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Bibliometric Mapping and Trend Analysis of Beta Regression Modeling: A Decade of Development (2015–2024)

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Abstract: Beta regression is a statistical model designed to handle dependent variables that assume values within the open interval (0, 1), such as rates, proportions, or percentages. The study aimed to determine the development of beta regression over the last 10 years with a bibliometric approach. The source of the article database used comes from the Scopus website. The tool used for analysis is R software with a bibliometrix package. The results of this study show that there are 293 articles published in the Scopus Journal. Research develops in various research fields. The author with the most articles is Cribari-Neto, F., with the most significant number of documents, i.e., 12. According to the author's country of origin related to the beta regression method, Brazil has the most countries, while Indonesia is in 12th place. Therefore, research on beta regression still has excellent potential to continue to be developed.

Keywords: *Beta; Bibliometric; Modelling; Rate; Rregression*

INTRODUCTION

Beta regression is a statistical model designed to handle dependent variables that assume values within the open interval (0, 1), such as rates, proportions, or percentages (G. H. A. Pereira, 2019) (Gheno, 2022) (Abonazel et al., 2023)(Cribari-Neto & Zeileis, 2010). Applications of Beta Regression in Real-World Scenarios are widely employed in several areas, such as medicine, environmental research, finance, and natural sciences, to model continuous response variables in the unit interval. They are based on the assumption that the dependent variable is beta-distributed and that its mean is related to a set of regressors through a linear predictor with unknown coefficients and a link function. This model is beneficial for analyzing continuous outcomes that are naturally bounded, making it a popular choice in various fields of science (Seifollahi & Bevrani, 2023)(J. I. Figueroa-Zúñiga et al., 2022). The model includes submodels for both the mean response and the precision parameter, which may depend on different regressors (Cribari-Neto et al., 2024).

There are several limitations of the beta regression model. Severe impact by outlying observations that the beta distribution does not handle well (J. I. Figueroa-Zúñiga et al., 2022). Lack of robustness in the presence of outliers leads to severe bias and misleading conclusions (Maluf et al., 2025). It cannot be used when the data contain observations that equal zero or one, as the models are tailored for responses within the standard unit interval (T. L. Pereira & Cribari-Neto, 2014)

Some challenges in developing beta regression models include Finding residuals that approximate the standard normal distribution. Quantile residuals have been found to perform better in this regard (G. H. A. Pereira, 2019). In addition, the problem of Multicollinearity can severely affect the variance of maximum likelihood estimates. A new bias, the two-parameter estimator, has been developed to address this problem, outperforming other familiar estimators (Abonazel et al., 2022). Model Specification is also a challenge in beta regression modeling. Tests based on the information matrix equality can help ensure correct model specification, with reasonable control of type I error probability when data resampling is used (Cribari-Neto et al., 2024). Developing the Variable Selection process is also a concern in beta regression modeling. New model selection criteria, such as the Predictive Residual Sum of Squares (PRESS)-like tool, have been proposed to account for leverage, residuals, and influence of observations (Espinheira et al., 2019).

The researchers also developed several beta regression modeling techniques. Bayesian Approaches, including Gibbs sampling, have been applied to handle errors-in-variables and to incorporate prior information into the analysis (J. I. Figueroa-Zúñiga et al., 2022) (J. Figueroa-Zúñiga et al., 2018)(Branscum et al., 2007). On

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the other hand, Robust Alternatives: The rectangular beta (RB) distribution offers a robust alternative to the traditional beta distribution, handling outliers and heavy tails more effectively (J. I. Figueroa-Zúñiga et al., 2022).

Although beta regression has gained increasing popularity, comprehensive overviews of its development in both theoretical advancements and practical applications are still limited. Most existing reviews tend to emphasize either mathematical formulations or specific application areas, without capturing the broader intellectual landscape and knowledge evolution within the field.

This study aims to address that gap by conducting a bibliometric analysis of beta regression research over the past decade. Specifically, it seeks to identify publication trends, influential works, dominant themes, and collaborative networks, while also assessing how the interplay between theoretical innovation and applied implementation has shaped the development of this modeling approach.

METHOD

This study adopts a bibliometric analysis approach to examine the development and intellectual structure of beta regression research. Bibliometric analysis quantitatively investigates bibliographic data from scientific publications using statistical and mathematical techniques to understand patterns, trends, and scholarly influence within a specific field (Mukhlisa & Hasan, 2024).

The data source was the Scopus database, which is selected due to its comprehensive coverage of peer-reviewed literature. The search was conducted using the query:

"TITLE-ABS-KEY (Beta Regression)"

This query targets documents where the term "beta regression" appears in the title, abstract, or keywords. Only journal articles written in English were included. Duplicates, non-research content (such as editorials, book reviews, and notes), and inaccessible full texts were excluded from the analysis. Data were downloaded during the last week of May 2025.

