

# Inflation Properties in Count Data Distributions: A Three-Decade Bibliometric Analysis

(Sifat Inflasi dalam Agihan Data Bilangan: Suatu Analisis Bibliometrik Tiga Dekad)

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## ABSTRACT

Researchers have been proposing inflated models for count data since 1992, which was pioneered by Diane Lambert. In inflated models for count data, the inflation points commonly occurs either at zero and/or one. A comprehensive bibliometric analysis has been conducted to investigate how popular the studies on inflated models have been since 1992. A total of 724 documents have been retrieved from Scopus database, which include all types of documents and languages. The publications growth rate for the inflated count data models was 16.27%, proving that many researchers were attracted to this area of study. Majority of the documents were articles and written in English. One article published in the R Journal has obtained the most acceptance among the community as seen from the average number of citations each year. The United States of America may have been collaborating with lots of researchers from other countries but the University of São Paulo, Brazil has published the greatest number of documents related to the inflated count data models.

Keywords: Inflated models; one-inflated; zero-inflated; zero-one-inflated

## ABSTRAK

Penyelidik telah mengemukakan model terinflasi untuk data bilangan sejak tahun 1992, yang dipelopori oleh Diane Lambert. Dalam model terinflasi untuk data bilangan, titik inflasi biasanya berlaku di sifar dan/atau satu. Analisis bibliometrik komprehensif telah dijalankan untuk mengkaji seberapa popular kajian mengenai model-model terinflasi sejak tahun 1992. Sejumlah 724 dokumen telah diperoleh daripada pangkalan data Scopus, yang merangkumi semua jenis dokumen dan bahasa. Kadar pertumbuhan penerbitan untuk model data bilangan terinflasi adalah 16.27%, membuktikan bahawa ramai penyelidik tertarik dengan bidang kajian ini. Sebahagian besar dokumen adalah artikel dan ditulis dalam Bahasa Inggeris. Satu artikel yang diterbitkan dalam R Journal telah mendapat penerimaan terbesar dalam kalangan komuniti seperti yang dapat dilihat daripada jumlah purata sitasi setiap tahun. Amerika Syarikat mungkin telah bekerjasama dengan banyak penyelidik dari negara lain tetapi Universiti São Paulo, Brazil telah menerbitkan jumlah dokumen terbesar berkaitan dengan model-model data bilangan terinflasi.

Kata kunci: Model terinflasi; satu-terinflasi; sifar-satu-terinflasi; sifar-terinflasi

## INTRODUCTION

In count data distribution, it is natural for the observations to be excess values of zeroes and/or ones. These phenomena are called zero-inflation and one-inflation properties, respectively. Sometimes, the inflation at zero and one may happen simultaneously, hence called zero-one-inflation property. The first documented article which developed and published on zero-inflated Poisson distribution is by Lambert (1992). From that, many studies have developed and studied the inflated models or distributions in numerous fields of study. Some examples of studies on zero-inflated models include zero-inflated negative binomial (Faroughi & Ismail 2017b; Fávero 2017; Gholiabad et al. 2021; Ridout, Hinde & Demétrio 2001; Yale, Yoshizaki & Fávero 2022), zero-inflated mixed Poisson (Bertoli et al. 2019),

zero-inflated generalized Poisson (Faroughi & Ismail 2017a; Hassankiadeh et al. 2017; Zamani & Ismail 2014), and zero-inflated mixed negative binomial (Aryuyuen, Bodhisuwan & Supapakorn 2014; Bodhisuwan & Kehler 2021; Bodhisuwan, Samutwachirawong & Payakkapong 2018; Saengthong, Bodhisuwan & Thongteeraparp 2015) distributions.

Other than zero-inflation, one-inflation has also been incorporated to develop zero-one-inflated models (Tajuddin et al. 2022). The addition of one-inflation property is to account for any excess ones that are failed to be explained by the baseline distribution. In the case of truncated count data, one-inflated positive count data distributions (Godwin & Böhning 2017; Tajuddin, Ismail & Ibrahim 2022, 2021) were developed as well.

