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The Montreal Protocol as a Model for Global Environmental Governance: Performance, Discursive Construction, and Limits of Replicability

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Abstract

This article examines the Montreal Protocol as both a high-performance environmental regime and an evolving governance paradigm in international environmental politics. Combining longitudinal bibliometric analysis (1987–2025) with a qualitative systematic review, it investigates how the Protocol has been reframed from a sectoral regulatory response into a reference model for international environmental governance. The results identify a marked shift in the literature, from a technical focus on ozone depletion toward governance-oriented frameworks emphasizing compliance, financing, institutional design, and multilateral cooperation. This transformation is associated with the consolidation of an epistemic community and with the increasing use of the Montreal Protocol as a benchmark in debates on climate change and other environmental regimes. While the regime's effectiveness is supported by well-documented outcomes and a robust institutional architecture, the article argues that its elevation to a governance model cannot be explained by performance alone. Rather, it reflects a discursive process that abstracts and reconfigures the specific conditions underpinning its success, shaping its perceived replicability. The analysis further shows that the transferability of the Montreal model is structurally constrained by differences in problem complexity, economic embeddedness, and geopolitical context. As a result, replicability is better understood as a conditional and context-dependent process rather than as a universal institutional blueprint. By integrating bibliometric and qualitative approaches, this study contributes to debates on environmental governance and policy transfer, offering a more critical understanding of how "success stories" are constructed and mobilized in international policy contexts.

1. Introduction

The intensification of global environmental degradation has challenged the capacity of existing governance systems to deliver effective and sustained responses. Despite growing scientific consensus on planetary limits, global environmental governance remains constrained by persistent asymmetries, geopolitical tensions, and implementation gaps (Biermann et al., 2007; Hale et al., 2013; Keohane & Victor, 2011). This gap between international commitments and tangible outcomes has intensified interest in understanding why some environmental regimes perform more effectively than others.

The Montreal Protocol on Substances that Deplete the Ozone Layer is widely regarded as one of the most successful multilateral environmental agreements, due to its near-universal participation and demonstrable environmental results (UNEP, 2022; Young, 2011). Initially framed as a sectoral response to a specific atmospheric problem, the Protocol has been progressively reinterpreted within broader debates on international cooperation and governance, leading to its elevation as a paradigmatic case (Haas, 1990; Benedick, 1998; Parson, 2003).

As a result, the Montreal Protocol has gradually shifted from being treated as a bounded environmental agreement to being conceptualized as a transferable governance template, frequently invoked in debates surrounding climate change and other large-scale ecological crises—an issue that gains renewed

relevance in the context of contemporary climate negotiations such as COP30. However, this framing raises important analytical concerns. The conditions that enabled its effectiveness, such as concentrated industrial actors, available technological substitutes, and strong scientific consensus, are not easily replicated in other domains (Keohane & Victor, 2011; Falkner, 2016).

Consequently, its uncritical use as a model risks obscuring contemporary environmental governance challenges. Moreover, this shift raises concerns regarding the risks of decontextualization (Dolowitz & Marsh, 2000). The elevation of the Montreal Protocol to a paradigmatic model may inadvertently obscure the historically contingent conditions that enabled its success, including specific industrial configurations, relatively low economic disruption, and a favorable geopolitical context (Benedick, 1998). Recognizing these limitations is essential to avoid oversimplified policy transfer and to advance a more nuanced understanding of institutional effectiveness in global environmental governance (Dolowitz & Marsh, 2000; Young, 2011).

While the literature has extensively examined the outcomes and institutional design of the Montreal Protocol, less attention has been devoted to understanding how it has been constructed and stabilized as a paradigmatic model within scientific and policy discourse. In particular, there is a lack of studies that combine longitudinal bibliometric analysis with qualitative approaches to capture both the evolution of the field and the discursive dynamics that sustain its status as a governance reference.

Rather than treating the Montreal Protocol solely as an empirically successful environmental regime, this article adopts a constructivist-informed governance perspective that emphasizes how institutional success is discursively produced, stabilized, and mobilized within scientific and policy debates. In doing so, the analysis draws on insights from discursive institutionalism and policy transfer literature to examine how the Protocol has been transformed from a sector-specific regulatory arrangement into a paradigmatic reference for global environmental governance.

This article argues that the elevation of the Montreal Protocol to a paradigmatic model is not solely the result of its empirical effectiveness, but rather the product of a discursive process that abstracts and reconfigures its enabling conditions, shaping its perceived replicability across environmental governance contexts. By shifting the analytical focus from outcomes to discursive construction, the study contributes to the literature on environmental governance by offering an integrated analytical framework that combines bibliometric and qualitative approaches, providing a more reflexive understanding of how “success stories” are produced and mobilized in policy debates.

2. Theoretical Foundations: Public Policy and Global Environmental Governance

The intensification of the ecological crisis, reflected in the transgression of planetary boundaries and the degradation of natural systems, has reinforced the need for institutional arrangements capable of coordinating effective responses at the global scale (Rockström et al., 2009). The transboundary and

cumulative nature of environmental problems requires governance mechanisms that integrate scientific knowledge, political decision-making, and economic dynamics within multilateral frameworks (Dryzek, 2013; Keohane & Victor, 2011; Biermann et al., 2009).

Birkland (2011) conceptualizes public policy as the set of processes through which societies organize responses to collective problems, structuring mechanisms of regulation and coordination. Similarly, Kraft et al. (2018) define public policy as governmental choices regarding what to do—or not to do—in response to public issues, emphasizing their strategic and decision-oriented nature.

However, the formal adoption of a policy does not guarantee its effectiveness. Implementation constitutes a critical phase of the policy process, involving interactions among formal decisions, administrative capacities, political incentives, and institutional contexts (Birkland, 2011; Kraft et al., 2018). Approaches such as backward mapping and scenario definition, proposed by Weimer and Vining (2017), are particularly relevant for analyzing the chain of actions linking policy decisions to outcomes, especially in multilevel governance systems such as international environmental regimes.

Policy evaluation represents an equally central dimension of institutional analysis. Bovens et al. (2006) argue that evaluation is a normative process that may foster institutional learning or become an instrument of political contestation. In the context of environmental governance, this evaluative dimension is particularly relevant, as it allows for the assessment of whether complex multilateral arrangements are capable of producing effective and equitable outcomes. Kraft et al. (2018) identify key criteria for policy evaluation, including effectiveness, efficiency, equity, cost-benefit balance, risk, and political feasibility. These criteria provide a robust analytical lens for examining the performance of international environmental regimes.

Within this framework, the Montreal Protocol emerges as one of the most frequently cited environmental regimes. Scientific evidence on ozone depletion supported the adoption of the Vienna Convention (1985) and the Montreal Protocol (1987), which established legally binding targets for the phased elimination of ozone-depleting substances and achieved universal ratification in 2009 (Jovanović et al., 2019; Rei et al., 2017; United Nations, 2020).

The literature highlights key elements underlying its effectiveness, including the central role of scientific knowledge, action under uncertainty, political leadership, and the use of market-based mechanisms to foster technological innovation (Benedick, 1991; Birmpili, 2018). Its institutional design combines binding targets, adaptive governance through amendments, and enforcement mechanisms such as trade restrictions, which incentivize participation and reduce free-riding (Zhang, 2009; Brack, 1998).

The regime also incorporates a distributive dimension, particularly through the Multilateral Fund, which operationalizes the principle of common but differentiated responsibilities by supporting technological transitions in developing countries (Birmpili, 2018). Evidence suggests that the benefits of eliminating ozone-depleting substances have outweighed associated costs, reinforcing its perceived cost-effectiveness (Zhang, 2009).

From a policy evaluation perspective, the Montreal Protocol is frequently characterized by high levels of environmental effectiveness, economic efficiency, distributive equity, and political feasibility (Benedick, 1998). Taken together, these dimensions have led scholars to interpret its integrated institutional architecture as a landmark model of global environmental governance (Keohane & Victor, 2011; Biermann et al., 2014). This consolidation, however, reflects a broader shift in the literature: from an initial emphasis on technical and scientific dimensions toward more expansive debates on governance design, institutional replicability, and normative frameworks for international cooperation.

This transition raises analytical challenges, as the transposition of institutional features across governance contexts is neither straightforward nor free from the risk of uncritical generalization (Keohane & Victor, 2011). The elevation of the Montreal Protocol to a paradigmatic model is not simply a reflection of its empirical performance, but the outcome of an interpretive process through which specific enabling conditions have been selectively abstracted and stabilized within the literature. This article examines precisely how such interpretations have been constructed and sustained, with particular attention to the role of epistemic communities in shaping the Protocol's status as a governance reference (Haas, 1992).

3. Historical Trajectory and Institutional Architecture of the Montreal Protocol

As discussed in the previous section, the Montreal Protocol has been widely consolidated in the literature as a benchmark of successful global environmental governance (Benedick, 1998; Biermann et al., 2014). To understand the foundations of this characterization, this section revisits key elements of its historical trajectory and institutional architecture.

The emergence of the Protocol reflects the interaction between scientific knowledge, political negotiation, and economic interests. Scientific concern over ozone depletion dates back to the 1970s, although significant uncertainty persisted until the 1980s, when a more robust international consensus enabled coordinated political action (Jovanović et al., 2019).

