amongst them.

Based on the previous discussion, ITT projects have the potential to positively affect the cultural fabric of populations, which guided the authors to suggest that the cultural impact is likely to be positively connected with innovation on the subject of developing countries, as in the following hypothesis:

- **H2:** The ITT projects focused on economic results enable positive cultural impacts in developing countries.

2.5. Technological Impacts

Innovation is the key element in the modern theories of development and growth (Fagerberg et al., 2005). It is also closely tied up with shifts in the economic structure, technological upgrading in production systems, and promoting higher value-added activities in various global production chains.

This technological upgrade is reflected in a new generation of machinery and equipment and a new generation of well-educated workers. Products and process technology also have an indirect impact, which results from formal and informal investments in research and development (R&D), capabilities, and on-the-job learning. Direct and indirect technological changes are the reasons for

increasing global production, which have been found to explain more than half of the difference in economic growth rates between countries (Helpman, 2004). However, these shifts not only boost the quantity of economic output, but also the quality of the products manufactured.

The powerful impacts of the technological changes are accordingly described by (Lipsey et al., 2005), where the writers affirm that people living in the first decade of the 20th century did not benefit from modern medical advancement, electronic industry advancements, affordable universities, and so on. Therefore, technological change has transformed the human life.

The endogenous growth and evolutionary growth theories indicate that the common factors of production, such as the capital and labor, are subject to decreasing the return of the capital, while investment in knowledge has growing returns due to a set of positive factors in the connection between economic actors. The endogenous growth theory explains that the advanced economies with the best system for innovation profit more from investment in knowledge than less advanced ones for some reasons. First, R&D applications and scientific progress are notably concentrated in the most advanced economies. Second, the transfer of knowledge and technology from first movers to followers is fast, so that innovation quickly spreads throughout the economy.

However, innovation and technological advances can further speed up the catch-up in developing countries because they can absorb and creatively modify global technological knowledge to reach accelerated growth. Some theories argue that latecomer economies may profit from the advantages of technological backwardness. They may benefit from the global spread of technology because they can obtain new technologies without carrying all the costs and risks of an investment in new knowledge.

Nonetheless, it is also important to take into account the context of developing countries for developing new technologies from a coming from a developed one. When a company is planning an ITT project, in a developing country, it may be necessary to be adapted in such technology for the local market.

According to previous discussions, the ITT project can have a positive impact on the technological status of the country, which guided the authors to suggest that technological improvements are probable to be positively impacted by ITT in the environment of developing countries, as shown by the subsequent hypothesis:

- **H3:** The ITT projects focused on economic results in positive technological enhancements in developing countries.

2.6. Environmental Impacts

The difficulties of global economic competition, social disparities, and the dimension of environmental problems have raised consciousness and deepened attention about the need of modifying the current technology to alter the models of social behavior and to bring it up a way to a more sustainable manner of growth (Teng et al., 2002).

Taking into account, more specifically, the impacts of new products, processes on the environment, the companies are more concerned about such aspects. Hence, many methodologies are found in literature, whose main goal is to tackle these impacts. However, the establishment of indicators aiming at environmental issues is crucial for firms, providing references for measuring the environmental behavior and outcomes of industries.

The establishment of indicators aiming at environmental innovation should reflect the fact that all phases of production can influence the environment (i.e.), from the selection of materials to the specification of the production processes features and products manufactured. Furthermore, the environmental consequences are not limited to the production phase, but they likely can occur during the complete life cycle of the product.

There are two principal classes for environmental innovations. The first is based on the reasons for the advancement of these innovations, whereas the second is focused on their purpose. In other words, while in the first the primary effort is done to generate a product responsible for decreasing the environmental pollution, the second class includes innovations that were not developed for environmental goals, but have had positive or negative environmental impacts (Kemp et al., 2000).

The existence of two main classes requires two different sets of indicators to measure the impacts: one for innovations created in response to laws and another able to recognize environmental elements of other types of innovations. As such, regardless of the categories of ITT project aforementioned, the important aspects to be considered and analyzed in a project in terms of environmental parameters are as following: 1) Pollution control; 2) Waste management; 3) Clean technology; 4) Clean products; 5) Recycling; 6) Innovations for developing new products, and 7) Clean-up technology.

The above considerations and the views of the ITT project on the environmental effects have a negative impact on the environment where it is inserted, which prompted the author to propose that the environmental impacts are likely to have a negative correlation with innovation. The situation in developing countries, as shown by the following hypothesis:

- **H4:** The ITT projects focused on economic effects in a negative manner on the environment in developing countries.

2.7. Delphi Method

The Delphi technique is a systematic method that elicits expert opinions. Its expected result is to reach a reliable agreement in the selected expert group. Usually, Delphi is carried through a set of questionnaires. Group members remain anonymous to each other, and their interactions are managed in a completely unknown manner (Robinson, 1991). After each round of the survey, the response will be investigated, and based on the evaluation, a second questionnaire may be developed and sent to the same team members in the next round. The iterative character of the methodology makes it possible to provide members with each round that involves feedback on new information. Therefore, they can reconsider based on the overall results, the information they provided in the previous rounds. The process lasts for a predetermined amount of rounds, or until some proposed criteria are met, i.e. reaching a consensus in the research group (Mullen, 2003).

