Measuring Knowledge Transfer in Innovation Projects: A Comparative Analysis

Beatriz Helena Neto*, Jano Moreira de Souza, and Jonice Oliveira

***Abstract*—Collaboration of organizations with universities and research institutes is a way of decreasing not only the time but also the cost of R&D activities in innovation projects. This paper is a study on knowledge transfer measurement models in order to analyze their metrics and identify the use of techniques for measuring the flow of knowledge between companies, public research institutes, and universities in national innovation surveys. The comparative analysis of these models is part of a study to evaluate the ways to measure the impact of universities on society through innovation projects.**

***Index Terms*—Innovation, collaboration, knowledge management, knowledge transfer**

I. Introduction

The conversion of information into knowledge is related to its use by individuals or organizations. Subsequently, the industrial context transforms this knowledge into action as projects and activities [1]. Consequently, the application of knowledge results in actions and competences, but it requires investment.

Therefore, organizations seek external sources of basic and applied technology in order to reduce the time and cost necessary for both obtaining knowledge and developing innovative products. These external sources are obtained through collaborations and partnerships in R&D activities with universities, research institutes, and even competitors in innovation projects.

Measuring the transfer of knowledge and the processes that transform knowledge into benefits for society is essential and strategic, in an effort to evaluate actions and improve activities relevant to the development of innovations. In view of this scenario, this study aims to analyze and compare the knowledge transfer measurement models, considering the use of knowledge flow measurement techniques between companies, universities, and research institutes in national innovation surveys.

In this way, we seek to understand the goal metrics of each model and elicit requirements for a new model to be proposed. The objective is to improve knowledge transfer among the actors of the National Innovation System (NIS) in the development of R&D activities for innovation projects. In the next section, there is a review of the literature on knowledge transfer and innovation impact. Section III analyzes the knowledge transfer models and identifies their metrics and their importance in assessing knowledge transfer and innovation impact. Finally, Section IV provides a comparative analysis of models and suggests future work associated with this research theme.

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II. The Transfer of Knowledge and the Impact of Innovation

Innovation consists of the practical application of knowledge in the creation of a new product or process, while knowledge indicates an understanding of information and the ability to use it. According to OECD and Eurostat [2], knowledge transfer is difficult because it requires the recipient to learn this knowledge. Thus, knowledge transfer activities represent a cost to the innovation process. Considering that technology is scientific knowledge used for practical purposes, Langrish *et al*. [3] reveals technology transfer as an activity linked to innovation, because he defines technology transfer as the application of technology to a new use or by a new user.

Knowledge transfer aims to maximize the two-way flow of technology, intellectual property, and ideas. It allows companies, non-academic organizations, and the public sector to promote innovation, resulting in economic and social benefits. In addition, publicly funded research organizations (PROs) advance research and teaching [4].

Universities, technology transfer offices (TTO) and industry are the main actors involved in knowledge transfer [5]. TTOs support technology transfer through the management of intellectual property, mainly patenting and licensing activities [6]. Measuring the flow of knowledge between such actors is a way of evaluating not only the strategic role of these actors, but also the need to implement actions to increase the efficiency of innovation projects.

Finne *et al*. [7] consider the transfer of knowledge a broader concept. This concept has many forms, activities, processes and actors, which are responsible for transforming the knowledge resulting from research into benefits for society. The best method to measure it is through a number of indicators that represent different aspects of its complexity. The authors propose the development of indicators considering three categories of knowledge transfer: i) transfer of knowledge through trained people; ii) phases of institutional cooperation in R&D and other phases of the innovation process; and iii) commercialization of research. This study focuses on the knowledge transfer foreseen in the second category.

Transfer of knowledge impact in the SNI is another way of measuring the flow of knowledge. According to Holi [8], the definition and measurement of impact in a knowledge transfer

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context requires the following previous actions: define what impact is, and then identify it in the knowledge transfer context. Impact is divided into two types: gross impact (outcomes) and net impact. Both impacts originate from an input – a particular knowledge transfer activity. Fig. 1 shows the impact model in the Knowledge Transfer Ecosystem.

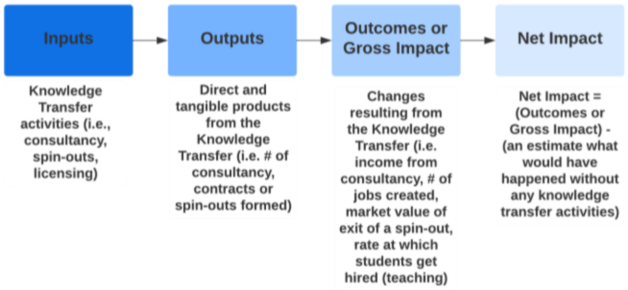

Fig. 1. Model of impact in the knowledge transfer ecosystem [8].