Since studying count datasets with inflation properties and developing new inflated count data models have been steadily done since 1992, it is interesting to look objectively and visually at how far the researchers have expanded this area of research. One easy and straightforward way of investigating this is by conducting a comprehensive bibliometric analysis. Besides becoming a tool for visualizing the evolution of research, bibliometric analysis also serves as a guidance for readers to identify the relevant sources for publications and potential collaborators for future submissions. In this study, the bibliometric analysis is conducted to answer the following research questions (RQ):

- RQ1: How are the documents related to inflated count data models distributed in terms of types and languages of the documents?
- RQ2: How are the publication trends for documents related to inflated count data models?
- RQ3: Which journals publishes more documents related to inflated count data models?

- RQ4: Who are the most active researchers and what are highly productive institutions in publishing documents related to inflated count data models?
- RQ5: What are the top impactful research documents related to inflated count data models?
- RQ6: What are the top keywords used in the documents related to inflated count data models?
- RQ7: How does the collaboration map between countries look like for the published documents related to inflated count data models?
- RQ8: How are the transitions of themes from 1992 until 2022?

DATA AND METHODS

Scopus database is utilized for data retrieval and analysis. The data was retrieved on August 1<sup>st</sup>, 2023, and imported into CSV format. A search framework used in the study is presented in Figure 1.

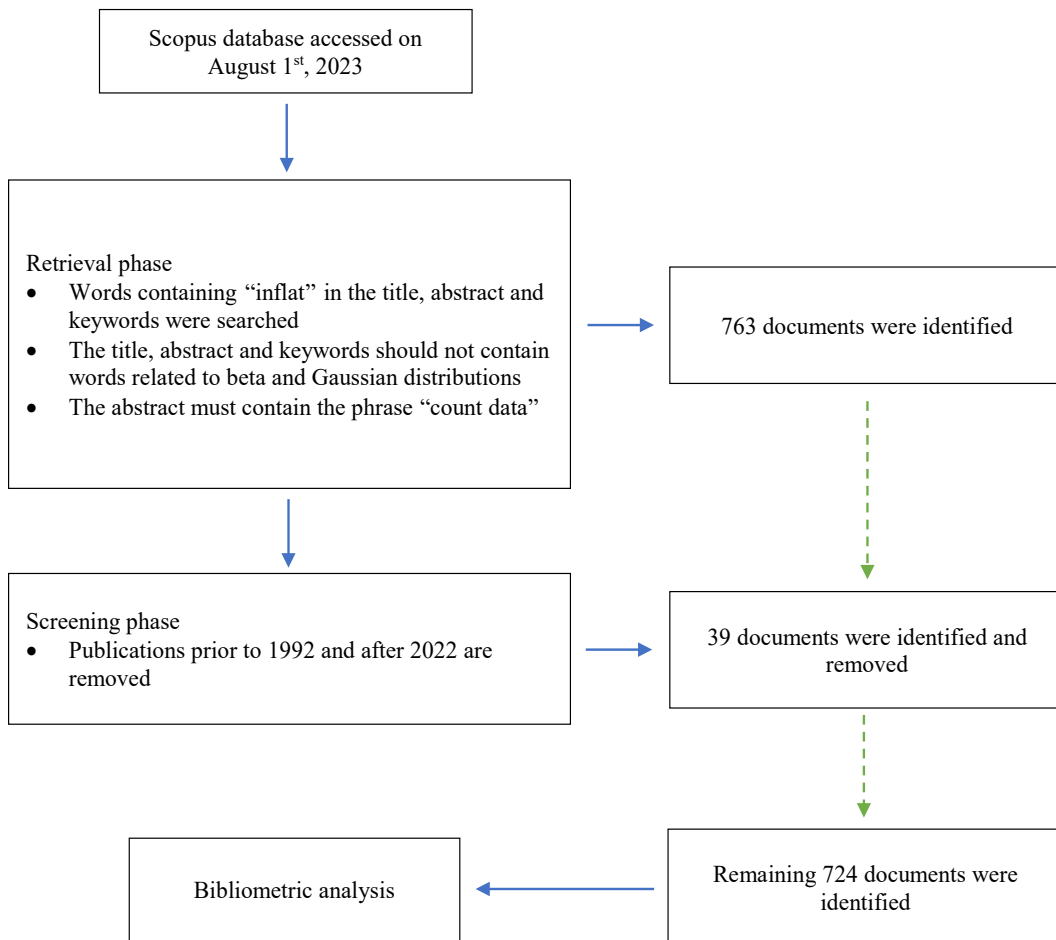


FIGURE 1. Search framework used in Scopus database. Source by authors

Table 1 shows the retrieval and screening phases of preliminary analysis in detail. In the retrieval phase, The TITLE-ABS-KEY field code is used as it allows for bigger collection of documents from different disciplines of study. The command *\*inflat\** searches for zero-inflated, zero-inflation and others in either title, abstract or keywords. Since inflated can be associated with beta or Gaussian distributions, AND NOT “beta” as well as AND NOT “Gauss\*” commands are added. In this phase, a total of 763 documents were collected. Since 2023 has not ended as the date of retrieval, only data prior to 2023 (1992 – 2022) are included, which yielded 724 documents. These 724 documents are utilized for data analysis.