This process culminated in the Vienna Convention (1985), which established a framework for cooperation, followed by the Montreal Protocol (1987), which introduced legally binding targets for the phased elimination of ozone-depleting substances (Rei et al., 2017; Weiss & Jacobson, 2009; McKenzie et al., 2019). The scientific recognition of ozone depletion as a global environmental threat gained symbolic prominence with the awarding of the 1995 Nobel Prize in Chemistry to Paul Crutzen, Mario Molina, and F. Sherwood Rowland, underscoring the fundamental role of atmospheric science in shaping environmental policy agendas.

A defining feature of the regime is its near-universal participation, achieved in 2009, and frequently interpreted as evidence of an exceptional level of global coordination (United Nations, 2020). This broad adhesion was not spontaneous, but resulted from a deliberate institutional design that combined binding

commitments with differentiated obligations, financial incentives through the Multilateral Fund, and trade-based enforcement mechanisms that created strong incentives for non-parties to join the regime (Benedick, 1998; Zhang, 2009; Birmpili, 2018).

However, this process was not free of tensions. Developing countries initially resisted binding commitments, arguing that the problem had been caused predominantly by industrialized nations and that the costs of technological transition should not be borne equally (Benedick, 1991; Parson, 2003). The establishment of the Multilateral Fund in 1990 was, in large part, a response to these distributional conflicts, operationalizing the principle of common but differentiated responsibilities and enabling broader participation. Unlike many previous environmental agreements, the Montreal Protocol is often described as reflecting a precautionary approach, grounded in emerging but still uncertain scientific evidence rather than solely in fully observed environmental damage. As highlighted by Benedick (1998), this anticipatory orientation required the acceptance of short-term economic costs in exchange for long-term environmental and public health benefits, marking a significant shift in the logic of international environmental governance.

The long-term effectiveness of the regime has been widely attributed to a combination of institutional and structural factors. According to Birmpili (2018), three elements are particularly central: (i) broad international participation and coordinated action; (ii) the integration of scientific knowledge with financial and technological cooperation mechanisms; and (iii) the temporal dimension of policy effectiveness, requiring sustained commitment over multiple decades. These elements are frequently interpreted as illustrating the importance of structured interactions between science, policy, and diplomacy within a governance framework that is both robust and adaptable.

Building on this experience, Benedick (1998) identified a set of key principles that have informed subsequent debates on global environmental governance, including the centrality of scientific expertise, the need for precautionary action under uncertainty, the role of public engagement, the importance of political leadership, and the relevance of institutional flexibility. Together, these principles highlight the multidimensional nature of the regime and help explain why the Montreal Protocol has increasingly been mobilized in the literature as a reference point for broader discussions on environmental governance.

Together, these features have contributed not only to the regime's empirical performance but also to its reinterpretation as a paradigmatic case of global environmental governance. This trajectory was further reinforced by the Kigali Amendment (2016), which expanded the regime's scope to include hydrofluorocarbons (HFCs), demonstrating the Protocol's capacity for institutional adaptation in response to emerging environmental challenges (Birmpili, 2018). However, this reinterpretation raises analytical questions regarding the extent to which its institutional configuration can be replicated in other environmental contexts, particularly those characterized by higher levels of economic embeddedness and political complexity.

3.1 Market and Trade Mechanisms in the Montreal Protocol Regime

The Montreal Protocol introduced significant institutional innovations by integrating trade measures into its regulatory framework, addressing tensions between environmental protection and international trade (Faber, 2003). A central feature is the use of trade restrictions as an enforcement mechanism: parties were required to ban the import and export of controlled substances with non-parties, creating incentives for treaty accession and reducing free-riding (Zhang, 2009; Brack, 1998).

These provisions are interpreted as serving multiple functions, including restricting markets for harmful substances, encouraging participation, and safeguarding environmental integrity by limiting the relocation of production (Benedick, 1998; Barrett, 2003). However, their incorporation into the regime was not without controversy, as trade measures embedded in multilateral environmental agreements raise questions about compatibility with WTO disciplines, particularly regarding non-discrimination principles and the scope of environmental exceptions under GATT Article XX (Faber, 2003; Brack, 1998). Beyond their functional role, they have been framed as a core institutional "lesson" of the Protocol, contributing to its consolidation as a reference model (Keohane & Victor, 2011; Biermann, 2014).

A critical complement to these measures was the establishment of the Multilateral Fund in 1990, which operationalized the principle of common but differentiated responsibilities by supporting technological transitions in developing countries (Birmpili, 2018). According to Birmpili (2018), between 1991 and 2018, the Fund disbursed over US$ 3.8 billion, a feature frequently highlighted as central to the regime's effectiveness. The interaction between trade restrictions and financial mechanisms is widely identified as a key explanatory factor for the Protocol's success, highlighting the need for alignment between enforcement and cooperative instruments (Zhang, 2009).

The outcomes associated with this architecture are frequently described as substantial. Estimates suggest that the global phase-out of CFCs may generate cumulative health-related benefits between 1987 and 2060 of approximately US$ 1.8 trillion, including significant reductions in skin cancer incidence, as well as hundreds of billions of dollars in avoided damages to agriculture, fisheries, and materials (Zhang, 2009; Birmpili, 2018). This combination of trade-based enforcement and redistributive mechanisms has been consolidated as a defining feature of the regime, though the conditions enabling this alignment warrant careful consideration before transposition to other governance contexts.

4. Research Design and Methodological Approach

This study adopts a mixed-methods strategy combining systematic literature review and comparative bibliometric analysis to examine the Montreal Protocol as a model of global environmental governance and assess how its potential replicability has been addressed in the literature. The approach integrates quantitative mapping of scientific production with qualitative analysis guided by public policy evaluation criteria.

Data were collected from the Web of Science (WoS) and Scopus databases, selected for their broad interdisciplinary coverage and standardized metadata. The temporal scope spans from 1987, marking the adoption of the Montreal Protocol, to 2025, enabling a longitudinal analysis of nearly four decades of scholarly production.

The search strategy was structured around three analytical dimensions: (i) the international regime (Vienna Convention; Montreal Protocol), (ii) its financial mechanism (Multilateral Fund for the Implementation of the Montreal Protocol; MLF), and (iii) governance and policy-related concepts (governance; public policy; environmental policy; best practices; lessons learned; financing; compliance). Equivalent Boolean queries were applied in both databases, conducted in February 2026.

The records were exported in BibTeX format and processed using the Bibliometrix package in R (Aria & Cuccurullo, 2017). After merging the databases and removing duplicates based on DOI and title similarity, the final corpus consisted of 453 unique documents. Data cleaning included standardization of author names, journal titles, and keywords.

A qualitative systematic review was subsequently conducted. Inclusion criteria required that studies explicitly address the Montreal Protocol and engage with governance, institutional design, financing, compliance, or policy evaluation. Studies restricted to atmospheric chemistry without institutional analysis were excluded. A three-stage screening process (titles, abstracts, and full texts) was applied to identify the most relevant contributions.

The interpretative analysis was guided by public policy evaluation criteria, including effectiveness, efficiency, equity, cost-benefit considerations, risk, and political feasibility (Kraft et al., 2018). This framework enables the assessment of the Protocol as an institutional arrangement and supports the analysis of how its features have been interpreted as transferable to other contexts.

The qualitative component of the analysis was conducted through an iterative thematic coding process. Initial deductive categories were derived from the public policy evaluation framework, including effectiveness, efficiency, equity, political feasibility, and institutional adaptability, the latter added to capture the adaptive governance dimension of the Montreal Protocol regime. These categories were subsequently complemented by interpretive coding focused on governance narratives, discursive constructions of institutional success, and representations of replicability within the literature. The coding process involved repeated readings of the selected corpus to identify recurring interpretive patterns and shifts in how the Montreal Protocol has been framed across different analytical contexts.

By combining longitudinal bibliometric analysis with qualitative review, the study provides both structural insights into the evolution of the field and a critical interpretation of how the Montreal Protocol has been framed as a successful and potentially replicable governance model.

For purposes of transparency and reproducibility, the search strategies applied in Scopus and Web of Science are detailed below.

In Scopus, the following query was applied: TITLE-ABS-KEY (“Vienna Convention” OR “Montreal Protocol” OR “Multilateral Fund for the Implementation of the Montreal Protocol” OR “MLF”) AND TITLE-ABS-KEY (“governance” OR “public policy” OR “environmental policy” OR “best practices” OR “lessons learned” OR “financing” OR “compliance”). Subject area filters applied were: Environmental Science; Social Sciences; Business, Management and Accounting; Economics, Econometrics and Finance; Decision Sciences; and Multidisciplinary. Language was restricted to English, Portuguese, and Spanish, yielding 355 documents.

In Web of Science, an equivalent strategy was applied: TS=(“Vienna Convention” OR “Montreal Protocol” OR “Multilateral Fund for the Implementation of the Montreal Protocol” OR “MLF”) AND TS= (“governance” OR “public policy” OR “environmental policy” OR “best practices” OR “lessons learned” OR “financing” OR “compliance”). Document type filters (articles and review articles) and subject categories were applied, including Environmental Sciences; Environmental Studies; Green Sustainable Science Technology; Public Administration; Political Science; International Relations; Law; Development Studies; Multidisciplinary Sciences; and Social Sciences Interdisciplinary, resulting in 226 documents. The initial combined dataset comprised 581 records, which, after deduplication, yielded a final corpus of 453 unique documents. The screening process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, applying a three-stage procedure covering titles, abstracts, and full texts.

