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# INFORMATION VISUALIZATION TO SIMPLIFY UNDERSTANDING INDICATORS FOR EVALUATION OF SCIENCE AND TECHNOLOGY

VISUALIZAÇÃO DE INFORMAÇÃO PARA SIMPLIFICAR O ENTENDIMENTO DE  
INDICADORES SOBRE AVALIAÇÃO DA CIÊNCIA E TECNOLOGIA

VISUALIZACIÓN DE LA INFORMACIÓN PARA SIMPLIFICAR INDICADORES DE  
ENTENDIMIENTO PARA LA EVALUACIÓN DE LA CIENCIA Y LA TECNOLOGÍA

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**RESUMO:** O crescimento da atividade científica e o desenvolvimento de novas tecnologias voltadas para a divulgação do conhecimento contribuíram para a geração de diversos indicadores, muito utilizados como instrumentos de avaliação da ciência e tecnologia. O Brasil estabeleceu uma infraestrutura própria para avaliar a atividade científica do país e, mais especificamente, da Pós-Graduação, liderada pela Coordenação de Aperfeiçoamento de Nível Superior (Capes), que faz uso de indicadores no seu processo de avaliação disponíveis para acesso público. Visando facilitar a compreensão dos indicadores científicos, o objetivo geral desta pesquisa foi elaborar e analisar um conjunto de indicadores científicos, com base na área da visualização de informação. Como método de pesquisa foi utilizado o estudo de caso e a unidade caso foram nove Programas de Pós-Graduação da área de Economia avaliados pelo Sistema de Avaliação da Capes no triênio de 2013. Os resultados alcançados constituíram-se em um conjunto de indicadores sobre as dimensões do Sistema de Avaliação da Capes. Com base no referencial teórico e na discussão dos resultados alcançados, concluiu-se que é viável utilizar os conceitos da área de visualização de informação para facilitar a compreensão das dinâmicas da ciência, em especial sobre a atuação dos PPG, com a elaboração de indicadores a partir dos dados e informações disponibilizados pelo Sistema de Avaliação da Capes, auxiliando os tomadores de decisão a respeito da implementação de políticas públicas e na gestão dos PPG.

**PALAVRAS-CHAVE:** Bibliometria. Indicadores científicos. Visualização de informação. Coordenação do Aperfeiçoamento de Pessoal de Nível Superior. Pós-Graduação. Ciências Econômicas.

**ABSTRACT:** The growth of scientific activity and the development of new technologies for the dissemination of knowledge contributed to generate various indicators, used as evaluation tools of science. In addition, Brazil has established its own infrastructure to assess the scientific activity in the country and more specifically, the graduate courses, led by the Coordination of Superior Level Staff Improvement (CAPES), which makes use of indicators in the evaluation process of such courses, which are available for public access. In order to enhance the understanding of scientific indicators, the overall goal of this research was to develop and analyze a set of scientific indicators, based on the information visualization area. The chosen research method was a case study that contemplates nine graduate program in the economics area. The data was extracted from the CAPES evaluation system report from the 2013 triennial. The results achieved are a set of indicators on the dimensions of the Capes Evaluation System. Based on the theoretical background as well as the discussion of the obtained results, the conclusion is that it is feasible to make use of the concepts of information visualization area to enhance the understanding of the dynamism of science, in particular the performance of graduate programs, through the development of indicators based on data and information provided by the CAPES evaluation system, helping decision makers in the implementation of public policies and the management of such programs.

**KEYWORDS:** Bibliometrics. Scientific indicators. Information Visualization. Coordination of Superior Level Staff Improvement - Capes. Graduate-Brazil. Economics Sciences.

**RESUMEN:** El crecimiento de la actividad científica y el desarrollo de nuevas tecnologías para la difusión del conocimiento han contribuido a la generación de diversos indicadores, hoy en día ampliamente utilizados como herramientas de evaluación de la ciencia. Junto a esto, Brasil estableció su propia infraestructura para evaluar la ciencia de la actividad país y, más específicamente, el posgraduación, dirigido por la Coordinación de Mejora de Personal de Nivel Superior (CAPES), que hace uso de indicadores en el proceso de evaluación, disponible para el acceso público. Para facilitar la comprensión de los indicadores científicos, el objetivo general de esta investigación fue desarrollar y analizar un conjunto de indicadores científicos, basada en el área de visualización de la información. Como método de investigación utilizado fue el estudio de caso y la unidad de estudio de casos fueron nueve Programas de Postgrado de la área de Economía evaluados por el Sistema de Evaluación Capes en el 2013 trienal. Los resultados obtenidos son un conjunto de indicadores de las dimensiones del Sistema de Evaluación de la Capes. Con base en el marco teórico y discusión de los resultados obtenidos, se concluye que es factible hacer uso de los conceptos de área de visualización de la información para facilitar la comprensión de la dinámica de la ciencia, en particular, sobre el papel de los PPG de mediante el desarrollo de indicadores basados en los datos y la información proporcionada por el Sistema de Evaluación de la Capes, para ayudar a los tomadores de decisiones en cuanto a la implementación de políticas públicas y la gestión de PPG.

**PALABRAS CLAVE:** Bibliometría. Indicadores Científicos. Visualización de información. Coordinación de Mejora de Personal de Nivel Superior. Posgraduación. Ciencias Económicas.

## 1 INTRODUCTION

The scientific research presents a significant impact in the social and economic development of countries. It is through science that man seeks to know the world and find answers to numbers of situations and phenomena (DORTA-GONZÁLEZ, 2010). In Brazil, public universities have been the place that concentrates researchers e contributes to the expansion of *stricto-sensu*<sup>1</sup> postgraduate programs, which are responsible for the majority of the brazilian scientific production and its qualitative and quantitative growth in the last 40 years (DANTAS, 2004).

Research activity consumes a considerable amount of public and private resources, reason why it is important to assess the results it produces, as well as its impact in different dimensions – scientific, environmental, economic and social (DAVYT; VELHO, 2000; ZACKIEWICZ, 2003; BAUMGARTEN, 2004; DORTA-GONZÁLEZ, 2010). One way to measure science is the creation of indicators regarding the scientific and technological production through metric studies of the science (OKUBO, 1997; GREGOLIN, 2005; LIBERAL, 2005; FARIA et al., 2011). Brazil established its own infrastructure for the evaluation of science, in particular the results achieved by the Postgraduate Programs (PPG), conducted by the Coordination for the Improvement of Higher Education Personnel (CAPES), which comprises an ingenious combination of elements, involving peer evaluation and the collection of systematic data on PPG performance, such as quantity and quality of publications, qualification of the teaching staff, number of students among others (SCHWARTZMAN, 2013).