Bibliographic metadata were exported in BibTeX format and analyzed using R software with the Bibliometrix package(Aria & Cuccurullo, 2017). The following bibliometric indicators and analytical techniques were applied:

Table 1 Bibliometric Indicators and Analytical Techniques

Indicator / Technique	Purpose / Description	References
Total Citations	Measures the cumulative number of citations received by publications related to beta regression, indicating overall scholarly influence.	(Adnan & Ullah, 2018) (Moed, 2009)
H-index	Assesses both productivity and citation impact of authors or sources, by quantifying how many papers have received at least *h* citations.	(Sillet, 2013) (Canavero et al., 2014)
G-index	Enhances the H-index by giving more weight to highly-cited publications, offering a more inclusive view of impact distribution.	(Supian & Ismail, 2022)
Top-Cited Documents	Identifies the most influential studies in the dataset and their core thematic contributions.	(Baylor et al., 2023).
Journal Impact Analysis	Evaluates which journals are most frequently used for dissemination of beta regression studies, indicating reach and visibility.	(Canavero et al., 2014)
Co-authorship Analysis	Maps collaboration networks among authors, institutions, or countries, to understand research cooperation patterns.	(Kandeel et al., 2023)
Institutional Impact	Assesses which institutions are most productive and impactful in beta regression research.	(O'Connor et al., 2017).

*name of corresponding author

Publication Trends	Analyzes publication volume over time to detect growth phases and shifts in thematic focus.	(Xie et al., 2024).
Keyword Co-occurrence / Thematic Mapping	Reveals emerging research areas and thematic clusters through analysis of frequently co-occurring keywords.	(Tomé, 2024).

This methodological framework enables a structured and reproducible assessment of the knowledge development and research dynamics in the beta regression literature.

RESULT

Based on the Scopus database, 293 articles with titles related to beta regression analysis from 2015 to 2024. The development of beta regression research from year to year tends to increase and can be seen in the following table:

Table 2. Annual Scientific Production

Year	Articles
2015	19
2016	19
2017	31
2018	25
2019	29
2020	26
2021	34
2022	33
2023	39
2024	38
Total	293

Table 3. Average Citations Per Year

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2015	13.95	19	1.27	11
2016	13.68	19	1.37	10
2017	9.77	31	1.09	9
2018	23.44	25	2.93	8
2019	20.93	29	2.99	7
2020	17.04	26	2.84	6
2021	9.91	34	1.98	5
2022	9.06	33	2.27	4
2023	5.05	39	1.68	3
2024	0.97	38	0.48	2

Table 3 presents the average citations per article and per year for beta regression publications from 2015 to 2024. The data reveal important insights regarding the temporal dynamics of scholarly impact in this field.The year 2018 stands out with the highest *Mean Citations per Article* (23.44) and a corresponding *Mean Citations per Year* of 2.93, suggesting that publications from this year made notable methodological or applied contributions that were widely recognized by subsequent research. Similarly, articles published in 2019 and 2020 also show elevated average citations per year (2.99 and 2.84, respectively), indicating sustained relevance during a period when interest in advanced modeling techniques, such as beta regression, likely grew in response to increased data availability and interdisciplinary adoption.

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Conversely, the sharp decline in citation metrics for 2023 and 2024 (with MeanTCperArt of 5.05 and 0.97, respectively) is not necessarily indicative of low quality or relevance. Instead, this reflects a citation lag effect, where recently published articles have not yet had sufficient time to accumulate citations. This pattern is typical in bibliometric studies and underscores the importance of considering *Citable Years* (the number of years in which articles could have been cited) as a contextual factor.

An interesting trend is the stability of citation impact between 2016 and 2017, despite a rise in the number of published articles in 2017 (N=31). The relatively lower average citations during this period may suggest either a diffusion of attention across a broader set of works or the publication of more niche, less broadly referenced studies.

Overall, the data illustrate that the scholarly influence of beta regression literature is time-sensitive and shaped by multiple factors, including the maturity of the topic, the dissemination context, and the thematic resonance with contemporary scientific discourse. These findings highlight the need for future research to not only publish novel contributions but also position them within active, high-impact subfields to optimize visibility and citation potential.