5. Bibliometric Results

The bibliometric analysis conducted using the Web of Science (226 documents) and Scopus (355 documents) databases, consolidated into a final corpus of 453 unique documents after the removal of 128 duplicates, enables not only the examination of the quantitative evolution of scientific production on the Montreal Protocol but also the identification of qualitative shifts in how the regime has been interpreted within the international literature. By integrating bibliometric mapping with qualitative systematic review, this section seeks to address the central research question: to what extent has the Montreal Protocol been framed as a replicable model of global environmental governance in the context of contemporary challenges related to power asymmetries, financing, and international inequality.

5.1 Temporal Evolution of Scientific Production

The annual evolution of scientific production, presented in Figs. 1 and 2, reveals a clear upward trajectory over the period analyzed (1987–2025). In the decades immediately following the adoption of the Protocol, publication output remained relatively limited, followed by gradual growth from the early 2000s and a more pronounced increase after 2010, as illustrated in Figs. 1 and 2. This pattern reflects the growing academic interest in the Protocol across the period analyzed.

In the Web of Science dataset (Fig. 1), the growth pattern appears relatively stable, with moderate fluctuations and occasional peaks in more recent years. In contrast, the Scopus dataset (Fig. 2) exhibits a more marked expansion from the mid-2010s onward, with a higher concentration of publications in

recent years. This difference likely reflects both the broader interdisciplinary coverage of Scopus and the distinct thematic filters applied to each database during the search process.

It is also important to note that the apparent decline in the final year of the series is attributable to the fact that it represents an incomplete year at the time of data collection and should not be interpreted as indicative of a downward trend.

Overall, the temporal dynamics of scientific production indicate not only an expansion of academic interest in the Montreal Protocol but also a progressive diversification of analytical perspectives. This evolution provides an initial indication of how the regime has been increasingly repositioned within the literature—from a case primarily associated with atmospheric science to a reference point in debates on environmental governance—an interpretation that is further explored through subsequent bibliometric and qualitative analyses.

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

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5.2 Authors and Epistemic Communities

The analysis of the most relevant authors (Figs. 3 and 4) confirms the consolidation of an epistemic community structured around the Montreal Protocol regime. Despite variations in author concentration across databases, a relatively stable core of recurring authors is identified in both, contributing not only to the accumulation of empirical knowledge but also to the construction and diffusion of shared interpretative frameworks central to the functioning of epistemic communities in international environmental governance.

From an analytical perspective, the consolidation of such a community is particularly relevant, as it supports the continuous reinterpretation of the Protocol and contributes to its framing as a successful and potentially replicable model. In this sense, the epistemic community does not merely reflect the evolution of the regime but actively participates in shaping its legitimacy and its projection into broader debates on global environmental governance.

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

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The temporal analysis of authorship further reinforces this interpretation. Figures 5 and 6 indicate that a significant share of the most productive authors intensified their contributions from the 2010s onward—a period marked by the expansion of debates on comparative environmental regimes and by the growing incorporation of the Montreal Protocol as a reference case within climate governance discussions.

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

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5.3 Journals and Thematic Dispersion

The structure of the most relevant sources (Figs. 7 and 8) highlights the thematic diversification of the field and reinforces the evolution of the Montreal Protocol as an object of interdisciplinary inquiry.

In the Web of Science dataset, leading journals include Environmental Science & Policy and Environmental Science & Technology, followed by Atmospheric Chemistry and Physics, Atmospheric Environment, and International Environmental Agreements: Politics, Law and Economics. This distribution reflects a clear overlap between technically oriented atmospheric science journals and outlets focused on environmental policy and international relations, indicating that the regime is simultaneously examined through scientific and institutional lenses.

A similar pattern emerges in the Scopus dataset, although with a higher concentration of publications in technically oriented journals such as Environmental Science and Technology and Atmospheric Environment. At the same time, the presence of journals such as Environmental Policy and Law, Environmental Politics, and Journal of Environmental Studies and Sciences expands the legal and political dimension of the debate, confirming the growing relevance of governance-oriented approaches.

Taken together, these patterns suggest not only thematic heterogeneity but also a process of disciplinary expansion, in which the Montreal Protocol operates as a boundary-spanning object across distinct fields of knowledge. This dispersion, bridging atmospheric science and institutional analysis, indicates that the regime has been progressively incorporated into broader scholarly debates on environmental governance.

From an analytical perspective, this interdisciplinary embedding is particularly significant, as it supports the framing of the Montreal Protocol not merely as a successful environmental agreement, but as a reference model whose relevance extends beyond its original domain. The dispersion of publications across scientific, legal, and policy-oriented journals thus reflects both the complexity of the regime and its increasing role in shaping discussions on global environmental governance.

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

5.4 Geographical Distribution of Scientific Production

The longitudinal analysis of scientific production by country, presented in Figs. 9 and 10, reveals a highly uneven geographical distribution, with a clear concentration of output in a limited number of countries. The United States maintains a consistently dominant position throughout the entire period analyzed (1987–2025), not only in terms of publication volume but also as a central node in the production and diffusion of knowledge on the Montreal Protocol.

Beyond the United States, China shows the most significant growth from the 2010s onward, alongside stable contributions from the United Kingdom, Germany, and Brazil, reflecting broader asymmetries in global knowledge production.

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

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This epistemic concentration suggests that, despite the universal formal participation in the regime, the academic production surrounding the Montreal Protocol remains largely centered in scientific institutions located in the Global North, with only partial exceptions such as the recent increase in Brazilian contributions in the Web of Science dataset.

This configuration reflects broader structural asymmetries in the global production of knowledge and raises important analytical implications. It suggests that the dominant interpretations of the Protocol—as well as its framing as a successful and replicable model—may be shaped disproportionately by perspectives rooted in the Global North.

At the same time, the observed shifts suggest a gradual, though partial, decentralization of epistemic authority. This dynamic is particularly relevant in the context of global environmental governance, as the geographical distribution of scientific production influences not only the interpretation of the Montreal Protocol but also its framing as a replicable model in different regional and institutional contexts.

From this standpoint, the limited geographical diversification of scientific production highlights the need for expanding research agendas that incorporate perspectives from the Global South, not only to enhance representativeness but also to critically reassess the conditions under which the Montreal Protocol can be interpreted, adapted, and potentially replicated in diverse socio-economic and institutional contexts.

5.5 Semantic Analysis and Conceptual Evolution

The analysis of keyword frequency (Table 1) highlights the centrality of terms directly related to atmospheric science, such as ozone, ozone depletion, and chlorofluorocarbons, alongside a progressive expansion toward governance and policy-related concepts, including governance, environmental policy, climate change, and compliance. This pattern reveals the coexistence of two semantic domains, one grounded in atmospheric science and another oriented toward institutional analysis, and a process of conceptual reframing across the period analyzed.

In the initial period (1987–1999), the field is characterized by the predominance of terms directly associated with atmospheric chemistry and ozone layer depletion, reflecting a strong focus on the biophysical dimensions of the problem. Between 2000 and 2009, there is a noticeable shift toward concepts related to compliance and international agreements, indicating a growing concern with the institutionalization of the regime and the mechanisms supporting its implementation.

In the most recent period (2010–2025), terms such as climate change, governance, and environmental policy become increasingly prominent, pointing to a broader analytical reframing. In this phase, the Montreal Protocol is no longer addressed solely as a case of successful environmental regulation but is increasingly mobilized as a comparative reference in debates on contemporary environmental regimes and global governance.

Table 1
– Comparative Word Frequency (WoS × Scopus).

Period	Web of Science – Predominant terms	Scopus – Predominant terms
1987–1999	ozone; ozone depletion; chlorofluorocarbons	ozone; ozone layer; ozone depletion
2000–2009	compliance; emissions; international agreement	environmental policy; greenhouse gas; international cooperation
2010–2025	climate change; governance; environmental policy	climate change; governance; environmental protection

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

It is important to note that bibliometric analysis enables the identification of structural patterns in scientific production, but does not replace in-depth investigations of the political dynamics underlying negotiation processes, implementation mechanisms, and institutional revision within the regime.

6. Discussion

Building on the bibliometric and qualitative findings, this section discusses the Montreal Protocol across four dimensions: its performance as a policy regime, its reinterpretation as a governance paradigm, the structural limits of replicability, and the role of narratives and epistemic asymmetries in shaping its status as a global reference.

6.1 The Montreal Protocol as a High-Performance Policy Regime

The Montreal Protocol has been widely interpreted in the literature as a high-performance policy regime, whose effectiveness is underpinned by a set of interrelated structural features. Four dimensions emerge as particularly relevant in explaining this performance.

First, the existence of a consolidated and periodically updated scientific consensus played a crucial role in reducing uncertainty and conferring epistemic legitimacy to policy decisions (Benedick, 1991; Haas, 1990; Birmpili, 2018). Second, the legally binding design of the regime established progressive targets combined with formal revision mechanisms, ensuring regulatory predictability and institutional adaptability over time. Third, the creation of the Multilateral Fund introduced a redistributive mechanism

that operationalized the principle of common but differentiated responsibilities (Birmpili, 2018; Zhang, 2009; United Nations, 2020), reducing resistance from developing countries and enabling broader participation. Finally, the incorporation of trade restrictions and market-based incentives contributed to mitigating non-compliance risks while fostering technological innovation.