The growth of scientific production, combined with the development of technologies for the dissemination of scientific results, contributed to the increase in the amount of data and information available to society on the results, such as research activities carried out by PPGs. Through the Capes Evaluation System<sup>2</sup> it is possible to access a diversity of documents, among them the Book of Indicators and the Indicators Spreadsheets. However, the difficulty of understanding the information contained in these documents, that despite its availability for public access and in various formats, due to the volume, organization and presentation of this information, make it difficult to the society to perform analysis on PPG performance, in particular, by decision-makers.

The overload of data and the study of how to represent them in a visual way, in order to facilitate their understanding, has been one of the main concerns of studies in the area of

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<sup>1</sup>Stricto-sensu Postgraduate Programs are considered "master's and doctoral programs that admits candidates graduated in undergraduate courses", and who are "subjected to the requirements of authorization, recognition and renewal of recognition provided by force of law - Resolution CNE/CES #1/2001, as amended by CNE/ESC Resolution #24/2002" (MEC, 2016, p. 01).

<sup>2</sup> <http://www.capes.gov.br/avaliacao>

information visualization, which comprises the investigation of the graphical representations to present information, aiming to enhance comprehension, also to in helping individuals in deducing new knowledge based in what is presented (FREITAS et al., 2001).

Organizing data and information on science and technology in indicators based on concepts of the information visualization area can contribute to maximize the understanding of the results of the scientific and technological initiatives, in which brazilian researchers are involved, as well as guide the decisions concerning the development and implementation of more rational and sustainable science and technology policies, by providing insights about possible differences in the scientific research cultures among the PPGs, especially in the area of Economics.

Therefore, in order to facilitate the understanding of research activities impact, using indicators developed from the data provided by the Capes Evaluation System, the objective of this work was to elaborate and analyze a set of scientific indicators based on the area information visualization. To achieve this objective, a case study was conducted including nine PPGs from the economics area that were evaluated by the Capes System in the year of 2013, which corresponds to the triennium 2010, 2011 and 2012. The economics area was selected because of its impact on issues related to Brazil's economic and social development.

### 1.1 Science Evaluation

One of the science evaluation objective is to the measure the investments efficiency and the effectiveness of their results regarding social, environmental and economic impacts (ZACKIEWICZ, 2003). According to Liberal (2005) "indicators represent, describe and characterize a certain phenomenon, in addition to identifying its nature, state and evolution." In (PRESSER; SILVA; SANTOS, 2010, p. 251) vision "the main characteristic of an indicator is its ability to synthesize a set of information, representing only the essential meaning of the analyzed aspects", for Bellen<sup>3</sup> (2005 apud PRESSER; SILVA; SANTOS, 2010, p. 251), "indicators aggregate and quantify information so that its significance becomes more evident."

In Brazil, as in other countries, universities have a direct involvement in scientific research through PPG *stricto-sensu*. Thus, the Capes Evaluation System is of significant relevance to understand the dynamics of Brazilian science, with the necessary elaboration of PPG performance indicators. Capes, belongs to the Ministry of Education and Culture (MEC) is the main agency of the National Postgraduate System (SNPG), and is recognized as the responsible body for the elaboration of the National *Stricto-Sensu* Postgraduate Plan. According to Meijia Trujillo (2013, p. 09), it is responsible "to elaborate, evaluate, monitor and

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<sup>3</sup> BELLEN, H.M.V. **Indicadores de sustentabilidade**: uma análise comparativa. Rio de Janeiro: Editora FGV, 2005.

coordinate activities related to higher education", together with the national science and technology system. Furthermore, "it authorizes the opening of new PPGs, and evaluates periodically PPGs in operation" (PACIEVITCH, 2016, p. 01).

Capes Evaluation System includes several qualitative and quantitative indicators (SOARES, 2002; HORTALE, 2003): number of professors, bibliographic production, theses and dissertations, research projects, among others. In order to carry out the evaluation activities, representatives are constituted, responsible for coordinating the evaluation in their respective areas of knowledge and forming commissions, responsible for the triennial evaluation of PPGs. Thus, according to Baumgarten (2004, p. 43), the academic scientific community is present in the area commissions, which "perform a regular and systematic work schedule along with Capes". The results of this evaluation process are expressed by the assignment of a grade in scale of "1" to "7", 6 and 7 grades area exclusively for doctorate degree programs with a high level of international excellence; 5 is the maximum grade for master's programs; 4 indicates good performance; 3 represents the minimum quality standard, over which the PPGs obtain approval and renewal to continue in activity, and consequently have a valid license until the next evaluation; programs that receive grades 1 and 2 are no longer recognized by Capes and their authorizations to offer courses are canceled.

The results of the evaluation have a financial impact on PPGs, since research funding agencies at the federal or state level take the result of the PPG evaluation as their main indicator in the definition of their financing strategy (HORTA; MORAES, 2005, p. 101). This PPG evaluation process is carried out every 3 years and is called the "Triennial Evaluation". This evaluation follows the rules and requirements established by the Scientific Technical Council of Higher Education (CTC-ES)<sup>4</sup>.

According to Hortale (2003, p. 1839), foreign observers followed the process of evaluation of the PPG *stricto-sensu* of some areas of knowledge in the year of 2001, which is the model that continues to this day "and were unanimous in consider the evaluation model adopted by Capes as consistent in its generality and with a high evaluative quality". However, according to Hortale (2003, p. 1839) "from the comments made by the observers, what most drew attention was that the Capes Assessment System is more oriented to research than to the quality of teaching." It was observed that "in the evaluation instrument used, there are no specific indicators to evaluate teaching methods, since the quality of the courses is inferred based on the analysis of the number of publications, the qualification of the teaching staff, concluded orientations and the teaching hours in the program". Leaving aside "pedagogical

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<sup>4</sup> The CAPES CTC-ES is composed of two representatives from each of the major areas (Humanities, Health Sciences, Exact, Technological and Multidisciplinary Sciences) indicated by the area representatives, as well as from the president and three CAPES directors, a Representative of the National Forum of Pro-Deans of Research and Undergratuation-FOPROP and of a Representative of the National Association of Post-Graduates-ANPG.

and scientific skills that do not always emanate from research activities”, as Spagnolo and Calhau<sup>5</sup> concludes (2002 apud HORTALE, 2003, p. 1839).