#### RESULTS

A comprehensive bibliometric analysis is conducted using the 724 documents with the help of Biblioshiny application (Aria & Cuccurullo 2017). Table 2 provides a summary of bibliometric analysis. From Table 2, the 724 documents were authored by 1805 authors, of which 67 documents were single-authored and published in 361 sources. Therefore, on average, it takes 5 authors to develop two documents and publish them in one source. Besides that, one average, each document gets 31.73 citations. The

annual publications growth rate is 16.23%, marking how attractive this area of study.

#### RQ1 – DISTRIBUTIONS BY TYPES AND LANGUAGES

Table 3 shows the types of documents and its associated frequency. From Table 3, majority of the documents were articles and followed by conference papers, review papers, chapters in books, books, and notes. Table 4 shows the distribution of documents by languages. From Table 4, majority of the documents were in English and followed by Chinese, Spanish, Portuguese, Korean and Turkish.

#### RQ2 – PUBLICATION TRENDS OVER TIME

Figure 2 shows the annual scientific publications from 1992 which shows an increasing exponential trend as years go by. There is a slight drop in the annual scientific production in 2020, then a spike in the production can be seen in 2021 and 2022. From the exponential trend, it can be expected that the number of documents published related to the inflated models will increase. As of August 1<sup>st</sup>, 2023, there has been 39 documents published in this area of study and this is the number of documents removed because they were published in 2023.

TABLE 1. Retrieval and screening phases

Phase	Scopus code command	Number of documents
Retrieval	TITLE-ABS-KEY (“*inflat*” AND NOT “beta” AND NOT “Gauss*”) AND ABS (“Count Data”)	763
Screening	TITLE-ABS-KEY (“*inflat*” AND NOT “beta” AND NOT “Gauss*”) AND ABS (“Count Data”) AND PUBYEAR > 1991 AND PUBYEAR < 2023	724

TABLE 2. Summary of bibliometric analysis

Feature	Value
Number of authors	1805
Number of single-authored authors	67
Annual growth rate	16.23%
Average citations per document	31.73
Sources	361

Source: Scopus and Biblioshiny

TABLE 3. Types of documents

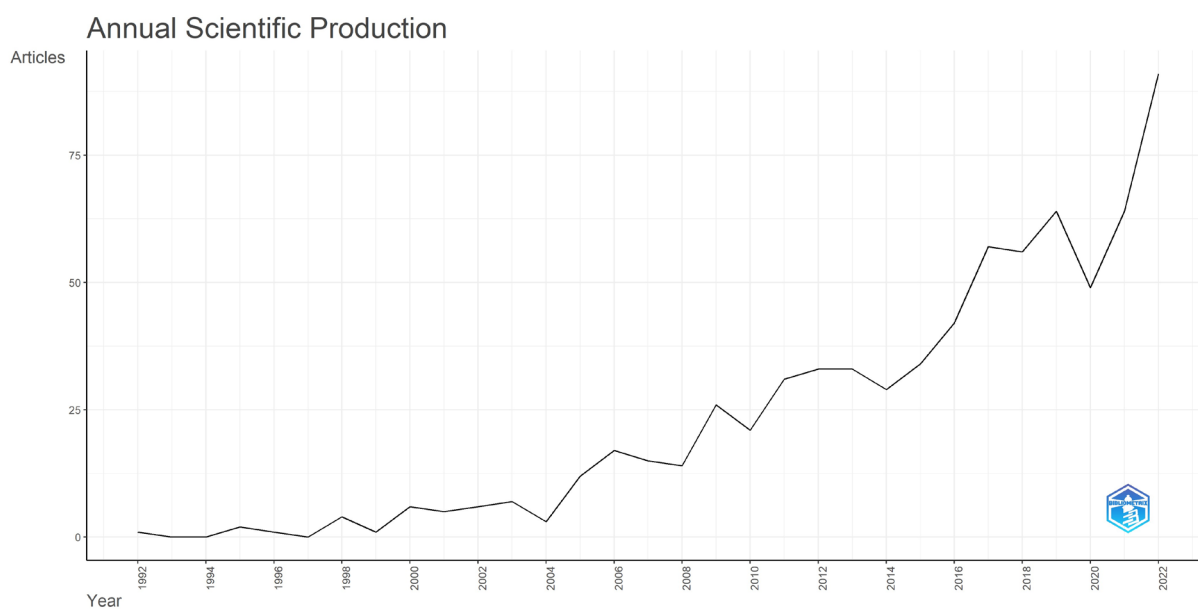
Type of documents	Number of documents	Percentage of documents (%)
Articles	661	91.30
Conference papers	30	4.14
Review papers	19	2.62
Chapters in books	10	1.38
Books	3	0.41
Notes	1	0.15
Total	724	100