From the perspective of public policy evaluation criteria—effectiveness, efficiency, equity, and political feasibility (Kraft et al., 2018), the regime demonstrates consistently high performance across these dimensions (Benedick, 1991; Zhang, 2009). Environmental effectiveness is evidenced by the substantial reduction of ozone-depleting substances and the ongoing recovery of the stratospheric ozone layer. Efficiency is reflected in the favorable cost–benefit ratio of the measures adopted. Equity was operationalized through redistributive financial mechanisms, while political feasibility is demonstrated by near-universal participation and the long-term stability of the institutional framework.

This configuration, however, needs to be examined not only in terms of its empirical outcomes, but also in relation to the discursive process through which it has been elevated to a governance paradigm, as analyzed in the following section.

6.2 From Sectoral Regulation to Governance Paradigm: The Discursive Shift

The bibliometric results presented in Section 5 indicate a clear transformation in how the Montreal Protocol has been interpreted within the scientific literature. Initially framed as a sectoral regulatory response to a specific atmospheric problem, the Protocol has progressively been rearticulated as a paradigmatic case of global environmental governance (Haas et al., 1993; Keohane & Victor, 2011; Hale, 2020).

This shift is reflected in the transition from a semantic core centered on atmospheric science to governance-oriented vocabularies, moving from terms such as ozone depletion, stratospheric ozone, and chlorofluorocarbons toward a discourse increasingly dominated by governance, compliance, international cooperation, and environmental policy (Biermann et al., 2009; Young, 2011; Hale, 2020). This transformation becomes particularly pronounced after 2010, as governance-oriented frameworks gained prominence in environmental policy research, and is reinforced by the diversification of publication outlets into policy, law, and international relations.

From an analytical perspective, this shift carries important implications. First, it legitimizes the application of governance and public policy frameworks to the analysis of the Protocol, enabling its evaluation through multidimensional criteria beyond environmental outcomes. Second, it helps explain why the Montreal Protocol has been increasingly mobilized as a comparative benchmark in debates on other global environmental regimes, particularly climate governance (Benedick, 1998; Keohane & Victor, 2011; Falkner, 2016).

From this perspective, the elevation of the Montreal Protocol to a governance model is not analytically neutral, but reflects broader processes of framing and policy model construction (Dryzek, 2013; Dolowitz & Marsh, 2000; Young, 2011). By elevating the Protocol to a paradigmatic reference, the literature tends to abstract from the structural, technological, and political conditions that enabled its success, transforming it into a constructed reference point within global environmental governance.

More broadly, this shift can be understood as part of a wider process of model construction in international policy discourse, whereby specific cases are selectively framed, simplified, and stabilized to function as references for future governance arrangements. Such processes are inherently non-neutral, as they involve the exercise of epistemic authority, the delineation of disciplinary boundaries, and the strategic mobilization of evidence. Consequently, the Protocol's status as a governance model derives not only from its empirical outcomes, but also from how it has been narrated and disseminated across academic and policy communities.

6.3 Replicability Under Constraint: Structural Limits and Policy Transfer

The recognition of the Montreal Protocol as a governance paradigm has positioned it as a reference model for other environmental challenges, particularly in debates on climate governance and international cooperation (Benedick, 1998; Keohane & Victor, 2011; Falkner, 2016). However, the findings of this study indicate that any attempt at transposition is inherently conditional.

A key limitation lies in structural differences between the ozone regime and contemporary environmental challenges. In the case of ozone depletion, the problem was concentrated in a relatively limited set of industrial sectors, with available technological substitutes and a strong, unified scientific consensus (Benedick, 1991; Parson, 2003; Young, 2011). By contrast, issues such as climate change involve systemic transformations of energy, production, and consumption systems, with deeply embedded economic interests and higher levels of political contestation (Keohane & Victor, 2011; Falkner, 2016).

The geopolitical context has also evolved substantially. The relatively cooperative international environment of the 1980s has given way to a more fragmented and conflict-prone global order, complicating the coordination of collective action and the stabilization of long-term commitments (Biermann et al., 2007; Hale, 2020). The absence of robust and predictable financial mechanisms comparable to the Multilateral Fund further constrains the feasibility of transferring the Montreal model to other environmental domains (Birmpili, 2018; Young, 2011).

The role of trade measures provides a particularly illustrative example of these limitations. While the Montreal Protocol successfully incorporated trade restrictions as enforcement tools, the broader literature cautions against assuming their generalizability without generating distortions or conflicts within the international trade system (Brack, 1998; Faber, 2003; Zhang, 2009). Such measures require careful calibration and must be embedded within broader institutional arrangements that ensure legitimacy, proportionality, and distributive equity (Birmpili, 2018; Falkner, 2016).

Taken together, these factors indicate that the Montreal Protocol is best understood not as a universally replicable model, but as a context-dependent configuration of institutional, economic, and scientific conditions (Young, 2011; Keohane & Victor, 2011). Rather than direct replication, a more appropriate approach is selective adaptation, in which specific mechanisms are recalibrated to fit distinct political and economic contexts (Dolowitz & Marsh, 2000). This shift is particularly critical in complex domains such as climate change, where core assumptions underpinning the Montreal framework—such as technological substitutability and limited actor concentration—no longer hold (Falkner, 2016; Hale, 2020).

6.4 Success as Construction: Narratives, Power, and the Politics of Exemplarity

Beyond its empirical achievements, the Montreal Protocol's status as a "success story" reflects not only its material effectiveness but also discursive and epistemic dynamics within global environmental governance (Dryzek, 2013; Young, 2011). Bibliometric evidence indicates that this reputation has been progressively reinforced through its reinterpretation within governance-oriented scholarship (Biermann et al., 2009; Hale, 2020).

In this sense, the Protocol operates simultaneously as an empirical case and as a normative reference, influencing how policymakers and scholars conceptualize the possibilities and limits of global environmental cooperation (Keohane & Victor, 2011; Hale, 2020). However, this dual role introduces analytical risks: the elevation of Montreal as a paradigmatic success may encourage oversimplified analogies and misguided policy transfer if underlying structural conditions are insufficiently scrutinized (Dolowitz & Marsh, 2000; Young, 2011).

The bibliometric analysis also reveals persistent geographical asymmetries in knowledge production, with a predominance of contributions originating in the Global North (Biermann et al., 2009). This concentration raises concerns regarding whose perspectives and priorities are embedded in the narratives that sustain the Protocol's status as a global reference, and how epistemic authority is distributed across regions and institutions (Hale, 2020).

These findings resonate with a growing body of literature that critiques linear models of policy diffusion and emphasizes the importance of translation, reinterpretation, and contextual embedding in policy transfer processes (Dolowitz & Marsh, 2000; Young, 2011). From this perspective, policies do not circulate as fixed templates but are reshaped as they move across institutional, political, and geographical contexts. Consequently, the Montreal Protocol is best understood not as a blueprint to be replicated, but as a contingent and historically situated reference within a broader repertoire of global environmental governance strategies. The argument is not that the Montreal Protocol is wrongly classified as successful, but that its success has been selectively framed, normalized, and elevated into a governance archetype.

7. Conclusions and Implications

This article examined the Montreal Protocol as both a high-performance environmental regime and an evolving governance paradigm, asking to what extent its institutional configuration can be understood as replicable across different environmental governance contexts. The findings indicate that its elevation to a governance model reflects not only empirical effectiveness, but also a discursive process through which its enabling conditions have been selectively abstracted and stabilized within the literature.

The longitudinal bibliometric analysis covering the period from 1987 to 2025, combined with a qualitative systematic review, indicates that the Montreal Protocol has become a central reference in the international literature on global environmental governance.

The findings suggest that the performance of the Montreal Protocol cannot be fully understood solely in terms of its environmental outcomes, despite the robust evidence provided by the recovery of the ozone layer. Its analytical relevance lies in the configuration of its institutional architecture, which combines a stable scientific foundation, legally binding and progressively strengthened targets, and the strategic use of trade-related measures to mitigate free-riding. The establishment of the Multilateral Fund was particularly critical, as its redistributive function enabled the participation of developing countries and operationalized the principle of common but differentiated responsibilities. From a public policy perspective, the regime exhibits high levels of effectiveness and political feasibility, while still encompassing distributive tensions and structural asymmetries.

The interaction between international trade and environmental governance further illustrates both the strengths and limits of the regime. While the Montreal Protocol demonstrates that trade measures can be incorporated into environmental agreements with a degree of legitimacy—when supported by scientific justification and compensatory mechanisms—this compatibility does not eliminate underlying tensions. Rather, the relative stability of the regime appears to stem from its institutional capacity to manage and mediate such conflicts over time.

At the same time, the replicability of the Montreal model remains inherently constrained. Contemporary environmental challenges, particularly climate change, involve far more complex and systemic transformations affecting energy systems, production structures, and consumption patterns. These challenges unfold within a more fragmented geopolitical context, characterized by heightened competition and reduced prospects for consensus. Under such conditions, the direct transposition of the Protocol's institutional design is unlikely. Nevertheless, certain elements remain analytically and practically relevant, including the stabilization of scientific knowledge, the provision of predictable financial mechanisms, and the development of effective monitoring and enforcement systems.