Authors Horta and Moraes (2005, p. 101) complement on the impact that this type of evaluation can cause by stating that the model becomes a vicious circle where “professors of programs with higher grades dedicate more time to scientific production, thus guaranteeing its maintenance, and the financing by the agencies that consider the note fundamental in the moment of funds distribution”, in oppose to teaching quality. On the other hand, professors of programs with lower grades “desperately seek to have all their students graduate as soon as possible, so that their programs do not lose the scholarships of Capes” (HORTA; MORAES, 2005, p. 101).

Despite the criticism, Capes has been looking for to improve its evaluation system, and in 2014 has launched a new and important tool to collect information, perform analysis and evaluations, whose objective is being a reference for the SNPG. This is the Sucupira platform (MEC, 2014), whose name is a tribute to Newton Lins Buarque Sucupira, who instituted the Brazilian postgraduate as it is to this day (BOMENY, 2014).

With the implementation of this platform, the computerized system known as "Capes-Collect" was reformulated and became one of the modules of the new platform. The information collected on PPGs, after analysis, are disclosed to society, through the Book of Indicators and the Indicators Spreadsheets of Capes. In addition to providing Capes with “necessary information to plan its fomentation programs and to delineate its institutional policies”, it also contributes “to the creation of the post-graduate memory, which is the collection of consolidated information on the SNPG” (MEC, 2014, p. 06). The platform aims to optimize the data collection, as well as it gives immediate visibility and greater transparency over the information regarding the PPGs performance to society, which contributes to the “reduction of time and effort in the execution of the SNPG evaluation”. In addition provides "greater reliability, accuracy and information security", among other benefits (MEC, 2014, p. 07).

## 1.2 Information Visualization

In the indicators presentation it is possible to make use of different typologies of charts in an attempt to reveal useful information to the cognitive process for analysts and decision makers. The Information Visualization area studies how visual representations can be implemented with the aid of information technology (computers and software), supporting and facilitating the cognition process (SILVA, 2006). In this sense, information visualization

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<sup>5</sup> Spagnolo, F.; Calhau, M. G. Observadores internacionais avaliam a avaliação da CAPES. **Infocapes – Boletim Informativo da CAPES**. Brasília, v. 10, n. 1, p. 7-34, 2002.

researches indicates that it is necessary to know and apply the rules of vision in order to enhance data understating, thus providing a more rational and sustainable decisions.

Based on Few (2009) studies, it is possible to state that 90% of the data analysis carried out by most organizations could be elaborated using a simple set of competencies, since they only require a basic understanding of a set of vision rules to explore data and discover significant patterns. Information visualization contributes to the success of communication, when its tools and processes are aligned with the strengths of human visual perception and cognition allowing to identify relationships, patterns, trends and exceptions. Therefore, information visualization must also be based on an understanding of how people think; only then visualizations can support the cognitive operations that will make sense of the information, so to display information in a way that makes sense, it is necessary to understand and follow the following vision rules to succeed in the communication process (FEW, 2009):

- a) Shape: length, width, size. These shapes are often used to represent and compare values easily. The most common are bar/column charts, which use columns (vertical length) or bars (horizontal length) to represent values. Another example is charting boxes that are used to display the distribution of a whole set of values from lowest to highest, along with significant points in the middle, such as the median (mean value). In network charts, the width of the lines represents the number of connections. Treemaps, however, can show two quantitative variables simultaneously: one represented by the size of each element and another represented by color (intensity), however, tree maps are not designed to support precise quantitative comparisons as bar charts, but it is a type of visualization that can display the maximum of hierarchically structured items at one time. That is, the form is used to organize data, from largest to smallest, as well as to represent quantitative values (FEW, 2009);
- b) Color: color/tint, intensity (weak/strong). According to Few (2009), color is among the vision rules that are easier to perceive. Color is perceived not in absolute terms, but the difference between the focused color and the surrounding color. In many chars, such as scatter plot, bar and line, it can be used, for example, tones (color tint = major/minor, color intensity = major/minor) to associate objects (bars or lines) and specific categories. Another example is the use of the “heat map”, which encodes values on a geographic map, where colors are used to represent temperature or precipitation variations;
- c) Spatial position: 2-D position/location, spatial grouping. The position is perceived quantitatively with a high degree of precision because it represents very clearly the information: major/minor that is related to the spatial grouping of data (horizontal position along the X-axis and vertical position along the Y-axis). Location allows us to see patterns, trends, and exceptions as it facilitates comparing one value with another simply because the values are close. Still according to Few (2009), data can also be represented through 2-D positions by simple objects (points, squares, triangles, and so on) to encode the values. Finally, lines using the 2-D positions of connected points can also be used to form a series of values;

d) Movement: direction. By observing the direction of the data in an image, it is possible to track its changes and modifications. For example, in the case of quantitative values that have been altered over a continuous period of time, the line graph turns visible the sequential flow of these values and how they changed over time. By its very nature, a line clearly traces the connection from one value to the next and through its inclination exhibits the extent and direction of the change. The scatter plot, for example, allows the observation of values over a period of time that tend to move in a similar direction or in a different direction, moving upwards, from left to right (positive correlation), downwards, from left to right (negative correlation) (FEW, 2009). There are other types of charts, such as Gapminder, which makes possible to use the motion rule because it is dynamic.

According to Volpato (2011, p. 148) the scientific community needs to appropriate itself from the concepts of the information visualization area, “unfortunately, we are amateurs in visual communication, but, using common sense already helps a lot.” Scientific journalism has benefited from the information visualization for the preparation and presentation of the results of scientific researches, which have contributed to the diffusion of science and scientific knowledge, creating a closer relationship with the common citizen. Alves (2010), Modolo (2007) and Schmitt (2006) report experiences on the use of information visualization in scientific journalism. In fact, it is important to mention that in many works it is possible to find the term “infocharts” as a synonym for information visualization.

