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RELATIONSHIP BETWEEN ENVIRONMENTAL CATASTROPHES AND BRAZILIAN TECHNOLOGICAL PRODUCTION

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Abstract

Waste from mining is the responsibility of companies and tailings and derived waste becomes one of the biggest problems, making it necessary to implement public risk management policies. The objective of this study is to identify impacts of environmental catastrophes on Brazilian technological production. Scientific publications deposited in the SCOPUS Database and patents deposited in the patent office of the National Institute of Intellectual Property (INPI) were considered the universe of this study. The analyzed sample consisted of scientific publications resulting from research with the keywords 'iron ore', 'tailings' and 'dams'. A search was also carried out in the INPI database using the keywords 'RESIDUO AND MINERA*. The nonlinear regression of the number of deposits shows two curves. The first is ascending and the second descending. Curves in the years 1998 and 2015 are identified. The first identifies a trend towards an increase in the number of deposits and the second represents the stabilization of this growth in the number of deposits. The search in the SCOPUS database resulted in 223 publications. The year 2007 was identified as the moment of deflection of the curve with an increase in the number of publications. It is possible to affirm that Brazil is a center that generates science in the area of Dams and Iron Ore Tailings. On the other hand, it is not possible to identify any reflex of technological production from environmental catastrophes events. This suggests that Brazil is a country that does/finances science and does not produce technology in this area.*

Palavras Chave: Mining; Science; Technology and Innovation Indicators; Science, Technology and Society

Introduction

According to Brazilian legislation, it is up to companies or Permissionaires of Lavra Garimpeira to prepare and implement the Risk Management Program (PGR). The PGR should include steps such as anticipation and identification of risk factors (Brasil, 1999). Among the risks, the health of workers is considered during their activity and after it. The balance of the environment also fits into the risk factors, not only as an immediate consequence of the activity but also of possible future results. The residues from this activity are the responsibility of the companies and the production of these tailings or residues derived

from this activity becomes one of the biggest problems arising from mining, making it necessary to implement public policies for the management of environmental risks and disasters (DE QUEIROZ LEMOS; DA SILVA PIMENTEL, 2021)

It is possible to exemplify this situation by analyzing recent disasters in Brazil. The disaster in Mariana, through the trail of destruction, forced Brazil to turn to the mining issue, seeking a reassessment of government inspection methods, outlining improvements. With the Brumadinho dam failing four years later, it was realized that the necessary change had not taken place in the country (SOUSA; DE FREITAS, 2019). The socio-environmental damage is immeasurable and the greatest burden is being paid by the population of the region, and by the natural system destabilized by the impact of the tailings mud along the affected rivers.

Authors suggest that access to clean technologies can also be achieved through organizations and training so that clean technologies can be used with minimal environmental impact (BORMA; SOARES, 2001). Technology has always been associated with iron mining. Its history dates back to the beginning of the occupation of the mining region, during the gold mining cycle and the need for tools for prospecting and mining that were rudimentary in the first iron foundries (CASTRO, 2021) and continued to evolve not only to optimize the mining and for subsequent control of residues and by-products resulting from the manipulation of ore.

Pott and Estrela (2017) explain that polluting activities go through regulatory and licensing processes even before they are implemented, promoting planning in all its phases, from conception to operation of any enterprise. In this way, public policies, through their laws, resolutions and regulations originated from catastrophes that occurred, serve to protect against new accidents, which, even so, still occurred.

From this perspective, the present study seeks to understand whether environmental catastrophes act as a driving force for technological production, in a retrospective way. Identified failures that generate catastrophes, the production of technology would be sought to avoid the repetition of negative events. Thus, the objective of this study is to identify impacts of environmental catastrophes on Brazilian technological production.

Method

This is an inductive study as it seeks answers to a problem from the gathering of identified evidence. Data were collected in document search with bibliometry and patentometry and analyzed quantitatively.

Sample

The universe of this study were scientific publications deposited in the SCOPUS Database and Patents deposited at the patent office of the National Institute of Intellectual Property (INPI) and available on its official portal. The analyzed sample consisted of scientific publications resulting from research with the keywords 'iron ore', 'tailings' and 'dams' as search filters. There were 223 publications since 1977.

A search was also carried out in the INPI database using the keywords 'RESIDUO* AND MINERA*', resulting in 388 patents filed since 1991. The years 2022 and 2021 were not considered, as the

filing of patent applications only are published 18 months after that date. The filter by the International Patent Classification (IPC) was applied to these records, gathering only those that presented Class B, C or E, leaving 331 records.