This study is subject to limitations that should be acknowledged. The reliance on Web of Science and Scopus introduces known biases, particularly regarding the underrepresentation of Global South scholarship and non-indexed literature. Moreover, bibliometric analysis, even when complemented by qualitative review, cannot replace in-depth investigations of negotiation processes or domestic political dynamics. These limitations point to promising avenues for future research, particularly comparative analyses across environmental regimes and the incorporation of more diverse empirical sources.

In response to the central research question, the Montreal Protocol can be considered one of the most consistent examples of successful global environmental governance documented in the literature. However, its success should not be interpreted as a universally replicable model. Rather, it reflects a context-dependent configuration of institutional, economic, and political conditions. Accordingly, the Protocol is better understood as a source of selectively adaptable mechanisms than as a blueprint for direct replication.

Finally, this study highlights that the elevation of the Montreal Protocol as a paradigmatic success is itself part of an ongoing process of knowledge production within global environmental governance. By tracing its discursive transformation in the scientific literature, the findings suggest that its influence extends beyond material outcomes, shaping policy imaginaries, expectations, and governance benchmarks. Future research should therefore examine not only the performance of environmental regimes, but also the epistemic dynamics through which certain cases come to function as global reference points.

Declarations

Author Contribution

W.H.M. conceived the study, led the manuscript writing, and conducted the qualitative systematic review. J.A.B. and L.F.F.L. were responsible for data collection and bibliometric analysis. P.H.M. contributed to the critical review of the manuscript. All authors reviewed and approved the final version.

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Figures

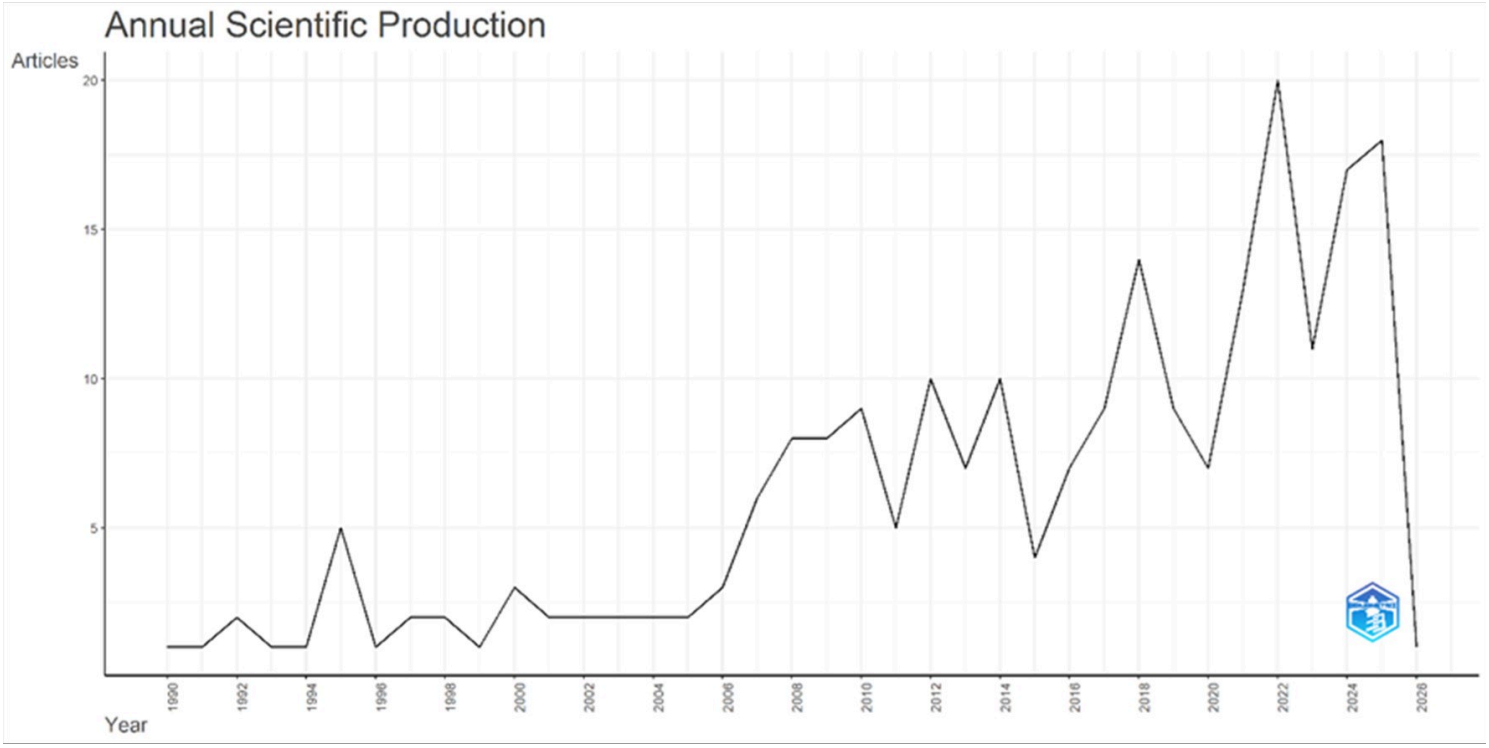


Figure 1

Annual Scientific Production (Web of Science, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

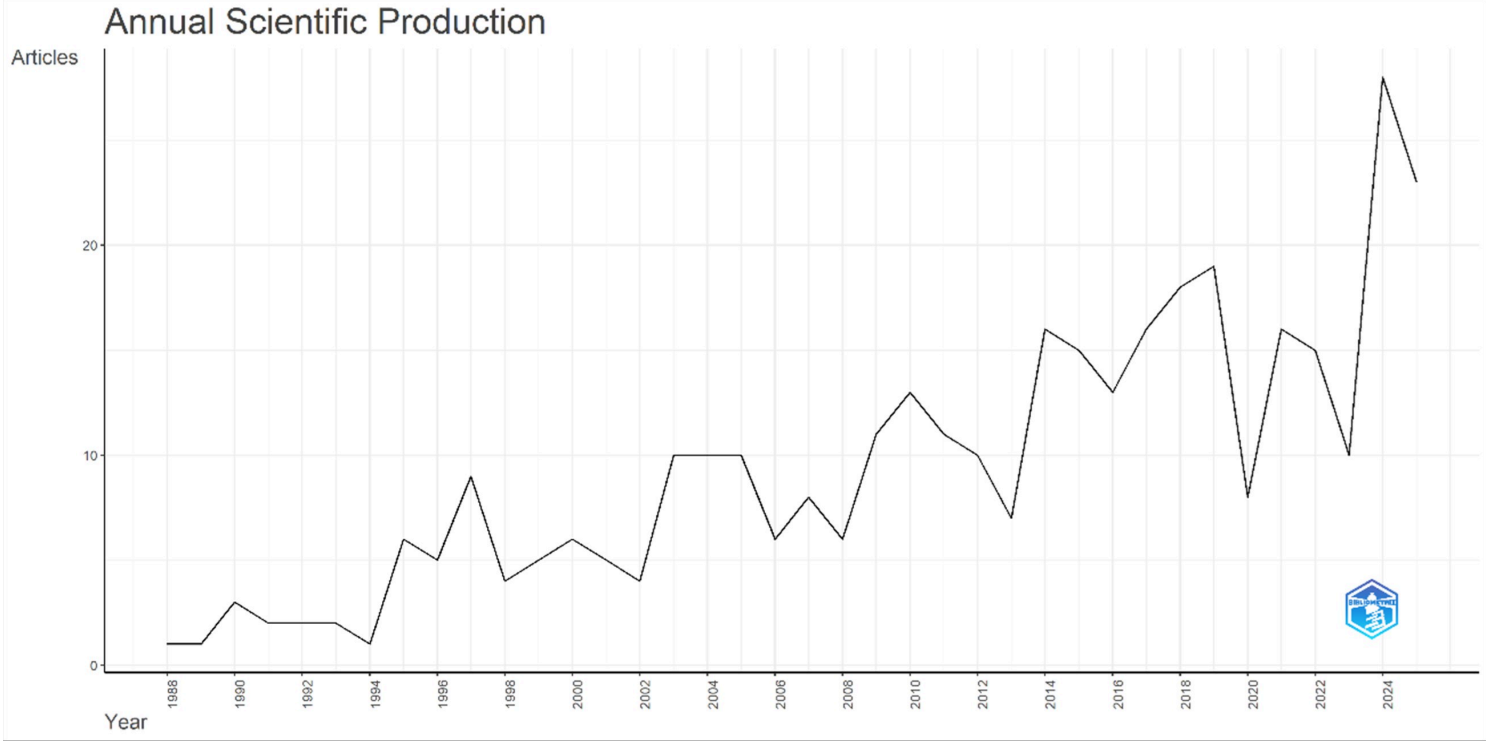


Figure 2

Annual Scientific Production (Scopus, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