The method has been used in a broad applications area, such as in engineering, health, social science, business evaluation, among others, where the researchers need to raise information from experts in the development of quantitative or qualitative researches (Yeoh & Koronios, 2010). Thereby, from the discussion of the main indicators and the hypotheses definition, Figure 1 illustrates the developing research method for ITT assessment.

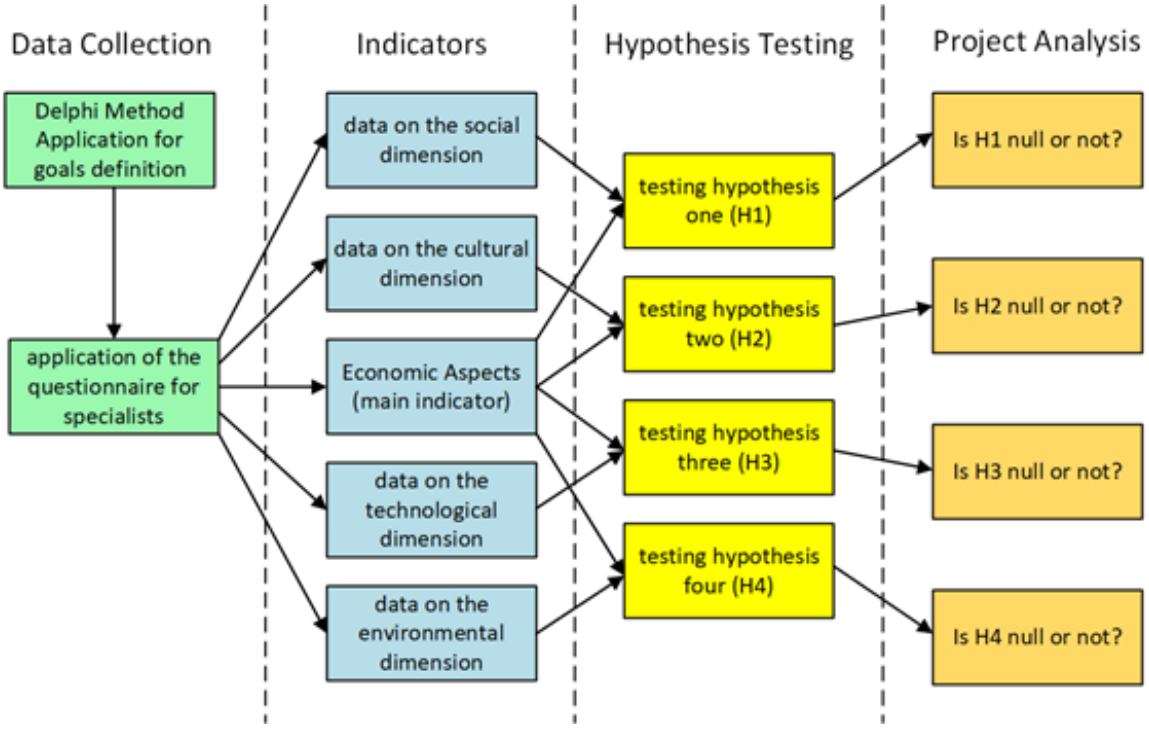

Figure 1. Developing research method for ITT assessment.

3. METHOD

This section presents the research methodology, data collection, and the statistical approach to evaluate and respond to the research question. It must be noticed that the approach adopted in this research is quantitative descriptive, whose goal is to establish the association between the variables.

3.1. Research Method Proposed

The capacity of a company to transfer advanced technology and perceive the benefits expected from its deployment will rely on the technical capacities existent internally. However, a different management approach can influence meaningfully ITT projects. Hence, the proposed methodology for evaluating projects considers the crucial steps and factors and their respective impacts before a decision has been taken. Figure 2 illustrates the common stages used by companies to evaluate an ITT project and in the green steps, highlighted in green, are the places where the proposed methodology can be applied by companies.

The problem identification stage consists of the actions for identifying the main features of the product, regarding elements such as the volume of sales estimated, price, and cultural aspects where the product will be inserted. Once they are established, then, the second stage lies in identifying and studying the best possibilities available to satisfy the initial requirements.

In sequence, it is necessary to plan strategies and policies to attend and organize the priorities to be committed to executing the plan. From the previous steps accomplished, then, the companies must make a decision to transfer or develop the technology locally, which depends on the economic interest, strategic plan, among others. Furthermore, in case of an agreement for developing the project, another judgment is mandatory and it is related to the development internally the company by investing in a Research & Development team or buy the technology of local suppliers.