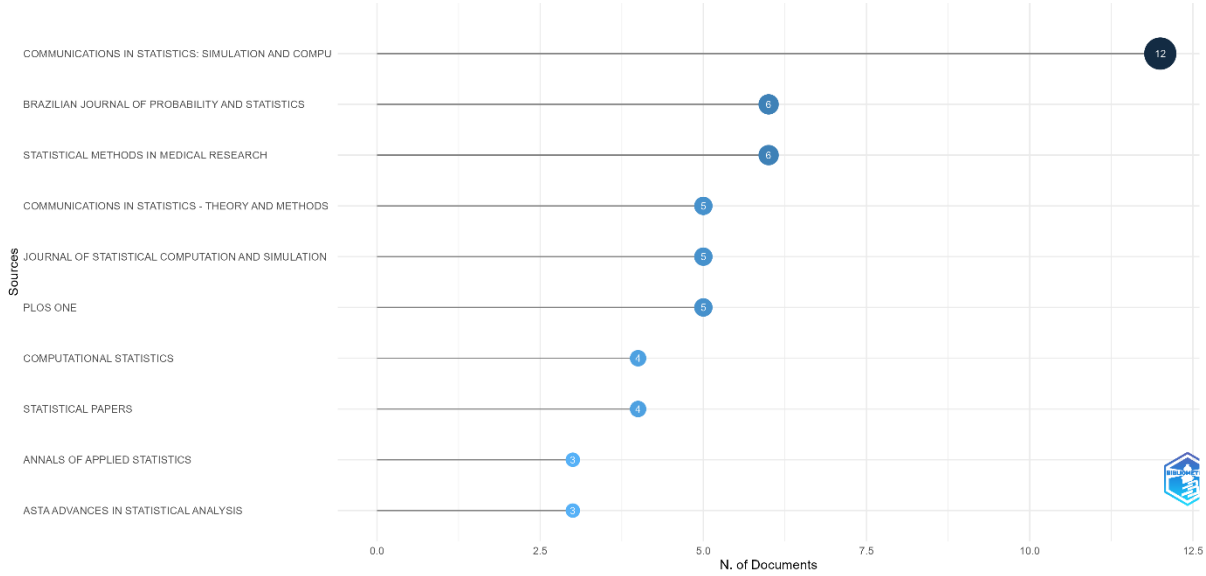

Figure 1. Most Relevant Sources

The graph illustrates the distribution of papers published in various journals focusing on statistics and related methodologies. The Communications in Statistics: Simulation and Computation occupies the top position with a significant number of documents, which is as many as 12, indicating that this journal is the primary source in this field. This research was followed by several other journals, such as the Brazilian Journal of Probability and Statistics and Statistical Methods in Medical Research, which each published six papers, showing the significant contribution of these publications to the development of research in statistics and related methodologies. With four papers each, journals such as Computational Statistics and Statistical Papers also provide a platform for statistics-related research, although their contribution is slightly lower than that of the top journals. Overall, this data illustrates the number of publications in several significant journals that actively contribute to disseminating the latest knowledge and methodologies in statistics. This rise shows the importance of these journals in shaping the direction and sustainable development of statistical science.

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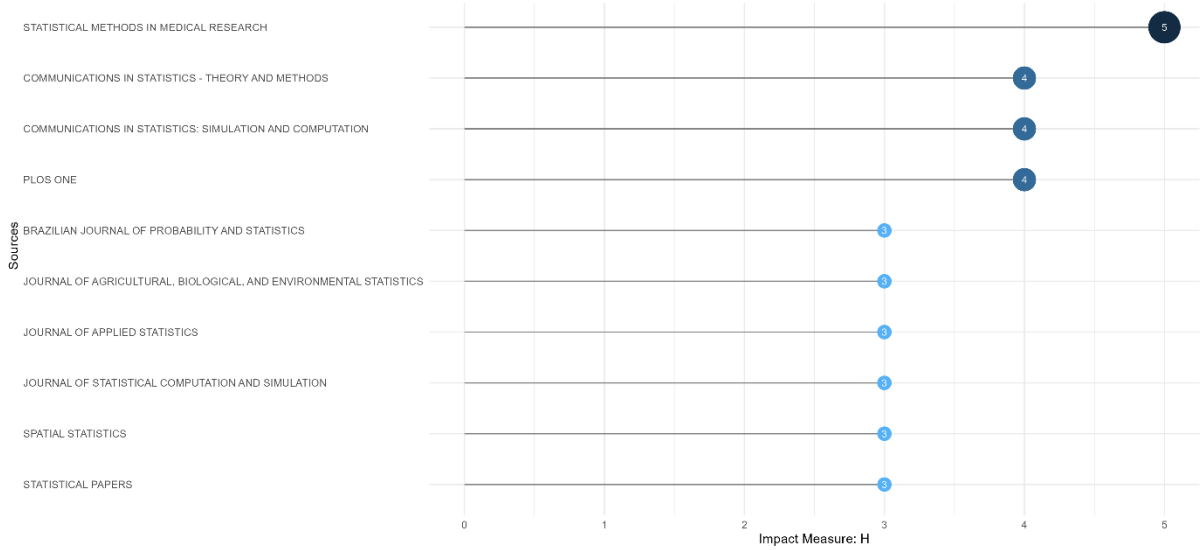

Figure 2. Sources' Local Impact

The graph illustrates the local impact of statistical journals measured based on the H index, reflecting the consistency of publications and citations in those journals. The journal Statistical Methods in Medical Research showed the most significant impact with the highest H index value of 5, followed by other journals such as Communications in Statistics - Theory and Methods, Communications in Statistics: Simulation and Computation, and PLOS ONE, each of which has an H index of 4. This research shows that these journals have a strong influence in the field of statistics and have gained substantial recognition in the scientific literature through consistent citations. In contrast, some journals such as Spatial Statistics, Statistical Papers, and the Journal of Statistical Computation and Simulation have lower H-index values, reflecting a more limited impact in terms of citations and lower relevance in the academic community. Overall, this graph provides insight into the relative influence of various journals in the statistical research community, with the top journals showing a significant impact on the development of science in this area.