Information visualization is still not very explored to assist in indicators analysis and understating related to scientific activities performance, but there are some initiatives that to be highlighted:

- a) National Science Foundation (NSF): Provides a set of interactive indicators on American science (NATIONAL, 2014).
- b) SCImago: It includes initiatives that contribute to the visualization of scientific indicators, allowing the creation of ranks that provide means to analyze and evaluate the scientific production of universities and institutions, and the analysis of the main scientific indicators contained in the Scopus database for each country. It is “an information system whose objective is to obtain a graphical representation of Ibero-American Scientific Research. This representation is conceived as a collection of interactive maps that allow navigation through the semantic spaces formed by the maps” (SCIMAGO, 2011, p. 01);
- c) GeoCapes: This tool presents “interactive maps that display, in color scale, the numeric variation of selected indicators, for each municipality, unit of the Federation or country”. In addition, the tool offers options for displaying graphs and tables with data for various indicators. Capes also provides the reports and worksheets related to Triennial Evaluation 2013, which “can be viewed in graphical format, with possibilities of filters by area, region, note and IES” (CAPES, 2015, p. 01);



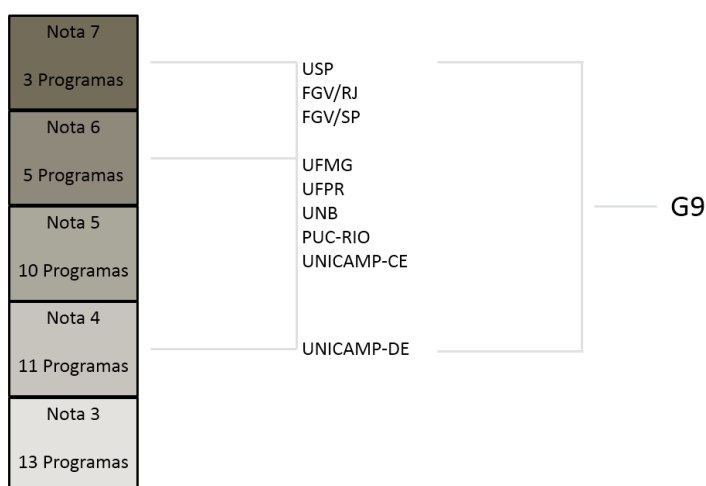
- d) Vlab4u: an information research group comprising the treatment and analysis of large volumes of free access data on the web (VLAB4U, 2016).
- e) Lattes Panel: CNPq initiative to represent the performance and distribution of researchers in Science, Technology and Innovation, using statistical data from the Lattes Platform. The available visualization depicts several macro indicators of Brazilian science (PAINEL, 2016).

The use of information visualization helps in the understanding large amounts of information, since it simplifies and facilitates the understanding of the data with the use of visual representations of the research results, thus contributing to the scientific dissemination, transposing the existing barrier between the academic community and society.

## 2 METHOD AND RESEARCH DEVELOPMENT

As a research method, the case study was used and chosen case unit was nine PPGs of the economics area that were evaluated by the Capes Evaluation System in the triennium of 2013. In addition to the fact that the economics area has an impact on issues related to economic and social development in Brazil, the area was chosen because there is great interest in understanding the results of the triennial evaluation of Capes, because it presents a very interesting case for this research. The Institute of Economics of the University of Campinas (Unicamp) has two masters programs and two doctoral programs that, peculiarity, have distinct notes, although participated in the same evaluation process. Unicamp's Economics Development program, which received a score of four, also made part of the selected sample, although firstly, only programs with 7 and 6 scores were selected. Thus, the elaboration of indicators based on the concepts of visualization can facilitate the understanding of the differences in the PPGs performance.

The 09 programs selected among the 42 PPGs in the area of economics in Brazil were: the three programs that received a score of seven in the Triennium of 2013, Economics (USP), Economics (FGV/RJ), Economics of companies (FGV/SP), the five programs that received a score of six, Economics (UFMG), Economics Development (UFPR), Economics (UNB), Economics (Puc-Rio), Economics Science (Unicamp-CE), and the program that received a score of four from the same institution (UNICAMP-DE - Economics Development), totaling nine programs synthesized in FIGURE 1, with their respective notes.



**FIGURE 1** - Research sample - PPG in Economics - G9

Source: Created by the authors based on extracted data from the Indicators spreadsheet (CAPES, 2014).

Have been used as information source: the 2013 Triennial Evaluation Document, the 2013 triennial Evaluation Report, the Evaluation Files, the Capes Book of Indicators and the Indicators Spreadsheets for the three-year period of 2013. In Marconi and Lakatos (2010) vision, documents constitute a powerful source of information, since they provide data of a certain context, in addition, the documents can explain a certain object and the phenomena related to the problematic's research.

The methodological procedures employed in this research involved the steps synthesized in FIGURE 2 and in TABLE 1.



**FIGURE 2** - Synthesis of methodological procedures - graphical visualization

Source: Created by the authors.

**TABLE 1 - Methodological procedures**

Methodological procedure	Description
Sample selection	The five programs that received grade 06 (UFMG, UFPR, UNB, PUC) were selected from the 42 PPGs in Economics of Brazil, the three programs that received grade seven in the Triennium of 2013 (USP, FGV / SP and FGV / RJ) -RIO, UNICAMP-CE - Economic Science), and a program with grade 4 (UNICAMP-DE- Economic Development), totaling nine programs, that compose the sample analyzed in this research. In order to maximize the understanding when comparing the evolution of each program in relation to some of the dimensions of the Capes Evaluation System, we chose to name this G9 group (group of 9).
Data collection	Data were obtained through the documentary analysis of 03 of the 12 of Capes Book of Indicators: TE - Thesis and Dissertations, PB - Bibliographical Production, CD - Faculty Staff, Association and Academic Formation corresponding to the master's degree programs and PhD in Economics, and the Indicators Spreadsheet available on the 2013 Capes Triennium website.
Data Preparation	Data was then compiled into Microsoft Excel and Gapminder spreadsheets.
Exploratory analysis	Exploratory analysis for the development of the charts to present the indicators, once the data presented by Capes are not available in adequate and visual formats to make comparisons of PPGs performance of the Economics area, making it difficult to understand their performance.
Indicators definition	Definition of a set of indicators to allow the analysis and comparison among PPGs based on the dimensions of the Capes Evaluation System.
Indicators creation and visualization	Selection, creation and presentation of the indicators based on the concepts of the information visualization area.

Source: Created by the authors.