Statistics Canada [9] distinguishes between outcomes and impacts, the former arising directly from S&T activities, while the latter are the consequences for the social, political, and environmental systems, as well as for science. The impacts for science take longer to emerge, and they are often more difficult to identify and trace back to their source. There is also a distinction between impacts that affect the socioeconomic system and those that affect the environment around S&T activities. The impact on the socioeconomic system is the result of launching innovation, while the impact on the environment of S&T activities is the result of changes in social, economic, or political organization.

OECD [10] proposes four main techniques to measure the flow of knowledge between companies, universities, and public research institutes in national innovation surveys. These techniques are: i) joint research activities, ii) patents and joint publications, iii) citation analysis, and iv) research with companies. This paper uses these techniques as a criterion for a comparative analysis between the knowledge transfer models presented in section III.

III. The Knowledge Transfer Measurement Models

This research analyzes knowledge transfer models, which involve the diffusion of knowledge among NIS actors in innovation projects. The criteria for selecting the models were the following: the involvement of university or society actors; the university as the institution responsible for transferring knowledge to the external environment; and the scientific rigor of the models.

A. Knowledge Transfer Model of United Kingdom

Library House has developed a framework to analyze data on knowledge transfer at universities. It is the result of a study commissioned by UNICO (The University Companies Association). Different stakeholders participated in the framework development process. They suggested the framework's knowledge transfer mechanisms and quantitative and qualitative measures [8]. Table I shows the knowledge transfer mechanisms and their respective metrics.

The availability of quantitative knowledge transfer metrics is satisfactory, with few gaps in the structure that make it difficult to obtain data. However, the situation for qualitative data is reversed, as there are few quality measures in the eight knowledge transfer channels. Universities collect some of these measures and may incorporate them into future research, while others are more difficult to collect and are dependent on the development of projections for their achievement. An initial benchmarking analysis among UK universities used this framework. The result suggests that these universities are actively involved in knowledge transfer activities.

TABLE I: Knowledge Transfer Framework [8]

Mechanism of Knowledge Transfer	Measure of Quantity	Measure of Quality
Networks	# of people met at events which led to other Knowledge Transfer activities	% of events held which led to other Knowledge Transfer activities
Continuing Professional Development (CPD)	Income from courses, # of courses held, # people and companies that attend	% of repeat business, customer feedback
Consultancy	# and value/income of contracts, % income relative to total research income, market share, # of client companies, length of client relationship	% of repeat business, customer feedback, quality of client company, importance of client relative to their company
Collaborative Research	# and value/income of contracts, market share, % income relative to total research income, length of client relationship	% of repeat Business, customer feedback, # of products successfully created from the research
Contract Research	# and value/income of contracts, market share, % income relative to total research income, length of client relationship	% of repeat Business, customer feedback, # of products successfully created from the research
Licensing	# of licenses, income generated from licenses, # of products that arose from licenses	Customer feedback, quality of licensee company, % of licenses generating income
Spin-outs	# of spin-outs formed, revenues generated, external investment raised, market value at exit (IPO or trade sale)	Survival rate, quality of investors, investor/customer satisfaction, growth rate
Teaching	Graduation rate of students, rate at which students get hired (in industry)	Student satisfaction (after subsequent employment), employer satisfaction of student
Others Measures	Physical migration of students to industry, publications as a measure of research output	----

Subsequently, the survey interviewed Senior Technology Transfer Officials (STTO) representatives of American universities. They suggested new measures for the framework, which correspond to the measures identified by the UK focus group earlier, with the exception of the technology transfer channel. In addition, American respondents suggested publications and physical migration of students as mechanisms for knowledge transfer, as shown in "Others Measures", resulting in the creation of a new version of the knowledge transfer framework. Thus, the similarities between the measures proposed by the UK focus group and the American STTOs demonstrate a high level of agreement in the choice of knowledge transfer measures.

B. European Union Knowledge Transfer Model

The Joint Research Centre (JRC) of the European Commission's Science and Knowledge Service proposes a model for measuring knowledge transfer within a Public Research Organization (PRO) or among a group of PROs. The model uses a set of core indicators consisting of knowledge transfer input and output indicators, which allow the PRO to analyze the effects of external factors or internal operational factors [4]. Fig. 2 shows the four quadrants model of knowledge transfer indicators.