Source: Scopus and Biblioshiny

TABLE 4. Language of documents

Language of documents	Number of documents	Percentage of documents (%)
English	711	98.20
Chinese	5	0.69
Spanish	4	0.55
Portuguese	2	0.28
Korean	1	0.14
Turkish	1	0.14
Total	724	100

Source: Scopus and Biblioshiny



Source: Scopus and Biblioshiny

FIGURE 2. Annual scientific production of publications

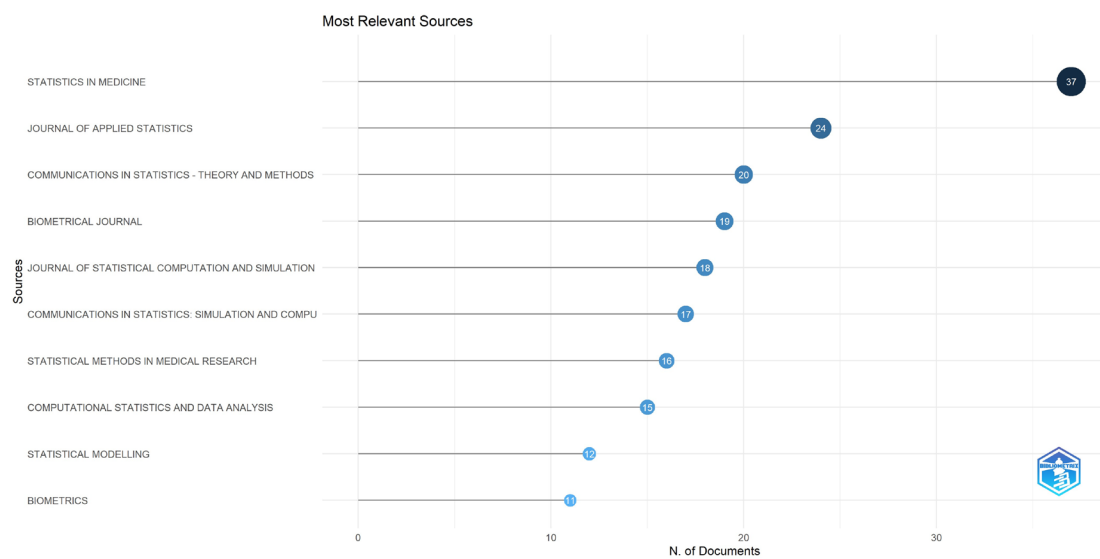
## RQ3 – PUBLICATION PLATFORMS

Figure 3 shows the top 10 most relevant and popular sources of publications. From Figure 3, *Statistics in Medicine* has published a good portion of documents related to the inflated models for count data, followed by *Journal of Applied Statistics*, *Communications in Statistics – Theory and Methods*, and *Journal of Statistical Computation and Simulation*. It is not surprising that *Statistics in Medicine* has been a great platform for publishing articles regarding inflated models because in medical and healthcare fields, it is relatively common to study datasets that are inflated at zero and  $k$ . Inflation at  $k$  means that there is a spike in  $k$ -valued datasets (Arora & Chaganty 2021; Arora, Rao

Chaganty & Sellers 2021; Finkelman et al. 2011; Lin & Tsai 2013; Tajuddin 2023). On the other hand, *Journal of Applied Statistics*, *Communications in Statistics – Theory and Methods*, and *Journal of Statistical Computation and Simulation* are flagships for theoretical and applied statistics research and hence, become common publishing outlets for researchers.