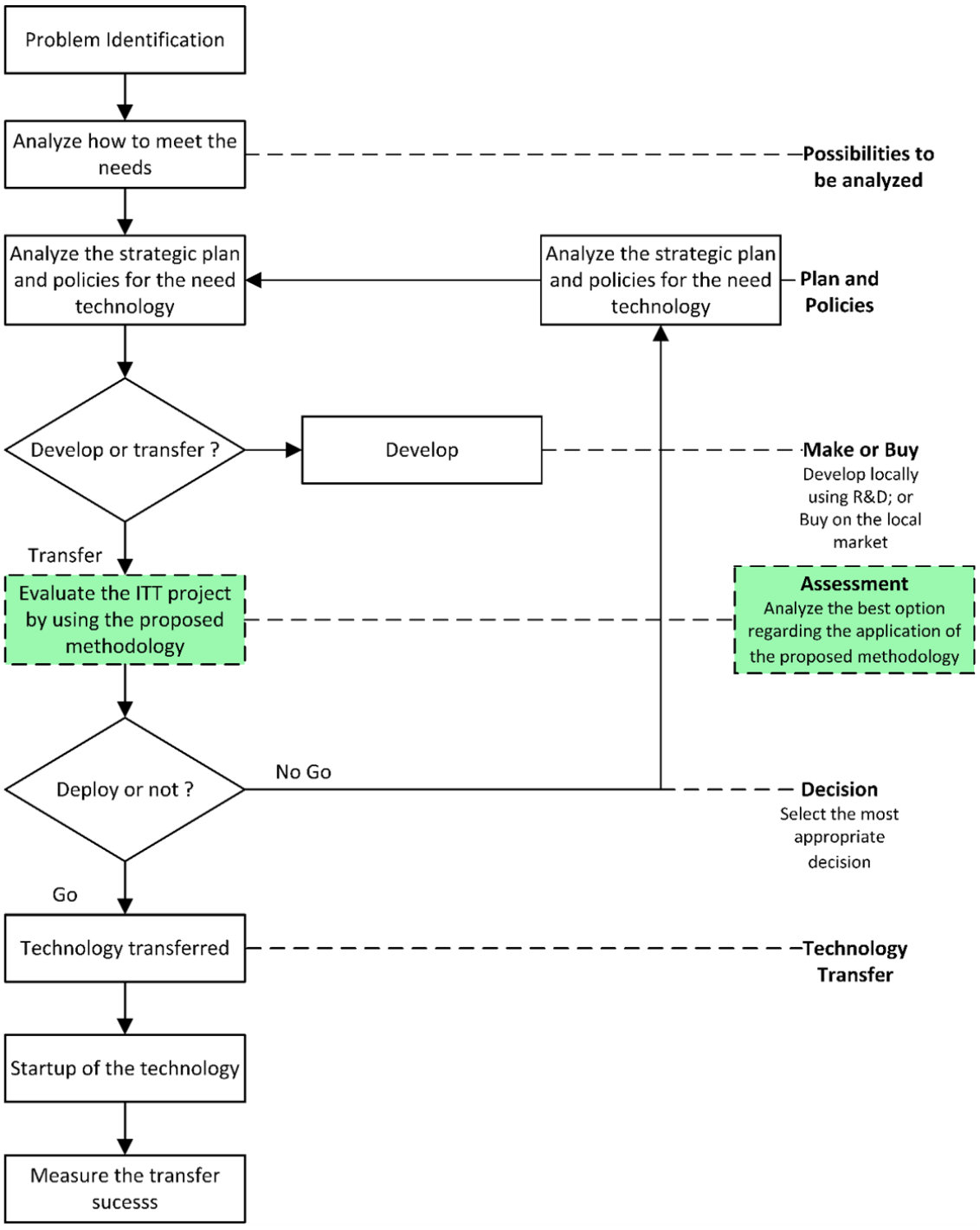

Figure 2. Technology transfer model adopted by companies with the proposed methodology adoption.
Source: Authors (2019).

In the case of a transfer decision, then, the proposed methodology must be applied and it contributes effectively when the managers analyze the project's impacts to make a decision based on a clear assessment that indicates the realistic project impacts in five dimensions, which is the main contribution of this research. Such a stage is made of three phases: 1) A deep analysis of the existing five dimensions and the questionnaire definition; 2) Data collection by digital questionnaire application; 3) Data measurement by using student T-test.

After the evaluating stage, then, among the possibilities, in terms of technologies available, the most appropriate is selected. If there is no satisfactory option to fill the initial requirements, the strategic plan and policies should be reconsidered.

In the next two stages, the physical transfer process aims to proceed with the real installation of the material and all the needed elements. It includes all processes of purchase, transportation, and installation accomplished by a well-trained team. The startup stage is the final process where the implementation is effectively accomplished and in sequence, the commissioning and the operation startup occur.

Once the entire transfer process is completed, it is necessary to measure the failure or the achievement of the ITT project in such a way that the mistakes that occurred on it can bring acknowledgment for future projects.

3.2. Data Collection Proposed and Statistical Method

The novelty methodology for the ITT project is based on five pillars and a survey conducted with all professionals somehow involved in it. Thereby, the Delphi method has been adopted to do so because it is a structured process commonly used to raise quality indicators data (Wang et al., 2012) and it can be applied to the respondents by using web-based platforms, which is an enormous advantage for researchers.

First, the structured questionnaire to collect data following the characteristics of the innovation to be evaluated is developed and deployed. Such research addresses the products of the electronic Brazilian manufacturers. Thereby, the questionnaire is prepared regarding the aspects of economic, social, cultural, technological and environmental aspects involved in projects of ITT. Within each area, the impacts are evaluated in accordance with the features of each product under transferring, as shown in Table 1.