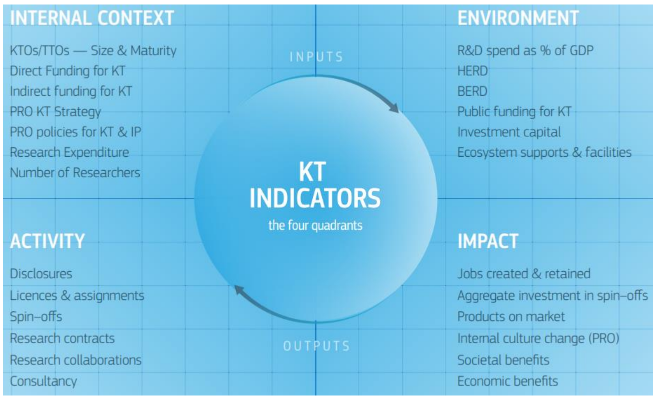

Fig. 2. The four quadrants and its input and output KT indicators [4].

Input indicators are divided into two categories: internal context – characteristics of PROs and Knowledge Transfer Office (KTO); and environment – national factors that influence the environment. Output indicators are divided into: activity – delivery carried out through channels of knowledge transfer and actions of PROs and KTOs; and impact – long-term economic and social outcomes. Thus, internal indicators describe the environment in which knowledge transfer is carried out by PROs at regional and national levels. They can have a significant impact on the results obtained, which will be measured mainly by external indicators.

The scope of KT indicators should reflect the variety of knowledge transfer channels. So, they should not be limited to identifying patents, licensing volume, spin-offs, and commercial revenue. Knowledge transfer channels are: publications and presentations; teaching, networks and events; consultancy; professional development; collaborative research; research contracts; licensing and company creation. The impact indicators are both social and economic.

The model allows the construction of a profile for the PRO as an evaluation tool that has measurement scales for the indicators and considers the knowledge transfer channels used. Data must be collected annually, so it is possible to follow the PRO profile over the years.

C. Performance Review of the Australia's Innovation, Science and Research System

The Australian Innovation, Science and Research System (ISR System) is an open network composed of diverse actors that interact to produce and disseminate innovations that have economic, social, and environmental value. Innovation and Science Australia (ISA) is a statutory and independent committee whose mission is to provide government guidance on issues related to science, research and innovation [11].

The framework is composed of innovation activities, enablers, outputs, and outcomes. It considers a set of performance metrics that characterize the current Australian innovation, science and research system. Some metrics are compared to the performance of other OECD countries, in addition to China, Taiwan and Singapore.

The ISR System Review performs the assessment through three innovation activities: knowledge creation, knowledge transfer, and knowledge application. Innovation is not an outcome of all these activities. The involvement of any one actor in one of these three innovation activities is sufficient. The innovation activities combined with the enablers produce innovation outputs through the ISR System, such as new products, processes, services, and so on. The adoption of innovation outputs, including those originating from international systems, generates outcomes such as well-being, prosperity, economic growth, increased life expectancy, and a more resilient ISR System.

Enablers support ISR System actors and innovation activities. The framework identifies six categories of enablers of innovation activities: policy, money, infrastructure, skills, networks and culture. The links between facilitators and innovation activities to achieve results are shown in Fig. 3. The ISR System Review analyzes the strengths and weaknesses of each of the six enablers as well as the ISR System's output indicators through analysis of knowledge creation, knowledge transfer and knowledge application.

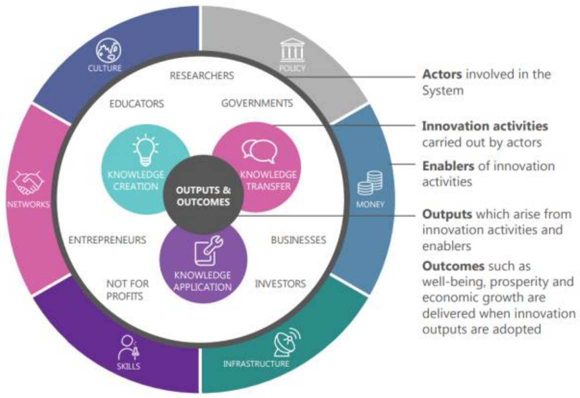

Fig. 3. Performance framework to assess the Australian ISR system [11].