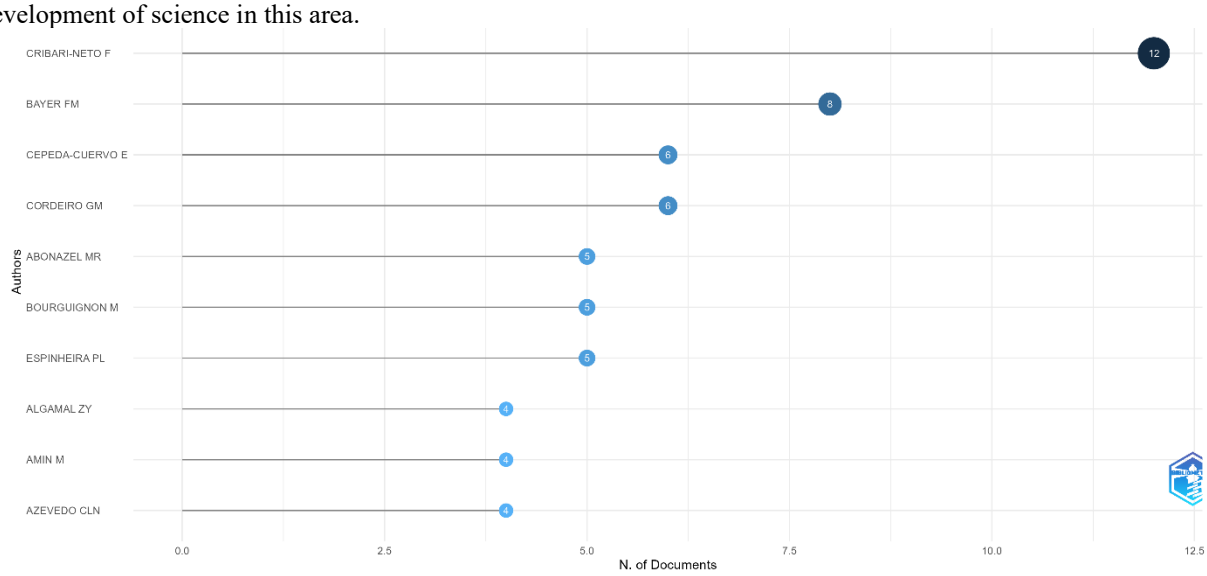

Figure 3. Most Relevant Authors

The graph presented illustrates the authors' most relevant information in the field of research related to beta regression based on the number of papers that have been published. Author Cribari-Neto, F., with the most significant number of documents, i.e., 12, stands out as a major contributor to this topic, demonstrating its central role in developing and advancing beta regression research. Followed by Bayer's author, F.M., who has eight documents, and Cepeda-Cuervo, E., and Cordeiro, G.M., each with six documents, which also contributed significantly to the development of the theory and application of beta regression. With five documents each, other writers such as Abonazel, M.R., Bourgignon, M., and Espinheira, P.L. strongly influenced this field. Although their number of publications is slightly lower, their contributions remain relevant in enriching the literature in this field. With four papers each, writers such as Algamal, Z.Y., Amin, M., and Azevedo, C.L.N. demonstrate their involvement in beta regression research, although their contributions were more limited than those of the other

*name of corresponding author

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lead authors. Overall, this graph provides a clear picture of the distribution of scientific contributions from various authors in the field of beta regression, with some authors dominating the literature and playing a key role in the progress of this research.