In sequence, the questionnaire aims to collect data of a predetermined group using the web-based Delphi method, whose goal is to structure a communication process aiming for a specific group of specialists, allowing the researchers to discover their technical opinion about dealing with complex problems and detect the current scenery in Brazilian industries. Such a method must be applied following three basics premises: 1) anonymity; 2) interaction with controlled feedback; and 3) generation of statistical responses. Table 2 illustrates the questions defined and their respective scale of the response.

Finally, a student T-test statistical method is used to treat the data collected, which results in a detailed quantification of the impacts of the ITT project and as a result, the correlation among the variables is displayed. The student T-test confirms or not the hypotheses about the mean of a small sample extracted from a population normally distributed when the population standard deviation is unknown. Consequently, it is possible to assess the impacts of the ITT project by comparing the variables' correlation.

Table 1
Proposed assessment factors.

Assessment Factors				
Economic	Social	Cultural	Technological	Environmental
Human resources (technical and interpersonal skills);	Organizational factors, structure, flexibility for change, decision-making power;	Cultural factors (habits, flavors, among others).	Physical Facilities - Support infrastructure and technology;	Geographic and climatic conditions;
Capital, land and other raw materials;	Social factors (religion, language, ethnicity);	Ethical conduct (honor, respect, among others).	Services and Systems (Operation, maintenance, updating);	Unbalanced ecological systems, effects against human health;
Economic conditions.	Political Factors (Political instability and corruption).			Environmental destruction and scarcity of resources;
Market Rights and Properties (Patents and Licenses)				

Source: Authors (2019).

From the hypotheses defined previously, then to analyze and the impact correlation, the T-test is applied as follows: the economic dimension is elected as the main variable and a series of student T-test, with two independent variables, are applied, to compare the economic impacts versus the social, cultural, technological and environmental ones.

Mathematically, assuming that the two independent samples of variables have equal variances (i.e., $\sigma_1^2 = \sigma_2^2$), the T-test is given as:

$$t = \frac{\overline{x_1} - \overline{x_2}}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (1)$$

with:

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \quad (2)$$

where:

$\overline{x_1}$ = Mean of the first sample;

$\overline{x_2}$ = Mean of the second sample;

n_1 = Sample size of the first sample;

n_2 = Sample size of the second sample;

s_1 = Standard deviation of the first sample;

s_2 = Standard deviation of the second sample;

s_p = Pooled Standard deviation.

The calculated t value is then compared to the critical t value from the t distribution table with degrees of freedom $n_1 + n_2 - 2$ and the chosen confidence level. If the calculated t value is greater than the critical t value, then the null hypothesis must be rejected (Zimmerman, 1997).

Table 2

Questions that compose the survey applied to the companies' employees.

Goal	Question	Type and scale of the response
Identification	Company name Initial Background	Fill the e-form with objective response
Company Characterization	Area of innovation of R&D Type of innovation (incremental or disruptive) Where the R&D is developed Where the R&D product is manufactured	Multiple choice for classification
Relevance of the Dimension	Economic Social Cultural Technological Environmental	Multiple choice with scale ranging from 1 to 3
Economic	Contribution to local economic growth Financial feedback	Multiple choice with scale ranging from 1 to 5
	Is the innovation possible to be commercialized? Are the innovation developed able to induce others?	Multiple choice with two options
Social	Improve the local infrastructure Number of jobs generated Improvement of the local quality of life Number of accidents reduced Risk of population	Multiple choice with scale ranging from 1 to 5
Cultural	Improvement in education Improvement in other areas Improvement in the accessibility	Multiple choice with scale ranging from 1 to 5
Technological	Impacts in local infrastructure Impacts in services and/or systems existents Innovation in new industrial processes	Multiple choice with scale ranging from 1 to 5
	Risk of competition from technology reproduction	Multiple choice with two options
Environmental	Interference with biodiversity Renewable energy Use of natural resources Possible damage to human health Visual pollution Noise pollution	Multiple choice with scale ranging from 1 to 5

Source: Authors (2019).

4. METHOD APPLICATION AND RESULTS ANALYSIS

The Brazilian electro-electronic industry covers the manufacturing of all equipment for the generation, transmission, distribution, and automation. It is a set of economic activities involved in R&D developed locally, ITT transfer, and the manufacture of diverse products, where more than $20 billion is invested per year. Nonetheless, transmission and distribution remain the key elements that affect the final price of electrical energy for the citizens in the country. Therefore, owing to the scenery mentioned, the selection of the segment is relevant to test the method.

The impacts in the five dimensions was defined as the variables for the proposed model because they are the most important aspects to be considered for the specialist of the area and among the authors found in the literature. Additionally, the questions were applied to the respondents and the form, based on the web and was is available by google forms and with responses collected in an online spreadsheet.

The questionnaire was sent (by email) to more than 300 professionals (diverse types of engineering, managers, bachelor in law, among other occupations) of Brazilian companies that working directly in the ITT project and R&D for the sector of energy. As a result, 117 (response rate close to 40%) people responded to it confidentially without personal identification. Figures 3 and 4 show the company identification and the initial background of the respondents.