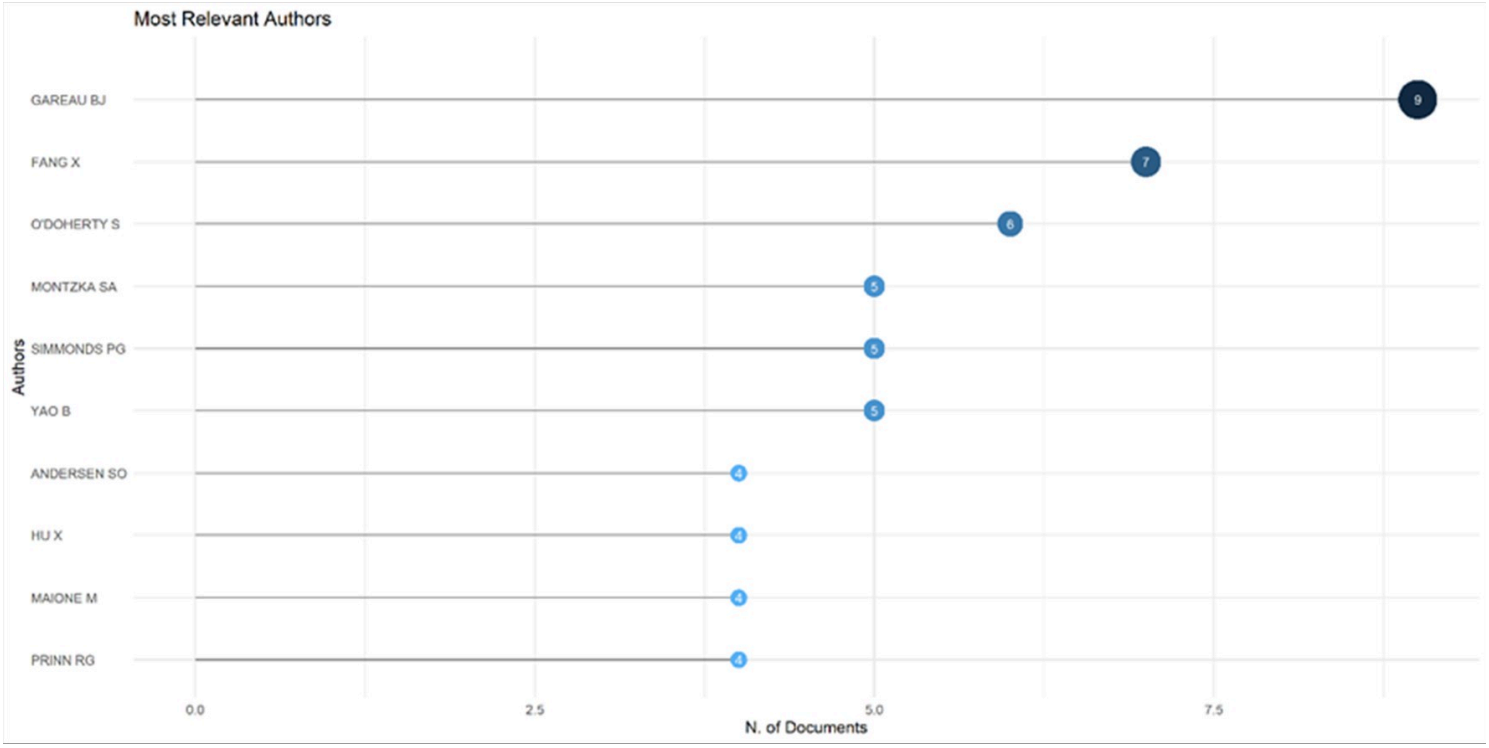


Figure 3

Most Relevant Authors on the Montreal Protocol (Web of Science, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

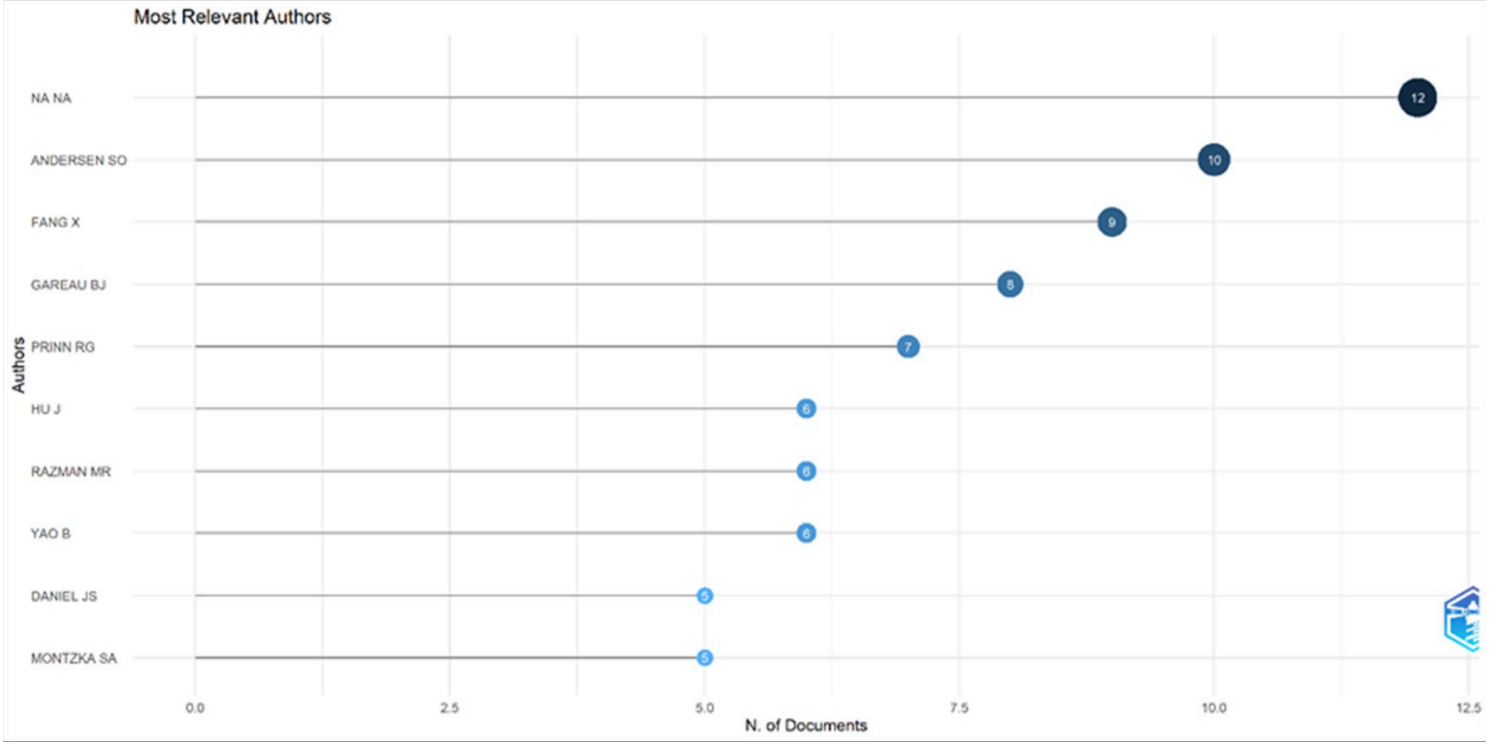


Figure 4

Most Relevant Authors on the Montreal Protocol (Scopus, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

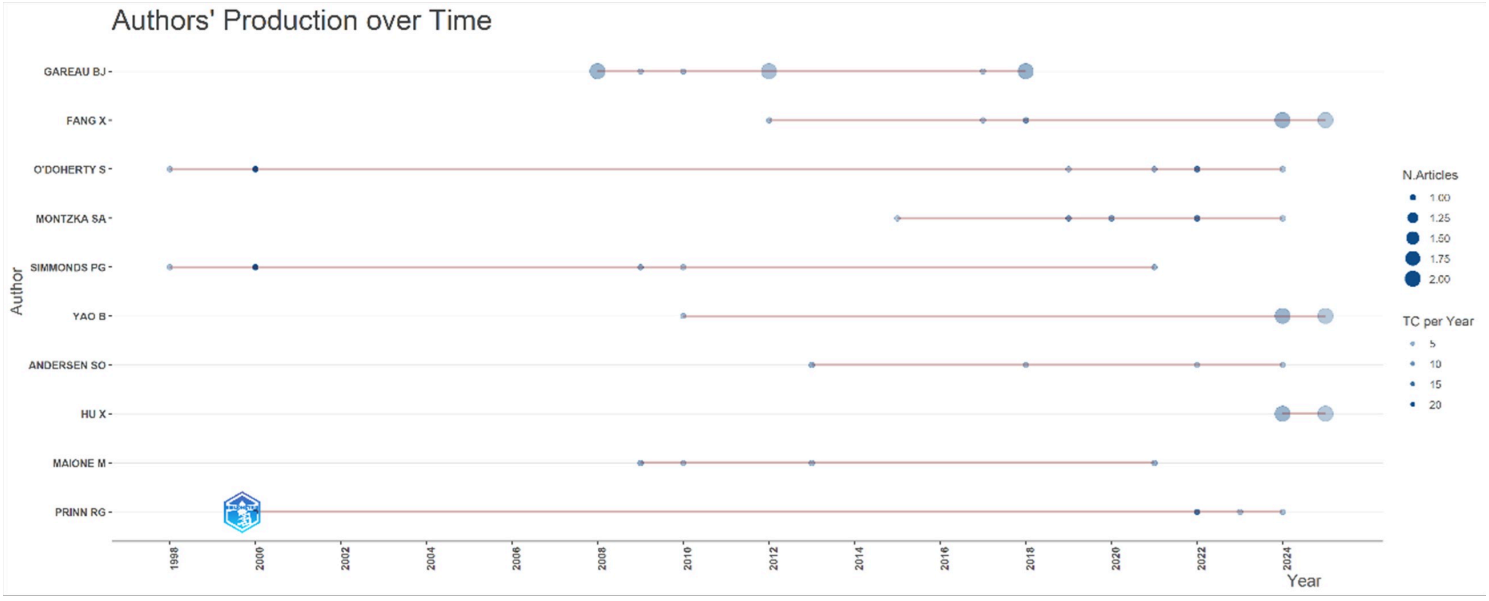


Figure 5

Authors' Production Over Time (Web of Science, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