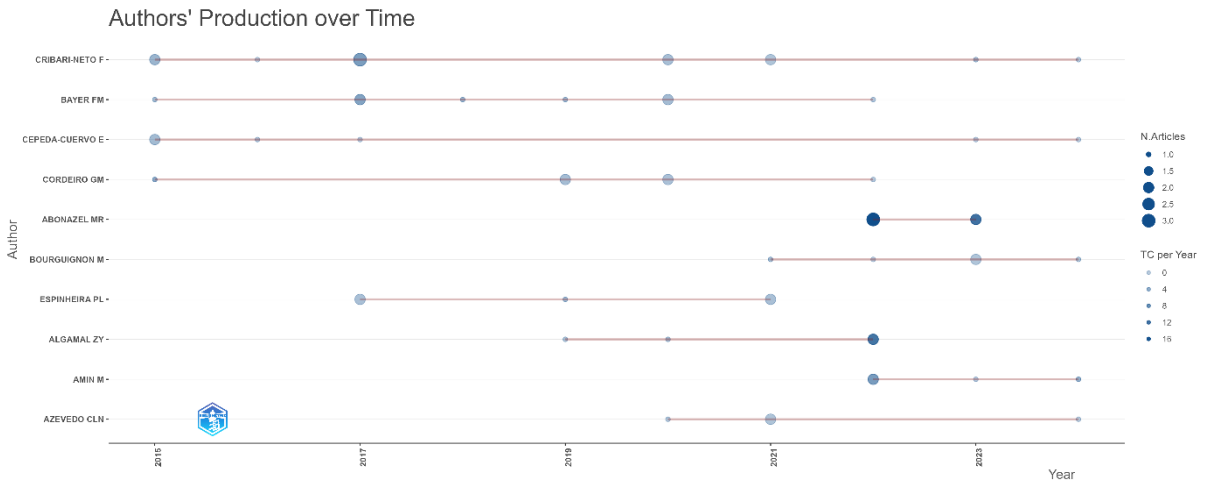

Figure 4. Authors' Production over Time

The graph presented illustrates the publication production of the principal authors in the field of beta regression over time, visualizing the number of articles published (N. Articles) and the annual citations (TC per Year) received. Cribari-Neto, F. demonstrated consistent productivity from 2015 to 2023, with several spikes in the number of articles and citations in 2018 and 2021, signaling the significant impact of his work in beta regression-related research. Bayer, F.M. also contributed significantly, with several articles published evenly throughout the year. At the same time, Cepeda-Cuervo, E. and Cordeiro, G.M. show an increase in the number of articles in specific years, with a greater concentration of publications in 2020 and 2021. Other writers such as Abonazel, M.R., Bourgignon, M., and Espinheira, P.L. show a more sporadic pattern, with some articles published in several years without a consistent trend. In addition, writers such as Algamal, Z.Y., Amin, M., and Azevedo, C.L.N. have a more limited contribution regarding the number of publications and citations. Overall, this graph shows a varied pattern in the authors' scientific production, with major authors such as Cribari-Neto, F. and Bayer, F.M. dominating publications and citations in the field of beta regression all the time. In contrast, other authors contributed with fewer articles but still impacted the development of beta regression theory and applications.

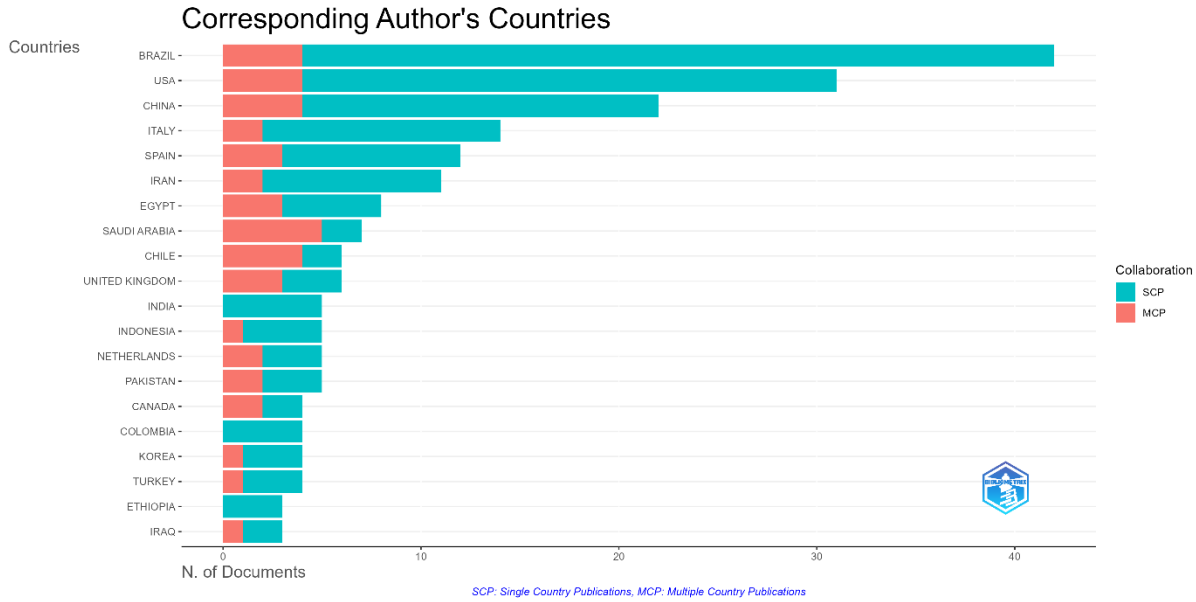

Figure 5. Corresponding Author's Countries

The graph presented shows the distribution of the number of documents based on the country of origin of the corresponding author by separating publications carried out individually (Single Country Publications - SCP) and

*name of corresponding author

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those that involve international collaboration (Multiple Country Publications - MCP). Brazil stands out as the country with the highest number of publications carried out singly and in collaborations, followed by the United States and China, which also significantly contribute to international publications. European countries such as Italy, Spain, and the United Kingdom have played important roles in beta regression-related research collaborations, with more significant contributions to publications involving multiple countries. Meanwhile, countries such as India, Indonesia, and Pakistan show a more diverse pattern, with most of their publications being done through international collaborations. Overall, this graph reflects a growing trend of global collaboration, with many countries contributing to the development of beta regression-related science through international cooperation, although some countries, such as Brazil, have shown a tendency to produce significant domestic publications.