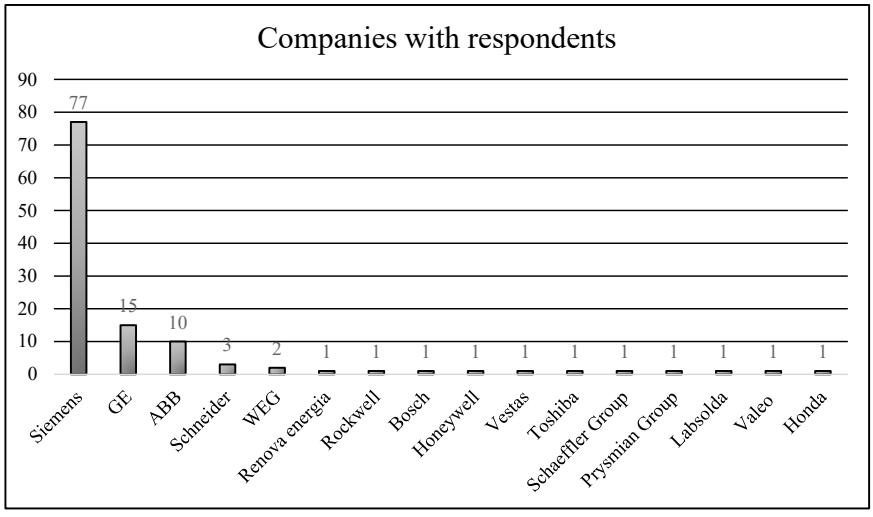

Figure 3. Graph of companies consulted. Source: Authors (2019).

As shown in the graph, the companies consulted summed 16 and they are the biggest acting in the Brazilian market with annual revenue of billion dollars.

Completing the identification step, the initial background analysis illustrates a heterogeneous profile in the initial formation of the employees and their respective occupations inside companies, which is relevant and expected for ITT projects.

In terms of the filed that the companies are acting on, Figure 5 illustrates the specific areas where each company is developing their projects.

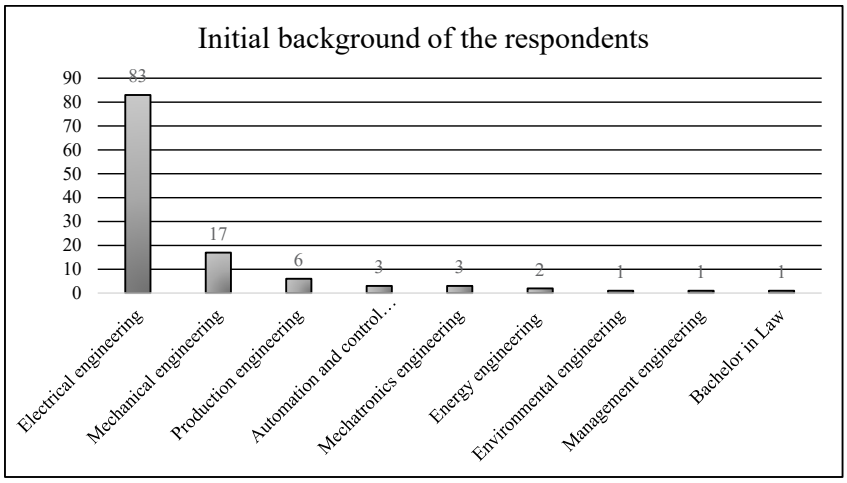

Figure 4. Graph of the initial background of the respondents. Source: Authors (2019).

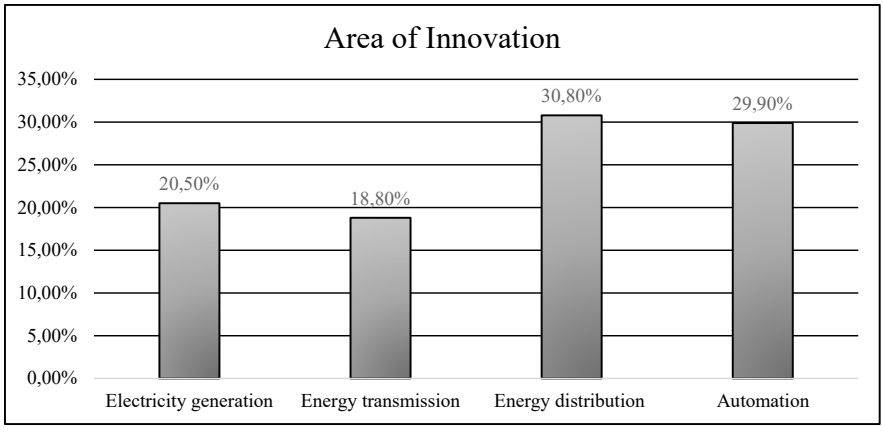

Figure 5. Graph of the participation of each subsector. Source: Authors (2019).

As shown in the graph, more than 60% of the firms develop products in the field of energy distribution and automated equipment for managing energy consumption. While electricity generation and transmission are the focus of less than 40% of the companies' business. Completing the responses of companies' characterization, Table 3 typifies the type of innovation, where they are working on.

Table 3
Compilation with the responses for illustrating firms' activity in Brazil.

Question	Percentage of the responses	
Type of Innovation	44% disruptive	56% incremental
Local of R&D activity	15% in Brazil	85% abroad
Local of R&D product manufacturing	40% in Brazil	60% abroad

Source: Authors (2019).

