Discrete & Continuous Models & Applied Computational Science
ISSN 2658-7149 (Online), 2658-4670 (Print)

2026, 34 (1) 145–149
http://journals.rudn.ru/miph

Research article

UDC 519.87
DOI: 10.22363/2658-4670-2026-34-1-145-149 EDN: UYXCCK

A model of cumulative advantage for conference dynamics

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(received: December 15, 2025; revised: January 10, 2026; accepted: January 16, 2026)

Abstract. This paper attempts to modify the standard Verhulst model to describe the dynamics of scientific conferences taking into account cumulative advantage.

Key words and phrases: scientometrics, conferences, the Matthew law

For citation: Ermolayeva, A. M. A model of cumulative advantage for conference dynamics. *Discrete and Continuous Models and Applied Computational Science* **34** (1), 145–149. doi: 10.22363/2658-4670-2026-34-1-145-149. edn: UYXCCK (2026).

1. Introduction

The problem of conference evaluation is currently very pressing for researchers in the field of scientometrics, as there is no universal methodology for evaluating all conferences in all fields. Several conference rankings exist, such as the Australian CORE, the Chinese CCF Conference Rankings, the Brazilian QUALIS, and the industry-specific Microsoft Academic Conference Rankings. All of these rankings are compiled for computer science conferences, due to the extremely important nature of conferences in this field, as over 60% of research results are published in conference proceedings.

A study of the development of scientific conferences showed that conferences develop unevenly, with some becoming stellar, while others quickly fade away. This led us to use the standard Verhulst model [1] for our study, but to expand it by taking into account the Matthew effect [2].

2. Basic model

Let there be n conferences in a given scientific field. Let $R^i(t) \geqslant 0$ denote the numerical measure of the ranking of the ith conference at time t. The ranking is considered as a single aggregate value.

Let the ranking dynamics of each conference be determined by the following mechanisms:

- internal growth;
- competition;
- natural decay;
- external influences.

Internal growth is associated with the desire to increase ratings through internal efforts (attracting renowned speakers, improving the quality of peer review, and improving organization). Competition is caused by the mutual inhibition of conferences, as resources (people, money) are limited. Natural decay (dissipation) is associated with obsolescence, loss of relevance, etc. External influences are caused by unpredictable factors (black swans) (e.g., changes in program committees, publication of breakthrough results, scandals).

We will use the Verhulst model for an isolated conference as a basis:

$$\frac{dR}{dt} = rR\left(1 - \frac{R}{K}\right) - \delta R,$$

where r is the maximum growth rate, K is the capacity (the maximum achievable rating in the absence of competitors), δ is the decay coefficient.

Then the equilibrium rating is:

$$R^* = K(1 - \delta/r), \qquad r > \delta.$$

We'll introduce competitive inhibition for several conferences. The growth of each conference is slowed not only by its own rankings, but also by the rankings of other conferences.

$$\frac{dR^i}{dt} = r_i R^i \left(1 - \frac{\sum_{j=1}^{n} \alpha_{ij} R^j}{K_i}\right),$$

where α_{ij} is the coefficient of influence of conference j on conference i. It is natural to assume $\alpha_{ii} = 1$. α_{ij} for $i \neq j$ shows how strongly competitors suppress the growth of the ith conference.

Let's add attenuation and external influences:

$$\frac{dR^i}{dt} = r_i R^i \left(1 - \frac{\sum_{j=1}^{n} \alpha_{ij} R^j}{K_i}\right) - \delta_i R^i + \gamma_i F_i(t),$$

where:

- $r_i > 0$ — potential growth rate,
- $K_i > 0$ — maximum possible rating in the absence of competitors,
- $\alpha_{ij} \geqslant 0$ — competition coefficients,
- $\delta_i \geqslant 0$ — natural decay rate,
- $\gamma_i \geqslant 0$ — sensitivity to external influences,
- $F_i(t) \geqslant 0$ — external impulse function.

In a more compact form, we can rewrite:

$$\frac{dR^i}{dt} = R^i \left(r_i - \frac{r_i}{K_i} \sum_{j=1}^{n} \alpha_{ij} R^j - \delta_i\right) + \gamma_i F_i(t).$$

The term $-\frac{r_i}{K_i} \alpha_{ij} R^i R^j$ describes mutual inhibition.

3. Accounting for Matthew's law

Matthew's Law (for to everyone who has, more will be given, and he will have abundance; but from him who does not have, even what he has will be taken away) is a manifestation of cumulative advantage. The higher a conference's rating, the easier it is to attract the best authors, receive more citations, and, consequently, further increase its rating.

3.1. Dependence on the current rating

Let's add the term $\beta_i R_\theta^i$, which increases the growth rate proportionally to the current rating:

$$\frac{dR^i}{dt} = r_i R^i \left(1 - \frac{\sum \alpha_{ij} R^j}{K_i}\right) + \beta_i R_\theta^i - \delta_i R^i + \gamma_i F_i(t),$$

where:

- $\beta_i \geqslant 0$ — intensity of the cumulative advantage,
- $\theta > 0$ — nonlinearity index.

3.2. Capacity dependence on rating

Let's make the capacity K_i dependent on the rating:

$$K_i = K_i^{(0)} + \varkappa_i R^i,$$

where $\varkappa_i \geqslant 0$.

Then the logistical constraint becomes less severe for the leaders, which facilitates their further growth.

3.3. Asymmetric competition

To take Matthew's law into account, we can make α_{ij} dependent on the difference in ratings:

$$\alpha_{ij} = \alpha_{ij\,\text{base}} \cdot \exp\bigl(-\lambda(R^i - R^j)\bigr), \qquad R^i > R^j,$$

where $\lambda > 0$.

A conference with a higher rating R^i experiences less inhibition from a conference with a lower R^j. This creates a positive feedback loop: leaders become less vulnerable to competitors.

3.4. Threshold effect

If the cumulative advantage is very strong, the system may exhibit bistability. The conference either becomes a leader or remains at a low level. To achieve this, we add a threshold term:

$$\frac{dR^i}{dt} = R^i \bigl(\rho_i(R^i - R_{\text{th}})\bigr) - \delta_i R^i + \ldots$$

3.5. Cumulative advantage

Cumulative advantage means that the rating increase is proportional to the current rating (or its degree) with a positive coefficient. In the simplest case ($\beta_i > 0$, $\theta = 1$) at the initial stage we obtain:

$$\frac{dR^i}{dt} \approx (r_i + \beta_i) R^i.$$

This leads to exponential growth, limited only by the capacity K_i and competition. If two conferences initially have similar parameters, but one gains a small advantage ε, this advantage will increase over time, and the system may converge to an equilibrium with a strong leader dominance. The equilibrium becomes unstable, and a "winner-takes-all" regime emerges.

Author Contributions: All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data can be sent by the authors on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Declaration on Generative AI: The author has not employed any generative AI tools.

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УДК 519.87
DOI: 10.22363/2658-4670-2026-34-1-145-149 EDN: UYXCCK

Модель динамики конференций с учётом кумулятивного преимущества

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Аннотация. В статье делается попытка модифицировать стандартную модель Ферхюльста для описания динамики научных конференций с учётом кумулятивного преимущества.

Ключевые слова: наукометрия, конференции, эффект Матфея