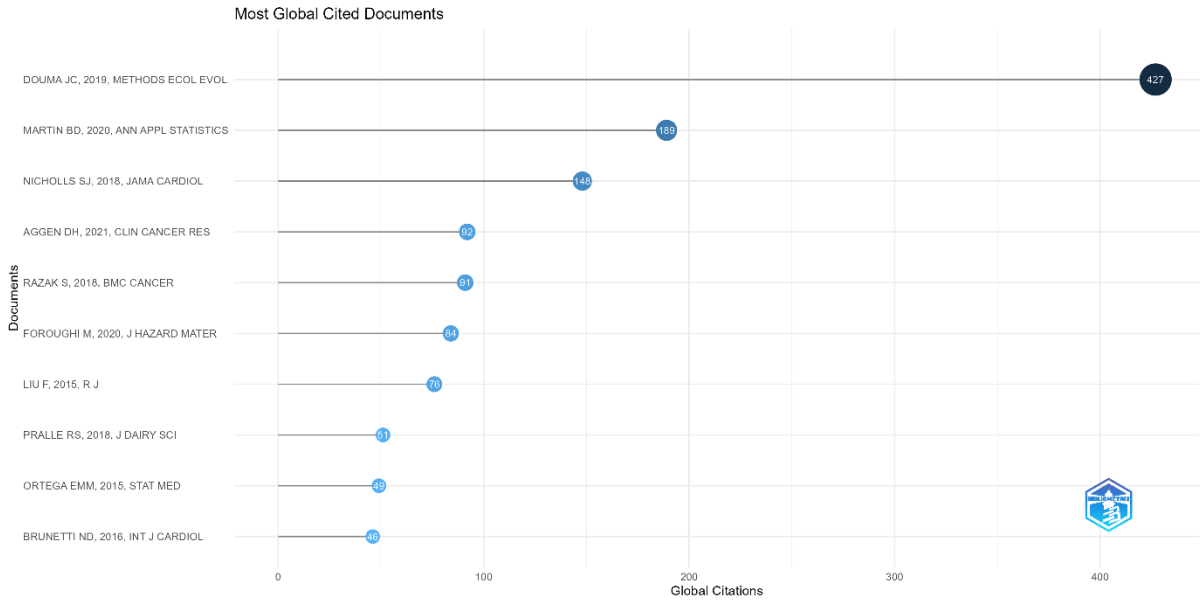

Figure 6. Most Global Cited Documents

The graph presented shows the most cited documents globally, with the number of citations reflecting important influences and contributions to the scientific literature in related fields. The article Douma JC (2019) published in Methods in Ecology and Evolution stands out with the highest number of citations, reaching 427 citations, which shows that this document has had a tremendous impact on the development of science in the field. This research was followed by Martin BD (2020), published in the Annals of Applied Statistics with 189 citations, and Nicholls SJ (2018) in JAMA Cardiology with 148 citations, which also shows significant influence in statistics and medicine. Other documents, such as those published by Aggen DH (2021) in Clinical Cancer Research and Darazak S (2018) at BMC Cancer, also have more than 90 citations, demonstrating the important impact of these studies on related topics. Overall, this graph illustrates how several publications in statistics, medicine, and health research have gained global attention, proving these works' relevance and scientific quality in driving the advancement of knowledge at the international level.

Figure 7. WordCloud

From the word cloud displayed, it can be seen that "regression analysis" is the most dominant main topic, with related words such as "statistical model," "beta regression," and "regression modeling." This word cloud suggests

*name of corresponding author

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that regression is crucial in research, specifically those involving statistical models and beta research. Other words such as "human," "female," "male," "animal," "controlled study," and "mice" indicate that regression is used in studies involving a variety of subjects, both human and animal, in the context of controlled experiments. The word "article" also indicates that many of these studies are published in scientific journals. In addition, "models," "simulation," and "intelligent systems" denote the use of simulation techniques and their application in intelligent systems, which adds a broader dimension to the use of regression in scientific and technological research. This word cloud reflects the importance of regression in understanding the relationships between variables in various experimental and study contexts.