Although it is easy to access Capes information, the Books of Indicators are available in PDF format files, making it difficult to extract and compile the data, since they need to be exported to a Microsoft Excel spreadsheet for data editing. On the other hand, the Indicators Spreadsheet is already available in Microsoft Excel format making it easy to extract and compile the data contained in it. Finally, when using graphical resources, it is possible to interact with the collected data, which makes it possible to extract more information quickly than the data presented in tables, worksheets, etc., in textual form (SILVA, 2006).

### 3 RESULTS

The systematics used to define and elaborate indicators based on the information visualization area to represent and compare the performance of PPGs is summarized in Tables 2, 3 and 4 - Dimensions of the Triennial Evaluation 2013, comprised by the Capes Evaluation System, which provides comparisons between the performances of the PPGs of the Economics area.

These tables describe some of the selected indicators, the analysis of how they are made available by Capes, and also, what cannot be seen in the way they are made available. After

analyzing what cannot be visualized, some charts were elaborated based on the area of information visualization, and finally the benefits achieved were presented.

**TABLE 2** - Dimensions of Capes evaluation in the 2013 triennium - Faculty Staff - Endogeny Indicator.

How are made available by Capes	What is not possible to visualize	Proposed visual presentation	Information visualization rules	Benefits when using the information visualization rules
This indicator is present in the Book of indicators 2010-2012 “CD - Faculty Staff, Relationship and academic formation” in PDF format, and the total data of teachers are in the Indicators Spreadsheet in Microsoft Excel format.	These documents do not allow comparisons because besides the data separated into several files (one for each year), the document format (PDF) does not make it easier to generate charts.	Chart - Gapminder. Among the charts used in this research, Gapminder is the only one that allows movement exploring, which enables visualizing data evolution for a certain period. In addition, unlike the others, it enables the interaction with the data in a quick way, with a click of mouse allowing various analysis.	Color, size, position and movement.	Gapminder makes possible to use four rules of the information visualization area: the color to categorize; size of the circles to represent quantity; position and movement to visualize the evolution of the data, reaching a good communication. In addition, there are several ways to interact with data that are especially useful for understanding, and among these is the re-visualization with quickly exchange of data - with a mouse click - enabling various analysis. Thus, when the information is visually presented, it is easy to obtain insights that would have been difficult or impossible to perceive from the same data presented textually and in a static way (FEW, 2009).

Fonte: Create by the authors.

**TABLE 3** - Dimensions of Capes evaluation in the 2013 triennium - Student Body, Theses and Dissertations - Amount of concluded theses and dissertations.

How are made available by Capes	What is not possible to visualize	Proposed visual presentation	Information visualization rules	Benefits when using the information visualization rules
This indicator is available in the 2013 Triennial Evaluation Indicators spreadsheet in Microsoft Excel format.	Information on the amount of concluded theses and dissertations are available in tables that allow individual reading of values (one at a time), as it is the	Chart - Gapminder. It allows movement exploring, and to visualize the evolution of data for a certain period. It also makes possible to	Color, size, position and movement.	Gapminder allows a broad view of all information. It was possible to use four rules of the information visualization area: the color to categorize the programs; the size of the circles to represent the quantity/average; position and the movement to visualize the evolution of all the data during the Triennium of 2013. Furthermore, when quantitative values are presented as visual images that present

	way we perceive the tables, so it is not possible to obtain a broad view of all the information contained therein.	quickly review or exchange of visualized data.		significant patterns, the information is fragmented in these images, so it is possible to analyze a greater volume of information at the same time than if using tables or text alones, because charts multiply the number and complexity of the insights that may arise (FEW, 2009). With this specific chart (Gapminder) it is possible to get interaction between the data in several ways, for example: add variables, etc.
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Source: Created by the authors.

**TABLE 4** - Dimensions of Capes evaluation in the 2013 triennium - Intellectual Production – Area productivity weighted by the amount of publication vehicles.

How are made available by Capes	What is not possible to visualize	Proposed visual presentation	Information visualization rules	Benefits when using the information visualization rules
This indicator is available in the Indicators spreadsheet of the 2013 Triennial Evaluation in the Microsoft Excel format.	Spreadsheets are good to individually data analysis, but do not allow comparisons and pattern behavior detection.	Bar chart. To Yau (2012), the bar char is one of the most common types and can be used to several types of data.	Bar char: width and color.	According to Few (2009), our eyes are naturally attracted to patterns and exceptions that would be difficult or impossible to find in tables or spreadsheets. Information visualization is ideal to exploratory analysis of data. In this case, the bar chart was used and the utilized rule was the width of the columns, because it is possible to easily compare them, and the color to categorize the programs. Thus, making it possible to have an individual analysis as well as a general view. To Few (2009) a general view is very important. It reduces search time, allowing the detection of global patterns and assists the user in choosing the next movement. There is, generally the heuristics of the visualization starts with a general view, that allows the user do quickly access information

Soure: Created by the authors.

The use of information visualization concepts facilitates the understanding of the dynamics of science and provides significant insights for decision makers, who especially work in the implementation of public policies and in the management of PPGs.

The dimensions of the 2013 Triennial Evaluation that evaluates the PPGs are based on five standardized questions for all areas of knowledge, namely: program proposal; faculty members (professors); student body, theses and dissertations; intellectual production; social

insertion and relevance, and each area commission defines the weight for each item, disclosed in an Area Document. For the area of Economics, the requirements of the “Student Body”, “Theses and Dissertations” and “Intellectual Production” are considered more relevant in the evaluation and represent the results of the programs in terms of new graduates and their scientific production associated to the production of the professors. The Faculty Members question is considered a key point, since all the analysis are based on the number of permanent professors that each program has.