Instruments and Procedures

The resulting data were analyzed using a non-linear regression with a third degree polynomial curve fitting with the independent variable the year and the dependent variables the quantitative of patent applications and scientific publications available in the SCOPUS database. For each dependent variable, a graph was created with the consequent curve and a line or slope was drawn between the maximum and minimum points of these curves. Subsequently, the greatest perpendicular distance between the straight line and the curve was calculated, indicating the deflection point of the curve. The same procedure was adopted with the registration of patent deposits.

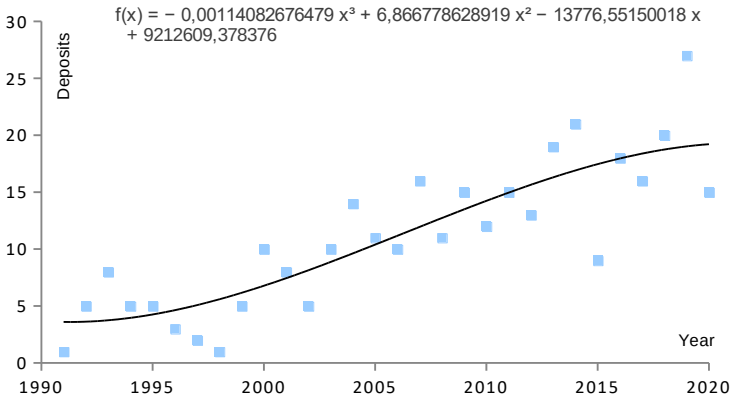
Regarding the records resulting from the search for scientific publications, the countries of origin and the language of the publications were also analyzed. Additionally, the nationality of the research funding bodies was recorded. Among the researches with declared funding, they were divided into 'Brazilian', 'not Brazilian' or 'Undefined' entities.

Results and discussion

Initially, the deposits of patent applications at the INPI were analyzed. Figure 1 shows the number of deposits over the years prior to the 18-month period of secrecy. Performing a nonlinear regression with third-order curve fitting, it is observed that the result presents two curves. The first is ascending and the second descending.

Applied to the theory of greater perpendicular distance between the line generated between the initial and final points, it is identified that the curves present in the years 1998 and 2015. The first identifies a trend of increase in the number of deposits and the second represents the stabilization of this growth in the number of deposits.

Figure 1 - Number of patent filings related to Mining Waste, with IPC 'B', 'C' or 'E'.



Environmental disasters related to waste dams are perhaps the most devastating events in recent years. On November 5, 2015, the Fundão dam collapsed and burst, causing an unprecedented

environmental disaster in the history of Brazil (LOPES, 2016). Its logical consequences, in addition to destruction, would be the search for technology to increase the safety of other dams. With a greater amount of technology developed, it would be fair to have more patent applications filed on the subject. The problem is clear, so the search for solutions that contribute to the solution of the problem suggests a greater amount of technology developed.

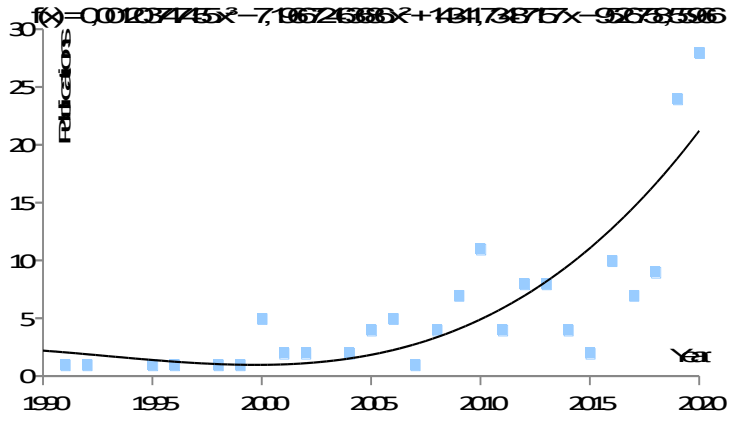
After the event in Mariana (MG) in 2015, the dam of Córrego do Feijão da Vale SA. in Brumadinho (MG) also collapsed in 2019. These two events are among the biggest environmental disasters in the world in the mining sector. In the case of the Fundão dam collapse, 60 million cubic meters of toxic mud were dumped along a 663-kilometer stretch of the Gualaxo do Norte, Carmo and Doce rivers (LASCHEFSKI, 2019).

A report from the United Nations Environment Agency containing records of accidents such as these indicate that they were the largest dam failures since 1985. In the last 5 years alone (so 2015 to 2019), eight major accidents have occurred around the world (PASSARINHO, 2019) , justifying the need to increase efforts to develop specific technologies. If the system so far is flawed, it would need to be improved. But one cannot fail to consider the option of flaw or human error. Neglect may be the biggest contributor to meltdowns. In this case, it would still be necessary to develop technologies for fault control, process control and risk monitoring.