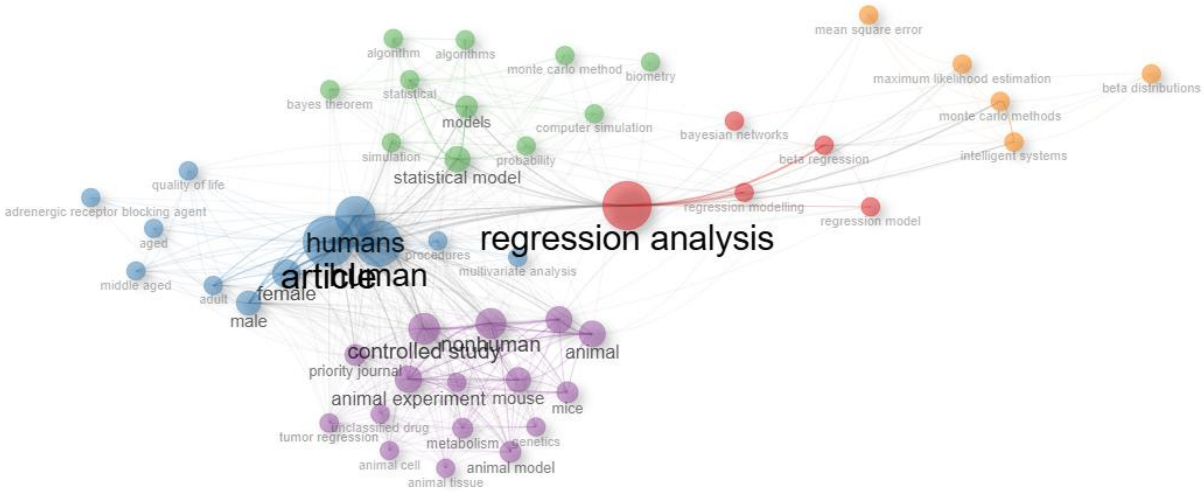

Figure 8. Co-occurrence Network

This co-occurrence network describes the relationship between various interrelated concepts in regression analysis, with "regression analysis" as the center. The network shows how terms such as "statistical model," "beta regression," and "regression modeling" are closely intertwined with various fields of research, both involving humans and animals. Related groups of words, such as "humans," "mice," and "animal experiment," describe the application of regression in experimental studies. In addition, words such as "simulation," "Bayesian networks," and "intelligent systems" indicate the application of regression in intelligent technologies and systems. The network reflects the diverse applications and interconnectedness of regression analysis concepts, including medicine, biology, statistics, and technology.

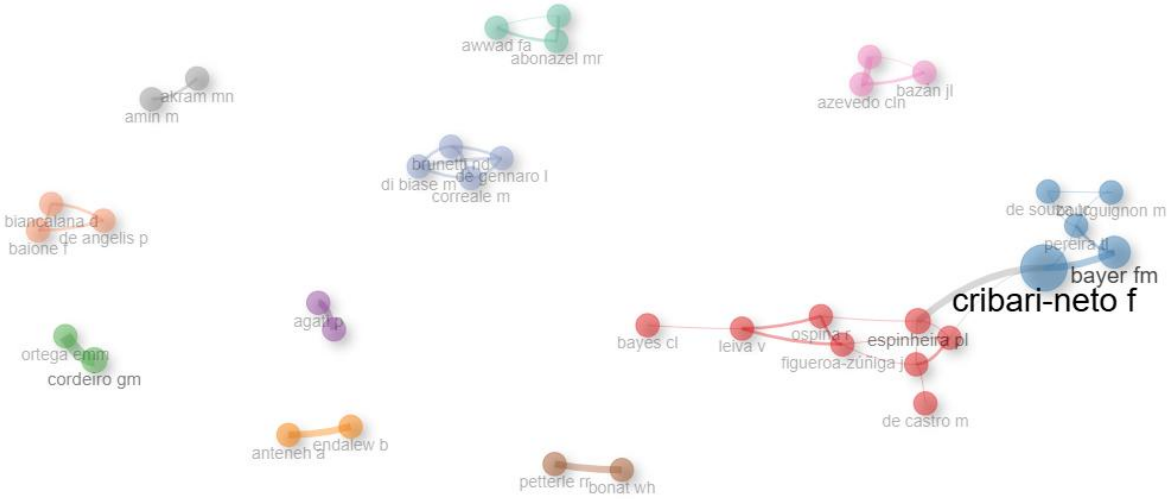

Figure 9. Collaboration Network

The collaboration network shown illustrates the relationship between authors or researchers based on their joint publications. The interconnected researchers showed intense collaboration in research, with some names, such as Cribari-Neto F and Bayer FM, appearing more dominant, pointing to their role as centers within these networks. Nearby groups of interconnected writers, such as de Souza-Guignon M, de Castro M, and Pereira, show a close relationship in publishing their works. Meanwhile, more separate groups, such as Leiva V and Ospina,

*name of corresponding author

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show more limited collaboration but remain interconnected. This network provides a visual overview of the relationships between researchers, the patterns of collaboration that occur in research, and how this collaboration forms a more extensive network in the field under.

DISCUSSIONS

The overall dynamic and expanding landscape of research is captured in the bibliometric analysis of the Beta regression modeling field from 2015 to 2024. A steady growth in annual scientific outputs as shown in Table 1 is highly suggestive of a sustained and increasing academic interest on Beta regression as a powerful statistical tool for addressing bounded response data. This expansion mirrors the growing awareness of its significance in various sciences.