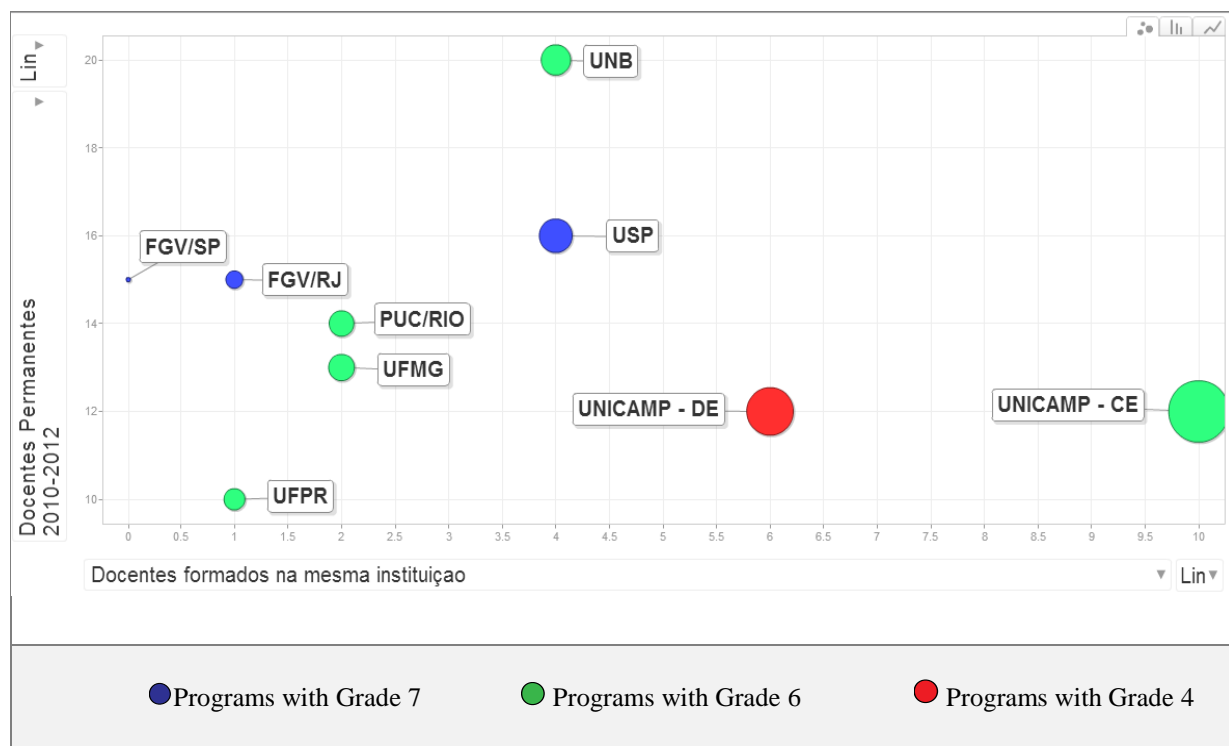
### *3.1 Faculty staff (professors)*

In the Evaluation Report of the 2013 Triennial, in the Faculty Members subject some indicators were evaluated: the academic degree, the professors's performance within the program, if there is research exchange, if there is endogeny etc. In general, for Capes, the quality of the teaching staff corresponds to a diverse background, so endogeny is a negative indicator, and may jeopardize the program to reach the maximum grade within this category. This indicator is calculated by the number of permanent professors (DP) postgraduated in the same institution divided by the total number of permanent professors.

The data related to the professors academic formation of the programs are present in the Book of indicators 2010-2012 “CD - Faculty staff, Association and Academic Formation” Capes (2010), and the first difficulty found to analyze these data is that besides being in PDF format, they are divided by year. It was necessary to extract the data from the three documents of the 2010, 2011 and 2012 years and compile then in a spreadsheet from Googledocs to generate the externalized faculty members indicator through the Gapminder chart. Also, inconsistencies were detected in Capes data related with permanent professors quantity. A hypothesis for this inconsistency may be related to dynamics of professors admissions, which may directly influence the number of professors considered permanent during the PPG evaluation. Later, a simulation was performed with the data present in the Books, but it was not possible to find significant changes in the permanent professor’s admission behavior. Finally, in order to arrive a common denominator in relation to the number of permanent professors, the Area Commission defines the amount that will be used at the evaluation time, based on data from the three years corresponding to the triennium, and are made available in the Indicators Spreadsheet.

Therefore, it was decided to use the Gapminder chart, only to explore the discrepancy between the endogeny presented by the PPG. When elaborating CHART 1, it was possible to use four rules of the vision area: color to categorize; circles sizes to quantify; position and movement to visualize the evolution of the data during the Triennial 2013 in a dynamic way allowing a good communication. However, it was not possible to explore the movement rule. In Few's view (2009) the effectiveness of information visualization depends on two factors: the ability to clearly and accurately represent the information and the ability of interractions in

order to understand it. Gapminder enables quick data interaction with the click of amouse for various analysis.



**CHART 1** - Faculty staff profile – G9 - Endogeny

Note: Circle size represents the amount of permanent professor<sup>6</sup> postgraduated in the same institution divided by the total amount of permanent professors = Endogeny

Source: Created by the authors from the available information in the Book of Indicators of 2012 “CD – Faculty Staff, Relationship and academic formation” (CAPES, 2010) and the Indicators Spreadsheets (CAPES, 2014).

It is possible to identify in CHART 1, both by the position and the size of the points that the two PPGs of Unicamp stand out in relation to the number of permanent professors postgraduated in the same institution. That is, their degree of endogeny is high. This finding corroborates with Schwartzman (2013) that most graduated doctors end up working very often in the same universities from which they graduated. When analyzing the programs with grade seven, there is a pattern of behavior regarding the amount of permanent professors presenting little or no endogeny. In the case of programs with grade 06 there is no pattern of behavior regarding the number of permanent professors and endogeny.

In fact, having a more diverse professor staff contributes to the quality of PPGs, since it is possible to incorporate experiences from other institutions. Therefore, there is a need to better understand the endogeny in the area of Economics, taking into account the studies of Horta

<sup>6</sup> Classified, declared and reported annually by the program, and that meet all the requirements of Capes Order #02 of 04 January 2012.

(2012) that categorizes the academic career in several endogenous profiles, and as Braga and Venturini (2013) points out, the academic career has undergone for several changes over the years and deserves to be re-examined. In order to understand the discrepancy between PPGs, a possible way is to analyze how the faculty formation area is given, this can be accomplished by investigating the number of theses and dissertations of each of the analyzed PPG.

### 3.2 Student body, theses and dissertations

In this aspect, several indicators are evaluated, such as the number of theses and dissertations concluded by the students of the program, the average number of orientations completed by permanent professors, student's scientific production, etc. This data can be found in the Microsoft Excel Spreadsheet format, which only allows the reading of individual values (one at a time), which makes it difficult to analyze when there is a large amount of data.