The fact that it is possible to identify two deflection curves in the Nonlinear Regression suggests a first moment of increased interest in technology production in 1998 and a second moment of stabilization in 2015. This second moment is close to the first accident that the dam in the city of Mariana collapsed, but the change in trajectory is for the stabilization of deposits. If there were any consequences of the accident in the production of Brazilian technology, it was retraction, which would not be desirable in this case.

Following the data searches, the SCOPUS database was accessed and scientific documents related to the study topic were searched. The filter adopted required the keywords 'iron ore', 'tailings' and 'dams' in the title or abstract. There were 223 publications available in this Database. A nonlinear regression with third-order curve fitting was also performed (figure 2) resulting in a single ascending curve. Applied to the theory of greater perpendicular distance between the line generated between the initial and final points, the year 2007 was identified as the moment of deflection of the curve. This is considered to be the moment when the trend changes with an increase in publications.

Figure 2 - Number of publications on 'dams' 'tailings' 'iron ore' over time and third-order nonlinear regression curve fit.

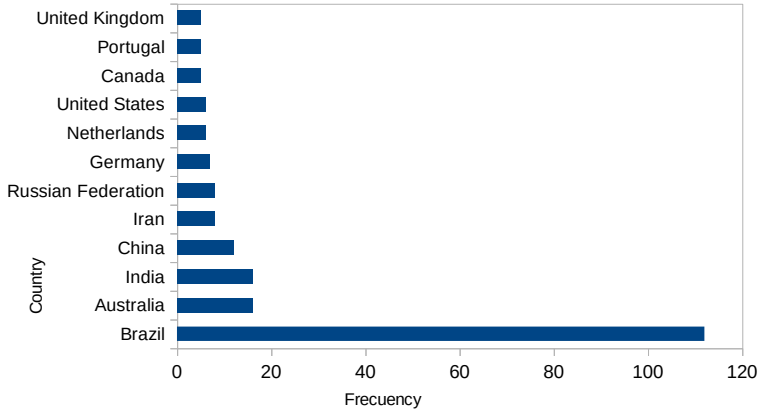


The deflection of the Regression curve occurred after 9 years of the same event related to the filing of patents, related to the increase in production, in this case, scientific. The date also does not come close to the events of the collapse of the Dams, but demonstrates the growth of interest in doing science on the subject. Science, along with technology. it is a part of the so-called Innovation Systems. This is a strong indicator of the countries' development because it is believed that in the most developed countries, the integration between scientific and technological institutions and the productive system takes place in a much more complete and natural way than in developing countries, where the scientific sector and technological would tend to be more isolated (SCHWARTZMAN, 2002).

Thus, although the effects of the environmental catastrophes suggested in this study are not perceived in the scientific production resulting from the search, it is possible to perceive that there is a lot of information shared by the scientific community, which suggests that knowledge is maturing and, consequently, there is theoretical support for the development of new technologies.

When analyzing the countries where the research originated, it can be seen that Brazil is the largest producer of research related to dams, iron ore and tailings (figure 3) with 112 publications. There are also 128 publications with affiliation of the authors in Brazilian Federal Universities distributed in 22 different Universities.

Figure 3 - Originating countries with 5 or more publications.

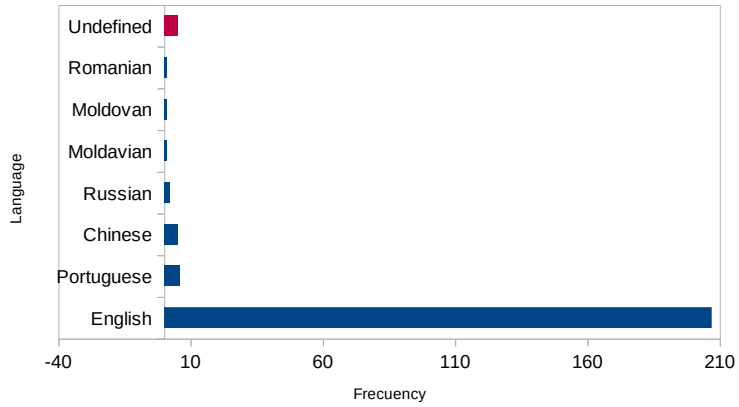


Since Brazil is the largest producer of science in this area and the research arising from studies carried out by researchers belonging to the framework of Federal Universities, the governmental origin of the interest is evident. This may be explained if the Triple Helix thesis is considered, which argues that the university is no longer having a secondary social role, albeit an important one, of providing higher education and research, and is assuming a primordial role equivalent to that of industry and the government, as a generator of new industries and companies (ETZKOWITZ; ZHOU, 2017). In this case, the Federal University is maintained by the government and, although it performs its role as a generator of new industries, it can be confused with the figure of the government in this definition.