The oscillating but overall influential citation dynamics (Table 2) also reflect the discipline's coming of age. The peak of average citations per paper that occurred in 2018 also indicate time periods when high-impact contributions that had a marked effect on ensuing research were made. Recent articles, as one would expect, have a lower "MeanTCperYear"; however, the “MeanTCperYear" trend persisted for older publications, suggesting that early works have a continued relevance and are fundamental to the ongoing conversation. This indicates that the most methodological innovations, as well as original applications, still remain quoted, and together with them, serve as a stable foundation for recent developments.

The clustering of papers in certain journals (Leading among them are Communications in Statistics: Simulation and Computation and Statistical Methods in Medical Research; As shown in Figure 1) and their high H-indexes (See Figure 2) suggests Communications in Statistics: Simulation and Computation and Statistical Methods in Medical Research as central intellectual foci in the research on Beta regression. Their pre-eminence reflects the contribution these specialist statistical and medical statistics journals make in communicating methodological advances and influential applications in the field. Such results confirms a strong methodological and practical foundation of Beta regression in health data, being found in medical journals.

The investigation of authorship and collaboration networks provides greater insight into the field’s intellectual leadership and cooperation. Cribari-Neto, F.: a founding father of Beta regression and still remarkably active (Figure 3), showing his lasting influence. The temporal dynamics of production (Figure 4) clearly indicate repetition contribution from lead authors and not single shot or isolated interest research. These collaborative networks (Figure 9) show dense clusters of connected researchers (especially around the stars), confirming active sharing of knowledge and working together to try and improve the methods and explore new applications. This collaboration is essential for addressing the inherent challenges of statistical modeling.

Brazil is by far the largest contributor in terms of geographical output (Figure 5) also for single-country publications, highlighting that this country independently possesses substantial research capacity in this field. However, the large share of Multiple Country Publications (MCP) from countries such as, India, Indonesia and some European countries may imply that the international collaboration is strong and increasing. This international cooperation setting allows more diverse research lines and applications, contributing to spread Beta regression beyond its original geographic concentrations.

The thematic analysis reveals essential and emerging issues in Beta regression. The WordCloud (shown in Figure 7) and Co-occurrence Network (shown in Figure 8) both reinforce "regression analysis," "statistical model," and "beta regression" as central themes, indicating the methodological orientation, which has consistently been present3. Importantly, the word "human" and the words "female” and "male,” “animal” “controlled study” in the thematic clusters point to the strong level of application of Beta regression in the empirical and experimental studies, which span various subjects but particularly in medical and biological domains. The triad of the terms "simulation," "Bayesian networks," and "intelligent systems" suggests a progress in Estimation techniques and that Beta regression is moving towards more computational and machine learning techniques, which is complemented with the ideas discussed in the introduction in the aspect of new methodologies.

Relating these bibliometric results back to the problems and advances introduced in the Introduction, the increase in the number of publications and in the number of citations demonstrates ongoing attempts to overcome limitations of Beta regression, such as the treatment of outliers and zero/one outcomes (e.g., by robust counterparts and alternative link functions). ""Statistical model" and "simulation " are key words in the analyses used, which indicates an ongoing methodological development process, which, for example, has led to new estimators of multicollinearity and better model specification tests. The growing number of partnerships and diverse geographic contributions suggest a community-wide effort to address these issues, which may result in more generally applicable and robust Beta regression methods. The applications in various sectors (medical, environmental, finance) show that scientists are actively generalizing Beta regression for solving practical complexities.

In a nutshell, the bibliometric panorama of Beta regression modeling is one of continuous expansion, close collaborative networks, and an explicit tendency toward theoretical refinement as well as practical application in a wide range of areas. The area is attempting to cope with its own limitations and to express itself as with a trend that flabergasts to more robust and computationally complex methods.

*name of corresponding author

CONCLUSION

This bibliometric study shows that research on beta regression modeling has grown consistently over the past decade, both in volume and scope. The increasing number of publications and expanding thematic applications reflect the model's growing relevance across disciplines. In particular, beta regression is no longer limited to theoretical development, but has been widely adopted in applied fields such as medicine, environmental science, and biology.

The findings also point to key contributors, influential journals, and emerging research collaborations. At the same time, several methodological challenges remain, including sensitivity to outliers, multicollinearity, and model specification issues. Although approaches such as Bayesian estimation and robust alternatives have been developed, further improvements are still needed to enhance flexibility and accuracy in various contexts.

This study contributes by mapping the structure and evolution of beta regression literature. However, the analysis is limited to the Scopus database and English-language publications. Future research may benefit from including other databases and examining intersections with advanced computational methods. Overall, beta regression continues to evolve as a valuable tool for analyzing bounded data, with strong potential for further development in both theory and practice.

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