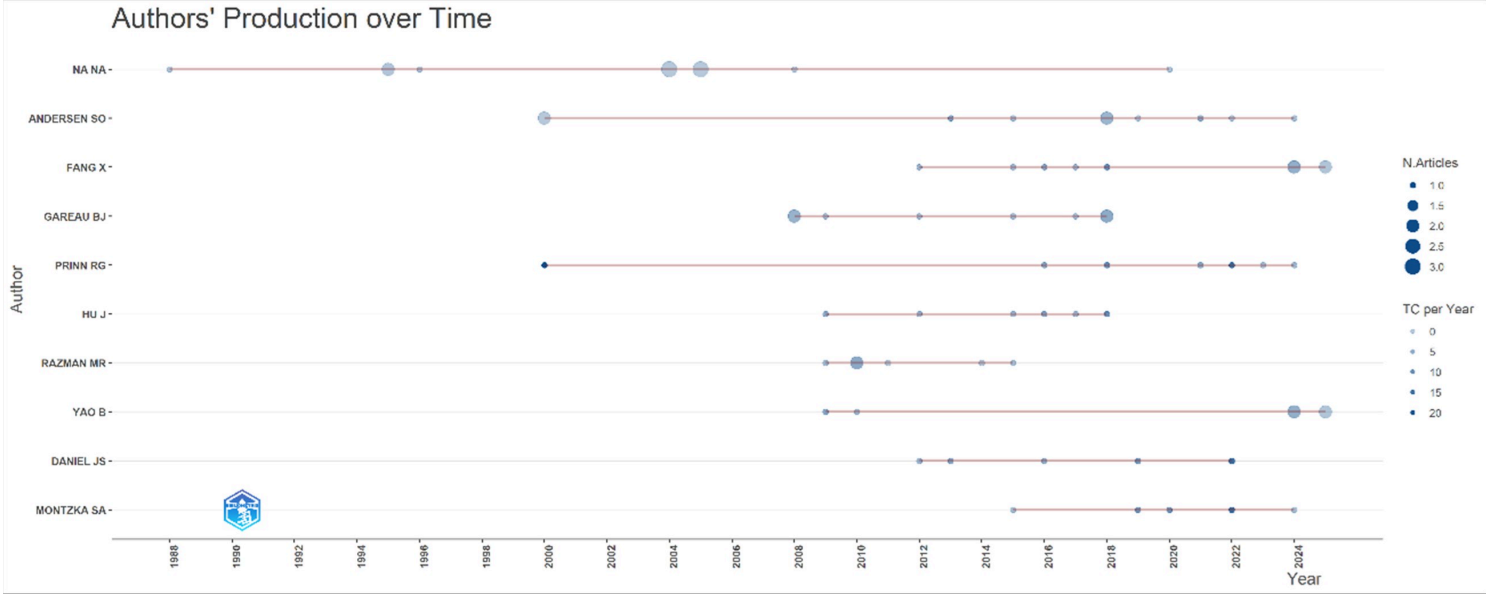


Figure 6

Authors' Production Over Time (Scopus, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).

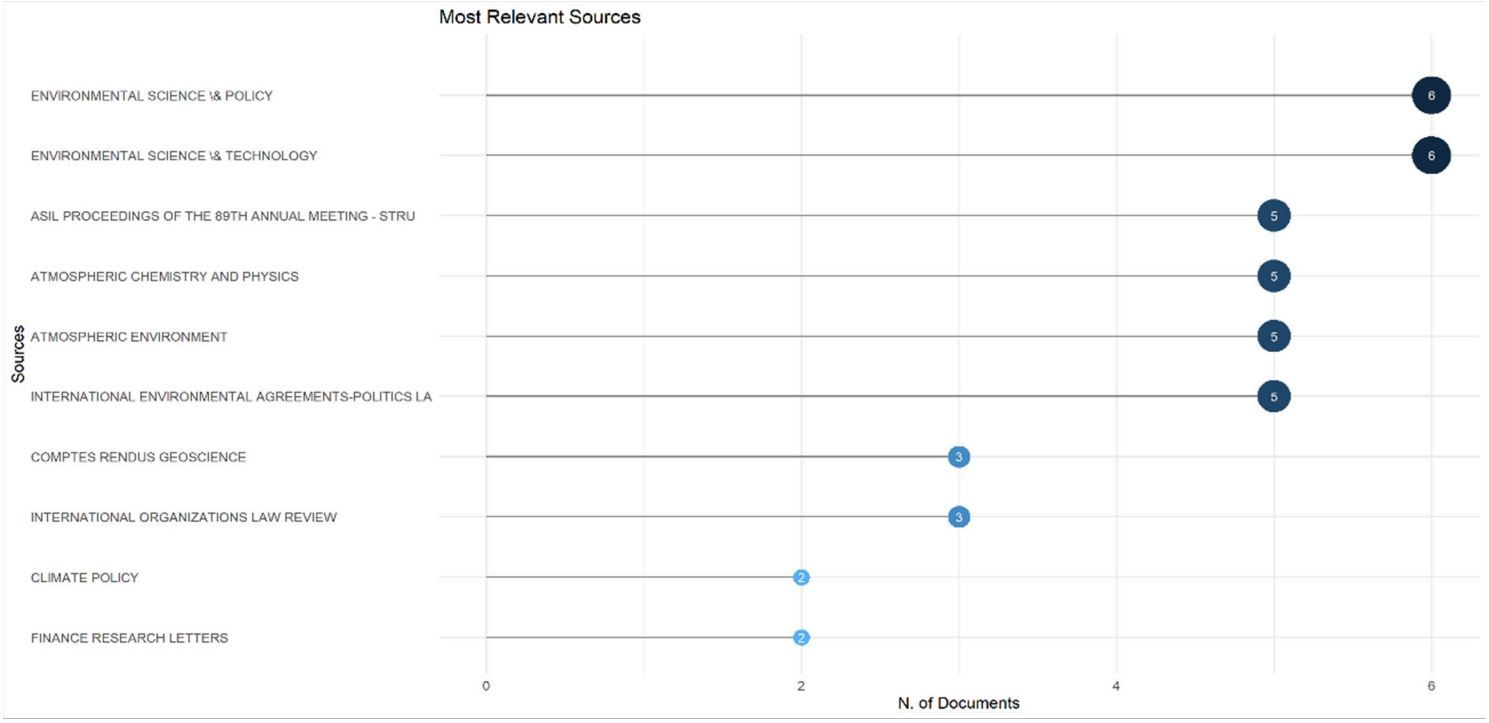


Figure 7

Most Relevant Sources (Web of Science, 1987-2025).

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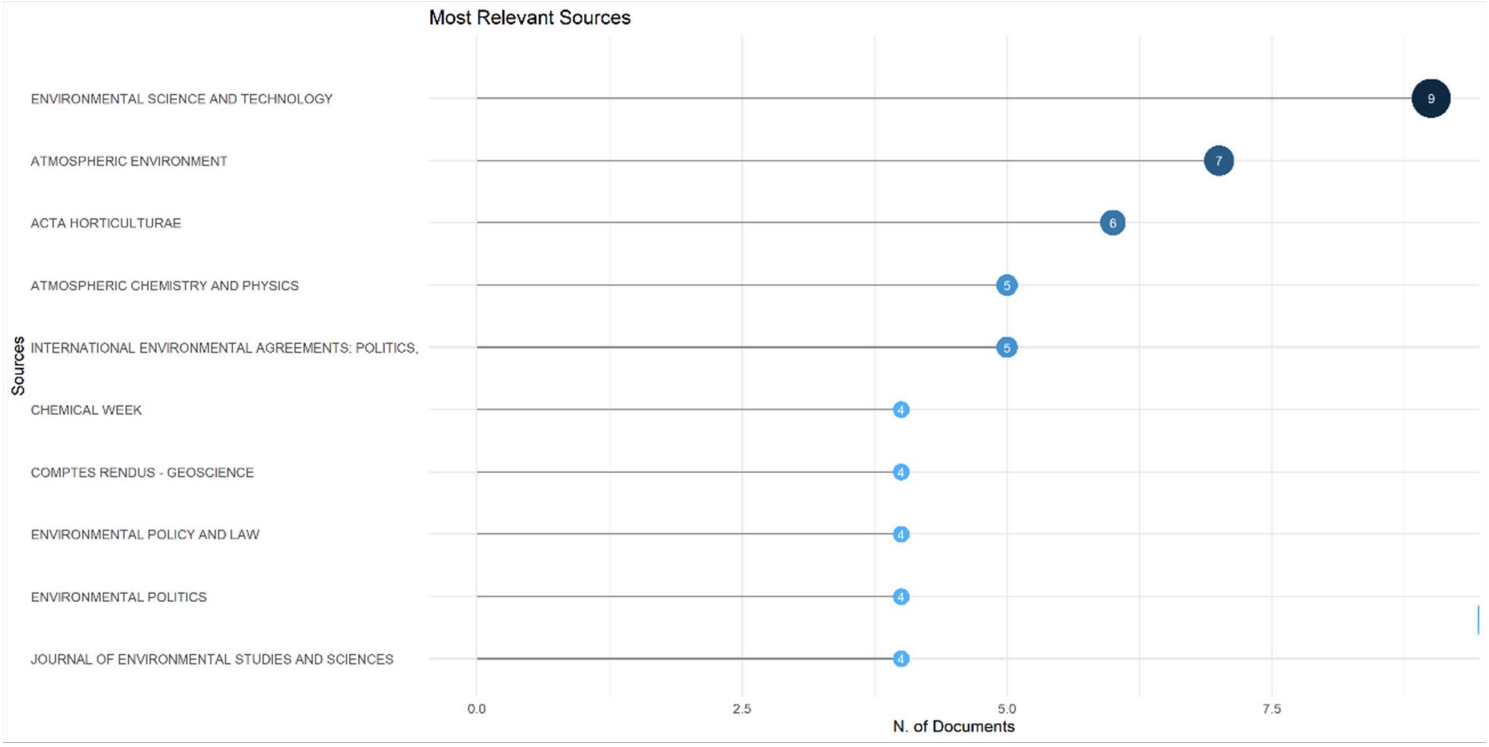