This position is corroborated by Audy (2017) when he states that in the context of the third mission of Universities, they take on a new and renewed challenge, that of acting as vectors of the economic and social development of society, expanding their basic missions, teaching and research. . Anyway, it is possible to relate the origin of scientific production with the Brazilian Federal Universities, even if not identifying in them any reaction to the environmental events considered in this study.

Figure 4 presents the language of the publications resulting from the search. It is evident that the English language is the official language of science, as it dominates the number of publications. The Portuguese language, although being the second most frequent, assumes almost null values, as well as the other registered languages. It is worth mentioning the low number of publications that do not have a defined language in the database.

Figure 4 - Language of publications.

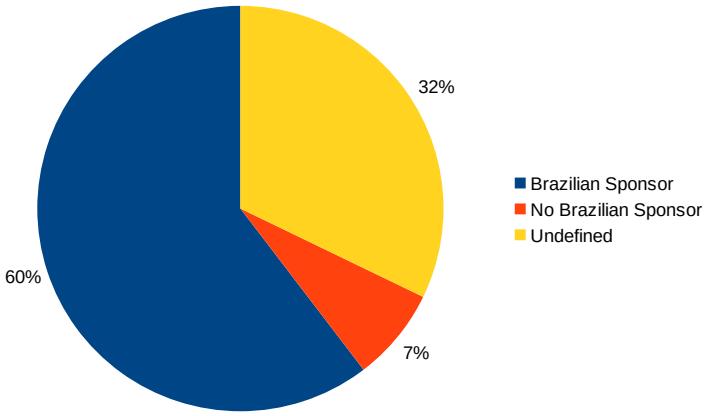


If the publications of scientific studies in the area come from Brazil and most of the researchers worked on them within Federal Universities, the language of the studies is a very interesting indicator to be analyzed. The official language of science is English and in almost all areas the percentage of publications in English is over 80% (LUCENA, et al. 2018; JOB, 2018).

Thus, one more piece of data that shows the relevance of the publications. By publishing in English, researchers seek to be read more easily. They seek to increase the scope of their study results, which indicates the possibility of good scientific advances, including the interest of peer-reviewed journals and publishers in publishing the topic.

After identifying that Brazil is the largest producer of science in the area, it is observed that it is also the largest funder of studies. Figure 5 shows that Brazilian funding agencies financed almost twice as many studies compared to funding from other countries.

Figure 5 - Distribution of research funding bodies according to the country indicated by the researchers.



It seems logical that scientific research carried out in Brazil based on researchers belonging to Federal (public) Universities receive funding from Brazilian bodies. However, this is not the rule. Fostering bodies exist in all countries and there are also researchers from other countries. This result shows again the nature in Federal Universities.

It is important to emphasize that in scientific environments, the financial and material resources provided by States are, in general, limited and where, at the same time, there is no wide range of alternatives to obtain these same resources (FARIA, 2019). The same author reinforces that, in this context, the elaboration of research in exchange for funding, filed with external, public and private entities, can help to overcome the supposed gap between research.

This creates a spiral in which the state maintains the University and its researchers. Scientific research is financed by national bodies and, in this case, mainly public bodies, which, if not the only, is the best source of funds. This logic is not repeated when analyzing the specific technology produced, using the same search criteria, but in a specific environment of technology records.

Conclusion

Considering the analyzed data and the identified evidence, it is possible to affirm that Brazil is a center that generates science in the area of Iron Ore, Dams and Tailings. It was also evident that the cradle of research in this area are the Public Universities and that there is an interest of Brazilian funding agencies in stimulating the production of knowledge in the area and a growing interest in the subject.

On the other hand, it is not possible to identify any reflex of technological production from environmental catastrophes events. The evidence that was found suggests the opposite, because when the worst disasters happened, related patent filings took a downward trend. This suggests that Brazil is a country that does/finances science and does not produce technology in this area.

Finally, it is always interesting to point out that research requires investment and financial support. It has low potential and monetary return. The Technology produced, although it needs investments, has a great potential for return, either through transfer or through exploitation of the product and/or service proposed by it. Thus, it would not be absurd to say that research is money.

Conflicts of interest

No conflicts of interest.

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