Assess the amount of theses and dissertations completed by PPGs can help to understand the discrepancy between PPGs regarding endogeneity, since it is directly linked to the place of professor academic formation. Therefore, to try to understand the behavior of the programs in relation to the number of theses and dissertations concluded and the average of the per-professor orientations of each of the PPGs analyzed, we again chose the Gapminder chart, which makes it possible to use four vision rules: a color to categorize programs; the size of the circles to represent the quantity/average; the position and the movement that allowed to visualize the evolution of the data during the 2013 Triennium. According to the statistician John Tukey (1965)<sup>7</sup> apud Few (2009) a great virtue of the good graphical visualization is that it can serve to present clearly and effective a message whose calculation or observation may not be simple, as is the case of CHART 2, where some calculations were required that are behind the representations.

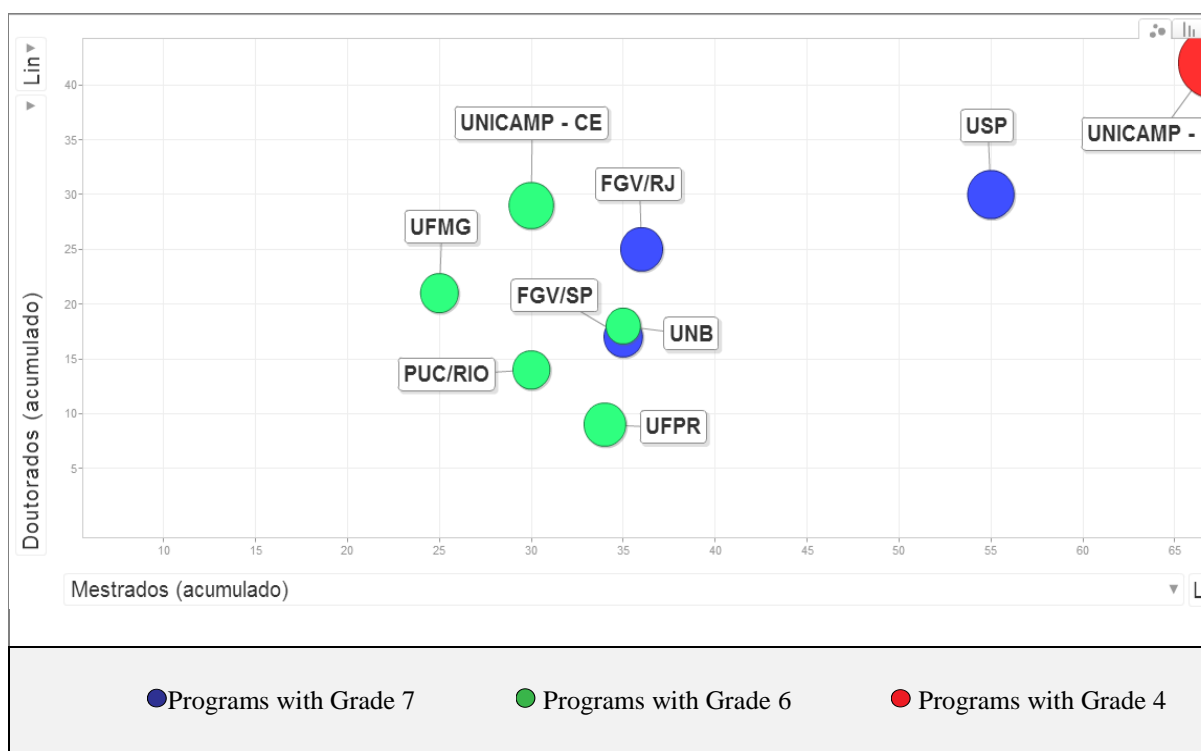
When analyzing CHART 2, it is possible to identify that the two programs of Unicamp stand out in relation to the number of theses and dissertations concluded, together with the USP program, that is, curiously among the analyzed programs, institutions that have a high index of Endogeneity are also those who most graduate doctors in the Triennium of 2013. When analyzing specifically the Economics Development Program of Unicamp, it is possible to note that it is a leader in the graduating both masters and doctors, however, although this leadership is recognized by Capes in the evaluation, there is also an alert that the program has a high degree of endogeneity, and it is recommended that the program incorporate more diversified postgraduate professors in its future admissions.

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<sup>7</sup> Tukey, J. W; M. B. Wilk, **Proceedings of the Symposium on Information Processing in Sight Sensory Systems**. Pasadena CA: California Institute of Technology, 1965.



In such cases, it is important to carry out a more in-depth analysis, since, according to Faria (2011), the elaboration and use of indicators depend strongly on the focused context and the intended purposes, therefore, it is fundamental to carry out studies that consider incorporating the specificities and interests of what is being analyzed. In addition to the number of masters and doctors, Moreira and Velho (2008) also raise the question of quality and not only the quantity of research, which is the great challenge for those who create science and technology policies: rethinking the formation of human resources to create mechanisms and establish a strong bound between researches and the reality and needs of the country.



**CHART 2** - Concluded theses and dissertations - triennium - G9

Note: Circle size represents the average of concluded theses and dissertations by professors in the triennium.

Source: Created by the authors from the available informations in the Book of Indicators from 2010, 2011 e 2012 “TE —Theses and Dissertations” (CAPES, 2010) and the Indicators Spreadsheets (Capes, 2014).