Figure 8

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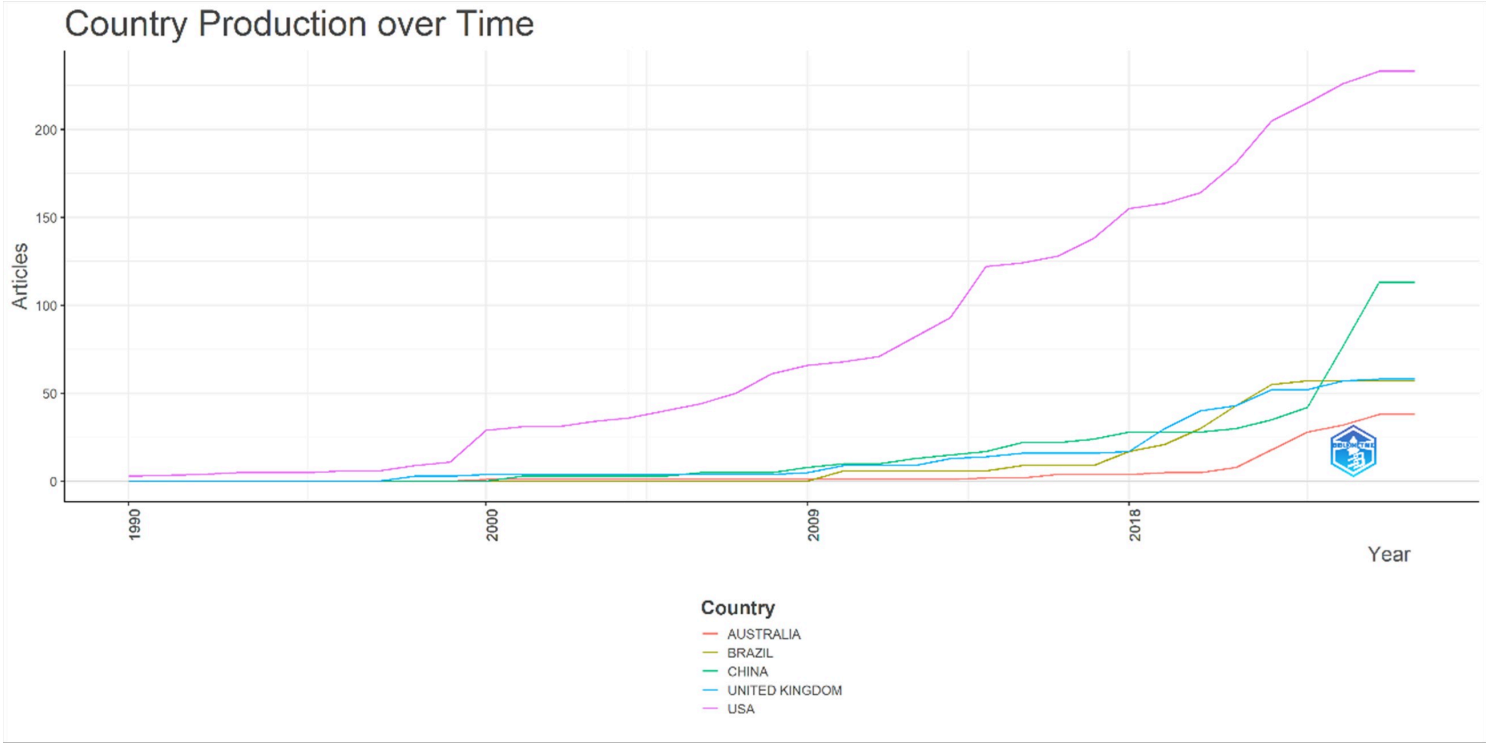


Figure 9

Country Production Over Time (Web of Science, 1987-2025).

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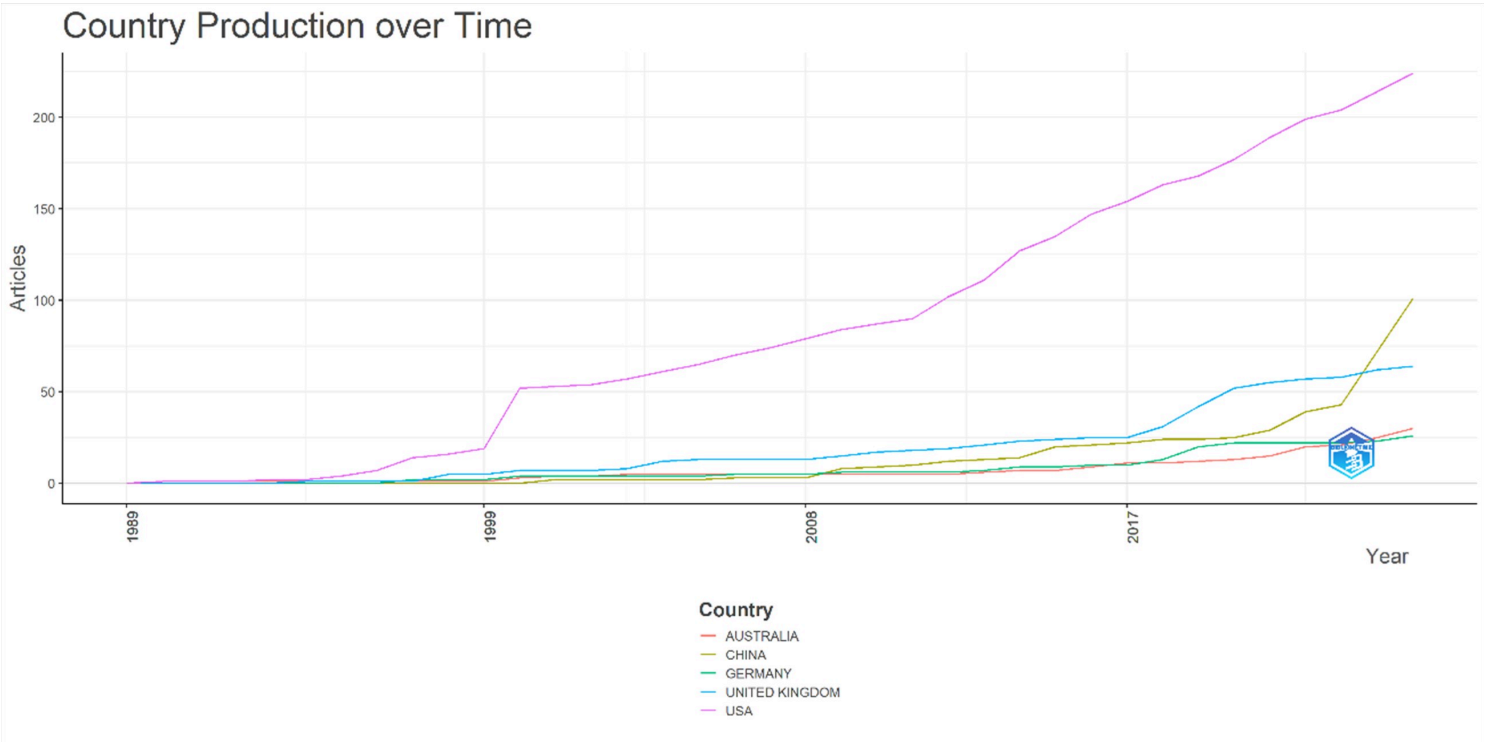


Figure 10

Country Production Over Time (Scopus, 1987-2025).

Source: Prepared by the authors based on Bibliometrix (WoS and Scopus, 1987–2025).