As detailed in the characterization, the Brazilian companies mostly work on incremental technologies, which means that the existent products are receiving updates gradually, while only 15% of all the R&D activities are executed in the national territory. Furthermore, only 40% of the products are produced locally.

In terms of the relevance among the five dimensions selected previously, the questions options follow a Likert scale ranging from 1 to 3, whose goal is to understand the most important aspects considered by firms about their ITT projects assessment. Table 4 brings the factors classification.

Table 4
Classification of the factors according to the companies.

Dimension	Average
Economic	2,873
Technological	2,695
Environmental	2,136
Social	1,795
Cultural	1,703

Source: Authors (2019).

From the survey analysis, the economic dimension is the most relevant aspect for a company to decide, if the ITT project will go on, which corroborates with the initial statement. In sorting order, the technological, environmental, social, and cultural factors are the dimensions considered by firms. Therefore, the economic dimension can be confirmed as the principal dimension for the T-tests.

Thereby, from the results of the set of questions for each dimension, with the questions options following a Likert scale ranging from 1 to 5, then, a series of four student T-test are conducted to verify the initial hypothesis (**H1**, **H2**, **H3**, and **H4**).

The first hypothesis to be tested is H3, in which an ITT focused on economic aspects impact positively the technological dimension. Statistically, it is given, as follows:

$H3_0 : \mu_{economic} = \mu_{technological}$ is the null hypothesis;

$H3_1 : \mu_{economic} \neq \mu_{technological}$ is the alternative hypothesis.

Table 5 shows the results of the student T-test aided by the software Excel ®.

According to the t-test and the two-tailed P (T <= t) value for being greater than 0.05, it can be concluded that the null hypothesis is rejected and the alternative hypothesis is accepted. It means that in only 5% of the cases in which a technological transfer performed with an economic focus impacts positively on technological enhancements o infrastructures, services, and systems, and industrial processes.

The second hypothesis (H4) is that an ITT focused on economic aspects has negative impacts on the environment dimension. Statistically, it is given, as follows:

$H4_0 : \mu_{economic} = \mu_{environmental}$ is the null hypothesis;

$H4_1 : \mu_{economic} \neq \mu_{environmental}$ is the alternative hypothesis.

Table 5
Results of student T-test for Economic x Technological dimensions.

T-test: Assuming that the two samples have equivalent variance		
	Economic	*Technological*
Average	2,872881356	2,889830508
Variance	0,1460959	0,133058091
Samples	118	118
Grouped data variance	0,139576996	
Mean difference hypothesis	0	
gl	234	
Stat t	-0,348471345	
P(T<=t) one-tailed	0,363899772	
Critical t one-tailed	1,651391475	
P(T<=t) two-tailed	**0,727799544**	
Critical t two-tailed	1,970153643	

Source: Authors (2019).

Table 6 shows the results of second the student T-test.

Table 6
Results of student T-test for Economic x Environmental dimensions.

T-test: Assuming that the two samples have equivalent variance		
	Economical	*Environmental*
Average	2,872881356	2,144067797
Variance	0,1460959	0,534622628
Samples	118	118
Grouped data variance	0,340359264	
Mean difference hypothesis	0	
gl	234	
Stat t	9,595633717	
P(T<=t) one-tailed	6,69558E-19	
Critical t one-tailed	1,651391475	
P(T<=t) two-tailed	**1,33912E-18**	
Critical t two-tailed	1,970153643	

Source: Authors (2019).

As stated in the t-test and the two-tailed P (T <= t) value for being less than 0.05, it can be concluded that the null hypothesis is true. That is, in more than 95% of cases in which an ITT is carried out with an economic focus, it affects negatively the local environment, i.e. interference with biodiversity, the use of natural resources, pollution, among other impacts.

The third hypothesis (H1) is that an ITT focused on economic aspects impact positively the social dimension. Statistically, it is given, as follows:

$H1_0 : \mu_{economic} = \mu_{social}$ is the null hypothesis;
$H1_1 : \mu_{economic} \neq \mu_{social}$ is the alternative hypothesis.

Table 7 shows the results of the third student T-test.

Table 7
Results of student T-test for Economic x Social dimensions.

T-test: Assuming that the two samples have equivalent variance		
	Economic	*Social*
Average	2,872881356	1,796610169
Variance	0,1460959	0,505287556
Samples	118	118
Grouped data variance	0,325691728	
Mean difference hypothesis	0	
gl	234	
Stat t	14,48586239	
P(T<=t) one-tailed	1,12E-34	
Critical t one-tailed	1,651391475	
P(T<=t) two-tailed	**2,23999E-34**	
Critical t two-tailed	1,970153643	

Source: Authors (2019).

According to the student T-test and the two-tailed P (T <= t) value for being less than 0.05, the null hypothesis has been accepted. In other words, in more than 95% of cases in which a technological transfer is carried out mainly focused on economic aspects, there is a positive social impact on job creation, local infrastructure, and quality of life.

The fourth assumption (H2) is that an ITT focused on economic aspects impact positively the cultural changes of the community where it is on service. Statistically, it is given, as follows:

$H2_0 : \mu_{economic} = \mu_{cultural}$ is the null hypothesis;
$H2_1 : \mu_{economic} \neq \mu_{cultural}$ is the alternative hypothesis.