Innovation outputs are the direct result of innovation activities performed by ISR System actors. However, the ISR System Review framework measures the innovation outputs produced only by the industrial sector and companies. The outputs are characterized by four types of innovation: product innovation, process innovation, marketing innovation, and organizational innovation. These outputs are classified according to four levels of novelty: new to the world, new to the industry, new to Australia, and new to the business. The classification of innovation outputs is also according to their impact on the market: incremental innovation and radical innovation.

The outcomes are the effects of innovations, which provide well-being, prosperity, employability, economic growth and technological development. The framework uses the following factors to measure the outcomes: economic, social, and environmental.

The ISR System Review framework identifies and lists strengths and weaknesses of actors involved in the system, innovation activities, enablers of innovation activities, outputs and outcomes. It proposes a performance scorecard approach to national research and innovation, that takes into account 20 performance indicators considering innovation activities, outputs, and outcomes.

D. The AUTM's Impact Assessment Model

Since 1993, the Association of University Technology Managers (AUTM) has evaluated U.S. universities, hospitals, and research institutes in its knowledge transfer activities. Besides that, it publishes the annual licensing survey of technology and related activities for academic institutions and non-profit organizations. AUTM proposed a framework composed of metrics to describe and assess the ability of a given research institution to impact society and the economy. It suggests creating a report with data from the proposed metrics combined with other metrics that the institution identifies as necessary for understanding how that institution impacts its community [12].

The AUTM model has a set of metrics to capture key areas and elements of the innovation ecosystem. The knowledge transfer model in an innovation ecosystem, developed by Dr. Kevin Cullen from the University of Glasgow, is used as area of metrics proposed by the AUTM. This way, the metrics proposed by the AUTM are divided into six areas: i) Institutional support for entrepreneurship and economic development; ii) Ecosystem of institution; iii) Human transfer activities; iv) Technology knowledge transfer activities; v) Network creation activities; and vi) Value creation activities.

AUTM underscores the importance of measurement breadth to the analysis of university contributions, as shown by UNICO's work in the UK discussed earlier. According to [8], the main knowledge transfer metric of this framework is the revenue obtained through intellectual property by AUTM through its Annual Licensing survey. But input metrics based on intellectual property are recognized as poor and incomplete knowledge transfer performance metrics. Therefore, the analysis of a range of activities demonstrates the scope of knowledge transfer better than the isolated analysis of the licensing activity.

E. U-Multirank Multidimensional Model

U-Multirank is an independent ranking system developed with funding from the European Commission's Erasmus+ program and overseen by an Advisory Board. U-Multirank is a multidimensional model as it compares the performance of universities, considering the following dimensions of university performance: teaching and learning, research, international orientation, regional commitment, and knowledge transfer [13].

The model uses indicators from the following groups to assess universities: Teaching and Learning, Research, Knowledge Transfer, International Orientation, Regional Engagement and General. The model does not calculate a combined or weighted score of its dimensions. Therefore, the overall ratings are not robust, since small changes in the assigned weights change the composite scores considerably. In this way, the model assigns scores – from A expressing "very good" to E expressing "weak" performance – to the indicators that make up the five performance dimensions [13]. Fig. 4 shows the sunburst graph with the scores of the Federal University of Rio de Janeiro in the five dimensions.

Fig. 4. Sunburst graph of Federal University of Rio de Janeiro [14].

U-Multirank's approach is strongly related to the user's search focus. The model provides decision-making information for users—students, deans, legislators, academics, or managers—and the user himself defines which indicators are most relevant among the 30 disciplines that make up the model. The U-Multirank combines different forms of ranking: institutional, based on academic disciplines, and "like-with-like". The institutional ranking focuses on the performance of the institution as a whole. The academic discipline-based ranking provides information on universities' performance in the selected academic discipline. And, the "like-with-like" principle ranking allows users to choose several profile indicators in order to compare institutions with similar profiles.

U-Multirank uses various data sources, such as external databases for bibliometric and patent data, as well as data provided by the institutions themselves. The forms of data collection are: preparatory research for the entire data collection process; institutional research to collect data on the entire institution; survey of professionals who collect data on faculties or departments in the researched fields; research on students' learning experiences; and publicly available databases of bibliometric and patent data.

F. CAPES Graduate Multidimensional Model

The Improvement Coordination of Higher Education Personnel (CAPES) proposed a multidimensional model for evaluating Brazilian stricto sensu graduate programs. This model is based on the U-Multirank model discussed in the previous section. The U-Multirank model ranks and enumerates educational institutions from various countries. Whereas the proposed model aims to include multidimensional evaluation criteria for graduate programs

[15].