## RQ4 – ACTIVE RESEARCHERS AND INSTITUTIONS

Table 5 shows the top 9 active authors in the study related to inflated count data models. From Table 5, Andrade and Conceição have published 13 documents each, followed by Lee, Louzada and Yao with 12 publications, Moghimbeigi



Source: Scopus and Biblioshiny

FIGURE 3. Annual scientific production of publications

TABLE 5. Top 9 active researchers in inflated count data models

Name of authors	Number of documents	Current affiliation	Country
Andrade, MG	13	University of São Paulo	Brazil
Conceição, KS	13	University of São Paulo	Brazil
Lee, AH	12	Curtin University of Technology	Australia
Louzada, F	12	University of São Paulo	Brazil
Yau, KKW	12	City University of Hong Kong	Hong Kong
Moghimbeigi, A	9	Alborz University of Medical Sciences	Iran
Rakitzis, AC	8	University of Piraeus	Greece
Ismail, N	7	Universiti Kebangsaan Malaysia	Malaysia
Tian, G-L	7	Southern University of Science and Technology	China

Source: Scopus and Biblioshiny

with 9 publications each, Rakitzis with 8 publications, and finally, Ismail and Tian with 7 publications each. The affiliation shown in Table 5 are based on their affiliations found in their current publications. Therefore, it is advised to remember that the research documents produced by these prominent authors may be affiliated with other institutions.

Furthermore, there are several authors named as Zhang X, but Biblioshiny has accumulated publications by them amounting to 9 documents. However, they cannot be affiliated with one institution and thus, not included in Table 5. The next author in line is Zhang C with 7 documents, and again, there are several authors with this name. Therefore, only Top 9 active researchers after excluding Zhang X and Zhang C are presented in Table 5.

Table 6 shows the 10 active research institutions in developing and studying inflated models for count data. From Table 6, University of São Paulo has published 43 documents followed by The University of Hong Kong, Shahid Beheshti University of Medical Sciences, and others.

#### RQ5 – IMPACTFUL RESEARCH DOCUMENTS

Table 7 summarizes the most impactful research documents in terms of global and annualized average citations. The annualized average citations in Table 7 shows the average increment in the number of citations every year. From Table 7, publication by Brooks et al. (2017) has reached nearly 4000 citations in just 6 years. They published an R package in the reputable R Journal which is used to model count data with zero-inflation. The R package *glmmTMB* is flexible than other existing packages available, which is one of the reasons why the article managed to grab a whopping number of global citations. They also received a massive 654 citations each year from 2017 on average. This further proves that the R package published by them is very useful and has been accepted in the scientific communities.

On the other hand, we have Lambert (1992), a pioneer in the development of zero-inflated models, which managed to obtain over 2500 citations. Any subsequent inflated models built related to count data will have relation with the one published by him. Inflated models are also quite popular in the area of ecology (Harrison 2014), environment (Tasser et al. 2007) and accident analysis (Anastasopoulos & Mannering 2009).

#### RQ6 – TOP KEYWORDS

Figure 4 shows the word cloud for the 50 top keywords often used in studies on inflated count data models. As expected, Poisson distribution is the most frequently used keywords, followed by regression analysis and statistical model. The Poisson distribution is not only a basic distribution for count data, the first zero-inflated model developed by Lambert (1992) is also based on the Poisson distribution.

#### RQ7 – COLLABORATION MAP

Figure 5 shows the collaboration map between countries. From Figure 5, it is quite clear that researchers affiliated with United States of America (USA) institutions collaborated with a lot of researchers affiliated with other countries based on the number of edges in USA. Some countries in the eastern region of Europe, northern region of Asia, central region of Africa as well as southern region of South America do not involve in the studies related to inflated count data models.