Table 8 shows the results of the fourth student T-test.

As reported by the student T-test and the two-tailed P (T <= t) value for being less than 0.05, the null hypothesis has been validated. It means that in more than 95% of cases in which an ITT is accomplished focused on economic aspects, there is a positive cultural impact on the level of people's education and other factors of the local culture.

Table 8
Results of student T-test for Economic x Cultural dimensions

T-test: Assuming that the two samples have equivalent variance		
	Economic	*Cultural*
Average	2,872881356	1,720338983
Variance	0,1460959	0,562146893
Samples	118	118
Grouped data variance	0,354121396	
Mean difference hypothesis	0	
gl	234	
Stat t	14,87670745	
P(T<=t) one-tailed	5,57392E-36	
Critical t one-tailed	1,651391475	
P(T<=t) two-tailed	**1,11478E-35**	
Critical t two-tailed	1,970153643	

Source: Authors (2019).

4.1. Results Analysis and Discussion

By applying the proposed methodology, first, the companies were characterized and classified by their areas of actuation, type of innovation developed, local where the R&D activity is done, and where the products resultant are manufactured.

The biggest players of the Brazilian market were consulted, and the current scenery shows that the companies are focused on incremental innovations, which means that they only are improving products to the Brazilian market and such a statement is supported by pointing out that only 15% of them are developing new any type of research locally. Finally, another important aspect is that only 40% of these products are manufactured locally, which means that the country is dependent on other countries to improve its efficiency in the field studied.

The second analysis aims to prove the main assumption, which is that the companies are focused on ITT projects relevant for their economic impacts, and the questions applied on a three-point Likert scale were responded and obeying the classification corroborates with the previous statement. Furthermore, the technological and environmental aspects are also important aspects to be considered, while the social and cultural aspects are at the margin of companies for deciding the ITT projects.

The third and most important evaluation comes from the application of the specific question in the five dimensions and the respective T-test analysis. By analyzing the results, was possible to correlate the effects among the dimensions and prove or not the four initial hypotheses. Among all the hypotheses tested, few important analyses can be inferred, as follows:

1) There is a positive social impact because these new ITT projects usually demand new jobs and they generate a better quality of life due to improvements in the local infrastructure, and it can be supported by the T-test result;
2) It is reported that ITT influences positively the level of education and other aspects of the local culture, which shows the T-test correlation;

3) The ITT transfer focused on economic aspects does not bring many benefits to the technological improvement because the transferring does not stimulate new processes aiming new industrial processes or new technologies on the companies' infrastructure. Therefore, it can be stated that only the transferring does not allow the local technological progress, which can be supported by the low rate of R&D projects developed locally and the T-test conducted;
4) The innovation brought by the companies affect negatively the environment where these products are installed, impacting the local biodiversity and so on, despite, in some cases, the innovations can impact positively, as supported by the T-test processed.

5. FINAL CONSIDERATIONS

Brazil has a great demand for electric energy and consequently, it requires new products and innovations. In this paper a study to assess the impacts of ITT and then propose a practical method for the companies to do so based on the theoretical aspects investigated.

According to the methodology, after defining the area, first, the five dimensions (economic, technological, environmental, social, and cultural) considered as the most important for ITT projects evaluation were defined, after a rigorous literature survey.

In sequence, then the questions were elaborated and applied to the companies' specialists, by using the Delphi method, and the responses were collected and organized to be evaluated. The descriptive data analysis was conducted to characterize the companies, respondents and then, a series of student T-test was performed to correlate the variables selected and concluded about their correlation. Finally, the team responsible for the ITT project can make a decision about it supported by an organized methodology, which is the main novelty of the study.

The results showed that the companies have not a structured method to assess ITT projects and they commonly elect the economic dimension as the main variable to decide the implementation of a project, however, the other four dimensions are also important, especially those that can bring advantages to national companies, i.e. the improvement of new processes.

From the statistical analysis can be stated that only in restricted ITT projects contribute with the advance of technology in Brazil, especially in the new process of manufacturing and R&D of new technologies conducted locally, while they impact negatively the environment and impact positively the social and cultural aspects related to it. Therefore, the current research was able to take a picture of the current scenery of the Brazilian companies regarding their ITT projects and the impacts of their deployment, as well as the main contribution of the research was to introduce a structured method to support the decision and the establishment main parameters to be considered in an ITT project.

Regarding the study's limitations, they are those inherent to all case studies, indicating that the outcomes consolidated in this research are not subject to generalization to other fields. The study was also focused on the Brazilian companies of the electricity generation chain. Thus, in terms of future research, it might be suggested to carry out more surveys and collect data on this issue to determine whether the results presented are susceptible to be generalized. The proposed methodology might also be expanded to focus on other fields and nations.

REFERENCES

Assembly, U. (2013). *A life of dignity for all: accelerating progress towards the Millennium Development Goals and advancing the United Nations development agenda beyond 2015*. A Report of the Secretary-General. https://www.un.org/millenniumgoals/pdf/A%20Life%20of%20Dignity%20for%20All.pdf

Audretsch, D. B., Lehmann, E. E., & Wright, M. (2014). Technology transfer in a global economy. *The Journal of Technology Transfer*, *39*(3), 301-312.