CAPES' multidimensional model is composed of five dimensions: i) Personnel Training; ii) Research; iii) Innovation and Knowledge Transfer; iv) Impact on Society; and iv) Internationalization [15, 16]. Each graduate program has a score for each dimension. Dimension indicators are formed by qualitative and quantitative aspects. The indicators of the "Personnel Training" and "Research" dimensions are well established, as they were already consolidated in the previous evaluation system. Meanwhile, the dimensions "Innovation and Knowledge Transfer", "Impact on Society", and "Internationalization" are responsible for the most significant changes in this new model [16].

The "Impact on Society" dimension assesses: regional and strategic aspects considering the work of Research Support Foundations (Fundações de Amparo à Pesquisa - FAPs) in programs and projects for the development of the region; the intellectual production; the qualified training of professionals; the social, economic, environmental and technological impacts produced by PPGs; the research applied to society that improves the population's quality of life; and the generation of impact in segments of society, markets or organizations.

The CAPES assessment uses minimum performance criteria, using a single cutoff score to accredit or disaccredit programs of the National Graduate System (Sistema Nacional de Pós-Graduação - SNPG) in Brazil. As a result, the CAPES' multidimensional model assigns different grades to each of the performance dimensions [15]. The grading scale is from 1 to 7, so each assessment dimension will have its own grade, and there will not be a single final grade. That is, each PPG will have five. The PG must get a minimum grade for each dimension; this way it remains in the SNPG. The dimensions "Personnel Training" and "Research" have a minimum score equal to 3, while the other dimensions will still have their scores defined. This CAPES multidimensional evaluation model consists of a proposal to improve the SNPG's evaluation system and quality induction process. The recommendations are for the evaluation period from 2021 to 2024 [16].

IV. Comparative Analysis of the Models

The flow of knowledge between people and organizations that make up the NIS is the main responsible for the innovation process. NIS' knowledge flows consist of four basic types of knowledge: i) interactions among companies; ii) interactions among companies, universities, and public research laboratories; iii) diffusion of knowledge and technology to firms; and iv) movement of personnel [10].

The second type of knowledge—the interactions between companies, universities, and public research institutes—is the type of knowledge relevant to the comparative analysis of the knowledge transfer models. The transfer of knowledge in R&D activities between universities and society, in addition to being the main asset of the innovation process, is the object of study of this research.

OECD [10] proposes four main techniques to measure the flow of knowledge between companies, universities, and public research laboratories in national innovation surveys. These techniques are used as a criterion for a comparative analysis of the knowledge transfer models presented in this paper. The techniques for measuring the flow of knowledge between the public sectors—universities and research institutes—and the private sectors—companies—are: i) joint research activities; ii) co-patents and co-publications; iii) citation analysis; and iv) firm surveys.

Table II shows a comparative table of the knowledge transfer models discussed in this paper with the knowledge transfer measurement techniques that each model uses. The comparison shows the scope of each model's analysis for the evaluation of knowledge transfer between the university and society. Most of the models concentrate their measures and metrics on just one technique. The Multirank model was the only one that used more than one technique – three of the five techniques.

TABLE II: Comparison of the Knowledge Transfer Models

Transfer Knowledge Model / Measurement Technique	United Kingdom	European Union	Australian System	AUTM	Multirank	CAPES
Joint research activities	√	√	--	√	√	√
Co-patents	--	--	--	--	√	--
Co-publications	--	--	√	--	√	--
Citation analysis	--	--	--	--	--	--
Firm surveys	--	--	--	--	--	--

V. Conclusion

We analyzed the metrics of different models to measure the flow of knowledge between the actors of NIS. In this way, it will be possible to identify inhibitory and motivational agents, establish new metrics that help decision making, and refine strategic planning to increase the potential for knowledge diffusion.

Besides that, we compared the models to identify which techniques to measure the flow of knowledge between companies, universities, and public research laboratories in national innovation surveys each one uses. The result shows the coverage of models in the use of such techniques. The main goal of this study is to make the environment more conducive to the development of innovations by indicating extension points on each model or even on a new model through unused techniques.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Jano Moreira de Souza established the group. Jano Moreira de Souza and Jonice Oliveira oriented the research, gave suggestions, and supported the process of finding the research topic. Beatriz Helena Neto identified the models and the comparison parameters. After that, Beatriz Helena Neto analyzed and compared the models and wrote the paper. All authors had approved the final version.

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