#### RQ8 – TRANSITIONS OF THEMES

Figure 6 shows the transition of themes (thematic evolution) from 1992 until 2022. The documents were separated into four-time frame – 1992 to 2012, 2013 to 2017, 2018 to 2020 and 2021 to 2022. For the first two decades, the

TABLE 6. Top active research institutions in inflated count data models

Name of institutions	Number of documents
University of São Paulo	43
The University of Hong Kong	22
Shahid Beheshti University of Medical Sciences	20
University of California	20
City University of Hong Kong	19
Curtin University of Technology	19
Medical University of South Carolina	16
University of South California	16
Duke University	15
Hamadan University of Medical Sciences	15

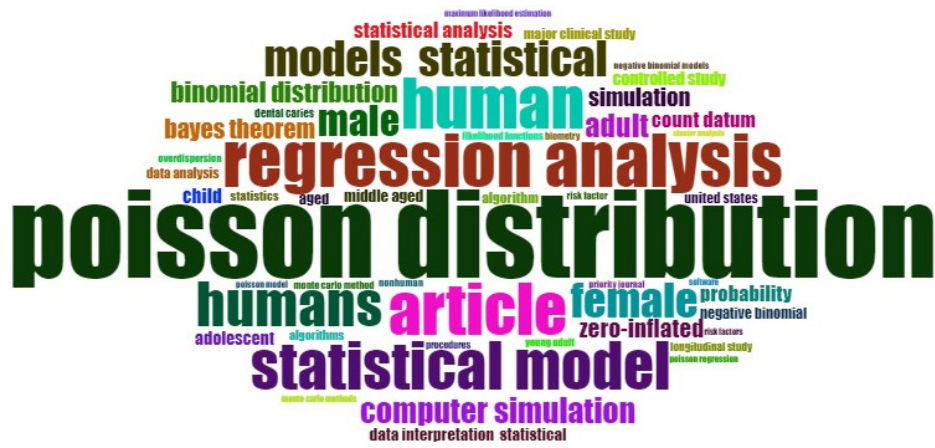
Source: Scopus and Biblioshiny

TABLE 7. Most impactful research documents

Document	Title	Source	Global citations	Average citations <sup>a</sup>
Brooks et al. (2017)	glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling	R Journal	3925	654.17
Lambert (1992)	Zero-inflated Poisson regression, with an application to defects in manufacturing	Technometrics	2554	82.39
Harrison (2014)	Using observation-level random effects to model overdispersion in count data in ecology and evolution	PeerJ	714	79.33
Hall (2000)	Zero-inflated Poisson and binomial regression with random effects: A case study	Biometrics	628	27.30
Anastasopoulos & Mannering (2009)	A note on modeling vehicle accident frequencies with random-parameters count models	Accident Analysis and Prevention	509	36.36
Atkins & Gallop (2007)	Rethinking how family researchers model infrequent outcomes: a tutorial on count regression and zero-inflated models	Journal of Family Psychology	382	23.88
Tasser et al. (2007)	Land-use changes and natural reforestation in the Eastern Central Alps	Agriculture, Ecosystems & Environment	340	21.25
Böhning et al. (1999)	The zero-inflated Poisson model and the decayed, missing and filled teeth index in dental epidemiology	Journal of the Royal Statistical Society Series A: Statistics in Society	286	11.92
Ridout, Hinde & Demétrio (2001)	A score test for testing a zero-inflated Poisson regression model against zero-inflated negative binomial alternatives	Biometrics	273	12.40
Min and Agresti (2005)	Random effect models for repeated measures of zero-inflated count data	Statistical Modelling	272	15.11

<sup>a</sup>Average citations are calculated by dividing the total number of citations with the number of years published  
Source: Scopus and Biblioshiny