Boddewyn, J. J. (2016). International business-government relations research 1945-2015: Concepts, typologies, theories and methodologies. *Journal of World Business*, *51*(1), 10-22.

Braga, E., Jr., Pio, M., & Antunes, A. (2009). O processo de transferência de tecnologia na indústria têxtil. *Journal of technology management & innovation*, *4*(1), 125-133.

Cirani, C. B. (2016). The role of public institutions for innovation support in Brazil. *BBR Brazilian Business Review*, *13*(6), 210-230.

Edquist, C., Hommen, L., & McKelvey, M. D. (2001). *Innovation and employment: Process versus product innovation*. Edward Elgar Publishing.

Fagerberg, J., Mowery, D. C., & Richard, N. R. (2005). *The Oxford handbook of innovation*. Oxford University Press.

Fernandes, C. R., & Machado, A. G. (2019). Technology Transfer Capability: Development dynamics in higher education institutions. *BBR Brazilian Business Review*, *16*(1), 1-15.

Gervais, M.-J., Marion, C., Dagenais, C., Chiocchio, F., & Houlfort, N. (2015). Dealing with the complexity of evaluating knowledge transfer strategies: Guiding principles for developing valid instruments. *Research Evaluation*, *25*(1), 62-69.

Giuliani, E., & Macchi, C. (2014). Multinational corporations' economic and human rights impacts on developing countries: A review and research agenda. *Cambridge Journal of Economics*, *38*(2), 479-517.

Guan, J. C. (2006). Technology transfer and innovation performance: Evidence from Chinese firms. *Technological Forecasting and Social Change*, *73*(6), 666-678.

Hall, B. H., & Rosenberg, N. (2010). *Handbook of the Economics of Innovation*. (Vol. 1). Elsevier.

Helpman, E. (2004). *The mystery of economic growth*. Harvard University Press.

Hübler, M., & Finus, M. (2013). Is the risk of North-South technology transfer failure an obstacle to a cooperative climate change agreement? *International Environmental Agreements: Politics, Law and Economics*, *13*(4), 461-479.

Iyer, C. K., & Banerjee, P. S. (2018). Facilitators and inhibitors in sector wide technology transfer projects in developing economies: An empirical study. *The Journal of Technology Transfer*, *43*(1), 172-197.

Kemp, R., Smith, K., & Becher, G. (2000). How should we study the relationship between environmental regulation and innovation? In J. Hemmelskamp, K. Rennings, & F. Leone, *Innovation-oriented environmental regulation* (pp. 43-66). Physica.

Khabiri, N., Sadegh, R., & Aslan, A. S. (2012). Identifying main influential elements in technology transfer process: A conceptual model. *Procedia-Social and Behavioral Sciences*, *40*, 417-423.

Lipsey, R. G., Carlaw, K. I., & Bekar, C. T. (2005). *Economic transformations: General purpose technologies and long-term economic growth*. Oxford University Press.

Lopes, J. N. (2018). Peeking beyond the wall: analysing university technology transfer and commercialisation processes. *International Journal of Technology Management*, *78*(1-2), 107-132.

Mullen, P. M. (2003). Delphi: myths and reality. *Journal of Health Organization and Management*, *17*(1), 37-52.

Ribeiro, Á. H., Monteiro, P. R., & Luttembarck, L. (2019). The Use of the'Job to Be Done'methodology to identify value co-creation opportunities in the context of the Service Dominant Logic. *BBR Brazilian Business Review*, *16*(1), 32-45.

Robinson, J. B. (1991). Delphi methodology for economic impact assessment. *Journal of Transportation Engineering*, *117*(3), 335-349.

Rogers, E. M. (2003). *Diffusion of innovations*, 5th ed. Simon & Schuster, Inc.

Rood, S. A. (2018). *Government Laboratory Technology Transfer: Process and Impact: Process and Impact*. Taylor & Francis Group.

Sachs, J. D. (2015). *The age of sustainable development*. Columbia University Press.

Sharif, N. M., & Haq, A. K. (1980). A time-level model of technology transfer. *IEEE Transactions on Engineering Management*, *27*(2), 49-58.

Teng, J. T., Grover, V., & Guttler, W. (2002). Information technology innovations: General diffusion patterns and its relationships to innovation characteristics. *IEEE Transactions on Engineering Management*, *49*(1), 13-27.

Wang, X., Gao, Z., & Guo, H. (2012). Delphi method for estimating uncertainty distributions. *Information: An International Interdisciplinary Journal*, *15*(2), 449-460.

Yeoh, W., & Koronios, A. (2010). Critical success factors for business intelligence systems. *Journal of Computer Information Systems*, *50*(3), 23-32.

Zimmerman, D. W. (1997). Teacher's corner: A note on interpretation of the paired-samples t-test. *Journal of Educational and Behavioral Statistics*, *22*(3), 349-360.

CONFLICTS OF INTEREST

We have no conflict of interest to declare.

AUTHOR'S CONTRIBUTION

The authors one, two and three contributed to the design, implementation of the research, to the survey, analysis of the results and to the writing of the manuscript.