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Network Dynamics of Scientific Fields: Centralization and Stability in Conceptual and Citation Structures

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Extended Abstract

Scientific fields evolve through the interplay of concepts, researchers, and institutions. We hypothesize that the rate of change in a scientific field, measured through the time-evolving network of keyword co-occurrences, correlates with citation inequality and turnover at the author and institutional levels. Specifically, we propose that faster-evolving fields exhibit greater turnover among top-cited authors, while slower-evolving fields maintain stable author hierarchies. We further explore whether institutional citation hierarchies remain stable across fields, regardless of their rate of change. Using keyword co-occurrence networks constructed on publication data from OpenAlex, we quantify field dynamics and contrast these with citation patterns to test this hypothesis.

Our framework models scientific fields as time-evolving networks, where nodes represent keywords and edges denote their co-occurrence in research articles [1]. We measure the rate of field evolution using the betweenness centrality of keywords, with changes in centrality rankings indicating conceptual shifts. To assess stability, we use Rank-Biased Overlap (RBO) [2] to track changes in rankings of high-centrality keywords, top-cited authors, and institutions over time. To capture a cross-sectional snapshot of centralization, we compute the yearly Gini coefficient for keyword betweenness centrality, author citation scores (MNCS), and institutional citation scores [3]. These metrics provide a multi-level view of scientific dynamics, as illustrated in Figure 1.

We apply this framework to keyword co-occurrence networks in Immunology & Microbiology (IM, 3,297,955 works, 41,903 keywords, 3,429,591 authors, 46,367 institutions) and Environmental Science (ES, 12,005,321 works, 60,660 keywords, 6,947,124 authors, 63,948 institutions) from 1975 to 2019. Both fields show high conceptual centralization (Gini ≈ 0.98) and stability (RBO > 0.85), indicating that a small set of keywords consistently dominates their intellectual core. At the institutional level across both fields, a declining Gini suggests increasing citation equality, yet a high RBO (> 0.8) indicates persistent dominance by elite institutions. In contrast, author-level dynamics reveal high citation inequality (Gini > 0.9) but low stability (RBO ≈ 0.25 IM, ≈ 0.18 ES) for both fields, suggesting rapid turnover among top-cited researchers (Figure 1).

Our preliminary findings suggest that Immunology & Microbiology and Environmental Science fields, characterized by fairly stable keyword centrality rankings, exhibit greater turnover in author prominence and high citation inequality, while institutional hierarchies remain stable across fields. This tension between volatile individual recognition and entrenched institutional dominance highlights the complex dynamics driving scientific progress. Our framework, as visualized in Figure 1, offers a robust tool for analyzing how conceptual shifts interact with citation patterns, providing insights into innovation and inequality in science. We are currently expanding this analysis to include all the major fields and longer timeframes to provide a more comprehensive understanding of network dynamics across scientific disciplines.

Ethics Considerations

This study uses publicly available OpenAlex data, posing no privacy concerns. We advocate for responsible use of our findings to inform equitable science policies, such as supporting early-career researchers in volatile fields, while cautioning against reductive evaluations of individuals based on these metrics.

References

[1] Srinivasan Radhakrishnan et al. "Novel keyword co-occurrence network-based methods to foster systematic reviews of scientific literature". In: *PloS one* 12.3 (2017), e0172778.

[2] William Webber, Alistair Moffat, and Justin Zobel. "A similarity measure for indefinite rankings". In: *ACM Transactions on Information Systems (TOIS)* 28.4 (2010), pp. 1–38.

[3] Mathias Wullum Nielsen and Jens Peter Andersen. "Global citation inequality is on the rise". In: *Proceedings of the National Academy of Sciences* 118.7 (2021), e2012208118.

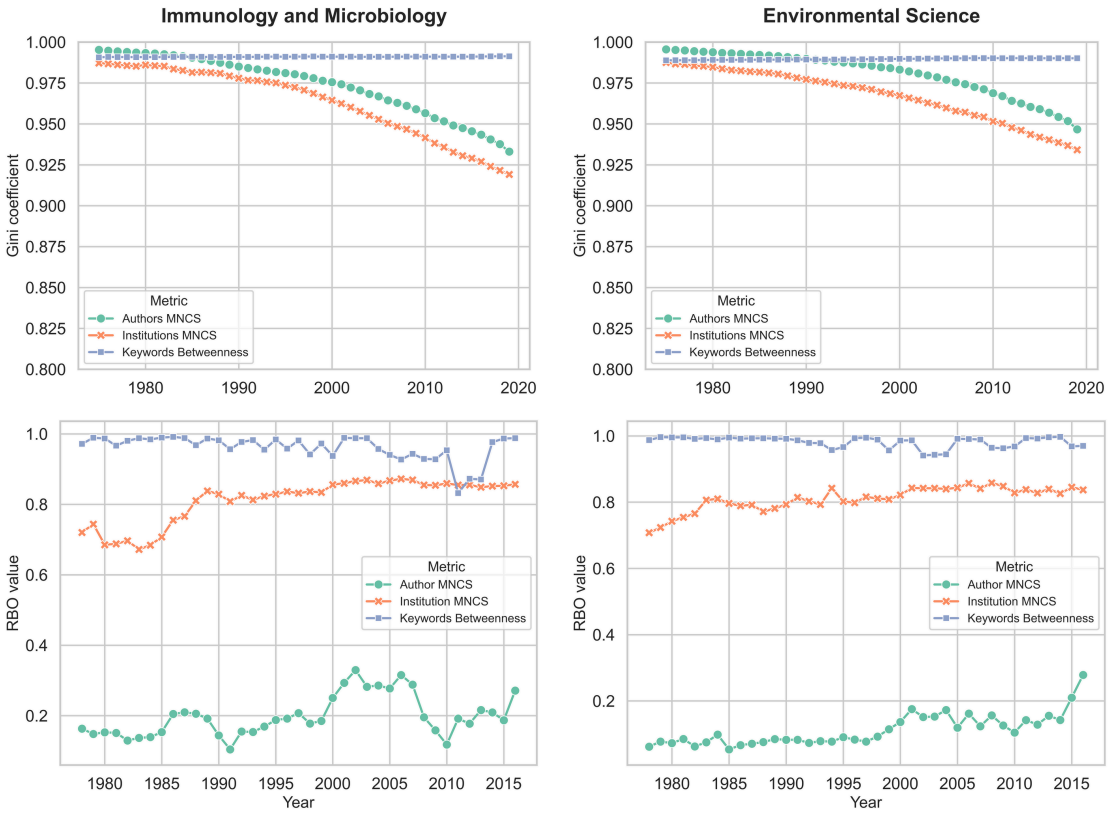

Figure 1: **Network Dynamics in Scientific Fields.** Top: Gini coefficients for keyword betweenness centrality, author MNCS, and institution MNCS from 1975–2019, where each point represents a cross-sectional snapshot of centralization for that year. Bottom: Rank-Biased Overlap (RBO) for the same entities across 3-year windows, indicating stability of rankings. High RBO reflects stable rankings; low RBO indicates turnover.