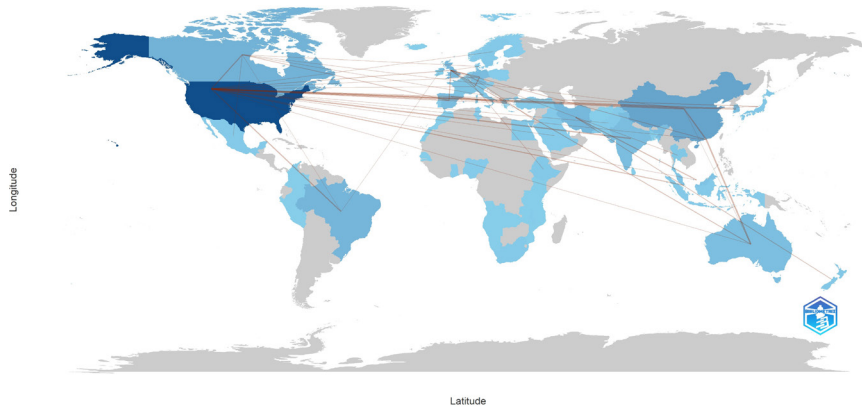




Source: Scopus and Biblioshiny

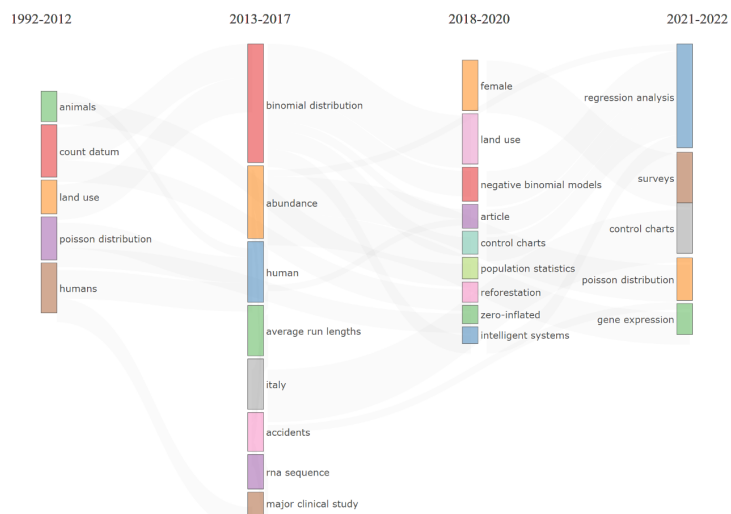
FIGURE 4. Word cloud for keywords used

Country Collaboration Map



Source: Scopus and Biblioshiny

FIGURE 5. Country collaboration map



Source: Scopus and Biblioshiny

FIGURE 6. Transitions of themes from 1992 to 2022



documents were mostly about Poisson distribution with applications to data related to humans and animals. From 2013 to 2017, the documents expanded to the applications related to accidents and clinical studies. For the next three years, more expansion can be noticed, especially regarding control charts, population statistics and intelligent systems. The phrase 'zero-inflated' has been used repeatedly from 2018 to 2020. From 2021 until 2022, surveys and gene expression were involved in the applications of inflated count data. It is important to notice that in the advancement of technology and artificial intelligence, only a small part of them, which is intelligent systems are incorporated in the studies related to the inflated count data. There is still a huge opportunity for the researchers to explore and incorporate inflated count data to artificial intelligence, data mining and machine learning.

#### CONCLUSIONS

Studies on the inflated count data models started with Lambert (1992) who introduced a zero-inflated Poisson distribution and its associated regression model for manufacturing data. Since then, the idea has been implemented for various distributions and further extended into zero-one-inflated models and general zero- $k$ -inflated models in the past three decades. The bibliometric analysis for the inflated count data models is conducted to see how popular the research field has become since its first development, back in 1992. Analysis from 724 documents considered in this study showed that most documents were articles, written in English and a good portion of them were published in distinguished *Statistics in Medicine* journal. However, an R package article published in the *R Journal* managed to capture nearly 4000 citations in a short time. Despite USA being the most active countries in the aspect of international collaborations, researchers from the University of São Paulo, Brazil has published more research documents than USA-affiliated researchers and three of them were listed in top 9 active researchers in this field.

Besides that, from this bibliometric analysis, it is important to note that in order to increase readability and citations of one's paper, the paper is advised to be a new R Package with comprehensive and important commands such as Brooks et al. (2017) or showcased a pioneering, novel idea that will reform the scientific community such as Lambert (1992). Besides that, if the paper contains novel ideas with real applications (Harrison 2014; Lambert 1992; Tasser et al. 2007), there is a good chance that the paper will receive a decent amount of citations and readability. Choosing the right, reputable and quality outlets to highlight one's work is important as well (refer Table 7).

This bibliometric analysis has shown the importance of inflated models using 724 documents by presenting the number of documents published, number of citations

obtained as well as international collaborations made for this research area. Therefore, future studies may consider this analysis as a reference for submissions, publication outlets as well as potential collaborators. Furthermore, it is found that there is a golden scope of study for the researchers which incorporates artificial intelligence, data mining and machine learning with inflated count data. Besides that, further in-depth analysis may be conducted to further look into the rationales behind the development of inflated models and the applications of the models via comprehensive review studies.

#### ACKNOWLEDGMENTS

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