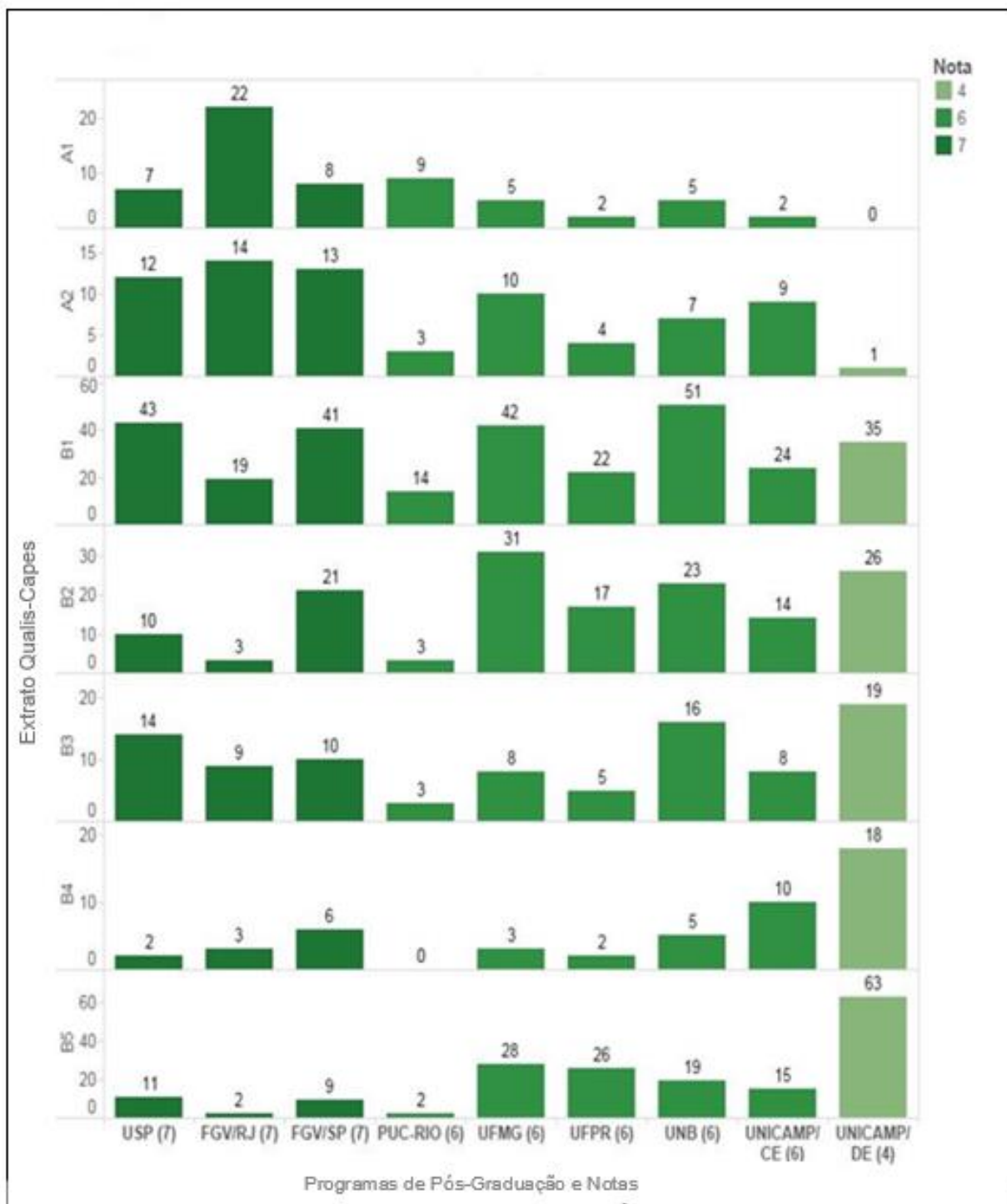
### 3.3 Intellectual Production

The intellectual production is the one that has the highest weight at the moment of the evaluation in the area of economics. According to the area document, this item is evaluated according to the per capita production of permanent professors in relation to the average productivity of the area, weighted by the quality defined by the Capes publication vehicles (2013). It occurs that a lot of data is present in a Microsoft Excel spreadsheet. As well as the understanding of this data is compromised due to the large amount of information, it was

decided to analyze the behavior of the programs in relation to the quantity of papers published in technical-scientific journals ascertained by Qualis-Capes, through the column chart, which is very common and at the same time allows to use several types of data ( YAU, 2012). It is used, for example, to compare items or show data changes over a period. There are several variations of this type of chart and the one that we present in CHART 3 is one of them.

In CHART 3, the length of the columns indicating the quantity and the color to categorize the programs were used as the vision rules. In addition, it enables an overview vision, while at the same time analyses each program individually with regard to publications by Qualis-Capes extract. For Few (2009) to have an overview is very important, it reduces the search time, allows the detection of global standards, because generally the visualization heuristic begins with an overview.

When analyzing CHART 3, a pattern of behavior is observed: the programs that have a higher grade (7) are those that have more publications in periodicals of superior Qualis-Capes extracts, whereas the behavior of the program with the lowest grade (4) is the reverse, that is, it presents more publications in lower Qualis-Capes extracts. In the case of the program with grade 4, it is important to analyze this indicator more closely, considering the specificity of the program, since it is a more focused program for national development issues. With regard to programs with grade 6, it was not possible to identify a behavior pattern. However, the PUC-Rio program stands out by presenting a smaller number of publications than the others, nevertheless, its few publications are concentrated in higher extracts, which guarantees the a grade 6. Therefore, we identify a program that opted for quality (measured by Qualis-Capes) instead of quantity. This indicator is in line with the Area Document (CAPES, 2013), which points out that the degree of internationalization of the programs results, mainly, from publications in international journals, identified in Qualis-Capes with the A1 and A2 classifications.



**CHART 3** - Amount of papers published in technical-scientific journals in Qualis extracts (A1-B5)

Source: Created by the authors from the available information in the Indicators Spreadsheet. (CAPES, 2014).

## 4 CONCLUSION

The present research elaborated and analyzed a set of scientific indicators, based on the information visualization area, in order to maximize the understanding of the dynamics of science, especially the information provided by the Capes Evaluation System on the performance of PPGs, using the information available in Capes Books and Spreadsheets. More specifically, it established best practices in the visualization of science, analyzing PPGs performance indicators, and finally presents the results achieved and discussed.

Regarding the best practices in information visualization a set of rules was identified and applied in the context of the scientific dynamics: color, position, length, movement, width, size and shape, and thus, different tools were selected, in the form of charts, to maximize the understanding of the scientific indicators on the performance of PPGs, based on data from the Book of Indicators and the Indicators Spreadsheet, from the 2013 Capes Triennial evaluation.

In respect to the dimensions of the evaluation, regarding the faculty members, among the PPGs analyzed, endogeneity appears strongly related to the two PPGs at Unicamp, which are also the ones that most graduates doctors and masters together with USP, suggesting the need to a deeper understating of the topic in order to assess the relationship between these two indicators. With respect to intellectual production, PPGs with grade 7 are the ones that publish mostly in journals with higher Qualis-Capes (A1 to A2), whereas in Qualis-Capes B5 journals the program grade order is in reverse. The results reinforce that the criteria of the Capes Evaluation System tend to reward the PPG with more international publications since the weight of this requirement in the system to the economics area is higher.

Based on the theoretical reference and the discussion of the results achieved, the conclusion is that it is feasible to make use of information visualization area concepts, to facilitate the understanding of the dynamics of science, especially about the performance of the Postgraduate Programs, through the elaboration of indicators based on the data and information made available by the Capes Evaluation System, assisting decision-makers regarding the implementation of public policies and the management of PPGs.

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